JESUIT SCIENCE

AND THE

REPUBLIC OF LETTERS

Edited by

MORDECHAI FEINGOLD

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Founded in 1540, the Society of Jesus was viewed for centuries as an impediment to the development of modern science. The Jesuit educational system was deemed conservative and antithetical to creative thought. The Order and its members were blamed by Galileo, Descartes, and their disciples for virtually every proceeding against the new science. No wonder a consensus emerged that there was little reason for historians to take Jesuit science seriously.

Only during the past two decades have scholars begun to question this received view of the Jesuit role in the Scientific Revolution. This book contributes significantly to that reassessment. Focusing on the institutional setting of Jesuit science, the contributors take a new and broader look at the overall intellectual environment of the

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Jesuit Science and the Republic of Letters

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edited by Mordechai Feingold

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Preface

Of the many backhanded compliments the Society of Jesus garnered after its dissolution in 1773, Macaulay's outshines most in wit, if not in malice. The Jesuits, Macaulay observed, "appear to have discovered the precise point to which intellectual culture can be carried without risk of intellectual emancipation." And with good reason! While they lacked "no talent or accomplishment into which men can be drilled by elaborate discipline," Macaulay asserted, "such discipline, though it may bring out the powers of ordinary minds, has a tendency to suffocate, rather than to develop, original genius." (*History of England to the Death of William III*, London, 1967, volume I, pp. 564, 568) Macaulay's overall perception of the Order and the cultural production of its members was perpetuated by generations of historians, whose interpretative framework has tended to swing between the polemical and the apologetic. Only recently have scholars begun seriously to transcend centuries of preconceived belief by granting the Jesuit experience rigorous and disinterested scrutiny.

Founded in 1540 as a brotherhood committed to the ideal of itinerant ministry, the Society of Jesus shifted its focus within 20 years as a result of its momentous decision to take on the mission of educating youth. Soon the Society became the greatest of all Catholic teaching orders. It was operating 144 schools by 1580, thrice that number 50 years later, and more than 850 on the eve of its dissolution, with an annual enrollment of hundreds of thousands of pupils (most of them non-paying). Heirs to Renaissance Humanism, the Jesuits proved remarkably successful at modeling their schools on the humanist program—so much so that even their antagonists acknowledged their preeminence in dispensing classical education (John W. O'Malley, *The First Jesuits*, Cambridge, Mass., 1993). Nevertheless, historians, insofar as they pay attention to the formative periods of major figures of any provenance, have been indifferent to this achievement, not least because of increasing marginalization of the classics.

Though humanism was regarded by contemporaries and by historians as the revolutionary "new learning" of the fifteenth and sixteenth centuries, after 1600 the appellation and its signification were increasingly appropriated by proponents of the new philosophies, who argued for their own views in direct counterpoint to ancient learning. The Society of Jesus did not fare well in this new atmosphere. As the "bulwark" of the Counter-Reformation, the Society was officially committed to shunning innovation and to defending Aristotle in philosophy and Saint Thomas in theology; as a result, the will and ability of its members to embrace in public new modes of thought became increasingly problematic. In view of the Society's official stance, the perception that its members were committed altogether to a sterile humanist pedagogy, to Aristotelian philosophy, and to Thomist theology ensured that they would not be considered contributors to subsequent developments. The Jesuits could be dismissed as pedagogues, even as obscurantists, who lacked something that has long been deemed central to the emergence of modern science: an explicit and active commitment to novelty and change. Another claim made against the Society was that its members actively persecuted proponents of new scientific ideas. During the early modern period, some found it useful to blame the Jesuits for virtually every proceeding against the new science. Galileo and Descartes did so, as did their disciples, as did their audience, even though the Jesuits were for the most part innocent. Strong anti-Jesuit sentiment nevertheless ensured that these charges stuck and were perpetuated. A consensus emerged that little reason existed for historians to study Jesuit science seriously.

During the past two decades, scholars have begun to take a new look at the nature and extent of the Jesuit contribution to the Scientific Revolution, aiming to produce a balanced treatment grounded in documentary evidence. To do so requires abjuring both apologetics and an exclusive concentration on revolutionary scientific figures as the appropriate exemplars against which to measure the Jesuit contribution. Central though they indubitably were, figures such as Galileo, Descartes, and Newton did not alone forge the novel ethos and procedures that coalesced during the seventeenth and early eighteenth centuries. Many others were involved in these developments, including Jesuits. To show this, historians are now broadening their focus to integrate the corporate and intellectual life of the Order and its members into their accounts, and this has resulted in the emergence of a more realistic appraisal of the interaction between Jesuit culture and the new philosophers. The essays in this volume contribute to this effort, presenting important evidence that will help us redefine the contours of the Jesuit encounter with the new science.

The institutional setting of Jesuit science is central to this reappraisal. Jesuits researched and wrote within their respective colleges, often in conjunction with their teaching. Hence, it is necessary to assess with precision the Jesuit assimilation and dissemination of new ideas both in and outside the classroom. Just such a careful study of Jesuit teachers at the Collegio Romano enables William Wallace to argue for a positive and enduring influence of Jesuit ideas on Galileo. And since a significant proportion of Catholic men of science were educated by Jesuits, the nature and the quality of their education bear directly on their careers. Telling in this respect is a 1618 diary entry in which the Dutch natural philosopher Isaac Beeckman marvels that Descartes, at the age of only 24, is well versed in the works of "many Jesuits and other learned men" (*Oeuvres de Descartes*, ed. Charles Adam and Paul Tannery, Paris, 1964–1974, volume X, p. 52). Philological as well as philosophical erudition was acquired by many others educated by Jesuits who eventually made science their vocation. Jesuit education also had substantial effects on graduates who, though not themselves practitioners of the new science, constituted a substantial part of its learned audience, as well as its influential patrons, and could be relied upon to befriend and assist promising younger members of the Order in their efforts to work the new vein.

An appreciation of the institutional and structural setting of Jesuit teaching also helps us to understand how members of the Order reacted to the new philosophies. As Roger Ariew points out, the Jesuit critique of Descartes was based in part on the implications of his principles for the teaching of philosophy, as well as on the philosophical basis of theology, and not altogether on claims concerning the natural world. That critique involved important pedagogical and methodological concerns with which other Catholics—and Protestants—grappled for decades.

Any new theory requires a lengthy process of assimilation, clarification, and modification, and this is inevitably accompanied by controversies, some ill-tempered and some amiable. Jesuit participation in the debates over the new science were not always, or even usually, motivated by simple malice, though such contemporaries as Galileo often chose to portray it in that manner for rhetorical purposes. Edward Grant and Alfredo Dinis emphasize this point in their discussions of the Jesuit contribution to the debates over the new cosmology, as does Roger Ariew in his elucidation of the Bourdin-Descartes controversy. The critique of Jesuit practitioners was often sound and germane—at least in the context of the time—and was certainly commensurate with criticisms made by other contemporaries. That they encountered dismissive, even abusive, reaction reflects the agonistic circumstances of the day rather than the innate characteristics of Jesuits themselves.

The ability of Jesuits to participate freely in such debates was, of course, circumscribed by institutional necessity. The Society's regulations limited their ability to teach unhindered and to pronounce publicly on the new ideas, to which many among them were nevertheless attracted, and this sometimes necessitated clever subterfuge. Contemporaries seem to have been well aware of this, though they were by no means sympathetic. This issue is raised, in various ways, by Ugo Baldini, Martha Baldwin, Alfredo Dinis, Brendan Dooley, Mordechai Feingold, Victor Navarro, and Geert Vanpaemel, who consider the ramifications of such constraints on the Jesuits' ability to teach, research, and publish. The pervasiveness of these constraints, however, does not mean that Jesuits were powerless to discuss controversial ideas, either in the classroom or among themselves. The repeated injunctions against the teaching of the new philosophies in Jesuit classrooms, the disciplining of countless members, and the testimonies of many students, altogether belie such an inference.

Ugo Baldini and Paula Findlen emphasize the centrality of the scientific community to the Collegio Romano, and their conclusions can be generalized to include other large colleges. They document how the Roman College functioned extraordinarily successfully as both a teaching institution and a research institution, and how both information and personnel flowed with ease from the College to every corner of the Jesuit world and beyond. The parallel studies of Vanpaemel and Navarro (on Antwerp and Madrid, respectively) are equally instructive with respect to the teaching and research opportunities within specific Jesuit colleges and with respect to the transfer of knowledge and techniques through correspondence and the assignment of members to other colleges.

By paying attention to the temper and the context of early modern Jesuit science, the contributors to this volume augment and expand upon recent scholarship on the Order's role in the scientific revolution. We now know that Jesuit practitioners were instrumental in elevating the status of mathematics over that of philosophy, that they made early and important contributions to the mathematization of physics, and that they were pivotal to the development of experimental science. Future research promises to uncover a wealth of new information in this regard. However, to understand the Jesuits in their special context requires consideration of the fact that, for them, scientific work fit into a special mold. Although the zeal and the commitment of a Jesuit practitioner were not all that different from those of a secular practitioner, a Jesuit *was* a member of a religious order with a clearly defined apostolic mission, according to which, in the words of Paul Guldin in his *De centro gravitatis* (1641), the saving of "a single human soul was more important than any mathematical problem" (Michael John Gorman, The Scientific Counter-Revolution: Mathematics, Natural Philosophy and Experimentalism in Jesuit Culture, 1580–c. 1670, Ph.D. thesis, European University Institute, Florence, 1998, p. 43).

Editor's Note

The Society of Jesus (founded in 1540, dissolved in 1773, reconstituted in 1814) is referred to variously as "the Jesuits," "the Order," and "the Society." No distinctions are intended.

Jesuits: Savants

Mordechai Feingold

One of the more famous “scandals” of eighteenth-century science, and one that persisted for more than 100 years, involved the strange case of Father Maximilian Hell. This talented and respected director of the Vienna Observatory headed one of the teams that set out with great fanfare to observe the 1769 transit of Venus. When the event passed and Hell failed to make his observations immediately public, a malicious rumor arose: The Jesuit either had not carried out observations or, it was even whispered, was awaiting the publication of his colleagues’ observations in order to adjust his own.[1]

The libel—apparently originating with Jérôme de Lalande, who seems to have taken umbrage at Hell’s reluctance to transmit his results directly to him—was given credence, in no small part, because Hell was a Jesuit. Such willingness to discredit an otherwise respected member of the scientific community was symptomatic of the highly charged feelings the Jesuits elicited on the eve of the dissolution of the Order.[2] Yet the bizarre mixture of admiration, aversion, envy, and malice toward the Society of Jesus and its members did not originate in the eighteenth century. From its very inception in 1540, the Jesuit Order engendered deep-seated ambivalence among friends and foes alike. That ambivalence created an atmosphere in which widespread regard, even reverence, for the intellectual achievement of the Jesuits coexisted with repeated attempts to denigrate the Order and everything its members might do.

The Jesuits “were everywhere” (so one historian has summed up the extent of their presence), “especially under the beds of zealous Calvinists and skeptical philosophers.” They were “pervasively feared and loathed as no single group of priests and thinkers had ever been before, and as none would be again until the Bolshevik Commissars of the 1920s.”[3] As unlikely as this analogy may seem, it underscores the nature of the contests that embroiled the Jesuits during the early modern period, which were as much over cultural hegemony as over religion—though one should not assume, as historians often do, that the former was merely an extension of the latter. Be this as it may, the violent reaction to the Jesuits in both realms was such that before long affixing the adjective "Jesuit" to whatever cultural production the Order happened to be engaged in was sufficient to conjure up nefarious and biased designs.

The aim of this introductory chapter is to get past the stereotypes that surrounded the Society of Jesus during the first 200 years of its existence and evaluate the scientific dimension of its intellectual contribution, independent of its religious mission. It is my contention that, by and large, the scholarly activities and aspirations of Jesuits were indistinguishable from those of other contemporary savants, secular or ordained, irrespective of denomination. True, constraints on the pursuit of secular learning were more stringent among Jesuits, as were the mechanisms regulating their teachings, publications, and contacts with outsiders. But this cannot be automatically construed to mean that the Jesuits harbored a greater number of reactionary, prejudiced, or bigoted scholars than did other Catholic orders (or, for that matter, the various Protestant churches). Indeed, my research indicates that while scholarship often served partisan goals in the charged religious atmosphere of the early modern period, Jesuit scientific practitioners as a group seem to have resisted the temptation to yoke science to other ends as well as did practitioners of any other religious denomination.

This conception of the Order as comprising many men of letters is controversial, challenging the received view that they ought to be considered first and foremost Jesuits. Likewise, the corollary attempt to exculpate numerous members from the charge that they were intractable enemies of modernity is certain to draw some fire. Almost as old as the Society of Jesus itself is the commonplace that its members' blind allegiance to scholasticism and Catholic dogma incited them, time and again, to obstruct "truth" by persecuting those committed to seeking it out. Though the condemnation of Galileo is perhaps the most celebrated scientific persecution blamed on the machinations of the Jesuits, opposition to Cartesianism, to atomism, and to other aspects of the new science in Catholic countries was also, from the start, pinned by many proponents of such ideas on Jesuit inspiration or orchestration.

Nowhere was the willingness to believe the worst about the actions and intentions of members of the Order more pronounced than in Protestant countries, where anti-Jesuit sentiments usually ran high. Consider, for example, the scorn with which Henry Oldenburg greeted Ignace-Gaston Pardies's respectful and merited criticism of Newton's theory of colors in 1672. "You see by the enclosed how nimble that sort of men is to animadvert upon new Theories," the secretary of the Royal Society spouted in his cover letter to Newton, as if to condition the latter's mind.[4] Ironically, several years earlier Oldenburg himself had been similarly forewarned (by John Beale, no less) to greet any Jesuit publication with distrust before the benefit of a fair hearing. The Jesuits "are to be suspected in point of candor, and severe truth," Beale wrote, "till your example and strict examination can render them cautious." Indeed, so taken for granted was the alleged trickery of the Jesuits in harnessing their intellectual endeavors to religious and political ends that even the most seasoned minds were cautioned to read them with utmost care.

Such prejudice persisted into the nineteenth century and beyond. Even today, the historical literature is rife with accounts rooted in early modern conceptions of the Jesuits as ultraconservative or, more recently, as dull plodders unworthy of serious inquiry. Consider, for example, Paolo Rossi's dismissive attitude toward efforts to credit the Jesuits with more than a marginal role in ushering in modernity. "It is fashionable to praise the science of the Jesuits," he recently noted. But while "their efforts were undeniably deserving of respect,"

> it is equally undeniable that, beyond all attempts at reevaluation, astronomy after the second condemnation of Galileo's writings in 1633 concentrated more on calculation and less on cosmology and that biology involved the analysis of organs and structures more and focused less on general theories concerning animate things. The "science" of Francesco Lana Terzi and Daniello Bartoli and the monumental works of Athanasius Kircher attempted a sort of grandiose compromise between the findings of the new science and the legacy of magical naturalism. . . . Science returned to an examination of the "marvelous"; once more it became a "pleasurable" activity important for its "utility." Scientific knowledge went back to being precisely what Francis Bacon had said it should not be: "a couch whereupon to rest a spirit, a terrace for a wandering and variable mind, a shop for profits or sale."[5]

Rossi's comments recall past views, such as the one that shaped the article on the Jesuits penned for the 1911 edition of the *Britannica*. Notwithstanding the Order's many endeavors, the authors noted, it was devoid of "really great intellects." Compared with the likes of Descartes, Pascal, and Voltaire, who transformed philosophy and religion, the Jesuits could boast of at best a "respectable mediocrity." And why? All because of "the destructive process of scooping out the will of the Jesuit novice, to replace it with that of his superior . . . and thereby tending, in most cases, to annihilate those subtle qualities of individuality and originality which are essential to genius."[6] But we can trace this sort of analysis back further still, to Helvetius, a former student of the Collège Louis-le-Grand, who, while praising the Jesuit contribution to education, neatly explained why the members of the Order fell short of greatness:

> The Jesuits afford a striking example of the power of education. If their order has produced few men of genius in the arts or sciences; if they have no Newton in physics, no Racine in Tragedy, no Huygens in astronomy, or Pot in chymistry; no Bacon, Locke, Voltaire, Fontaine, etc. it is not that the religious of this order never find among their scholars those who discover the greatest genius. The Jesuits moreover, from the tranquility of their colleges, have not their studies molested by any avocations, and their manner of living is the most favorable to the acquisition of talents. Why then have they given so few illustrious men to Europe? It is because surrounded by fanatics and bigots, a Jesuit dares not think but after his superiors: it is, moreover, because forced to apply themselves for years together to the study of the casuists and theology, that study, so repugnant to sound reason, destroys its efficacy on them. How can they preserve on the benches a just judgment! the habit of sophistry must corrupt it.[7]

On the rare occasions when Jesuits reflected on their order's contribution to secular learning, they reached similar conclusions—though, not surprisingly, without attributing it either to the mediocrity of the members or to their broken spirits. "Our Society values, and has contributed to literature, to culture," Gerard Manley Hopkins insisted,

> but only as a means to an end. Its history and its experience shew that literature proper, as poetry, has seldom been found to be to that end a very serviceable means. We have had for three centuries often the flower of the youth of a country in numbers enter our body: among these how many poets, how many artists of all sorts, there must have been! But there have been very few Jesuit poets and, where they have been, I believe it would be found on examination that there was something exceptional in their circumstances or, so to say, counterbalancing in their career. For genius attracts fame and individual fame St. Ignatius looked on as the most dangerous and dazzling of all attractions.[8]

Predictably, the privileging of novelty and so-called consequential figures has led modern scholars—who fail to detect "greatness" among members of the Order—to adopt a patronizing view of Jesuit scientific endeavors:

"mildly interesting, if unenviable, ancillary roles in a number of great moments in that grand story," as summed up by one scholar.[9] Recently, Isabelle Pantin provocatively employed a rhetorical question—"Is Clavius worth reappraising?"—to title her review essay on the "father" of Jesuit mathematics, so that the reader is hardly surprised to "discover" that he is not.[10] But whereas Rossi in the above quotation regretted the pursuit of the "marvelous" science practiced by Kircher and his colleagues at the Collegio Romano (which science is said to have been practiced by Jesuits more generally), what bothered Pantin was the alleged failure of teachers and textbook writers such as Christopher Clavius to make any significant contributions to science.[11] This dismissal of Jesuits as "mere" pedagogues has been reinforced by the general tendency of scholars to view early modern universities as bastions of scholasticism inimical to new ideas or, at best, as institutions successful only in training clerics and in imparting basic knowledge to the upper classes. Absent from both scenarios is an educational mission, no matter how limited, to advance the boundaries of scientific knowledge or to contribute appreciably to the formation of great thinkers. But perhaps the most interesting aspect of this historical overview is that the inability of such "academicians" to measure up to the likes of Galileo, Descartes, or Newton is viewed as something akin to moral failure, as if they might have reached such heights if only they had been more relentless in their search for truth.

The Jesuit context affords an excellent opportunity to appraise the contribution of a traditional institution of higher learning to "modernity," since, arguably, scholasticism was more rampant in the colleges of the Society than elsewhere, and the vast majority of Jesuit philosophy teachers (as well as many offering instruction in the mathematical sciences) were undistinguished. I shall have more to say on the quality of Jesuit teachers and on the nature of their instruction, but first other important topics bearing on the Jesuit educational context require elucidation. Essential in this context is the recognition that the Order embraced the educational *ministerium* only inadvertently, and that (understandably) its architects were from the outset explicit in enjoining the membership to consider secular studies only as a means to an end. "Teaching the youth pertains to the ministry of the word of God," wrote Jerónimo Nadal c. 1565. "[The Jesuits'] only reason for opening the schools was so that with this hook they might draw students of literature to piety." Two years later Nadal elaborated: the

Society "would never have undertaken the task of giving lessons in colleges, if it did not also understand that by so doing it was also giving a moral training. . . . So for us lessons and scholarly exercises are a sort of hook with which we fish for souls." Such a view, O'Malley has aptly concluded, confirms that the Jesuits "looked more to formation of mind and character, to *Bildung*, than to the acquisition of ever more information or the advancement of the disciplines."[12]

One is tempted to interpret Nadal's statements as a mandate to subjugate all intellectual endeavors to the religious and political aims of the Order, a putative *reductio scientiarum atque morum ad fidem catholicam*, reflected by the recurrence—nearly 300 times—of the Order's motto *ad maiorem Dei gloriam* in the *Constitutions*. This, according to Scaglione, signified "mortification of the human and social needs and subordination of knowledge, truth, and values to an external, abstract goal: allegiance to the Church and Roman faith." Small wonder, then, that modern scholars still maintain that "Jesuit science" should be viewed within the lens of the Order's religious mission. Thus, Harris argued, if certain members of the Society "found themselves deeply engaged in certain forms of early modern science . . . it was because they and their Jesuit superiors considered these forms of scientific practice to be legitimate and valued activities for members of the Society." Harris continues: "Certainly, for the first two hundred years of the Society's existence—and probably for its entire existence—one cannot speak of science as an autonomous cultural activity within the Society. Thus we may assume that the methods, practices, and goals of scientific activity within the Society were subservient to its religious program."[13]

Irrespective of the subservient conception of learning envisaged by the founders of the Society, subsequent generations of Jesuits faced changing circumstances. As education became central to Jesuit life, and as the Order increasingly capitalized on its members' reputation for erudition, certain adjustments in the official attitude toward learning became necessary. "Their strong religious motivation notwithstanding," Scaglione also observed, the Jesuits embraced the traditional ideals of Renaissance humanism, and "the interest in the humanities gradually ripened into genuine dedication" among members—albeit such activities "always lived side by side with the more basic concern for the ultimate point of reference, to wit, theology, or at least a strong confessional commitment." Yet, as Blum perceptively pointed out, even though all learning, in principal, was "purpose-bound, apologetical, and subordinate" to the Order's higher goals, "if absolutely everything is done for the greater glory of God . . . then human activity becomes a wide field for free development." The Jesuits, in other words, stumbled upon a variant of the doctrine of double truth: "If the orthodox faith is not touched . . . the sciences may pursue their immanent questions unhampered."[14]

Clearly, then, I find the common perception of Jesuit scientific activity as motivated by religious concerns problematic. In principle it is true, as one scholar put it, that "one was a Jesuit in order to defend the Council of Trent, not to make one's scientific career an end in itself."[15] But to further conclude that most Jesuit practitioners pursued their scientific studies strictly in conformity with the religious ends of the Order is untenable. Aware of the pious pronouncements of Jesuit practitioners, I nevertheless view many of them as rationalizations—a practice common among early modern clerical savants of all denominations. Yes, there may have been greater urgency for such lip service among Jesuits, in view of St. Ignatius Loyola's determination to "plan and regulate, macro- and microscopically" all aspects of Jesuit life.[16] But there is no mistaking the zeal with which many members embraced secular studies. And in view of this zeal, particularly the profundity of the involvement of the members of the Society in the sciences, I should like to address an issue that has never received proper scholarly attention: the *identity* of the Jesuit practitioners. All too often, it seems, Jesuit individuality is presumed to be an oxymoron. Yet, as Diderot facetiously but incisively mused long ago, the matter was far from obvious: "Qu'est-ce qu'un Jésuite?" he asked in the *Encyclopédie* article on "Jesuits." "Est-ce un prêtre séculier? est-ce un prêtre régulier? est-ce un laïc? est-ce un religieux? est-ce un homme de communauté? est-ce un moine? c'est quelque chose de tout cela, mais ce n'est point cela."[17]

Diderot understood the Jesuit mentality better than most. As well as being a veteran of several celebrated battles with members of the Order, he was a former pupil who had come close to joining. Beyond what concerned him in the above-mentioned article, though, Diderot understood that the identity of the scholar preceded his imprinting as a Jesuit. After all, one entered the Order at age 16, at the culmination of a rigorous period in the Collège, where the love of learning was instilled by enticing young students with accolades and glory—a cornerstone of the contemporary pedagogical system. The incongruity between the habits inculcated in the schools and those expected from a Christian—not to mention a cleric—were often commented upon, but never so poignantly as by the English spiritual writer William Law in his 1728 denunciation of "our modern education":

> The first temper that we try to awake in children is pride, as dangerous a passion as that of lust. We stir them up to vain thoughts of themselves, and do everything we can to puff up their minds with a sense of their own abilities. Whatever way of life we intend them for, we apply the fire of vanity of their minds, and exhort them to everything from corrupt motives. We stir them up to action from principles of strife and ambition, from glory, envy, and a desire of distinction, that they may excel others, and shine in the eyes of the world. We repeat and inculcate these motives upon them till they think it a part of their duty to be proud, envious, and vainglorious of their own accomplishments. And when we have taught them to scorn to be outdone by any, to hear no rival, to thirst after every instance of applause, to be content with nothing but the highest distinctions, then we begin to take comfort in them and promise the world some mighty things from youths of such a glorious spirit. . . . That this is the nature of our best education is too plain to need any proof. . . . And after all this, we complain of the effects of pride, we wonder to see grown men acted and governed by ambition, envy, scorn, and a desire of glory, not considering that they were all the time of their youth called upon to all their action and industry upon the same principles. You teach a child to scorn to be outdone, to thirst for distinction and applause, and is it any wonder that he continues to act all his life in the same manner?[18]

Diderot still fondly recalled in 1760 the prizes and praises showered on him more than 30 years earlier at Langres. And had he proceeded into the Jesuit Order (or any other order) he might well have struggled with the irreconcilable passions that perturbed his older contemporary, the future abbé Prévost, who had been a student of the Jesuits at Hesdin from 1711 to 1718 but who failed twice to follow through the Jesuit novitiate. "I know the weakness of my heart," Prévost admitted shortly after he was professed, "and I understand how important it is for my peace not to apply myself to sterile studies which will leave my heart dry and enfeebled. If I want to be happy in religion, I must conserve in all its force the inspiration of the grace which brought me to it. It is necessary that I unceasingly take care to remove all that could weaken it. I know only too well—I realize it daily—how far I can sink if I lose the great rule from sight for a single moment, or even if I look with the least complaisance on certain images which all too often intrude into my mind, and which still have great power to allure me, although they are half blotted out." As McManners remarked in regard to this passage, while the "young in their naïveté can scorn the glories of the world and believe that they will continue to do so," Prévost "knew from the start the fickleness and ambiguity of vocation."[19]

The ambiguity that troubled Prévost was undoubtedly shared by many Jesuit savants who, while rarely admitting its effect on their vocation and even more rarely committing their sentiments to paper, nonetheless left sufficient testimony of the fervor with which they pursued their secular studies, with the occasional hint of the anxiety it caused them. Thus, when in 1671 Pardies sought to establish contact with the Royal Society, he confided to its secretary his "extraordinary inclination towards the sciences," which stirred in him "an extraordinary respect and regard for people who work to improve them."[20] As we shall see below, such zeal proved for him a life-long source of consternation. Twenty-five years earlier, Giovanni Battista Riccioli had articulated his scientific zeal more forcefully. Writing in 1646 to Athanasius Kircher, the Bolognese professor of theology affirmed his vocation as a theologian while acknowledging that he had been fascinated by astronomy ever since his student days under Biancani. Indeed, Riccioli remarked, although his students and his superiors implored him to turn his attention to theological writings, he desisted, with the result that he was exempted from such a course and permitted instead to devote himself to astronomy for two years. As if to excuse his conduct, Riccioli rationalized that numerous Jesuits published in theology, while only a handful applied themselves to astronomy. And, having already amassed a substantial amount of material, he allowed himself to reiterate his stronger commitment to astronomy than to theology.[21] Publicly, too, Riccioli acknowledged his deep devotion to scientific investigation. In the introduction to the *Almagestum novum*, for example, he confessed that he "could never extinguish the enthusiasm for astronomy" once he had experienced it, and that eventually his enthusiasm had prompted his superiors to sanction his preferred course a decade and a half later: "We are devoted to these studies to the glory of God, first by request, and then by explicit order of the superiors."[22]

While the powerful grip of secular learning (scientific or otherwise) on many Jesuits does not in itself cast a shadow on their religious commitment, it thrusts into the foreground their motivation for joining the Order and any conflict that might have resulted from their pursuit of profane studies. As I have noted, the architects of the Society unambiguously enjoined the members to consider secular studies only as a means to an end. Nevertheless, the reputation that many Jesuits acquired for erudition enhanced the prestige of the Order and increasingly enticed talented individuals who yearned to excel in learning—though whether for the greater glory of God or for their own greater glory it was sometimes difficult to tell. This attraction to the Order was precisely what Juan Alfonso de Polanco had predicted: "Although Jesuits should not try to persuade anybody to enter the Society, especially not young boys, their good example and other factors will, nonetheless, help gain 'laborers to the vineyard.'"[23] The authorities, not blind to the imminent danger of misapplied talents, took great pains to ascertain the motivation of aspirants. In principle, only those found firm in their vocation were to be allowed to proceed with their studies. Yet the eagerness to recruit bright young scholars, combined with the inordinate difficulty of distinguishing between religious zeal and hankering for scholarly fame in one so young, made this a particularly difficult task. Nor were Jesuit authorities eager to dismiss those who, once admitted, retained youthful excesses or failed to keep a proper balance between scholarship and religious vocation.

Examples abound of men who were turned away for precisely these failings. Pierre-Daniel Huet's case, for example, may have been uncommon insofar as he was older than most candidates (having applied for admission after he had left school and made a name for himself), but the considerations for his rejection were not.[24] Having experienced a crisis of conscience that made him realize how "the pursuit of vulgar objects abstracts the mind from the worship of God and the contemplation of the celestial life, and even from a rigorous correction of the manners," Huet sojourned to La Flèche to join the annual retreat of the Jesuits. The serenity he experienced there fortified his conviction that he had allowed himself to be "borne away by the fire of youth, the allurements of the world, which by their variety so filled my breast, and closed up all its inlet with an infinite number of thoughts, that it gave no admission to those intimate and charming conferences with the Supreme Being"—and he thus asked to be admitted to the Order. To his surprise, his old teacher Pierre Mambrun, having carefully considered the matter and being "well acquainted both with [Huet's] disposition and manners, and with the discipline and rules of his order," discouraged him; "a mode of life absolutely dependent upon the will of another, was totally alien from the freedom of [his] spirit." At the turn of the eighteenth century, a more typical aspirant, Guido Grandi, was turned away for similar hubris. He had discovered mathematics while a student at the Jesuit College in Cremona under the private tutelage of Girolamo Saccheri, and, wishing to follow in the footsteps of his mentor, sought admission. The authorities, suspecting Grandi's zeal was misdirected, recommended he seek the "truth" elsewhere—which he promptly did, joining the Camaldolese Order instead.[25]

But such official scrutiny also failed, for the very reasons given above. Jean Bonfa is a case in point. The future astronomer joined the Order in the 1650s because, his biographer recounted, "he found nothing more conforming to his love of study."[26] Nor was he unique, though the dearth of documentation makes it difficult to impute motivation with certainty. Discussing the case of several mid-eighteenth-century Bohemian practitioners, one historian wonders whether they "were in any real sense heirs to and participants in Jesuit intellectual relations, or whether entry into the Society was merely an expediency resulting from limited educational and career opportunities." Perhaps McManners's general observation regarding recruits to Catholic religious orders holds true for some Jesuits as well: ". . . they wanted to lead a leisured existence with freedom to pursue their own interests, not easy in a society where tradition, hierarchy, and family constrained individuality."[27] For their part, the authorities rationalized that time and discipline would set straight the priorities of their precocious pupils. In this they often miscalculated. But before elaborating on the repercussions of such miscalculations, I should like to consider the practical implications of the perceived incompatibility between the Jesuit vocation and the pursuit of secular learning.

The propriety of single-minded application to scientific studies was problematic for many Jesuits not so inclined. For them, such studies were at best extraneous to the true needs and concerns of the Order; at worst they were harbingers of pernicious doctrines, especially as the seventeenth century progressed. More acute, though, was an even more immediate dilemma. As scientific talent manifested itself early, so did the desire of young Jesuits to devote themselves to such studies—even before they completed the philosophy course. Yet such eagerness to "specialize" was unlikely to elicit much sympathy. On the contrary, at this early stage in their career, scientifically minded Jesuits were most vulnerable to harassment from zealous colleagues and superiors who generally failed to appreciate the seemingly misguided passion of their young confrères. Nor were the accomplishments of budding mathematicians and astronomers sufficiently distinguished at this early stage—or sufficiently public—to attract outside support (which was quite often necessary to guarantee their pursuit, since superiors were generally eager to acquiesce to potential patrons).

The vicissitudes of an aspiring ordained mathematician may be glimpsed in the early career of a member of another religious order, the Jesuate Bonaventura Cavalieri. Having received minor orders in 1615, the 18-year-old Cavalieri was dispatched the following year to Pisa, where he met Benedetto Castelli and became his disciple. Not only did Castelli introduce his young protégé to Galileo; upon taking leave of his teaching position in Pisa in 1618 in order to teach in the Medici court, he persuaded Christina of Lorraine to intercede with Cavalieri's superiors to allow his pupil to substitute for him. What was supposed to be a summer job lasted two years, in the midst of which, in 1619, Cavalieri applied directly to the Senate of the University of Bologna for a chair of mathematics that had been vacant since Magini's death two years earlier. He was disappointed, in part because he had failed to secure Galileo's support. By the middle of 1620 his superiors ordered him to Milan to proceed with his theological studies. "I am now in my country," the despondent Cavalieri wrote Galileo a year later, "where there are these old men who expected of me greater progress in Theology as well as in preaching, you can imagine how unwillingly they see me so fond of mathematics." In the spring or summer of 1623 he was appointed Prior of S. Pietro in Lodi, from whence he launched a resolute campaign—availing himself of the good offices of, among others, Castelli, Galileo, and Cesare Marsili—designed to propel him into a professorship in mathematics. His efforts bore fruit only in 1629, when he was appointed to the chair in Bologna.[28]

Cavalieri's experience mirrored those of numerous Jesuits, though only careful scrutiny of extant correspondence enables us to piece together the tribulations of young Jesuits desperate to secure opportunities to devote themselves to scientific studies. Girolamo Saccheri is a case in point. He appears to have acquired some reputation for mathematical ingenuity early on, but upon completing his studies in Genoa he was sent to teach grammar in Cremona. In 1690, however, Saccheri was transferred to Milan to study theology. There he met Tommaso Ceva, the Professor of Mathematics, who took it upon himself to advance his confrère's career. It was at Ceva's behest that Saccheri published (in 1693) his *Quaesita Geometrica*, a small volume of solutions to several problems posed by Count Ruggerio di Ventimiglia that evidently was calculated to procure Saccheri patronage by demonstrating his ingenuity while paying homage to the nobleman and the Ceva family. Shortly after publication, Ceva forwarded a copy to Vincenzio Viviani in a further attempt to bolster Saccheri's contacts and reputation. The ensuing correspondence between the Jesuit and Galileo's last disciple proved short-lived, primarily because—as Ceva assured Viviani—Saccheri was preoccupied with his theological exercises. Subsequently, to Ceva's regret, Saccheri was not permitted to devote himself wholly to the study of mathematics but was sent instead by his superiors to teach philosophy and theology in Turin. Not until 1699 were Saccheri's friends and patrons able to secure for him the professorship of mathematics at the University of Pavia.[29]

Jean Bonfa's struggle was more protracted. Through much of the 1670s and the 1680s, the French Jesuit tried to keep up a variety of astronomical pursuits alongside his mandatory teaching of philosophy at Grenoble and, later on, of theology at Avignon. In the late 1670s Bonfa attempted to enlist the king's confessor, La Chaize, and the professor of mathematics at Clermont, Jean Fontenay, to his cause. Subsequently, the two proved instrumental in communicating his scientific work to the Académie des Sciences and in effecting his appointment as Royal Professor of hydrography at Marseilles. The appointment proved short-lived. By early 1683, Bonfa was back teaching theology in Avignon. And though he was permitted the following academic year to add the teaching of mathematics to his duties, this was but a temporary dispensation. Not to be deterred, Bonfa renewed his efforts to secure support from Parisian and Roman Jesuits as well as from the papal representatives in Avignon. At last he succeeded, and for the academic year 1687–88 he was appointed professor of mathematics at Avignon—a position he held until 1712.[30]

Equally vigorous were the efforts of Adam Kochanski to secure the conditions that would allow him to pursue his cherished scientific studies. Having entered the novitiate at Wilno in 1652, Kochanski fled the advancing Russian forces three years later. After a brief sojourn to Würzburg, where he helped Caspar Scott see *Magia universalis naturae et artisz* through to publication, Kochansky proceeded to Molsheim to study philosophy and metaphysics (1655–1657), then to Mainz to study theology and teach mathematics. Immediately upon completing his theological studies in 1664, Kochansky embarked on a campaign aimed at preventing his forced return to Poland and allowing him to devote himself to scientific research. He entreated Athanasius Kircher to intercede on his behalf with General Oliva, a ploy which resulted first in his being sent to teach in Bamberg and then, in 1666, in his being summoned to Florence to serve as mathematics tutor to Duke Ferdinand de Medici and his brother Leopold. In 1669, however, the happiest period in Kochansky's life came to an end when Oliva ordered him to Prague. Predictably, no sooner did Kochansky begin teaching mathematics there than a rift with the local superiors occurred. Not only did he avoid the tasks of pastoral care; he demanded suitable quarters for his scientific investigations, employed non-Jesuits, "owned private, unsupervised funds from his benefactors for scientific purposes," and "did not bring the College any evident profit." Small wonder that his colleagues attempted to get rid of him. Persisting in his refusal to return to his native country, Kochanski moved among various colleges in Bohemia. A fresh effort by the Lithuanian province to recall the recalcitrant Jesuit finally resulted in his being sent to Wroclaw in 1676. His priorities found no more favor there than they had in Prague, and a conflict was averted only when, in 1678, Jan III Sobieski requested that Kochansky be assigned as tutor to his son. The firebrand finally arrived in Warsaw in 1680.[31]

The struggles by many Jesuit practitioners en route to establishing a scientific vocation were only one aspect of the tribulation they endured. Multiple forms of obstruction from within the Order existed. Many of these impediments were related to the need to share living quarters with less understanding colleagues who held clashing ideologies. We know, for example, that in the late 1580s François Aguilón "constructed spheres, astrolabes and other 'mathematical' . . . tools. He had collected all parts in the attic and had only to put the last touch to the work when he found it all scattered, partly broken, and useless. Of course he regretted the time wasted but he did not complain nor did he allow investigations to discover the culprit."[32]

Again, examples drawn from other religious orders could shed light on similar attitudes and practices among the Jesuits. For instance, in 1696 the young Minim Louis Feuillée complained to the Royal Astronomer Cassini that his Provincial (i.e., overseer of his province) had confiscated a clock he had built and several books on astronomy "as being a waste of time."[33] Nor were such attitudes reserved only for junior members of religious orders.

When in 1670 John Locke visited the cell of the Capuchin Père Cherubin at the Order's convent on Rue St. Honoré in Paris, he was astonished at how such a talented optician was treated: "The Capuchins are the strictest and severest order in France," Locke recorded in his diary, "so that to mortify those of their order, they command them the most unreasonable things, irrational and ridiculous. . . . As soon as they find any one to have any inclinations any way, as Père Cherubin in optics and telescopes, they take from him all that he has done, or may be useful to him in that science, and employ him in something quite contrary; but he has now a particular lock and key to his cell, which the guardian's key opens not."[34]

Mirroring the perceived futility of a Jesuit's embracing secular studies was the Order's ambiguous attitude toward publication. The *Constitutions* were rather cryptic on the subject, merely pronouncing that "one who has talent to write books useful for the common good" may be allowed to do so. But the architects of the Order were explicit in articulating their mind on the subject, and their predisposition proved no less constraining with respect to the ability of future members to enter into print than did their promulgations regarding the need to shun novelty and defend the teachings of Aristotle and Aquinas. Cognizant of the inherent pitfalls of authorship, Alfonso Salmerón expressed diffidence regarding his own qualifications as an author, going so far as to call publishing "foreign to the Jesuit way of life" and incompatible with the Jesuit vocation: "We are called to a way of life characterized chiefly by simplicity, modesty, and unrestricted charity to our neighbor," he thundered. And though "the publication of books is not in itself incompatible with these qualities; it nonetheless can be an obstacle to more excellent works of charity and at times a distraction from them."[35] True, both Ignatius and Nadal encouraged publication of books tending to combat heresy or "guide souls to goodness and devotion," as the latter put it, but the publication of secular works was another matter.[36] However, in the 1590s—by which time the scholarly output of the Jesuits had reached alarming proportions, partly because of the need to provide textbooks on all subjects and partly because of the Jesuits' embroilment in numerous learned quarrels—General Acquaviva encouraged Suarez to publish but attempted to bridle the scholarly output of other members of the Order. "I am taking care not to allow the number of authors to grow," he wrote, further cautioning that "the publications of our Fathers are multiplying to such extent that we must moderate their zeal, laudable as it is, and we must be less easy about giving permissions" for new works. Likewise, in 1595 he informed the Provincial of Toledo: ". . . we have considered limiting these permissions, since we see our appetite for publicity increasing these last few years. It would be wiser not to grant, at least for the moment, the authorization that Father John de Salas asks, especially since Father Vasquez, Suarez, and Molina are writing on the same subject."[37]

Additional work is necessary to ascertain the reasons for the preponderance of *scriptores* and established professors among Jesuit authors. Telling in this respect is that less than 10 percent of the 244 Jesuits listed in Charles Lohr's *Latin Aristotle Commentaries: Renaissance Authors* ever ventured into print, while a handful of Parisian *scriptores* in the eighteenth century were "responsible for the majority of Jesuit publications other than missionary writings." Taking a broader view, Harris, too, notes the disproportionate representation of relatively few Jesuits among scientific and philosophical authors, with some 12 percent responsible for more than half of all Jesuit writings (including unpublished ones).[38] Clearly, then, for most Jesuits publication was the exception, not the norm—but not necessarily because they had nothing to contribute. I shall return to the constraints apropos publication, but here I wish to point out the corollary that Jesuit scientific production, especially before 1700, for the most part assumed the form of textbooks, compendia, and other reference books, not specialized treatises. This was hardly a coincidence. Censorship, including self-censorship, obviously accounted for the absence of many specialized—and "novel"—publications, as we shall see below. In addition, the prejudices regarding authorship that animated the architects of the Order continued to exert influence on subsequent generations; even that vague statement in the *Constitutions* permitting those with a "talent to write books useful for the common good" to do so was interpreted narrowly. The experience of André Tacquet was typical. Having presented General Goswin Nickel with a copy of his innovative *Cylindricorum et annularium libri IV*, Nickel responded by suggesting that Tacquet channel his talents into composing a mathematical manual for Jesuit students.[39] If the advice was not intended to disparage Tacquet's contribution, it nonetheless mirrored the official preference with respect to secular publications. Certainly, henceforth Tacquet's publications were invariably in the form of textbooks or compendia. General Carafa, too, appears to have endorsed similar views, for in 1648 he encouraged the young Francesco

Eschinardi to write a *Cursus physico-mathematicus*.[40] Naturally, even an "invitation" to write a textbook necessitated release from other duties or an established teaching position. For many years Eschinardi was not the beneficiary of either, and the book was not published until 1684. Along the way, the prospective Jesuit author had to weather numerous duties (and discouragements), as did Claude François Milliet Dechales, who taught mathematics in Lyon between 1657 and 1660 and published his celebrated textbook on Euclid that last year. Dechales was already at work on a much more ambitious textbook, *Cursus seu mundus mathematicus*, but it proved long in coming. He was dispatched on a mission to Turkey, and after his return he was assigned other duties. As Dechales intimated to Huygens in 1665, he did not know when he would be in a position to complete the third part of his book, for his superiors had assigned him to teach theology. Only after Dechales resumed his teaching of mathematics—first in 1669–70 as the King's professor of hydrography, then as a professor in Lyon and in Paris—was he able to work on his *Cursus*, which eventually appeared in 1674.[41]

Though original contributions could conceivably be "sneaked" into textbooks and other compendia, the medium was understandably restrictive. Indeed, beleaguered Jesuit authors often substituted erudition and exhaustiveness for novelty—a fact duly noted by critics quick to deride the size and pedestrian nature of most tomes. Joseph Scaliger pointed the way for such criticism when he targeted Martin-Antoine Del Rio's massive *Disquisitionum Magicarum Libri VI* (Mainz, 1593). It was an erudite book, Scaliger grudgingly admitted, but uncritical, its author a mere "collector of knowledge rather than a truly learned scholar." In no small part, Scaliger's judgement was colored by his enmity toward the Jesuits in general, and by his antipathy toward Del Rio in particular, for that "*stercus Diaboli*," as Scaliger dubbed him, not only helped win back Justus Lipsius to Catholicism but "belittled Scaliger's exposure of Pseudo-Dionysus as derivative before attacking it as unfounded."[42] Scaliger's attitude presaged a growing chorus of denigrators of the bulky treatises that became the trademark of the Jesuits. Seth Ward, Savilian Professor of Astronomy at Oxford, recalled in 1654 that his initiation into the analytical methods of Vieté, Harriot, and Descartes had been directly proportional to his deliverance from the "verbose way" and huge tomes of the likes of Clavius: "I was presently extreamly taken with it [the symbolic way], finding by this meanes, that not only the substance of those vast Volumes might be brought into the compasse of a sheet or two, but that the things thus reduced were more comprehensible and manageable." Six years later, Giovanni Alfonso Borelli showed outright disdain for Riccioli's *Almagestum novum*, which he regarded as "too expensive, too bulky, and too dull"—"a mere collection of what had already been previously published by others."[43] Less hostile, but to the same effect, was the concluding sentence of the reviewer of Dechales's *Cursus* in the *Philosophical Transactions*: ". . . what the Author hath performed *beyond* others, and how much also he hath borrowed *from* others without taking notice of his Benefactors, I must leave to the Intelligent and well-read Perusers of this Work to Judge."[44]

A critical factor in the proliferation of textbooks during the seventeenth century—and the reason for the authorities' predilection for the format—was the increasingly rigid attitude toward novelties that doomed most attempts by Jesuits to produce innovative, specialized treatises. Both the *Constitutions* and the *Ratio Studiorum* had explicitly warned members to shun novelties and follow Aristotle and Saint Thomas in their philosophical and theological studies. To ensure submission, philosophy professors were to be removed from their posts if found to be "too prone to innovations, or too liberal in their views."[45] In 1564 the young Benito Pereira put it as follows: "One should not be drawn to new opinions—that is, those which one has discovered—but one should adhere to the old and generally accepted opinions. In one's teaching one should avoid sophistic philosophizing and follow the true and sound doctrine." Two decades later, General Acquaviva exhorted members of the Order in similar terms: "Let us try, even when there is nothing to fear for faith and piety, to avoid having anyone suspect us of wanting to create something new or teaching a new doctrine. Therefore no one shall defend any opinion that goes against the axioms received in philosophy or in theology, or against that which the majority of competent men would judge is the common sentiment of the theological schools."[46]

Paradoxically, such regulatory measures notwithstanding, more often than not the Jesuits themselves were charged with begetting novelties during the late sixteenth and early seventeenth centuries. The Iberian philosophers and theologians, in particular, produced an immense scholarly edifice that not only alarmed Protestants but also provoked bitter and protracted disputes with the Dominicans, and it was in no small part in response to such controversies that General Acquaviva attempted to rein in both "novelties" and the literary production of Jesuits. In 1611 he issued an ordinance that attributed the failure of the Society to achieve its goals, despite great efforts, to an eschewing of uniformity and solidity of doctrine in Jesuit writings. Many members seemed to believe, the General complained, that it was permissible to endorse and publish any opinion so long as it had not explicitly been proscribed; others seemed to think that so long as they conformed to doctrine they could employ their talents freely to discuss a multiplicity of positions. Nevertheless, Acquaviva warned, new ways to defend accepted doctrines invariably attracted new principles, and soon novelty was added to variety. Nor was the General pleased with the increasing penchant to cite a passage from Aquinas, as if adhering to his doctrine, while otherwise belying it. Acquaviva concluded that, since admitting one daring idea often leads to a more daring one until nothing solid and uniform remains, more effective control was required. Two years later Acquaviva addressed an even more impassioned ordinance on the subject, ordering that individuals who maintained obscure and unworthy positions be removed from teaching and given other duties.[47]

A corollary of Acquaviva's claim that one daring idea leads to another might have been that each repressive measure begets another. Certainly the restrictive stance of the Generalate of Muzio Vitelleschi (1615–1645) regarding philosophical and scientific studies[48] set the conservative tone for the ensuing century. The debilitating effects of excessive control on the spirits and creativity of members was raised as early as 1578 by the German Provincial Paul Hoffaeus during discussions on the desirability of issuing a list of prohibited opinions. Writing to General Mercurian on the need to permit members a modicum of freedom in "matters pertaining to speculation," Hoffaeus insisted:

> . . . it is difficult for the intellect, which is further indulging, to be constrained until it remains within the boundaries of faith and virtue. For otherwise, a great opportunity will be missed for the exercise of ingeniousness if such narrow limits are laid down for those who deal with speculation. Indeed, very many professors, and especially the most talented among them, would be frightened if they were not allowed, for good reasons, to publish their new arguments and opinions in order to explain that which they propose, on the account of their arguing for novelty. . . . for it is the nature of these things and the nature of the best talents that they cannot do otherwise than always to discuss something new. And therefore, the variety of opinions has nothing that offends propriety except in endangering the faith and [causing] scandal.[49]

The late-sixteenth-century bid to impose a list of prohibited opinions came to naught, but Hoffaeus's observation on the likely effect of bridling *libertas philosophandi* proved prophetic. No sooner did Acquaviva issue the 1611 ordinances than officials of the Order began a more concerted effort than ever before to pressure innovators to toe the line. Particularly controversial at the time was the doctrine regarding the fluidity of the heavens. In 1614, Cristoforo Borri, who was among the first Jesuits to propagate the doctrine, ran afoul of his superiors in the Milan for teaching it. It was "improper for Jesuits to comport themselves like *novatores sententiarum*," they railed. Later that year, Acquaviva himself—who sanctioned the silencing of Borri—wrote to the young Christoph Scheiner to similar effect: "One ought not publish against the universal teaching of the Fathers and the scholastic doctors a new hypothesis which, basing itself on yet uncertain observations, maintains that the heavens are fluid, and that stars propel themselves there like fish in the ocean and birds in air."[50]

In the early years of Vitelleschi's Generalate, Christoph Grienberger, a professor of mathematics at the Collegio Romano, still attempted to press, behind the scenes, for greater openness. This is clear from Grienberger's effort to secure the publication of Biancani's *Sphaera Mundi*:

> A new *cosmographia* seems to be necessary because the old one has been changed a great deal in our day and many embellishments have been added to it. But the question has been raised as to whether it is proper for us Jesuits to do this. It seems to me that the time has now come for a greater degree of freedom of thought to be given to both mathematicians and philosophers on this matter [constitution of heavens], for the liquidity and corruptibility of the heavens are not absolutely contrary to theology or to philosophy and even much less to mathematics. . . . It seems that he [Biancani] has not exercised his talents sufficiently in writing the *Cosmographia*. But I am quite willing to excuse him about this. For up to now his hands have been tied, as have ours. Thus he has dealt with most topics in a way which is not adequate when he was not allowed to think freely about what is required.[51]

Grienberger's effort ultimately failed. However, at this early stage the fear of novelty was to a certain degree indistinguishable from the fear that the reputation of the Society would be tarnished if a Jesuit espoused a strange (and erroneous) opinion. Thus, for example, even after Scheiner was permitted to publish his observations of sunspots, his superiors forbade him to do so under his own name, "lest he be mistaken and bring discredit on the Society." Even more striking was the caution exercised with the publication of the work of Gregory of St. Vincent. Having made important contributions to mathematics during the 1610s and the 1620s (contributions that anticipated not a few of Cavalieri's results), Gregory requested permission to publish what he believed to be his most startling discovery: the squaring of the circle. General Vitelleschi referred the matter to Grienberger, who was not convinced. Even after the persistent Gregory was allowed to travel to Rome and work for two years with Grienberger, the latter desisted, judging that his confrère's effort "did contain the first steps of a solution to the problem" but that "for the moment the ideas were not sufficiently developed to lead to an acceptable result."[52] Gregory did what many Jesuits did under such circumstances: bide his time. Ultimately, his monumental *Opus geometricum* was published, with Habsburg support, in 1647, after the deaths of Grienberger and Vitelleschi.

Matters worsened once prohibited opinions were codified for the first time in 1651. "I see that I will not be able to publish my study on colors," Orazio Grassi wrote in 1652, "because of the rigorous orders made . . . in these last General Congregations, in which ours are forbidden to teach many opinions, some of which are the substance of my treatise, and they claim to prohibit them not because they consider them bad and false, but because they are new and not ordinary. It will thus be necessary for me to sacrifice them to Holy Obedience, by which I will undoubtedly gain more than I would by publishing them."[53] Whereas Grassi had responded to the 1651 Ordinance by suppressing his treatise, Melchior Cornaeus adopted a more mischievous style in dealing with proscribed doctrines. True, in a 1653 letter to Athanasius Kircher, Cornaeus derided individual unskilled in mathematics who nonetheless presumed to judge on statics, threatening that "if I am not permitted to write what I think, then I will never write anything at all." Yet even though General Nickel denied his petition to print prohibited opinions, Cornaeus published his *Curriculum philosophiae Peripateticae* in 1657, wherein he spoke his mind on a large number of delicate topics by means of a "philosophical dissimulation." Discussing the issue of levity at some length, for example, Cornaeus ultimately denied the existence of positive levity; yet, in view of the explicit proscription against such a conclusion, the German author added this: "What I have just taught about gravity and levity according to the opinion of learned men, I myself have openly taught and held for many years. Now because the authority of my superiors commands something else, I say that it is probable that gravity and levity are two positive qualities . . .

and because authority commands that we subscribe to this opinion, I subscribe and I approve it."[54]

The issue of Jesuit censorship, and the manner in which many would-be authors attempted to cope with it, has attracted considerable attention lately. Unfortunately, not enough attention has been given to an analogous issue: the general perception during the early modern period of the ambiguity with which controversial topics were often shrouded in Jesuit publications. Such ambiguity often exposed the Order to charges of dissimulation from critics who treated with indifference those who did not venture into print and with outright hostility those who published in a manner acceptable to the authorities. Instructive in this respect is the reaction to the 1672 publication of Pardies's *Discours de la Connoissance des Bestes*. "You have without doubt seen a little book by Father Pardies on the consciousness of animals," the Huguenot Esaie La Bourgeois wrote to Henry Oldenburg shortly after the book appeared. "In the first half of his book this Father puts Descartes' opinions in the best light in the world, and in such a way as to show that he accepts this opinion; and in the other half, where he speaks to refute it, you would say he only intends to jest. In the end you perceive that Father Pardies is speaking at the beginning and the Jesuit at the end."[55] Pierre Bayle, writing ten years later, concurred, depicting the book as a kind of "literary masquerade": "Everybody suspected Father Pardies to have wished to establish the opinion of M. Descartes adroitly, while pretending to refute him. Indeed, he answers well to his own objections, and those he leaves without response are so feeble, that it is not difficult to guess their meaning."[56] For his part, Father Daniel all but admitted that his confrère presented Descartes' arguments far more forcefully than he did their refutation, so that, effectively, he just about "convinced his readers." In fact, Daniel noted, the book "made the author pass among the Peripatetics for a prevaricator, who at the bottom was a Cartesian"—notwithstanding the pains he had taken in the second part of his book to refute Cartesianism and to "defend the ancient Philosophy, as to the souls of beasts." In his *Dictionary* Bayle reiterated the conclusion he had reached years earlier:

> [Pardies's book] may be reckoned among those that have been published to maintain Des Cartes' opinion; for the reasons of the Cartesians are proposed in it, with their utmost strength, and very weakly refuted. I believe nevertheless that he was not negligent in the second part of his work, and that he did all that was possible

to maintain the ancient opinion; but having also done all that he could do to represent faithfully, and in their best colors, the reasons of the new; he has made some suspect, that he had no real design to confute Des Cartes.[57]

It seems appropriate to cite contemporary estimations of Pardies's book at some length because they exemplify the inherent difficulty in inferring—then as now—the *precise* beliefs of Jesuit practitioners from their publications. Such difficulty arises not simply because the texts were obscure but because a fair judgment requires a "charitable" reading. Yet many early modern opponents of the Jesuits were averse to reading between the lines, instead welcoming the opportunity to castigate the veracity of the Jesuits on the basis of their vague (or contradictory) pronouncements. Not that such critics were blind to the predicament of members of the Order. Indeed, the need for discretion among Jesuits was common knowledge. Christoph Grienberger put it neatly in a 1613 letter to Galileo: "I don't have the same freedom as you." Two years later, Piero Dini assured Galileo that he understood that "many Jesuits are secretly of the same opinion, although they keep quiet."[58]

Galileo, though, was unwilling to empathize with the constraints facing Jesuit savants. Frustrated by their inability to publicly support him (or Copernicanism), he turned against the Order. Nor did other contemporaries prove more accepting of privately held novel theories, if they credited Jesuits with them at all. For example, when Christiaan Huygens informed Jean Chapelain in 1659 of the favorable reception of his Copernican theory of Saturn among Flemish Jesuits (he had Hessius and Tacquet in mind), his Parisian correspondent's response was as skeptical as it was damning: "I wonder that the good Fathers have become agreeable to the motion of the Earth and allow it to pass among you without opposition. But I fear that this tolerance is not general, and that for every one who will shut his eyes there are a hundred who open them wide, and find there grounds for excommunication." Several years later, having been informed of a similar open-mindedness, this time regarding two French Jesuits, Chapelain expressed little doubt but "that their mouths will be quickly stopped."[59]

Such a dismissive attitude notwithstanding, it is important to recognize that most Jesuit savants coveted membership in the republic of letters and, having once attained it, were quite open and adventurous in their discussions despite the suspicions that such exchanges, especially with "heretics," could elicit. Thus, within a year of the beginning of his correspondence with Henry Oldenburg, Pardies was made to understand that his superiors looked askance at his relations with the English. His last surviving letter to the Secretary of the Royal Society makes sad reading. After requesting Oldenburg to stop sending him issues of the *Philosophical Transactions*, Pardies asked the Secretary to stop writing to him directly:

You would also please me by using the means of a friend when one is to be found rather than the post; as I am here a member of a religious community I cannot do everything I should wish and it is reasonable to respect the opinions of those who rule over us. Nevertheless I hope that I shall lose nothing from you and that when the opportunity of a friend serves you will do me the kindness to send me what you would have sent by other routes.[60]

Discretion in communicating with non-Jesuit practitioners was not confined to Protestant contacts, as is evident from Baldigiani's instructions to Viviani—with whom he conspired to rehabilitate Galileo—regarding the handling of their correspondence:

I do not mind the delivery of the letters by means of the Fathers of the Mission, provided they content themselves with giving them personally to me and not in the presence of others, otherwise our superiors could greatly exaggerate and distort the matter [prendere ombre gagliarde]. If you do not want to go through the Fathers of the Mission, you can address the outside envelop [fare una sopraccarta] to the abbé Niccolò Baldigiani, who is my brother. Please do not communicate this paper of mine to anybody but Magalotti, whose opinion I would be very pleased to know for the time being, as well as yours, since I shall also consider you as my master. Furthermore, as this matter is so precious to me and to you, please have this paper delivered to me inclosing it in the first letter with which you will favor me.[61]

The participation of Jesuits in the republic of letters transcended personal and epistolary ties with non-members. Proud of their scientific (or literary) accomplishments, numerous Jesuit savants were determined to gain recognition by appearing in print, even if to do so required a certain amount of creative savvy: either they had to embed their results in vast compendia or they had to conceal their novelty. One such resolute member, already mentioned, was Gregory of St. Vincent. Another was Riccioli, who, as Dinis pointed out, "congratulated himself in his remarkable achievement" in managing to reconcile the Bible and the Church Fathers with recent astronomical observations. "We have saved the number of elements and of both the visible and invisible heavens," boasted Riccioli in the *Almagestum novum*, "without any superfluous orb, and with no disrespect for the work of God. We have saved the authority of the Bible, and of the Fathers and

Doctors, showing their substantial convergence. We have saved the common opinion of recent astronomers."[62]

Riccioli's protégé Francesco Maria Grimaldi took equal pride in his remarkable optical discoveries. "I am not unaware," he wrote in the preface to *Physico-mathesis de Lumine* (1665), "that he might easily suffer the charge of arrogance, who boasts, that in a matter up to now so difficult, he is able to offer something certain and evident from his own findings, contrary to what leading philosophers have found up to date in their researches and subtle arguments." Yet, Grimaldi continued, audacity could not be imputed to such a careful experimenter and observer. Rather, his search for truth forced nature to unveil certain of its secrets, compelling other practitioners to revise long-established opinions. However, getting the work published called for extraordinary measures. The censorship of Grimaldi's magnum opus, as Baldini demonstrated, focused entirely on the first volume, and it is almost certain that the second was composed hastily in the last eight months of the author's life (March–December 1662)—after the censors submitted their judgment—so that the formal structure of the second volume, with its modified scientific content, would enhance the far more controversial first volume's chances for publication. The work's title page conveys the compromise: "Two books of Physico-mathematics on light, colors, the rainbow, and other related topics, the first of which adduces new experiments and reasons deducted from them in favor of the substantiality of light. In the second, however, the arguments adduced in the first book are refuted, and the Peripatetic teaching of the accidentality of light is upheld as probable." Such a strategy could easily educe charges of duplicity, though sympathetic readers, such as the reviewer for the *Philosophical Transactions*, managed to overlook this. The first volume, the reviewer noted, "contained the several Experiments, which may favor the Doctrine of the *Substantiality* of Light, together with the Ratiocinations thence arising. In the *Second* is represented, What may be answered to all those Arguments, so as to save the *Peripatetick* Opinion of the *Accidentality* of Light: Which yet is done in such a manner, as that the Author leaveth a liberty to the Judicious Reader, to embrace which of these two Opinions he shall think the more probable."[63]

The conditions under which Jesuit publications saw light obliges us to give them the same charitable reading they were given by some contemporaries, notwithstanding the obligatory disparaging comments. As they were well aware, not only did Jesuit compendia contain important observations and experiments (as well as philosophical insights); in addition, at a time when the boundaries and the contents of the respective scientific disciplines were still unsettled, few practitioners considered the unequivocal commitment to a "modern" world view to be a sine qua non for inclusion in the scientific community. The Copernican issue is a case in point. It is striking that the vilification of both Scheiner and Riccioli in the aftermath of the Galileo affair did not prevent either the *Rosa Ursina* or the *Almagestum Novum* from acquiring influential status among astronomers, in both Catholic and Protestant lands, despite their authors' non-Copernican cosmology. Indeed, it was possible to discuss much of the subject matter of astronomy without addressing cosmology at all. But when the need arose, Jesuit practitioners increasingly opted for careful presentation of the various world systems, invariably insinuating their preference by the way they declared their allegiance to geocentrism. André Tacquet, for example, stated in his *Opera mathematica* that he adhered to the immobility of the earth "solely for theological reasons and for fear to wander off the faith, because the other proofs thus far given lack demonstrative value." Along the way, he dismissed Riccioli's efforts to prove the immobility of the earth as a waste of time, and he all but invited the Copernicans to put forth an irrefutable mathematical demonstration of the heliocentric theory. John Collins, who reviewed the book for the *Philosophical Transactions*, was not alone in inferring the true meaning of Tacquet's message. Though the Jesuit "knows no Argument, demonstrating the *Rest* of the *Earth* and *Motion* of the *Sun*," Collins wrote, "yet the Authority of the Holy Writ, now seconded by that of the Sacred Congregation of the Cardinals, put it out of doubt."[64]

Leibniz made use of the abundance of such pronouncements in Jesuit (and Catholic) writings in his efforts to induce the Catholic Church to lift its ban on Copernicanism. Dechales, Leibniz wrote, "frankly confessed that one cannot hope for another hypothesis which satisfies the mind, and most distinguished astronomers have openly admitted that they are held back from presenting the Copernican system only by the fear of censure."[65] Hence, Leibniz noted, if "the truth of a hypothesis should be taken to be nothing but its greater intelligibility," then "there would be no more distinction between those who prefer the Copernican system as the hypothesis more in agreement with the intellect, and those who defend it as the truth." For if it is "permissible to present the Copernican system as the simpler hypothesis, it would also be permissible to teach it as the truth in this particular sense." Thus, by maintaining the authority of the censors while enabling practitioners to teach, "we can finally restore philosophical freedom to those of ability, without damaging respect for the Church, and we will free Rome and Italy from the slander that great and beautiful truth are there suppressed, something that is known to be said and written widely among the English and the Dutch (not to mention the French)."[66]

Leibniz's efforts came to naught, and the official Catholic position regarding Copernicanism remained unchanged. Yet, as Heilbron has observed, although "words that seemed sincere when written by Baliani, Riccioli, or Tacquet rang hollow half a century later . . . freed from the constraint that may now seem its rationale, the hedge about the truth was not unsound. In one guise or another, the view that mathematical theories have only an instrumental value has recurred in Western thought without the guidance of the Catholic Church."[67] I will not elaborate here on the instrumentalist stance adopted by Jesuit practitioners in their publications, but it is important to recognize that whatever daring was exercised in published books was surpassed by Jesuit practices in and out of the classroom. In view of the fact that so many Jesuits taught philosophy at some stage of their career, it is hardly surprising that numerous surviving lecture notes are quite dreary in their exposition of natural philosophy—indeed, many of these simply regurgitated, sometimes verbatim, lectures delivered by their own teachers or friends. Yet the mounting evidence regarding Jesuits who got away with introducing up-to-date material into their teaching, or (more likely) got into trouble because of it, suggests the need to reconsider the scientific teaching of the Jesuits.

Consider the teaching of atomism. It was a doctrine far more controversial than cosmology, yet, beginning at the turn of the seventeenth century, not a few Jesuits incorporated the subject into their lectures. The recollections of the atomist Sebastian Basso are instructive in this respect. Basso had studied at Pont-à Mousson during the second half of the 1590s, and he was quite disparaging of the education he had received there. Yet he fondly recalled his philosophy teacher's warning not to take Aristotle as fairly representing the atomists: "I remember," Basso wrote, that "when he explained the views of Anaxagoras as given in Aristotle, our most learned preceptor Petrus Sinsonius, the outstanding professor of philosophy at the Academy of Pont-à-Mousson, said, ridiculing the faith in Aristotle: 'I believe that

Aristotle robbed these Ancients of their arms so that he could defeat them more easily unarmed.'" At Louvain around 1630, it was Willem Hesius who, "even before Descartes had done so . . . had abandoned all external qualities and distinct modes, admitted by some foolish Peripatetics as a necessary evil in dealing with generation and corruption, and instead made use of streams of particles emanating from the brain and the sun, the movements of which he lucidly explained."[68]

If philosophy teachers appear to have been initially undisturbed in their exposition of atomist ideas, by 1632 matters had changed radically, possibly as a consequence of the publication in that year of Roderigo Arriaga's *Cursus philosophicus*. "Pragam videre Arriagam audire" ran a seventeenth-century slogan, attesting to the popularity of Arriaga, a professor of philosophy and theology at Prague whose *Cursus* was approved for publication in 1630 or 1631. As was the case with Pardies three decades later, contemporaries were perplexed when it came to correlating the daring of Arriaga's philosophical ideas with his proclaimed adherence to Aristotelianism and Catholic dogma. Pierre Bayle, who admitted that Arriaga "seem[ed] to have succeeded much better in confuting what he denyed, than in defending what he affirmed," nonetheless dismissed the charges that "thereby he became a Favorer of *Pyrrhonism*." Rather, Bayle insisted, Arriaga's repeated protestations "that he was no *Pyrrhonist*" should be taken at face value:

> It would certainly be the highest injustice to suspect him of the least Prevarication, or of betraying the *Dogmatists*; for, if, on one hand, he exerted all his Strength in confuting a great number of Opinions; he employed it on the other, in supporting the Opinions, which he had embraced: It was easy to see, that he acted with Sincerity, and exerted himself to the utmost; and, if his Proofs are weaker than his Objections, the blame must be laid on the nature of the Things. . . . He gave up most of the received Opinions of the Schools in Points of Natural Philosophy, such as the Composition of the *Continuum*, Rarefaction, etc. and therefore undertook to defend the Innovators in Philosophy. It is pity so refined and penetrating a Genius had not had a better Notion of right Principles; for he might have carried them very far.[69]

Whether permission for its publication was granted because the *Cursus* was dedicated to Emperor Ferdinand II or because (as Arriaga argued later) such ideas were accepted in Prague, the spectacle of a renowned Jesuit maintaining atomism in public prompted the proscription of such ideas in Rome on August 1, 1632. Six months later, General Vitelleschi formulated his strong opposition to mathematical atomism in a letter he dispatched to Ignace Cappon in Dole: "As regards the opinion on quantity made up of indivisibles, I have already written to the Provinces many times that it is in no way approved by me and up to now I have allowed nobody to propose it or defend it. If it has ever been explained or defended, it was done without my knowledge. Rather, I demonstrated clearly to Cardinal Giovanni de Lugo himself that I did not wish our members to treat or disseminate that opinion." However, the routine reissuing of such injunctions in subsequent years and the unflagging efforts of the censors to expunge such a doctrine from Jesuit books attest to the continued dissemination of atomism within the Order.[70] Indeed, in 1649 the teaching of the "Zenonist doctrine" by an unnamed German professor who claimed to have followed Arriaga, coupled with the far more embarrassing public exposition of such ideas by Sforza Pallavicino in the Collegio Romano, provoked General Carafa to issue yet another injunction, which in turn precipitated the codification of a list of prohibited opinions two years later.[71] Not even that measure was sufficient to bridle Jesuit professors, as the case of Father Giuseppe Ricci makes clear. Ricci—Vico's teacher at Naples in 1683—is singled out in Vico's autobiography as "a man of penetrating insight, a Scotist by sect but at bottom a Zenonist." Ricci continued to expound his atomist ideas until 1687 when the Roman authorities issued a list of seven propositions that he was forbidden to teach. Ricci's superiors immediately removed him from teaching philosophy, and for the next 13 years he was assigned to teach cases of conscience.[72]

The measures taken against audacious Jesuits were not simply a manifestation of a conservative rejection of new ideas per se. Rather, they were often motivated by the determination to preserve the philosophical edifice upon which Catholic dogma rested and prevent the corruption of impressionistic youth. Hence, regardless of how compelling any alternative philosophical system might become, it could not be allowed to dominate the philosophy course. Tellingly, the 1651 Ordination culminated decade-long complaints from various provinces protesting not only the ominous spread of pernicious doctrines but also the professors' willful subverting the order of teaching, their wasting time in "endless disputes about useless questions," their failing to cover the required material, and their taking excessive liberty in mixing philosophy and theology. The Revisors further fueled the crisis by remonstrating that "Aristotle and Thomas had been laughed out of the Order."[73] It is against this background that we should read the 1646 admonition of Leone Santi, Prefect of Studies at the Collegio Romano:

Scholastic theology signifies none other than that which supposes Aristotelian philosophy. If, therefore, our authors commonly depart from Aristotle, they are transmitting not non-scholastic theology, but, as some would say, fantastic theology, for each individual forges his own with great confusion and perturbation to the Church. But how much less can someone defend and explain the theology of Saint Thomas in his theological conclusions . . . if in his philosophy he departs from the principles of Aristotle and the entire Peripatetic school? For unless minds are contained within certain limits their excursions into exotic and new doctrines will then be infinite, as will their ways of talking, with constant danger lest we should be brought before the Holy Tribunal of the Inquisition.[74]

The problem was hardly unique to the Jesuits. On both sides of the confessional divide we find theologians in consternation over the rupture of the philosophical basis of theology caused by the new science. In his famous 1642 letter to Father Dinet, Descartes himself enumerated the reasons for the opposition his philosophy encountered among Dutch Calvinists:

The professors reject this new philosophy for three reasons. First, it is opposed to the traditional philosophy which universities throughout the world have hitherto taught on the best advice, and it undermines its foundations. Second, it turns away the young from this sound and traditional philosophy and prevents them reaching the heights of erudition; for once they have begun to rely on the new philosophy and its supposed solutions, they are unable to understand the technical terms which are commonly used in the books of traditional authors and in the lectures and debates of their professors. And, lastly, various false and absurd opinions either follow from the new philosophy or can be rashly deduced by the young—opinions which are in conflict with other disciplines and faculties and above all with orthodox theology.[75]

But whereas the perceived need to preserve scholastic philosophy quickly abated among Protestants during the second half of the seventeenth century, it remained acute among Catholics. Indeed, as late as the middle of the eighteenth century we find Carlo Benvenuti, a protégé of Roger Joseph Boscovich, stirring up a storm at the Collegio Romano precisely for such reasons. Having expounded a truly modernist natural philosophy in two successive public disputations, the young Jesuit aggravated matters by immediately publishing the theses. Alessandro Centurione, the Superior of Italy—who would become General the following year—charged Benvenuti with disobedience and demanded his removal from the College. Significantly, however, Centurione was not particularly troubled by Benvenuti's substitution of Newtonian explanations for those of Aristotle or Descartes.

Rather, he complained that the *Synopsis physicae generalis* published by the young Jesuit had effectively turned natural philosophy into a mathematical and experimental science and "omitted almost entirely the traditional topics of physical ontology, pneumatology, and natural theology"—topics central to the educational objectives of the Society, which sought to unify physics, metaphysics, and theology. Benvenuti was banished from Rome, but Boscovich mobilized Pope Benedict XIV on his behalf. The outcome was described by the pope: "The flame of dissention which had erupted between the Fathers of the Collegio Romano and their General" (who, "being uniquely attached to the peripatetic philosophy, did not approve any of the theses held and defended in the Roman College, and applauded by those Fathers who were aware of the sound but modern philosophy") had died down. The theses were allowed to stand, and at the pope's demand Benvenuti was appointed professor of Sacred Liturgy at the Collegio Romano—a chair Benedict had founded a few years earlier.[76]

Removal of audacious Jesuits from teaching philosophy, as stipulated in the founding documents of the Society, became a popular measure against those charged with introducing novel ideas into the classroom. Cristoforo Borri, as I noted earlier, was removed from his teaching position in Milan in 1614 after senior members of the College complained to Acquaviva about his expounding, among other novel ideas, the doctrine of the fluidity of the heavens. Three decades later it was the superiors of the Lyons Collège who protested Honoré Fabri's controversial teachings. Fabri, a correspondent told Mersenne, was "at odds with the Fathers of his Society. And it is believed that they did all they could to make him leave, just as they did all they could to stop the printing of his works." Fabri was relieved of his teaching duties and sent to Rome as Penitentiary to St. Peter's. His onetime student Pardies found that his colleagues and superiors at La Rochelle, and then in Bordeaux (where he taught between 1666–1670), were equally resentful of his predilection to "pursue strange opinions avidly," and consequently Pardies ultimately found himself promoted to a professorship of mathematics at Clermont. For his part, Grimaldi was said to have been transferred from the chair of philosophy to that of mathematics for health reasons, yet it is quite likely that his radical ideas on the nature of light contributed to the decision.[77] Many others were made to reconsider their religious vocations by being appointed to teach theology or to engage in edifying writing—as was the lot of Giulio Cesare Cordara, a professor of philosophy at Macerata who was "removed from the chair for his inclination for innovation and called to Rome to finish the History of the Society."[78]

The handling of spirited Jesuits is better illustrated by the efforts made in the early eighteenth century to subdue Jesuit followers of Malebranche. Yves-Marie André was the most outspoken among them. His friendship with the Oratorian and his active role in disseminating Malebranche's philosophy resulted in his rustication at La Flèche in 1705. There Andrè joined Fathers Rodolphe du Tertre and Joseph-Michel Aubert and proceeded to convert other young Jesuits such as François de La pillonnière, who ultimately left the Society and turned Calvinist. The concerned superiors began their crackdown by removing Aubert from teaching philosophy and later sending him to teach mathematics in Caen. Du Tertre's disciplining was more severe: he was banished to Compiègne to teach rhetoric. Mortified, and claiming to have received no advanced warning, the Jesuit concluded that he had been made an example to intimidate others. Within a year, du Tertre began to reconsider his philosophical and religious positions, and in 1715 his retraction of previous beliefs was made public in his poignant *Réfutation d'un nouveau système de métaphysique*. André reacted bitterly to his confrère's about-face, even composing a "*burlesque métamorphose*" that derided the manner in which du Tertre, upon being demoted to teach a lower class, disowned his philosophy and all his convictions—"he went to bed Malebranchist and woke up the next morning a peripatetic." André himself was initially allowed to resume teaching philosophy, but he appears to have strained the patience of his superiors everywhere he turned, with the result that he was repeatedly disciplined and even incarcerated in the Bastille for a while.[79]

Ultimately, however, formal teaching mattered less than instruction outside the classroom, since interest in advanced scientific and philosophical ideas had always been the domain of a relatively small number of individuals who could be introduced to new ideas far more easily (and profitably) in private. The *Ratio* already acknowledged the importance of extracurricular instruction in the mathematical sciences. Inspired by Clavius, its authors allowed that "if there are some . . . who are fitted and inclined toward these studies, let them be practiced in them in private lessons after the end of the course." That was precisely what the professors did, sometimes on a large scale. For example, soon after he was appointed professor in the Collegio Romano, Baldigiani told Viviani that he could hardly spare an hour for his own studies as he tutored more than a hundred students—many of whom were members of the upper class—and expected to turn at least twelve of them into skilled geometers. These students did not include members of the Order, whom Baldigiani also trained.[80]

There is no mistaking the indispensability of private instruction to the formation of scientific interests among Jesuit and non-Jesuit students alike. One need only recall the contribution of the school of Clavius in Rome, or that of Gregory of St. Vincent in Flanders, to the formation of many seventeenth-century luminaries. Elsewhere, other committed Jesuits filled similar functions. I have already mentioned the influence of Biancani on Riccioli in Parma, and that of Ceva on Saccheri in Milan; I will now add Christoph Scheiner's private studies with Johann Lantz in Ingolstadt and Scheiner's own training of Johann Baptist Cysat after Scheiner became a professor of mathematics at Ingolstadt.[81] The non-Jesuit savants included Nicolas Fabri de Peiresc, who was "in a special manner inflamed with the study of Mathematicks" while at Tournon during the late 1590s. The astronomical observations carried on by the Jesuit fathers there, as well as in Avignon, undoubtedly helped inspire Peiresc's initiative in later years to coordinate global collaborative observations.[82] Similarly, Evangelista Torricelli, while studying mathematics and philosophy at Faenza in 1625 and 1626, exhibited such talent and aptitude that "his uncle was persuaded to send him to Rome for further education at the school run by Benedetto Castelli." Two decades later, Gian Domenico Cassini discovered mathematics and astronomy while a student at the Jesuit College in Genoa; he subsequently embarked on a study of astronomy under the guidance of Riccioli and Grimaldi in Bologna.[83] Late in life, Buffon recalled how his interest in mathematics had been ignited while he was at school in Dijon in the years 1717–1723. He "had studied mathematics at an early age with intensity," he recalled, always carrying a copy of Euclid in his pocket. Subsequently, under the tutelage of the professor of mathematics Jean-Baptist Péricaudet, Buffon was introduced to higher mathematics. Unlike Buffon, whose passion for mathematics stood in inverse proportion to his loathing of the literary aspects of the curriculum, Jérôme de Lalande excelled in both. After discovering astronomy at age 12 in 1744, when a comet appeared, Lalande proceeded to study mathematics and astronomy under Joseph-Laurent Béraud (also the mentor of Jean Étienne Montucla and Charles Bossut). He composed his first astronomical work while still at the Collège. In 1748 he assisted Béraud in observing a solar eclipse.[84]

Equally important, at any given moment most Jesuit colleges were likely to be inhabited by talented mathematicians and natural philosophers who did not officially teach these subjects but who were willing and able to privately enhance the studies of young members. One example should suffice. Pierre Daniel Huet studied at Caen during the mid 1640s and was introduced to mathematics by the professor of philosophy Pierre Mambrun, who took immediate notice of the youth and "resolved to bestow peculiar pains in forming" him outside the normal course. Huet, however, became enamored with mathematics and "spent days and nights" in the study of geometry, much to Mambrun's chagrin. Mambrun feared that such premature excessive preoccupation would hamper Huet's philosophical studies. But once Huet had completed the required course, Mambrun goaded him to resume his mathematical studies. Not being a mathematician himself, Mambrun approached Erade Bille, a professor of moral philosophy who "possessed consummate knowledge in the abstruse sciences, which was concealed under a veil of singular modesty," to assume the role of Huet's "moderator and guide." Two other philomaths then in the Collège—George Fournier (who taught mathematics at La Flèche, Dieppe, and Hesdin between 1628 and 1644) and another professor of philosophy, Pierre Gautruche—were equally enthusiastic in lending a hand to advance the mathematical knowledge of the talented and eager Huet.[85]

This example testifies to the need to cast a truly wide net in evaluating the caliber of Jesuit practitioners, especially those who did not publish. Luigi Confalonieri is a case in point. Educated at the Collegio Romano, he subsequently taught the triennial course of logic, natural philosophy, and metaphysics there before being sent in 1638 to teach theology and moral philosophy in Milan. Confalonieri shunned publication, and were one to rely solely on the account of him that Castelli sent to Galileo in 1637 one probably would form a rather low opinion of this Jesuit. Castelli—whose animosity toward the Jesuits was heightened after Galileo's condemnation—described a prank played on Confalonieri by his students, who solicited his opinion on an experiment pertaining to the relations between light and heat whose results they had skewed. Confalonieri allegedly produced an explanation that conformed to traditional Aristotelian philosophy and persisted in defending his original interpretation—even after the deception had been revealed—by contesting the validity of the experiment. Castelli concluded, with evident glee, that "the intellect and the brain of this philosopher find it easier and more ready to assent to false conclusions than to true ones: and then show how easily the mind is reduced to philosophize about falsehood rather than truth."[86] Yet the chance survival of the correspondence between Confalonieri and Giovanni Battista Baliani, which commenced shortly after the Jesuit's arrival in Milan, gives Confalonieri a depth absent from the caricature drawn by Castelli. Far from being a slavish follower of the Stagirite, Confalonieri emerges as both averse to Aristotelianism and receptive to new ideas. Indeed, he appears to have been one of the earliest readers of Descartes in Italy[87] and an adherent of atomism. Yet Confalonieri did not covet martyrdom, and in 1639 he freely admitted that he was not free to teach in public what he believed. "Confalonieri was probably an example of that doctrinal doubleness of which many Jesuits were accused," Constantini concluded:

> . . . while in their public function as teachers they leaned towards the compulsory uniformity of doctrine, which was sternly imposed in the Order during the 1640s, and with understandable repugnance put on the garments of the 'solemn peripatetic,' in a more personal and modest sphere of activity they joined many others . . . who, though within the limitations of recent condemnations pronounced by the Church, worked for a progressive dismantling of the assumptions of the traditional culture.[88]

We know more about Confalonieri's younger French contemporary, Jean Bertet. This talented Jesuit is generally mentioned, if at all, in order to charge him with inadvertently bringing about the placement of Descartes on the index of prohibited books by transmitting to Fabri the correspondence between Descartes and Mesland. However, not only is there no evidence to implicate Fabri himself in the 1663 action by the Congregation of the Index; Bertet would certainly not have been involved in such a plot. He entered the Society in 1637, at age 15. After completing his studies and then teaching humanities for eight years, he spent most of the 1650s teaching philosophy and practicing astronomy. He communicated his observations of the 1652 comet to Gassendi, whom he admired and in whose honor he composed *Soteria pro Petro Gassendo, huius aetatis philosophorum principe, Recens è Peripneumonia recreato* in 1654. By the end of the 1650s, though, Bertet had shifted his loyalty to Descartes. In 1659, having recently been appointed professor of mathematics at Aix, Bertet initiated a correspondence with Clerselier, informing the editor of Descartes's correspondence that thanks to his (Clerselier) efforts, young members of the Order—including Bertet himself—were beginning to become devotees of Cartesian philosophy. He abandoned Gassendi's physics, the Jesuit informed Clerselier, on the ground that it did not "penetrate to the very origin of things." It is quite possible, in fact, that Bertet was sent to teach mathematics in Aix after being removed, on account of his Cartesian views, from teaching philosophy at Grenoble.

Bertet wanted to do more than simply disseminate Descartes's philosophy among his confreres. Like Mesland in the previous decade, he was intent to rehabilitate Descartes's orthodoxy as well, and to this end he asked Clerselier's opinion on a small treatise he (Bertet) had composed on the philosophy of the Eucharist based on Cartesian principles.[89] In the aftermath of the proscription of Descartes's books, Clerselier allowed himself to be convinced that the Jesuits were to blame, and the correspondence with Bertet was terminated. But the latter remained an unwavering advocate of Descartes, and when in 1671 the University of Paris launched a campaign against Descartes, Bertet wrote wryly to John Collins: "There is a great rumor in the University of Paris concerning Cartesius's doctrine, which they would condemn as being contrary to the mystery of the Eucharist; but our faith may be explicated according to the principles of every philosophy." Bertet was also a convinced Copernican, and in 1665 he told Constantyn Huygens that the orbit of the then visible comet confirmed him in this belief. In 1689, no longer a Jesuit, Bertet could be found in Rome, conspiring with Leibniz and Baldigiani to get the ban on Copernicanism lifted.[90]

Both Confalonieri and Bertet were fully cognizant of the disciplinary measures taken by the Jesuit authorities to ensure conformity. It may seem surprising that, notwithstanding such measures (which must have been applied to hundreds of Jesuit philosophers and mathematicians in the course of the early modern period), only a few Jesuits left or were expelled from the Society as a consequence of such measures. In part, this is a testimony to the gravity with which Jesuit practitioners took their vows. But it is also clear that for most members—who never doubted the primacy of the religious mission of the Society even when they differed on the extent of the dangers that the new philosophies posed to the traditional relations between philosophy and theology—the constraints were a burden to be contended with from within the Order. Many continued to preach the benefit of at least a modicum of philosophical freedom, even in print. Honoré Fabri was among them, and in his *Euphyandrus* he made the following point:

In the field of politics it is characteristic of human society to have and maintain trust in another; in the field of literature however, it is not like that: for though authority may be of great weight, if it lacks entirely the support of reason, I do not see that Euphyander should assent and surrender himself to it. Hence he should not swear by the words of the master unless truth is the master; nor should he by the same token be bound to the Thomists or the Scotists; let all his friends be lovers of truth. . . . let Euphyander maintain freedom of thought, let him enslave himself to no party lest he be forced to serve error, let him remain always in that state which he may freely judge about the truth of a subject that is proposed, in brief let him surrender to reason and its demonstration alone.[91]

A younger contemporary of Fabri, Antoine Rochon, who got into trouble for espousing Cartesian philosophy, concluded his public retraction in a similar vein: "Allow me," he pleaded, "the liberty to choose that which will please me of Mr. Descartes, and in this manner I shall be able to well accommodate his philosophy to mine. For just as formerly God permitted the Hebrews to marry their captives, after they have purified and had washed from them the last traces of infidelity, so, after having scrubbed and purified the philosophy of M. Descartes, I might indeed be able to embrace his opinions. It is the opinion of Saint Jerome who made use of this example to show that Christians can accommodate the works of pagan Philosophers."[92]

Others practitioners complained in private of their (or the Society's) lot. "While I was in the Collegio Romano," Daniel Bartoli wrote Lana Terzi in 1677, "I wished to set up an academy dedicated to experiments, and to studies related to them, but I was unable, and realised that if one began to open one's eyes to modern things, there would be no market for the nonsense which we teach and the students would abandon the Master. We deserve the harm which we suffer. As regards the metaphysical nonsense, we do not teach natural philosophy nor do we know a thing about it. The explanation for this is that there are masters who impart errors through maliciousness rather than ignorance."[93] Nearly 100 years later, Boscovich still decried the myopia of those in power, who could scarcely differentiate between the new natural philosophy and heresy. "Believe me," he wrote to his brother in 1760, "I turn cold at the thought of having to return [to the Collegio Romano], I have lost all my love for that house though you should know that there are many people there who have been good to me. Those who are good don't count and the studies of those who count will come to nothing. There, if you are not a Peripatetic you are a heretic. . . . If you say that a material thing is active or is capable of moving it means to give admittance to disbelievers and approach materialism. I preach that the most harm done to Religion is to try to tie it to physical things."[94]

Many a Jesuit savant, like Boscovich, remained in the Order and, wearing the professor's gown, taught, experimented, and wrote at one of the several hundred colleges operated by the Society. And while these savants vehemently denied that the philosophy and science they taught (or wished to teach) was conducive to heresy, it became a truism long before the dissolution of the Order that the literary diet at Jesuit colleges was enough to usher in full-blown secularism—especially when compared with the dogmatism inculcated in Jansenist schools. "There was no humanistic nonsense in the Jansenist schools," one historian put it. "So they did not breed freethinkers or even deists, but only nonentities. Instead of producing Voltaire and Diderot they nurtured the trained gadflies who fed on these great men."[95] This brings us back to the educative mission of the Order. Long ago Samuel Johnson remarked that "not to name the school or the masters of men illustrious for literature, is a kind of historical fraud, by which honest fame is injuriously diminished."[96] We are still far from being fully conscious of the enormous contribution of Jesuit teachers to the formation of Catholic secular culture during the early modern period. That the Jesuit fathers cared for more than 200,000 children and adolescents each year is staggering in itself. But we may also recall that the Jesuits produced Torricelli, Descartes, Mersenne, Fontenelle, Laplace, Volta, Diderot, Helvétius, Condorcet, Turgot, Voltaire, Vico, and Muratori, to name but a few non-Jesuits. I will conclude by applying the insight of Father Porée—a renowned teacher of rhetoric at the Collège Louis-le-Grand—to the scientific and philosophical domains. When Porée, who entertained some literary pretensions, was told that his former student Voltaire had cited him as "not one of the great poets," the Jesuit promptly retorted: "At least [Voltaire] may grant that I have been able to make some of them."[97]

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Notes

1. George Sarton, "Vindication of Father Hell," *Isis* 35 (1944): 97–105. Hell's observations were in fact published in Copenhagen in 1770.

2. Hell's older contemporary Boscovich encountered similar prejudices, notably from D'Alembert. See e.g. Luigi Pepe, "Boscovich and the Mathematical Historiography of His Time. An Unpublished Letter by d'Alembert," in *R. J. Boscovich*, ed. P. Bursill-Hall (Rome, 1993).

3. Anthony Grafton, "The Soul's Entrepreneurs," *New York Review of Books*, March 3, 1994, p. 33.

4. *The Correspondence of Isaac Newton*, ed. H. Turnbull et al. (Cambridge, 1959–1977), volume I, p. 135. For the uncommon demands that Newton's terse and often obscure paper made on its readers, by virtue of its overturning "so many received ideas and introduced so many new concepts" as well as being deliberately belligerent, see Alan F. Shapiro, "The Gradual Acceptance of Newton's Theory of Light and Color, 1672–1727," *Perspectives on Science* 4 (1996), p. 66.

5. Paolo Rossi, "The Scientist," in *Baroque Personae*, ed. R. Villari (Chicago, 1995), pp. 285–286.

6. Richard F. Littledale and Ethelerd L. Taunton, "Jesuits," *Encyclopaedia Britannica* (Cambridge and New York, 1911), volume XV, pp. 341–342.

7. Helvétius, *A Treatise on Man* (London 1777; reprint: New York, 1969), volume I, pp. 76–77.

8. Gerard Manley Hopkins, *Selected Letters*, ed. C. Phillips (Oxford, 1990), pp. 163–165.

9. Steven J. Harris, "Introduction," *Early Science and Medicine* 1 (1996), p. 284.

10. Isabelle Pantin, "Is Clavius Worth Reappraising? The Impact of a Jesuit Mathematical Teacher on the Eve of the Astronomical Revolution," *Studies in History and Philosophy of Science* 27 (1996): 593–598.

11. See the essay by Baldini in this volume.

12. Michael John Gorman, The Scientific Counter-Revolution: Mathematics, Natural Philosophy and Experimentalism in Jesuit Culture, 1580–c. 1670, Ph.D. thesis, European University Institute, Florence, 1998, p. 18; John W. O'Malley, *The First Jesuits* (Cambridge, Mass., 1993), p. 214.

13. Aldo Scaglione, *The Liberal Arts and the Jesuit College System* (Amsterdam and Philadelphia, 1986), p. 5; Steven J. Harris, "Transposing the Merton Thesis: Apostolic Spirituality and the Establishment of the Jesuit Scientific Tradition," *Science in Context* 3 (1989), p. 31 and n. 4. See also Harris, "Confession-Building, Long-Distance Networks, and the Organization of Jesuit Science," *Early Science and Medicine* 1 (1996): 287–318.

14. Scaglione, *The Liberal Arts and the Jesuit College System*, p. 52; Paul Richard Blum, "Apostolato Dei Collegi: On the Integration of Humanism in the Educational Programme of the Jesuits," *History of Universities* 5 (1985), p. 109.

15. Pietro Redondi, *Galileo Heretic* (Princeton, 1987), p. 289.

16. Scaglione, *The Liberal Arts and the Jesuit College System*, p. 66. The Constitutions "wish to leave nothing to chance or improvisation, and one wonders whether such an aptitude to prescribe, formalize, and institutionalize, down to the most minute details could really be implemented."

17. Denis Diderot, ed., *Encyclopédie, au dictionnaire raisonné des sciences, des arts et des métiers, par une société de gens de lettres* (Paris, 1751–1765), volume VIII, p. 513a. Diderot may have derived such an image from Étienne Pasquier's ferociously anti-Jesuit *Catéchisme des jésuites* (1593). Pasquier vehemently denounced there the "hermaphroditic" character of "this monster which, being neither Secular nor Regular, was both things together, thereby introducing into our Church a Hermaphrodite Order" (cited in Jean Lacouture, *Jesuits*, Washington, 1995, p. 348).

18. William Law, *A Serious Call to a Devout and Holy Life*, ed. P. Stanwood (New York, 1978), pp. 250–251.

19. Henry Harrisse, *L'abbé Prevost; histoire de sa vie et des oeuvres d'aprés des documents nouveaux* (Paris, 1896; reprint: New York, 1972), p. 15. For a partial translation, see John McManners, *Church and Society in Eighteenth-Century France* (Oxford, 1998), volume I, p. 607.

20. *The Correspondence of Henry Oldenburg*, ed. A. Hall and M. Hall (Madison and London, 1965–86), volume VIII, p. 144.

21. Ivana Gambaro, *Astronomia e Tecniche di Ricerca nelle Lettere di G. B. Riccioli ad A. Kircher* (Genoa, 1989), p. 79. See the essay by Dinis in this volume.

22. Riccioli, *Almagestum novum* (Bologna, 1651), volume I, p. xvii; Riccioli, *Astronomiae reformatae tomi duo* (Bologna, 1665), p. xii, cited in Alfredo de Oliviera Dinis, The Cosmology of Giovanni Battista Riccioli, Ph.D. thesis, Cambridge University, 1989, p. 20.

23. O'Malley, *The First Jesuits*, p. 212.

24. The Constitutions explicitly discouraged recruiting older "men of letters who are both good and learned" because "of the great labors and the great abnegation of oneself which are required in the Society." The Society followed another path: "Our procedure will be to admit young men who because of their good habits of life and ability give hope that they will become both virtuous and learned in order to labor in the vineyard of Christ." (*The Constitutions of the Society of Jesus*, St. Louis, 1970, pp. 172–173)

25. *Memoirs of the Life of Peter Daniel Huet, Bishop of Avranches: Written by Himself* (London, 1810), volume I, pp. 238–241; Luigi Tenca, "Relazioni fra Gerolamo Saccheri e il suo Allievo Guido Grandi," *Studia Ghisleriana* 1 (1952), p. 23, cited in Linda Allegri, The Mathematical Works of Girolamo Saccheri, S. J. (1667–1733), Ph.D. thesis, Columbia University, 1960, p. 29.

26. Menard, *Histoire civile, écclésiastique, et littéraire de Nismes* (1755), volume VI, pp. 516–517. I owe this reference to Alice Stroup.

27. Paul Shore, "Universalism, Rationalism, and Nationalism among the Jesuits of Bohemia, 1770–1800," in *Progrés et violence au XVIIIe siècle*, ed. V. Cossy and D. Dawson (Paris, 2001), p. 77; McManners, *Church and Society in Eighteenth-Century France*, volume I, pp. 508–509.

28. *Le Opere di Galileo Galilei*, ed. A. Favaro (Florence, 1890–1909), volume XIII, p. 71; Enrico Giusti, *Bonaventura Cavalieri and the Theory of Indivisibles* (Bologna, 1980), pp. 5–11.

29. Antonio Favaro, "Due Lettere inedite del P. Girolamo Saccheri . . . a Vincenzio Viviani," *Rivista di Fisica e Scienze Naturali* 4 (1903), pp. 426, 430–431; Linda Allegri, The Mathematical Works of Girolamo Saccheri, S. J. (1667–1733), Ph.D. thesis, Columbia University, 1960, pp. 45–51.

30. Karl A. F. Fischer, "Jesuiten-Mathematiker in der Französischen und Italienischen Assistenz bis 1762 bzw. 1773," *Archivum Historicum Societatis Iesu* 52 (1983), pp. 61, 57; Alice Stroup, "Le Comté Venaissin (1696) of Jean Bonfa, S. J.: A Paradoxical Map by an Accidental Cartographer," *Imago Mundi* 47 (1995): 118–137, esp. pp. 122, 129, 136–137.

31. Ludwik Grzebien, "Kochanski and the Jesuits," *Organon* 14 (1978): 51–59.

32. August Ziggelaar, *François de Aguilón S. J. (1567–1617) Scientist and Architect* (Rome, 1983), p. 35.

33. Archives de l'Observatoire, Paris, B. 4. 10. I am grateful to Alice Stroup for this reference.

34. Peter, *Lord King, The Life and Letters of John Locke* (reprint: New York and London, 1984), p. 85.

35. Salmerón himself consented to publish only under pressure from the General, and only after he was provided with assistants.

36. William V. Bangert, *Claude Jay and Alfonso Salmerón: Two Early Jesuits* (Chicago, 1985), pp. 329, 335; O'Malley, *The Early Jesuits*, pp. 114–115; Constitutions of the Society of Jesus, p. 284.

37. Joseph H. Fichter, *Man of Spain: A Biography of Francis Suarez* (New York, 1940), p. 157.

38. C. W. T. Blackwell, "The Case of Honoré Fabri and the Historiography of Sixteenth and Seventeenth Century Jesuit Aristotelianism in Protestant History of Philosophy: Sturm, Morhof and Brucker," *Nouvelles de la Republique des Lettres* 1 (1995): 49–77, on p. 65; Catherine M. Northeast, *The Parisian Jesuits and the Enlightenment 1700–1762* (Oxford, 1991), p. 3; Harris, "Transporting the Merton Thesis," p. 40.

39. H. Bosmans, "André Tacquet (S.J.) et son Traité d''Arithmétique Théorique at Pratique,'" *Isis* 9 (1927), p. 72.

40. Cited in Maurizio Torrini, *Dopo Galileo: Una Polemica Scientifica (1684–1711)* (Florence, 1979), p. 88.

41. *Oeuvres Complètes de Christiaan Huygens* (The Hague, 1888–1950), p. 347; Fischer, "Jesuiten-Mathematiker," pp. 61, 62.

42. Mark Morford, *Stoics and Neostoics: Rubens and the Circle of Lipsius* (Princeton, 1991), pp. 119–120; Anthony Grafton, *Joseph Scaliger: A Study in the History of Classical Scholarship* (Oxford, 1983–1993), volume II, p. 700.

43. [Seth Ward], *Vindiciae Academiarum* (Oxford, 1654), p. 20; Dinis, Cosmology of Giovanni Battista Riccioli, p. 193.

44. *Philosophical Transactions* 9 (1674–75), p. 233.

45. *St. Ignatius and the Ratio Studiorum*, ed. E. Fitzpatrick (New York and London, 1953), p. 126.

46. *Monumenta Paedagogica Societatis Iesu*, volume II, p. 667, cited in Rivka Feldhay, *Galileo and the Church* (Cambridge and New York, 1995), p. 137; Camille de Rochemonteix, *Un Collège de Jésuites aux 17e et 18e siècles: Le Collège d'Henry IV à la Flèche* (Le Mans, 1899), volume IV, p. 12, cited in Roger Ariew, *Descartes and the Last Scholastics* (Ithaca, 1999), p. 17.

47. *Ratio studiorum et Institutiones Scholasticae Societatis* Jesu, ed. G. Pachtler (Berlin, 1890), volume 3, pp. 12–20.

48. Ugo Baldini, *Legem Impone Subactis: Studi su Filosofia e Scienza dei Gesuiti in Italia 1540–1632* (Rome, 1992), p. 242, n. 1.

49. *Monumenta Paedagogica Societatis Iesu*, volume IV, p. 745, cited in Feldhay, *Galileo and the Church*, pp. 142–143.

50. Michel-Pierre Lerner, "L'entrée de Tycho Brahe chez les jésuites ou le chant du cygne de Clavius," in *Les Jésuites à la Renaissance*, ed. L. Giard (Paris, 1995), p. 157; Joseph Brucker, *La Compagnie de Jésus*, second edition (Paris, 1919), p. 494.

51. Baldini, *Legem Impone Subactis*, pp. 235–236, tr. in Richard J. Blackwell, *Galileo, Bellarmine, and the Bible* (Notre Dame, 1991), p. 152 (translation slightly modified).

52. William R. Shea, *Galileo's Intellectual Revolution* (London, 1972), p. 49; Herman Van Looy, "A Chronology and Historical Analysis of the Mathematical Manuscripts of Gregorius a Sancto Vincentio," *Historia Mathematica* 11 (1984): 57–75, on p. 58. See also Paul P. Bockstaele, "Four Letters from Gregorius A S. Vincentio to Christopher Grienberger," *Janus* 56 (1970): 191–202.

53. Claudio Constantini, *Baliani e I Gesuiti* (Florence, 1969), p. 108, cited on pp. 181–182 of Gorman, "The Scientific Counter-Revolution."

54. Marcus Hellyer, "'Because the Authority of My Superiors Commands': Censorship, Physics and the German Jesuits," *Early Science and Medicine* 1 (1996): 319–354, on p. 345. See also Paul Richard Blum, "Science and Scholasticism in Melchior Cornaeus SJ," in *Proceedings of the 6th International Congress of Neo Latin Studies*, ed. S. Revard et al. (Binghamton, 1988), p. 576.

55. *Correspondence of Henry Oldenburg*, volume IX, p. 72.

56. Bayle, *Nouvelles de la République des Lettres* (1684), cited in Leonora C. Rosenfield, *From Beast-Macine to Man-Macine: Animal Soul in French Letters from Descartes to La Mettrie* (New York, 1941), p. 219, n. 24.

57. *The Dictionary Historical and Critical of Mr. Peter Bayle*, second edition, rev. Pierre Des Maizeaux (London, 1735 reprint: New York, 1984), volume IV, p. 902, note C. In 1726 an author in the *Mémoires des Trévoux* explained that "although [Pardies] swallowed Cartesian science to the extent to which it was generally accepted, he put up as strong a defense of the Peripatetic view of animal soul as possible."

58. *Opere di Galileo Galilei*, volume XI, p. 480; vol XII, p. 181.

59. *Oeuvres Complètes de Christiaan Huygens*, volume II, p. 529; *Lettres de Jean Chapelain, de l'Academie francaise*, ed. P. Tamizey de Larroque (Paris, 1880–1883), volume II, p. 67.

60. With marked heaviness, Pardies added that he would have accompanied the Duc de Béthune to Calais had there been an opportunity for him to travel "a little farther and coming to see you." He continued: "I confess to you that I should take great satisfaction in having the benefit of seeing you and so many of the famous people who make up your Royal Society." (*Correspondence of Henry Oldenburg*, volume IX, pp. 134–135)

61. Antonio Favaro, "Miscellanea Galileiana inedita," *Memorie del Reale Instituto Veneto di Scienze Lettere ed Arti* 22 (1882), p. 838, tr. in Domenico Bertoloni Meli, "Leibniz on the Censorship of the Copernican System," *Studia Leibnitiana* 20 (1988), p. 35, n. 81.

62. Dinis, Cosmology of Giovanni Battista Riccioli, p. 113.

63. Francis A. Mc Grath, Grimaldi's Fluid Theory of Light, MSC thesis, University of London, 1969; Baldini, *Legem Impone Subactis*, pp. 101–103 and p. 118, n. 130; *Philosophical Transactions* 6 (1671), p. 3068.

64. Bosmans, "André Tacquet," p. 74; *Philosophical Transactions* 3 (1668), p. 870. For a fuller discussion of Tacquet, see Vanpaemel's essay in this volume.

65. A reviewer of Dechales's *Cursus* pointed out that the author "explodes the Fear of a Vacuum" in his section on statics, and that when treating magnetism he "intimates . . . that if the Authority of the H. Scriptures did not hinder, the Consideration of the Verture of the Magnet would add much of Probability to the Copernican System." (*Philosophical Transactions* 9, 1674, p. 230)

66. *Leibniz, Philosophical Essays*, ed. R. Ariew and D. Garber (Indianapolis, 1989), pp. 2–93.

67. John L. Heilbron, *The Sun in the Church: Cathedrals as Solar Observations* (Cambridge, Mass., 1999), p. 206.

68. Philosophia naturalis adversus Aristotelem libri XII (1621), p. 13, cited in C. H. Lüthy, "Thoughts and Circumstances of Sébastien Basson, Analysis, Micro-History, Questions," *Early Science and Medicine* 2 (1997), pp. 36–37; O. Van de Vyver, "L'école de mathématiques des jésuites de la province flandro-belge au XVIIe siècle," *Archivum Historicum Societatis Iesu* 46 (1980), p. 269 (translation from Vanpaemel's essay in this volume).

69. *The Dictionary Historical and Critical of Mr. Peter Bayle*, volume I, pp. 506–507; K. Eschweiler, "Roderigo de Arriaga, S. J. Ein Beitrag zur Geschichte der Barockscholastik," *Spanische Forschungen* 3 (1931): 253–285.

70. Constantini, *Baliani e I Gesuiti*, pp. 59–60; Michael John Gorman, "A Matter of Faith? Christoph Scheiner, Jesuit censorship and the Trial of Galileo," *Perspectives on Science* 4 (1996), p. 297.

71. *Ratio studiorum et Institutiones Scholasticae Societatis* Jesu, ed. Pachtler, volume III, p. 75.

72. *The Autobiography of Giambattista Vico* (Ithaca, 1990), pp. 114; Romano Gatto, *Tra Scienza e immaginazione. Le matematiche presso il collegio gesuitico*

napoletano (1552–1670 ca.) (Florence, 1994), p. 264 and n. 640; P. Rossi, "I punti di Zenone: una preistoria vichiana," volume XIII (1998), pp. 377–426.

73. Brucker, *Compagnie de Jésus*, p. 769; Blum, "Science and Scholasticism in Melchior Cornaeus," pp. 573–580; Hellyer, "'Because the Authority of My Superiors Commands,'" p. 328.

74. Gorman, "Scientific Counter-Revolution," p. 177.

75. *The Philosophical Writings of Descartes*, ed. J. Cottingham et al. (Cambridge, 1984–91), volume II, p. 393, n. 1.

76. Ugo Baldini, "Teoria Boscovichiana, Newtonismo, Eliocentrismo: Dibattiti nel Collegio Romano e nella Congregazione dell'Indice a metà Settecento," in *Saggi sulla Cultura della Compagnia di Gesù (secolu XVI–XVIII)* (Padua, 2000); *Le Lettere di Benedetto XIV al Card. de Tencin, 1735–1758*, ed. E. Morelli (Rome, 1965), volume III, p. 169.

77. Domingo M. Gomes dos Santos, 'Vicissitudes da obra do P. Cristóvão Borri,' *Anais da Academia Portuguesa de História*, second series, 3 (1951), p. 143; *Correspondance du P. Marin Mersenne Religieux Minime*, ed. P. Tannery et al. (Paris, 1945–1988), volume XV, p. 245; DSB; Vasco Ronchi, "Padre Grimaldi e il suo tempo," *Physis* 5 (1963): 368–369.

78. Germano Paoli, "Boscovich and Enlightenment," in *Bicentennial Commemoration of R. G. Boscovich*, ed. M. Bossi and P. Tucci (Milan, 1988), p. 230.

79. Camille de Rochemonteix, *Un Collège de Jésuites aux 17e et 18e siècles: Le Collège d'Henry IV à la Flèche* (Le Mans, 1889), pp. 82–106.

80. *St. Ignatius and the Ratio Studiorum*, ed. Fitzpatrick, p. 130; Favaro, "Miscellanea Galileiana inedita," pp. 849–850. Among the Jesuits, Baldigiani singled out Pantaleo Balbi, who performed well during a public examination in the presence of the General but who could not devote himself entirely to mathematics since he was still a student of philosophy.

81. Steven J. Harris, "Les Chaires de mathématiques," in *Les Jésuites à la Renaissance*, ed. Giard, pp. 251–252.

82. Pierre Gassendi, *The Mirrour of True Nobility and Gentility. Being the Life of the Renowned Nicholaus Claudius Febricius Lord of Peiresc* (London, 1657), pp. 13–14. According to Pierre Humbert (*Les Astronomes Français de 1610 à 1667*, Draguignan, 1942, p. 61), Peiresc's passion was aroused through the teaching of Pierre Royer, who later served as Professor of Mathematics at Avignon just at the time when Peiresc began carrying out his telescopic observations at Aix. Fischer, "Jesuiten-Mathematiker," p. 57.

83. DSB s.v. Torricelli; Cassini.

84. "Hérault de Séchelles' visit to Buffon (1785)," in *From Natural History to the History of Nature*, ed. J. Lyon and P. Sloane (Notre Dame and London, 1981), pp. 364, 382; Hélène Monod-Cassidy, "Un astronome-philosophe, Jérôme de Lalande," *Studies on Voltaire and Eighteenth-Century Studies* 56 (1967), p. 907.

85. *Memoirs of the Life of Peter Daniel Huet*, volume I, pp. 23–29.

86. Galileo, *Opere*, volume XVII, pp. 121–123.

87. Confalonieri discussed the *Discours* with Antonio Santini, who was instrumental in the diffusion of the book in Italy, and with Baliani.

88. *Baliani e i Gesuiti*, pp. 19–69, 111–133, quote on pp. 21–22, cited in W. E. Knowles Middleton, "Science at Rome, 1675–1700, and the Accademia Fisicomathematica of Giovanni Giustino Ciampini," *British Journal for the History of Science* 8 (1975), p. 150.

89. The treatise was "Traité de la présence réelle, de la transubstantiation, du sacrifice de la Messe, oú toutes les disputes sur ce suject sont recueillies, avec une concorde de tous les anciens Péres avec les controversistes modernes."

90. Paul Lemaire, *Le Cartésianisme chez les Bénédictins: Dom Robert Desgabets* (Paris, 1901), pp. 105–111; Fischer, "Jesuiten-Mathematiker," pp. 57, 61; Humbert, *Astronomes Français*, pp. 22–23; *Oeuvres Complètes de Christiaan Huygens*, p. 327; S. P. Rigaud, *Correspondence of Scientific Men of the Seventeenth Century* (Oxford, 1841), vol I, p. 157; Meli, "Leibniz on the Censorship of the Copernican System," p. 33.

91. Honoré Fabri, *Euphyandrus* (Lyon, 1669), pp. 61–62, cited in Blackwell, "The Case of Honoré Fabri," p. 57.

92. Lettre d'un philosophe à un Cartésien. See Pierre-Antoine Fabre, "Dépouilles d'Egypt: L'expurgation des Auteurs Latins dans le Collèges Jésuites," in *Les Jésuites à la Renaissance*, ed. Giard, pp. 55–76.

93. Michael John Gorman, "Jesuit Explorations of the Torricellian Space: Carp-Bladders and Sulphurous Fumes," *Mélange de L'Ecole Française de Rome* 106 (1994), pp. 7–8.

94. Germano Paoli, "Boscovich and Enlightenment," in *Proceedings of the Bicentennial Commemoration of R. G. Boscovich*, ed. M. Bossi and P. Tucci (Milan, 1988), pp. 232–233.

95. Theodore Besterman, *Voltaire* (Chicago, 1976), p. 34.

96. Samuel Johnson, *Lives of the English Poets*, ed. G. Birkbeck Hill (Oxford, 1905), volume II, p. 81.

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The Academy of Mathematics of the Collegio Romano from 1553 to 1612

Ugo Baldini

A Historical-Institutional Portrait

Most recent studies on the contribution of the Collegio Romano to the origins of modern science focus on methodological, dynamic, and kinematic topics.[1] Consequently, since the division of disciplines in Jesuit higher education was still essentially scholastic, the contribution of members of the Order, and specifically their influence on Galileo, has been examined almost exclusively in relation to logic and natural philosophy, the disciplines that dealt with those topics. Those disciplines, however, were within the domain of the philosophers of the College, a community that by formation, methods, and epistemological ideals was highly distinct from that of the mathematicians. Admittedly, historians have studied Christoph Clavius, head of the mathematicians in the College, but this was done predominantly in order to discuss certain methodological or cosmological issues that were treated, explicitly or implicitly, in his writings—and with few exceptions connected with the debate over heliocentrism—rather than to analyze their scientific content in the technical sense. With a few exceptions, these ideas were in agreement with the general orientation of thought in the Society: a modified Thomistic Aristotelianism, the orientation of which had implications not only in astronomy and physics but also in epistemology and the philosophy of mathematics.[2] Be this as it may, it is certainly improper either to consider these topics as the most significant aspect of Clavius's works or to assume that they were sufficient to deny the autonomy and value of his entire scientific research. Furthermore, it has been documented that there was a divergence of opinion between Jesuit philosophers and mathematicians, both in the Collegio Romano and elsewhere, on such issues as the physical acceptability of the eccentric and epicyclical orbits.[3] Oddly enough, though, recent studies still prefer to consider the possible influence exerted on Galileo by some professors of the Collegio Romano whom he did not know personally, and whose interests and competence were quite different from his own, while the influence of members of Clavius's group, whose relations with Galileo were as important as they were public, has been considered only perfunctorily. When considered at all, the group's work was restricted to topics such as Clavius's commentary on Sacrobosco, or the confirmation by the astronomers of the Collegio Romano of the telescopic observations announced in the *Sidereus nuncius*.

Apart from the relations with Galileo, the substantive scientific activity carried on in the College before 1610 has been little studied. Even when specific theses and other results published by Clavius were examined by historians of mathematics and of astronomy, they were carried out independently of each other. Besides, there exists no adequate scientific biography of Clavius, and no reliable analysis of his role as teacher and author within the institutional structure of the Collegio Romano. Thus the work of his students and collaborators remains largely ignored and unanalyzed.[4] Nor has there been any attempt to differentiate Clavius's activity as a public professor of mathematics (a task assigned to others after 1590) and his activity as director of advanced instruction and research in the "academy of mathematics" at the College—a position he held until 1610, and informally until his death two years later. Consequently, the distinct pedagogical aim of all his works has been interpreted to mean that they were designed for the public course of study. Such an assumption is unwarranted, as the teaching of the mathematical sciences both at Rome and in other Jesuit colleges was quite elementary and did not include many advanced topics that were fully treated in Clavius's works.[5] Clavius stated in the prefaces to several of his works that they had originated as notes for his courses, but he was referring to his work in the Academy, not in the public lecture hall.

The structure and contents of Clavius's works provide invaluable information on the organization of the Academy and on its scientific work, although they were enlarged and modified before being published.[6] Other documents, both institutional and biographical, further permit us to reconstruct the life of the Academy and its role in the development of the mathematical sciences in the decisive years around the turn of the seventeenth century. This role was much more significant than that of supporting or opposing the ideas of Galileo—the almost exclusive context within which the

College has been considered. In other words, the relation of the mathematicians of the Collegio Romano with Galileo was only one aspect of an extensive activity in a broad range of research in the mathematical disciplines, including many sectors in which Galileo did not play much of a role. Furthermore, it is very difficult to point at similar examples (in Italy or elsewhere in Europe) during those years. For these reasons, the mathematical work of academicians merits full historical investigation for its own sake and not as a part or by-product of work focused on other figures or events.

It would be useful to begin the analysis of the institution with an examination of its title. In Renaissance Italy, 'Academy' was an ambiguous term. Originally derived from the school of Plato, it underscored the un-Aristotelian character of the educational program of academic groups while emphasizing the fact that their activity had to do with an advanced level of instruction. Insofar as Aristotelian philosophy furnished the conceptual structure for university instruction and for the higher forms of the religious orders, 'Academy' had been first used for various cultural sites outside those institutions. Nevertheless, in addition to using the term to denote private and informal assemblies (or ones having rules different from those governing the official institutions), there was soon added the designation of a scholastic institution of a higher level or a specialized nature. Consequently the semantic content of the term was broadened to include any group or pedagogical form whose object was the examination (through lectures or debates) of an advanced learned topic, or one sufficiently specialized not to be included in the ordinary course of instruction.

Because of this dynamic, 'academy' was applied to a remarkably diverse range of occasions, including a single lecture or debate on a given topic; a course of lectures on a specific theme; an extra-scholastic group (of the post-university variety) privately dedicated to cultural activities of various kinds; a special school for the study of subjects excluded from, or marginally treated in, ordinary instruction (e.g., the Florentine Academy of Design, which contributed to the formation of Galileo); advanced instruction carried on by a group within an official higher scholastic institution (e.g., a university or the *studium generale* of a religious order); and even the scholastic institution itself.[7]

The Jesuit system of instruction included "academic" components from the start, though in a limited sense, commensurate with the range of meanings listed above. For the most part, however, these "academic" components were either of the first type (lectures delivered weekly or monthly by the more accomplished students in the courses) or of the fifth (advanced courses in the various disciplines, intended for exceptional students of the ordinary course and those who had distinguished themselves it previous years).[8] Hence, they did not denote a specific and distinct level of the curriculum, much less special schools dedicated to topics or disciplines not covered by the ordinary course. Rather, they were activities, usually not obligatory, intended to enrich the ordinary program. As will be demonstrated below, the Academy of mathematics transcended such a typology. With Clavius as its architect, it contributed not only to the history of the mathematical disciplines and of scientific institutions, but also to the evolution of the system of education (and not only of the Jesuits)—a context within which it has seldom been considered.

In the Jesuit curriculum, 'mathematics' [mathematica, mathesis, mathematicae scientiae] retained its broad medieval and Renaissance sense. It included all the disciplines in which the use of arithmetical and geometrical methods was essential—not only "pure" mathematics, but also such "middle" or "mixed" disciplines as optics, statics, astronomy, and acoustics. The designation of a discipline as mixed meant that its demonstrations were identified with chains of syllogisms, at least one of which had as a premise, as well as a mathematical proposition in the strict sense (an abstract relation of quantity), a physical proposition—that is, the measurements, or the laws, of one or more objects or phenomena. Thus, the fact that a discipline was held to be "mathematical" resulted less from a conceptual "essence" than from the historical fact that some areas of research into nature had adopted, in the classical or medieval period, quantitative methods, while others had not. The latter, under the name of physics, remained within natural philosophy and included much of what was to become mathematical physics, especially mechanics in the sense of the theory of motion. Consequently, Archimedean statics and the theory of simple machines were excluded. Thus, if one premise of a demonstration in mixed mathematics pertained to a physical fact or law, irrespective of whether it was the original work of the mathematician who formulated it, it properly belonged to natural philosophy—that is, to the elaboration of the Aristotelian tradition interpreted by the philosophers of the Order. This circumstance is crucial to our understanding of Clavius's work and of the work of the Academy and of Jesuit mathematicians in general well into the second half of the seventeenth century.[9]

A second prerequisite for analyzing "Clavius's Academy," as it was often called, is establishing its chronology.[10] The Academy existed already during the period 1553–1560, when B. Torres was the first mathematics lecturer in the Collegio Romano.[11] But it appears to have been irregular then, with only a few students.[12] There exist no records about the Academy for the years 1561–1563, when the mathematics lecturer was a Bohemian named A. Baucek.[13] But the fact that Clavius, who arrived to Rome from Coimbra in 1561, continued his studies in mathematics during this period and, subsequently, was chosen to succeed Baucek—probably at the latter's recommendation—suggests that the informal activity continued. In any event, an academy existed from the time Clavius took over in 1563, since his course in the following year on Sacrobosco's *Sphaera* contains a much more advanced analysis than had been traditional in the public course.[14] Biographical details concerning Clavius's students in these years—the Scot J. Hay, the Englishman J. Bosgrave, and the Italian B. Ricci—further substantiate the pre-1570 existence of the Academy.[15] By 1580, Clavius also attempted to persuade his superiors to officially establish the Academy as a two- or three-year course for promising Jesuits. In a document titled *Ordo servandus in addiscendis disciplinis mathematicis*, he formulated in some detail three programs for it (respectively, for a one-year, a two-year, and a three-year course).[16] Although the superiors denied his request, they enhanced the status of the professor of mathematics and the status of the discipline—hitherto distinctly subordinate to philosophy and theology. A renewed effort by Clavius while the first draft of the *Ratio studiorum* (1586) was being written was opposed by the philosophers of the Collegio Romano, most notably by B. Pereira, and the Academy remained an informal course until 1593 or 1594. In the latter year, Clavius, whose prestige both within and outside the Order had increased considerably, in no small part thanks to his central role in the Gregorian reform of the calendar, presented fresh proposals to the new rector of the college, the future cardinal Robert Bellarmine (his friend since student years), and these were approved. The documents detailing these proposals are invaluable for our understanding of the epistemology, the practice, and the social uses of mathematics during the sixteenth century.[17]

Clavius's project, perhaps also presented to the Fifth General Congregation of the Order (1593–94), was ultimately implemented, albeit with some modifications and restrictions.[18] The Academy became a distinct pedagogical unit, and admission to it required nomination by the professor of mathematics in any Jesuit college as well as by the superiors of the province in which the student lived. In contrast to earlier practices, attendance at the Academy exempted the student from concurrently taking the two advanced courses of study specified by the Constitution of the Order: philosophy and theology. Attendance took place usually in the interval between the first course (the second year of which was devoted to mathematics) and the second. Ordinarily, during this interval young Jesuits were required to teach Latin grammar in one of the colleges; but those attending the Academy were exempted from such duty.

Until the reform of 1593–94, the advanced course taught by Clavius was an academy in the fifth sense described above (similar to those of rhetoric, philosophy, and theology but, unlike them, unofficial). After the reform, the course metamorphosed into something not precedented in the scholastic history of the Society—or perhaps of any organization. It became a pedagogical level that was both integral to an educational institution and independent of it, while at the same time carrying the ordinary *cursus* to a higher level. Clavius's original intention was even more ambitious, for his *Discursus de modo et via, qua Societas Jesu . . . augere hominum de se opinionem . . . possit* called for the founding of a new type of academy not only for mathematics, but for rhetoric, Greek, and Hebrew as well. These innovations were rejected, though they were later implemented in a much more modest form, but that did not diminish the importance of the project.

Such a chronology explains why only after 1594 did the *catalogi* of the Collegio Romano—which recorded all resident Jesuits superiors, professors, and students (though not the lay ones)—begin to specify a distinct group of *mathematicians* (the official title of those attending the academy). A list of these students can easily be assembled from 1594 on, though not for the preceding years, since the *catologi* would have registered such students under the headings of philosophy or theology. However, various documents, as well as Clavius's correspondence, enable us to identify about fifteen students for the period 1563–1594. For the next 18 years we find some 25 *mathematici*, denoting very small incoming classes. On average, attendance was shorter than originally envisaged by Clavius, as few stayed for three years.[19] During the second period, however, in addition to the official courses of the Academy, Clavius and his collaborators continued to offer integrative courses of the former type to students of philosophy or theology—including non-Jesuits—who wished to pursue further what they had learned in the ordinary course of mathematics. The number of such students cannot be determined with precision. However, from Christopher Grienberger's letters to Clavius, during the latter's stay at Naples in 1595–96, we learn about ten individuals for the period 1594–1596 alone.[20] It is not clear whether the two groups shared classes. The programs, however, were distinct, since the attendance of the non-mathematicians—who had to attend other courses as well—was necessarily affected, as was the length of time they could remain in the Academy. As to the mathematicians, the surviving documents and the expertise they subsequently exhibited, attest to the rigor of the program. There existed a symbiosis between students and professors, facilitated by a common membership in the Order and by the fact that both groups resided in the college. Furthermore, through the rigid structure of the Order and the close relations among its members, the outside world perceived the Academy as a tight collective body, for the official pronouncements of the professor of mathematics represented the judgment of the entire body (or its most qualified members),[21] while the results of students and collaborators were often included in the writings of Clavius or of his successors.[22]

Documentary evidence for the life of the Academy after Clavius's death is scanty. Informal advanced courses for students of philosophy and theology undoubtedly continued, to judge from the number of future professors of mathematics and scientists-missionaries that graduated the College. Until about 1630, the high technical level of such courses was also ensured thanks to teachers and collaborators such as Grienberger, O. van Maelcote, O. Grassi, P. Guldin, and Gregory of St. Vincent.[23] Yet the formal Academy seems to have dissolved not long after the death of its founder, as the *catalogi* fail to mention "mathematicians" after 1615. Whatever the causes, the demise of the Academy proved ominous. From about 1630, and especially after Grienberger's death in 1636, the mathematical school of the Collegio Romano lost its vitality for reasons that are still unclear.[24] A partial recovery of the technical level of the instruction, if not of the scientific productivity of the students, began when G. de Gottignies, who had studied in Belgium with A. Tacquet, was appointed professor of mathematics, but the trend was definitely reversed only during the tenure of O. Borgondio, Boscovich's teacher, between 1712 and 1740.[25]

Organizations and Programs

Clavius's writings, and the subsequent careers of his students, show that there were three essential reasons for the existence of the Academy. The first reason, which can be called internal, is the training of technical specialists (architects, surveyors, administrators) for the needs of the Order. The other two, which can be called external, are the training of a pedagogical corps for the growing number of colleges (the scarcity of instructors of mathematics was a recurring problem in all provinces in the first century of the history of the Order) and the training of missionaries with sufficient scientific expertise for the demands of their activity in remote places, where they could not avail themselves to the assistance of specialists. Ostensibly, these functions were not sufficient to impose particularly high standards, and hence there was seemingly little need to make the Academy the site of advanced research in addition to teaching. But, as Clavius observed, if the Jesuit colleges were to distinguish themselves from secular universities, especially Protestant ones, so that their pedagogical excellence would advance the religious aims of the Society, it was essential that the instruction in mathematics be of the highest level, and that the professors be renowned for their original contributions to the discipline as well as for their pedagogical competence. In addition, many documents show that it was considered desirable that the scientific training of at least some missionaries be sufficient not only to perform certain tasks but also to attach credit to their religious teaching. For these reasons, and also as a consequence of Clavius's talent, in the Academy pedagogy and research were closely associated from the start. This fusion, along with the institutional configuration of the academy and the almost global diffusion of the specialists it trained, made it unique in the scientific history of Europe before the middle of the seventeenth century.

Unfortunately, the documentation is still insufficient for a complete reconstruction. But it is clear that every year Clavius or one of his collaborators, like Grienberger and Maelcote, offered additional courses on specialized topics that were not treated, or were treated incidentally, in the official course. It is unlikely, however, that even in three years (the maximum period of attendance) all topics could be covered in separate courses. However, in view of the familiarity of the Academy's graduates with the greater part of the program, it is possible that the courses themselves treated only some topics—and not necessarily the same in every cycle—and that the rest were left for personal study, periodically supervised by Clavius and his collaborators.[26]

The gaps in the documentation also prevent us from fully understanding the mechanisms of certification that was followed. It is possible that an examination was given at the end of each year, and that, owing to the private nature of the academy, in the archive contains no traces of these examinations. It is also possible that formal examinations were held by "academies" in the first sense, those consisting of lessons taken by each student on assigned themes.

In his last years, Clavius was assisted by a small group who functioned either as teachers or as research assistants and technicians. This group included men who were to succeed Clavius as professors of mathematics after 1590 (C. Grienberger, G. Fuligatti, G. Alperio,[27] O. van Maelcote, O. Grassi) and former academicians capable of participating in research and of advising younger students, such as Lembo and Guldin. These persons performed most of the research carried out in the Academy and presented the mathematical culture of the College to the outside world on such occasions as Maelcote's lecture on the 1604 supernova, the lecture on Galileo's observations in 1611, and the reply by the mathematicians of the College to the letter of Cardinal Bellarmine, who had requested their judgment on such observations.[28]

The courses were interspersed with lectures by the students on themes agreed upon by the instructors. These lectures assumed the form of an examination in which the student was expected to demonstrate his ability to offer an up-to-date synthesis of knowledge or theories discussed. In addition, they could also present new results, since they could accommodate the student's own original research. Thus, results obtained by Grienberger or Maelcote were published in Clavius's works and in those of other Jesuit mathematicians, or were mentioned in Clavius's correspondence. It is well documented that theorems, projects for instruments, and other works by members of the Academy were not only circulated internally but also communicated to former students or researchers connected with the Academy. Consequently, their research was characterized by its epistemological distinctiveness and the contents of its programs, as well as by a certain control over results that came to be publicly known only after publication. And publication, when it happened, seems to have been determined by the head of the Academy rather than the author.[29]

The publication of members' results, as well as the diffusion within the Academy of work done by others, often correlated to the visits by Italian and foreign mathematicians to the Collegio Romano. J. H. Beyer, G. A. Magini, A. van Roomen, Galileo, F. Mordente, M. Ghetaldi, J. Schreck, and J. Remus Quietanus (Ruderauf) are but the better-known individuals who performed the almost obligatory pilgrimage to the Roman College before 1612. Some such visits failed to generate lasting scientific exchange; others resulted in scientific correspondence that often proved noteworthy both for its duration and content.[30] In the case of those who remained in Rome, the initial visit occasioned many subsequent meetings, not only with the head of the Academy but other members as well. The significance of this to the mathematical research carried on in the Academy can be illustrated by the following example. Between 1601 and 1605, M. Ghetaldi and then J. Schreck arrived at Rome. They had studied privately with Viète in France, and during their prolonged stay in Rome they were frequent visitors to Clavius and the Academy. En route from France to Rome, both Ghetaldi and J. Schreck stopped at Padua and Venice, and that itinerary accounts for the fact that the two principal centers for the study of Viète in Italy in the first decade of the seventeenth century were the Collegio Romano and a group of mathematicians in Venice—A. Sarpi, A. Santini, and G. C. Gloriosi.[31] Although it cannot be proved, it appears likely that Ghetaldi's and Schreck's frequent visits to Clavius and his collaborators (or those by others before and since) involved, in addition to conversations, active participation in the Academy's work.[32] In the case of Ghetaldi, that can be shown that there existed a scientific exchange with Clavius and that the tradition of the College influenced his interests and research.[33]

If the Academy was a point of attraction to foreign mathematicians who visited Rome, it was even more so to residents in the city or of the Pontifical State. Among the hundreds of students that Clavius trained during some 50 years of pedagogical activity in the Collegio Romano a significant minority attended the private courses he gave to non-Jesuit students (not admitted to the Academy), the content of which was probably the same of those imparted to academicians. Some continued to cultivate the mathematical sciences either professionally or in private; many of them (not necessarily clerics) remained at Rome or in its environs, and continued to visit the College or correspond with him. The best-known, Luca Valerio, became a mathematician of the first rank and established an important position as a professor of mathematics in the university of Rome. But others, too, published scientific works, or helped distribute those of members of the Collegio Romano, and some even reached high positions in the ecclesiastical hierarchy. They formed the nucleus of competent practitioners who inhabited the Pontifical State and mitigated the condemnation of heliocentrism in 1616, that of Galileo in 1633, and the somewhat general reaction against science that gained some ground in certain parts of catholic learning during the seventeenth century, and that threatened a more serious alienation of state and church from scientific studies.[34]

Before 1590 the academicians' major field of research—as distinct from their teaching and from applied domains such as gnomonics—appears to focus more on mathematics than astronomy. Moreover, during that period their interest in astronomy was primarily theoretical or calculatory, involving geometrical analysis of apparent motions, the construction of tables, and the theory of measuring instruments rather than sustained observational activity utilizing advanced methods. The inadequacy of traditional planetary models and the obvious discrepancies between what was observed and what available astronomical tables contained—a problem upon which Clavius reflected as early as 1580—did not give rise to observational work aiming to put the discipline on new foundations. Instead, Clavius and his students hoped that the geometrical analysis of apparent motions could produce a new geocentric schemes congruent with the traditional measurements, and expected the observational work of other astronomers to furnish data that would make possible such new schemes. After 1590 this attitude began to change as Tycho Brahe's observations became available[35] and thanks to such celebrated phenomena as the 1600 pseudo-nova in the Swan, the 1604 supernova, and the comet of 1607. Such phenomena appeared irreconcilable with Aristotelian physics and, consequently, had given them a higher theoretical potential. But in view of the new standards established by Brahe, the development of observational activity among the Jesuits of the Collegio Romano necessitated more exact instruments. Hence, before the telescope was introduced, members of the Academy began to construct instruments, and soon there existed two groups of specialists among the members. The first may be described as pure mathematicians—Guldin or St. Vincent, for example—even though they occasionally participated in observations. The second included individuals with a solid grounding in mathematics, but who were far more competent in the construction of instruments and observational astronomy, the likes of Grassi and, above all, Lembo.[36] The instruments, including the telescopes that were used in the crucial years 1610 and 1611, were partly constructed in the College and partly imported from Venice.[37] Unfortunately, we lack contemporary descriptions of them and records of observations, to allow us to infer their nature and quality. The many descriptions of instruments in Clavius's works are unhelpful, as they were written before the diffusion of Brahe's standards of precision, and before the Academy began to construct better ones.[38]

Another important part of the Academy's equipment, the mathematical library of the college (not to be confused with the general library, called *major*, or *secret*) had a different fate.[39] Reserved for the academicians' use, the mathematical library included some books that had been purchased and some that had been provided by the authors or by other benefactors. The library was founded in the 1550s, during Torres's term as lecturer in mathematics, and it appears that it was utilized by both Jesuit and external students.[40] Clavius's correspondence demonstrates that he had often received information of recent publications from Jesuit colleagues throughout Europe as well as from lay correspondents. (One faithful informant was A. Van Roomen, an habitual visitor at the Frankfurt book fair.) Thus, Clavius was able to furnish the Collegio Romano with many important publications. At the time of his death, the mathematical library was certainly one of the largest (perhaps the largest) of its kind in Europe. It included practically all the classics, as well as most contemporary texts in pure and mixed mathematical sciences. Consequently, a reconstruction of its catalogue and an examination of surviving books could offer invaluable information both on the manner in which Clavius synthesized contemporary mathematical learning and on the state of learning in Rome, as the library was the main repository of mathematical books in the city until the end of the eighteenth century, and much superior in this respect to the University of Rome's library. Hence it proved the training place for generations of practitioners, not only Jesuits but of lay specialists who played a central role in Roman, and Italian, cultural life. Many presentation copies include handwritten dedications by the authors, offering important—and little-used—clues to intellectual biography. Moreover, marginalia by Clavius or his pupils (mainly Grienberger) is often technically important.[41] A complete reconstruction, however, is difficult, both because of the way the college's books were absorbed into Rome's Biblioteca Nazionale and because of some dispersion that affected especially the mathematical books.[42]

Finally, an essential part of the organizational structure of the Academy were the programs of study. As mentioned earlier, these were laid out in the *Ordo servandus in adddiscendis disciplinis mathematicis*, written about 1580, and it is unlikely to have changed radically after Clavius's death. From these documents it is possible to extract an inventory of the thematic areas that were covered, whose order corresponded at least broadly to a chronological order of study (see appendix C):

1. elementary plane geometry (books I–IV of Euclid's *Elements* and their later developments)
2. elementary arithmetic and its applications
3. the sphere and ecclesiastical computation
4. theory of proportions and its applications to magnitudes (books IV–VI of the *Elements* and their later developments)
5. theory of measuring instruments
6. advanced arithmetic (books VII–X of the *Elements* and their later developments)
7. algebra
8. elementary solid geometry (books XI–XIII of the *Elements*, then the Pseudo-Euclidean books XIV and XV and their later developments)
9. plane and solid trigonometry
10. theory and use of the astrolabe
11. gnomonics
12. geography
13. practical geometry
14. optics
15. particular problems of astronomy
16. theory of the planets and of the eighth sphere, and the use of the tables
17. musical theory[43]
18. advanced geometry (works of Archimedes)
19. statics and theory of simple machines
20. problems of the geometry of conics.

In the *Ordo* Clavius explained that he would use as texts as many of his works as were already published, and that he intended to write others for the remainder parts of the program. He realized much of his design, as can be seen by an examination of his works, both printed and in manuscript.[44]

His original intention was that his works be coextensive with the entire range of the Renaissance mathematical sciences. He seems never to have doubted the basic lines of the classification of those sciences, and he seems to have intended to treat the developments between 1570 and 1610 in astronomy, in statics, and in optics as amplifications or modifications of existing domains, but not to radically redesign the disciplines and their relationships. Insofar as his death coincided with changes that rendered traditional classification obsolete in pure and mixed mathematics, it is probable that important programmatic changes were introduced during the period in which the Academy was directed by Grienberger (1612–1636). This period is not as well documented, and its history remains to be written.[45]

The Academy was conceived in order to train professors of mathematics as well as to provide missionaries (almost all of whom went to Asia) with proper scientific instruction. And since during the period under consideration the only European colonies east of the Indian Ocean were Portuguese and could be reached only by the royal Portuguese ships that sailed from Lisbon in March or April of every year, a union was established between the Roman College and two important Portuguese colleges: the College of S. Antâo at Lisbon and the College of Arts at Coimbra. Indeed, the schedule of the Academy sometimes allowed graduates to travel to Lisbon, rest there for a while before embarking on their mission, and complete their course of theology in Coimbra.[46] If a missionary had not completed his training in mathematics, he could do so at S. Antâo, where a course in mathematics was established in 1590 under J. Delgado, a former student of Clavius. Until the 1620s, the lectures were given by Delgado's students as well as by foreign professors (mainly coming from Rome), including Grienberger (1599–1602) and Giovanni Paolo Lembo (1614–1617). In subsequent years the teachers trained in the Roman school were replaced by others—mainly English and German until the 1690s and then Portuguese.[47] The Rome-Lisbon link, evident in many missionary biographies, was an important part of the Academy's life.[48]

The role of the Academy in the scientific formation of the Asian missionaries highlights the important contribution that its pedagogical and epistemological outlook and its staff played in the diffusion of European science in China and India. Historians have considered such diffusion primarily in the context of cosmology, and have found the Jesuit contribution wanting, for the Jesuits propagated the Ptolemaic and then the Tychonic model rather than the Copernican one. But regardless of the merit of such criticism, it is necessary to bear in mind that cosmology was only one part of the Jesuit contribution. The impact of their introduction of the axiomatic Euclidean model, central to their conception of science, has been studied only partially.

The Scientific Life of the Academy up to 1612

The content of the program of studies and research at the Academy was greatly influenced by three factors: traditional (including ecclesiastical) customs, practical exigencies, and the scientific interests and mathematical proficiency of Clavius and of his collaborators. Consequently, one should not expect the activities and priorities of the academicians to be the same as those of Galileo or of other renowned savants (not to say educational institutions) of the period. The religious element accounted, for example, for the ubiquity of calendar computation and (in part), of gnomonics—a subject highly cultivated by Clavius and his followers. Allegiance to the classical heritage of astronomy entailed greater attention to its theoretical part (geometrical construction of the astral movements) and to its computational part (tables) than to observations—though these, as we have seen earlier, increased after 1600. Not only did the influence exerted on Clavius by Italian reconstructions of classical Greek mathematics (whether in the philological sense of the school of Commandino or in the "divinatory" sense of Maurolico) inform his commentaries on Euclid and Theodosius; it is also responsible for the interest shown by him and some of his students in some as-yet-untranslated classical texts, such as Theon's commentary on the *Almagest* and the Arabic version of books 5–8 of Apollonius's *Conics*. Another interest derived from the school of Commandino—concerning the theory of centers of gravity [*centrobaryca*]—became central to Clavius and his school, so much so that virtually all writers on the subject between 1580 and 1630 (Valerio, Guldin, Ghetaldi, and Gregory of St. Vincent), were connected with the Collegio Romano.[49]

Cognizance of the above factors helps explain the absence from the Academy's program of mechanics, a topic that was central to Galileo's program. It has already been argued that in the disciplinary framework of the Jesuit schools the study of motion (essentially everything that falls today under the purview of kinematic and dynamic) was the preserve of the philosophers, being a "physical" and not a "mathematical" subject.[50] Such a division explains the dearth of kinematic analyses in the works of Clavius and his followers[51] and accounts for their marginalization from the conceptual core of the Galilean revolution: the extension of mathematical methods and concepts to the phenomena of movement. However, the exclusion of the phenomena of movement from Jesuit schools was not extended to the study of equilibrium (that is, statics) or to the theory of simple machines (to which the term 'mechanics' was exclusively assigned[52]), since both were already considered "mathematical" disciplines in the ancient and medieval tradition.

Despite this differentiated epistemological status, statics served for various authors of the period (Benedetti and Stevin among others) as an alternative medium in which to criticize Aristotelian "kinematics" and "dynamics." Hence, it is important to recognize that the 1580 program assigned the "mathematical" part of mechanics (in the modern sense of that term), and that Clavius contemplated writing a compendium on the subject.[53] And, although it seems that the project never materialized, Clavius's correspondence with Galileo during 1588—as well as his classification of the mathematical sciences and those of Biancani and Guldin—confirms that he considered statics a mathematical discipline in its own right.[54] Nonetheless, the absence of relevant parts of statics and "mechanics" from his works and manuscripts,[55] as well as from those of his direct followers, means perhaps that statics was treated in the Academy primarily in a highly idealized form, relative to the conditions of equilibrium of single bodies—that is, in the form of *centrobaryca*. The sophisticated use of static concepts in geometry, which Valerio and others have made, necessitates a familiarity with the discipline and with more advanced concepts than mere practical knowledge.[56] Significant proof for such familiarly exists in the writings of two of Clavius's close collaborators, J. B. Villalpando and Grienberger. The Spanish Jesuit was never officially a member of the Academy, but during his long sojourn in Rome (from 1591 or 1592 to 1606) he resided in the Roman College, and his great commentary on Ezekiel contains ample testimony to a close collaboration with the academicians. He also printed results that they communicated to him.[57] Thus, it is possible—although not yet demonstrated—that that part of his commentary relative to statics (which attracted the attention of Pierre Duhem) derived from courses or discussions among the academicians.[58] In any case, it is almost impossible that the doctrines and the knowledge it contained were extraneous to the mathematicians of the college. Duhem considered the statics of Villalpando an extension of the medieval tradition. Furthermore, the Jesuit does not use it as an instrument for analyzing movement. But an attempt in this direction is alluded to in Grienberger's criticism on the *Cosmographia* of G. Biancani, written in 1618 (after Clavius's death), as well as in other texts.[59] Hence, it seems that in the school of Clavius a "mathematical" mechanics began to dissolve the "philosophical" variety—albeit in a different way and to a much lesser degree than with Galileo—though the confirmation of this possibility requires new documents and careful analysis. [60]

A different case, but equally relevant, is that of algebra. There have been no detailed analysis of Clavius's late (1608) *Algebra*, commonly considered one of the last and fullest syntheses of cossic algebra. In particular, the peculiar selection of its sources (the presence of sixteenth-century Italian algebraists is less frequent than one would have expected, compared with that of German authors and of P. Nunes) has not been examined. An enigmatic aspect of the *Algebra* is that the notation and the type of problems there treated seem to reflect the situation existing before Viète's contribution to the discipline, although it has been noted above that from 1600 on the Academy was one of the two main centers in Italy to study the work of the Frenchman. Not only did the Academy's library own several of Viète's works, but Clavius and his collaborators were probably in possession of unpublished writings as well, through the good offices of Ghetaldi and Schreck (Terrentius).[61] The correspondence of Clavius, and what survives of that of Grienberger, do not clarify this enigma.

The presence or absence of certain other themes, or the manner in which they were treated, clarifies the research program of Clavius's school, in addition to distinguishing it from other schools or individuals, and even other Jesuit traditions.[62] In theoretical astronomy [*theorica planetarum*], as has been noted, the school partly opposed and partly distanced itself from the transition toward heliocentrism.[63] If we ignore the debate over the alleged role of the Order (and specifically of the mathematicians of the Collegio Romano) in the trials of 1615–16 and 1632–33, and concentrate instead on the situation during Clavius's lifetime, we shall see that the search for a planetary model other than the Ptolemaic (and the sixteenth-century derivations from it)—which Clavius regarded as unsatisfactory—was complicated by several factors. Perhaps more influential than religious (and, in particular, scriptural) constraints, it was the devotion to certain aspects of Aristotelian cosmology and mechanics that informed Jesuit choices, in view of their adherence to the scholastic distinction between physics and mathematics. Such an epistemology was much more important for the Jesuits than for lay practitioners, since it was intrinsic to the way in which the Order had actualized the *unitas et uniformitas doctrinae*—that is, a strict interdependence between theology, metaphysics, physics, and mathematics, which was considered essential for its religious policy.[64] Thus, though the technical and observational developments of astronomy between 1580 and 1610 resulted in a progressive abandonment of the classic geocentric model, religious and physical factors made it impossible for the Jesuits of the Collegio Romano to adopt heliocentrism, and they opted first for the modified geocentric model of Magini and then for that of Brahe.[65]

The fact that among the research activities of the school astronomy received a disproportionate attention (although this, too, is far from completely known) has been the result of the contribution (real or imagined) of the Jesuits to the Galileo affair. Such lopsided attention distorted the true nature of the researches of Clavius and his collaborators, which focused primarily on pure mathematics. Complicating matters further, Clavius's published mathematical works do not include all his researches into geometry and algebra, while those of Grienberger include a very small part, and perhaps not the best, of a corpus judged by contemporaries to be very extensive and of a high level. An inventory of the available data referring separately to the disciplines of computation and of advanced geometry can demonstrate the extent of the historical work that remains to be done.

In the field of calculation, excluding algebra, the best-known contribution of Clavius is the first generalization of the Brahe-Wittich formulation of prosthaphaeresis, which he knew through Ursus's *Fundamentum astronomicum*.[66] His results, published in the *Astrolabum* (1593), were the continuation of a work in trigonometry he published in the appendices to his 1586 edition of the *Sphaerica* of Teodosius, but which he began as early as 1575. Thus, though nothing is known about Clavius's or his students' work on prosthaphaeresis or on fundamental arguments of trigonometry after 1593, it is hard to imagine that members of the school discontinued their research in that area. At present, all that is known of such activity is an aspect that is theoretically marginal but technically quite advanced for the time: Grienberger's efforts in the years 1593–1596 to calculate tables of sines, secants, and tangents to a higher level of accuracy than was available at the time, even in the *Opus Palatinum* of Rheticus-Otho.[67]

Certain statements made by Clavius seem to suggest that he considered the study of discrete quantities (numbers) as conceptually the most interesting part of mathematics, and it is possible that such an orientation was shared by Grienberger. However, if we consider the work carried out by the school as a whole there is little doubt that the most common area of research, and the one producing the most interesting results, was geometry. Apart from elementary geometry (theorems and problems connected with Euclid's *Elements*), a characteristic feature is that their research was thematically, but to a large extent also methodically, much more Archimedean than Apollonian. That is, it involved the geometry of measuring areas and volumes, rather than determining the positions and properties of curves. This orientation is probably connected to certain characteristics of the geometrical work of the school of Commandino and of other local traditions in the Italian geometry of the sixteenth century, whose influence on Clavius seems to have been more decisive than that of the Italian algebraists.[68] Such an orientation also produced the interest in the most characteristic research activity of the academy: *centrobaryca*.

Clavius's group made also an important contribution to the discussions of the "analyses of the ancients" and to the identification (proposed in the late sixteenth century) of the heuristic method of Archimedes with the employment of the concepts of statics in geometry. A more problematic area, hitherto little studied, is the role of the school in advancing the "geometric algebra" introduced by Viète and developed by Ghetaldi. This line of study, which constitutes one of the historic links between sixteenth-century algebra and analytical geometry, is not explicitly documented in the work of the academicians. However, Ghetaldi made his contributions to the field shortly after he left Rome where, from 1600 to 1603, he was a regular visitor to the Collegio Romano and an active participant in the academicians' work. But then, to reiterate the paradox pointed out earlier, how are we to explain the seeming absence of practice of Viète's type of algebra in a center where the works of the French mathematician were so well known?

The contribution of the Academy to advanced research, and its pedagogical function in preparing professors of mathematics for many Jesuits colleges, do not exhaust its historical role. It should also be credited with coordinating the research of other individuals and groups within the Order, both in Europe and in the Asia missions.[69] It is well known that numerous geographical and astronomical observations, as well as other scientific information, were sent to the Collegio Romano, especially after 1600. Contemporary documents often refer to the transmission of such observation, but only a small number of them appeared in Jesuit publications—notably those of Kircher and Riccioli. The original texts of pre-1640 observations, which were certainly preserved in the Roman College, seem to have been disappeared, indicating, perhaps, that they formed a separate collection that was destroyed or dispersed, thereby rendering a proper evaluation of the scientific activity of the Jesuit missionaries much more difficult.[70]

In addition to weighing the Academy's program of research, it is necessary to evaluate certain characteristic epistemological features informing Jesuit activities. With respect to the Collegio Romano, the most important feature is the keeping of mathematics and physics distinct, on the one hand, and the intimate connection of both with metaphysical and religious presuppositions, on the other. A second feature, which historians have considered only in regard to Clavius, is the judgment on the logical status of scientific theories—that is, whether, and in what circumstances, the predictive adequacy of geometrical model of the movements of the celestial bodies justifies the physical reality of the model.[71] But other important features also need to be considered—for example, the role of the school in the transition from the inherited tradition of mixed mathematics to the new one of physico-mathematics, in the sense introduced by Galileo and developed during the seventeenth century.[72] Since most of Galileo's publications appeared only after the death of Clavius, the Jesuits' reaction to it must be sought in the work of his disciples. Thus far, however, scholars have studied only the theme *de certitudine mathematicarum*, which does not include the origins of physico-mathematics or quantitative experimentation among Jesuits.[73] The prevailing assumption is that Jesuit mathematicians, and not only philosophers, persisted in opposing the Galilean form of scientific inquiry well into the seventeenth century. Furthermore, whether the utilization of the new methods by Clavius's disciples, and the Italian Jesuit mathematicians more generally, during the first half of the seventeenth century was indebted to the teaching of Galileo, or whether both benefited from a shared scientific culture, still awaits a serious investigation.[74]

Finally, an analysis, however brief, of the role of the Academy in the scientific life of the sixteenth and seventeenth centuries must also consider the contribution of the College to the re-orientation of scientific writings, and in particular of disciplinary textbooks. The works of Clavius, though based on the annual courses of lectures that he delivered, were modified in various ways before publication. But the original form is documented by an unpublished course: that of the *theorica planetarum* (almost certainly from the academic year 1576–77), preserved in the whole section on the theory of the sun and in about half of that of the moon.[75] The lectures often mention other works that Clavius either had already published or intended to publish, and this, together with other documents, allows us to arrive at an approximate chronology of their composition.[76] As has been noted above, Clavius intended to devote a book to almost every branch of the mathematical sciences,[77] and this has important ramifications on the genesis of the modern scientific textbook. The works composed by members of the Academy were commentaries on a classical text (sufficiently spacious and generalized to constitute an effectively systematic *summa* of the knowledge and doctrine on the theme in question), or were written in an entirely new form conceived to systematize all the important contributions in a certain area. Both forms were crucial steps in the passage from a mathematical instruction based chiefly on the classics to one based essentially on textbooks—with all that this implies in a logical and epistemological sense. And since the graduates of the Academy popularized the new form throughout the world, Clavius must be credited with an essential contribution to this process.[78]

Some Concluding Considerations

The arguments I presented to demonstrate the importance of the Academy highlighted institutional, social, and pedagogical themes but did not touch on the conceptual history of science. Thus, they do not necessarily contradict the usual criticisms of the adverse contribution of the Order, and specifically of the Collegio Romano, to the "scientific revolution." Such criticisms include charges that the College persistently opposed (at least publicly) the heliocentric theory; that it did not contribute much to the diffusion of Kepler's results; that it did not contribute in any meaningful way to the development of the mathematics from Viète to Descartes and Fermat, nor did its members produce original results comparable with Cavalieri's; and that it did not participate significantly in the development of mechanics and optics, even though the latter received noteworthy contributions in other mathematical schools of the Order.

It is possible to reply to this criticism in two ways, one factual and one epistemological. First, the Academy's diminutive image is partly the result of the non-publication, or even non-preservation, of results produced there while it existed. Many investigations and results (especially in mathematics) that are recognized as having contributed significantly to science during the first half of the seventeenth century are usually considered to be unrelated to the activities of Clavius's school, because their authors—Valerio, Guldin, and Gregory of St. Vincent, for example—published them after leaving Rome. However, the interests of such individuals, and their methods of investigation, originated while they were in Rome, and some of those results were obtained while they were academicians. Second, a study of scientific creativity cannot be done in isolation from the educative process, from the inherited ontological doctrines and presuppositions, and from the process of socialization that was so crucial to the formation of practitioners. Hence, a study of the Academy improves considerably our comprehension of the nature of the "scientific revolution" of the seventeenth century.

When Clavius died, in 1612, the school was considered as second to no other European scientific institution. His immediate successors were the talented Maelcote and Grienberger, who could have easily carried on Clavius's tradition. But Maelcote died in 1615, just as the attack on heliocentrism was gaining momentum, and Grienberger found himself compelled to mediate, until his death in 1636, the burgeoning scientific movement, which discredited the cosmology upon which the Christian vision of the world had traditionally rested—and specifically its scholastic and Tridentine formulation—on the one hand, and the obligation that the Order comply with the decisions of the Catholic church and scholastic Aristotelianism, on the other. Under such circumstances, the mathematical school of the Collegio Romano adopted a defensive line of minimal exposure and either avoided treating the more daring subjects altogether or treated them strictly as hypothetical. In addition, or perhaps as a consequence, a marked impoverishment in technical skills among the Jesuits of the College made high-level research impossible. Thus, whatever role members of the Order played in the Galileo affair, in its aftermath the school of mathematics at the Collegio Romano also fell victim.

Finally, a study of the Academy is important for the light it sheds on the relations between science and "ideology." It has already been noted that, in the modified Thomism the Order adopted, the term 'science' was applied to a continuous doctrinal fabric, from the principles of metaphysics to the explanation of particular natural phenomena. In turn, the metaphysical principles were set down in strict correlation with the scholastic interpretation of Christian dogma. The mathematical sciences, therefore, were an integral part of a series of disciplines and topics that were considered instrumental for apologetic purposes and propaganda. Their development in the course of the seventeenth century, however, soon came to infringe on the constancy of the chain. As experts, the Jesuit mathematicians admitted the conceptual validity and factual truth of numerous new results and conceptions; as Jesuits, they attempted to interpret these in such a way as to preserve the chain and the cognitive status of all its constituents, through a suitable redefinition of their relationships. The Academy of the Collegio Romano, located at the center of the Catholic church and of the Order, defended for a long time, in a systematic manner, this project of the integration of scientific knowledge (in its present sense) with doctrines to which that designation could no longer be applied. The Jesuit synthesis assured a priori the congruence of scientific results with a body of metaphysical and religious doctrines, while other ideological syntheses have presented science as an instrument alternative to, or at least extraneous to, religion. But this difference in scope, obviously fundamental, does not imply a difference in the ways of establishing the connection between scientific data and ideological values. On the contrary, these ways of making connections display a striking invariance. In consequence, an analysis of the Academy's epistemology, and of the disciplinary and pedagogical compartmentalization it adopted (particularly the demarcation between *physica* and *mathematica*), can illustrate some of the most pervasive and profound mechanisms of modern intellectual history.

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Appendix A: Works Composed by Clavius for Courses in the Academy

1564

First draft of the Commentary on the *Sphaera* of Sacrobosco. Preserved in the Vatican Library, MSS *Urbinati latini* 1303–4. The text of MS 1303 corresponds in large part to the text of the 1570 edition of the Commentary. That of MS 1304 is a sort of technical appendix that includes, besides a part relating to the 1570 text others, partly developed later, in the *Astrolabium* and in the gnomonical writings, and in part were intended as the basis for a special work on astronomical instruments that Clavius never wrote. An interesting element is a rather refined treatment of astrology, which disappeared in Clavius's later writings.

Before 1570

First draft of the *Euclidis elementorum libri xv* (published in 1574).

Cosmographia (never published and apparently lost).

[In the introduction to his edition of the *Elementa* Clavius wrote that it grew up from materials which he had "collected with every care during many years for public and private teaching and communicated to learned men" (ed. 1574, fo a3v). The *Cosmographia* is mentioned repeatedly in the 1570 edition of the *Commentarius* to Sacrobosco (e.g. pp. 350, 361).]

Before 1576

First draft of the *Gnomonica* (published in 1581)

Primum mobile, not published nor preserved in manuscript (part of it probably included in the *Astrolabium*).

First draft of the *Triangula rectilinea*, the *Triangula sphaerica*, the table of sines and the commentary on Theodosius's *Sphaera* (all published in one volume in 1586).

Table of the average motion of the sun (never published, but partially utilized in constructing the gnomonical tables which Clavius later published).

[These works are mentioned often in the course on planetary theory (see for the year 1576–77). An expression by Clavius in the dedication of the *Astrolabium* ("I openly declare that this work of mine includes all the doctrine of the first mobile") shows that a part, at least, of the *Primum mobile* was absorbed in that work.]

1576–77

Course on the theory of planets (designed to be a first version of a *Theorica planetarum*, probably never written).

[Only the theory of the sun and part of that of the moon survive (Rome, Archive of the Pontificia Università Gregoriana, MS 776). The former was published in Baldini, *Legem impone subactis*, 469–564; the latter is discussed briefly in my "Cristoforo Clavio insegnante e teorico," *passim*.]

Before 1580

First draft of the *Arithmetica practica* (published in 1583) [The work's introduction declares that Lorenzo Castellani (note xxxvii) had for a long time impressed on the author to publish the text, hitherto restricted to the college's use.]

Appendix B: The Mathematical Academicians in the Collegio Romano until Clavius's Death (March 1612)

The *catalogi* of the Collegio Romano (preserved in the Archivum Romanum Societatis Iesu: ARSI) concern only the Jesuit students, and not the laymen and those belonging to the secular clergy or to other religious orders, who attended the ordinary courses, still less of those who attended the Academy informally. It has been said that the college provided two levels of mathematics teaching, intermediate between the ordinary courses and the formal Academy: private lessons or courses—given sometimes at the request of one or more students (clerics or lay) in the course of one year or part of it, on a certain topic—and informal academic courses (for Jesuits only) which, as sstated earlier, were the highest level before 1594 and survived after that year. While this distinction is substantiated by several documents, it is possible that, in fact, the private lessons were also attended by the informal academicians and perhaps, sometimes, also by the formal ones. In other words, while the status of academician was reserved for Jesuits, attendance at courses could be partially mixed. So those receiving mathematical instruction exceeded the list of persons whom the catalogues identify as *mathematici*, though there exists no systematic way to identify them. Moreover, even for Jesuits the attendance at the Academy is given differently in the *breves* and *triennales* catalogues. The former, written every year, indicate only the activity of a person in that year. For that reason they provide the precise attendance at a course. Those of the second type, written every three years, summarize the studies and activities pursued up that year, without specifying it precisely. For the years for which the *catalogi breves* have not been preserved (many before 1595), a precise dating is possible only by comparison with the *curricula* furnished in successive triennial catalogues, and by correlating them with other sources.

Thus, the following chronological list of academicians includes only Jesuits, and in many cases gives only approximate attendance; in this cases the period during which it happened is indicated between square brackets. Usually every person who attended the Academy (with the possible exception of Guldin) had already taken the public course of mathematics in the second year of philosophy. If it happens that a Jesuit followed such a course in the Collegio Romano, and in the absence of dates that indicate differently, his dates in the Academy is made to begin with his third year in philosophy. In the case of persons who followed the course of philosophy elsewhere, and who came to Rome to follow the course of theology, the attendance is made to begin in the first year of this course.

Those who attended are divided to three groups: the names of those who followed informal courses (all the Academicians up to 1594 and some of those afterwards) are between parentheses. The names of those attending the formal course (who, from 1594, are listed in the catalogue as *mathematici*) are is square brackets. The names of the collaborators of Clavius in the College (teaching in the public course of mathematics, or employed with instruments or observations), who had previously belonged to one of the preceding groups, are not in parentheses and precede the others.

[1566–1568]	(John Hay)[79]
[1567–1570]	(James Bosgrave)[80]
[1570–1574]	(Bartolomeo Ricci)[81]
1574–75	B. Ricci
[1574–1580]	(Giulio Fuligatti)[82]
1575–76	B. Ricci (Luca Valerio, Matteo Ricci, G, Fuligatti, Ferdinando Capece, Richard Gibbons)[83]
1576–77	F. Capece (L. Valerio, M. Ricci, G. Fuligatti)[84]
[1574–1578]	(Vincenzo Regio?)[85]
1577–78	(Paul Pistorius)[86]
[1580–1585]	Muzio De Angelis, Joâo Delgado)[87]
1584–85	(Jean Deckers)[88]
[1585–1590]	(Alessandro De Angelis)[89]

1586–87	G. Fuligatti (Carlo Spinola)[90]
[1590–1597]	(Gaspare Alperio)[91]
1591–92	Christoph Grienberger[92]
1592–93	C. Grienberger
1593–94	C. Grienberger
1594–95	C. Grienberger [Giovanni Giacomo Staserio] (Angelo Giustiniani; Giovanni Battista Luca?)[93]
1595–96	C. Grienberger (Giovanni Giacomo D'Alessandro, G. G. Staserio, Janos Nagy, Muzio Rocchi, Mario Gibelli, Benedetto Cerroni, Raphael Kobenzl)[94]
1596–97	C. Grienberger
1597–98	C. Grienberger [Giovanni Maria Camogli][95]
1598–99	C. Grienberger; Gaspare Alperio [Giuseppe Biancani?][96]
1599–1600	A. Giustiniani [G. Biancani][97]
1600–01	(Sabatino De Ursis?)[98]
[1600–1605]	(Bernardino Gennaro)[99]
1601–02	G. Alperio [Odon van Maelcote][100]
1602–03	C. Grienberger [O. van Maelcote; Giacomo Fuligatti, Ippolito Giannotti?] (Vincenzo Figliucci, Paolo Bombino, Alessandro Pernato, Giovanni Francesco Marzi)[101]
1603–04	C. Grienberger; O. van Maelcote [G. F. Marzi; I. Giannotti][102]
1604–05	C. Grienberger; O. van Maelcote [Orazio Grassi][103] (G. F. Marzi)
1605–06	C. Grienberger; O. van Maelcote [O. Grassi][104] (G. F. Marzi)
1606–07	C. Grienberger; O. van Maelcote[105]
[1606–1612]	(G. de St. Vincent)[106]

1607–08	(Giulio Aleni)[107]; (Ian Wremann)[108] (Giovanni Paolo Lembo)[109]
1608–09	O. van Maelcote (J. Wremann; G. P. Lembo)
1609–10	O. van Maelcote (G. P. Lembo; Paul Guldin)[110]
1610–11	C. Grienberger; O. van Maelcote (G. P. Lembo; P. Guldin)
1611–12	C. Grienberger; O. van Maelcote[111] (G. P. Lembo; P. Guldin)

Appendix C: Works of Clavius

1. Commentary on Euclid's *Elements* (books I–IV) [1574]

2. *Epitome arithmeticae practicae* [1583]

3. In sphaeram Ioannis de Sacro Bosco commentarius [1570]; Computus ecclesiasticus [1597]

4. Commentary on the Euclid's Elements (books V–VI)

5. Book I of the Geometria practica [1604] and for the astronomical instruments, parts of the nomonica [1581] and the Astrolabium [1593]

6. Commentary on Euclid's Elements (books VII–VIII)

7. Algebra [1608]

8. Commentary on Euclid's Elements (books X–XV)

9. Theodosii Tripolitae Sphaericorum libri III, with the trigonometric writings of Clavius appended to this edition [1586] and parts of the Astrolabium.

10. Astrolabium [1593].

11. Gnomonica [1581]; Fabrica et usus instrumenti ad horologiorum descriptionem [1586]; Tabulae ad cognoscendam magnitudinem diei ac noctis [1592]; Horologiorum nova descriptio [1599]; Compendium brevissimum describendorum horologiorum [1603]; Tabula altitudinum solis [1603]; Tabulae astronomicae nonullae ad horologiorum constructionem [1605].

12. Cosmographia (see appendix A).

13. Geometria practica [1604]

14. "Hanc nos conscribemus." Thus wrote Clavius in the Ordo (see Baldini, *Legem Impone Subactis*, p. 175). It is not known whether he began writing on this argument or delivered a course on it in the Academy. An indication to the contrary could be inferred from the fact that Grienberger later wrote a Perspectiva for his own courses in the Academy (see *Clavius, Corrispondenza* VI. ii. 79 n. 8. The manuscript is preserved in Rome, Biblioteca Angelica MS 1662). This may indicate that a work by Clavius on

the subject did not exist. The only known optical writings of Clavius is his notes on the Neapolitan edition of 1611 of F. Maurolico's Photismi de lumine, et umbra (Naples, 1611), edited by his student G. G. Staserio. But a documentary value concerning optical studies and research in the Academy should also be discerned in the extensive sections on optical in J. B. Villalpando's work.

15. "Haec nos ostendemus." Thus wrote Clavius in the Ordo (see Baldini, *Legem Impone Subactis*, p. 175). But he never published a specific treatment of the principles kinds of astronomical problems and does not seem to have written it. Many particular cases are considered in the Astrolabium, in the fragment of the Theoricae planetarum (see number 16) and in the digression to the De crepusculis of P. Nunes, appended to the late editions on the Commentary on Sacrobosco.

16. Tractatio de octava sphaera (a course of lectures held in the Academy probably in 1576, is mentioned in the surviving fragments of the Theoricae planetarum). Theoricae planetarum (a course on the theory of the planets held in the Academy in 1577). Of this the theory of the sun and part of that of the moon survive. See appendix A.

17. Apart from what is mentioned in number 20 this is the only part of the program which Clavius does not declare in the Ordo that he wished to dedicate a work. ("Haec tradita est a Fabro Stapulensi," Baldini, *Legem Impone Subactis*, p. 175).

18. "Horum aliqua commentariis illustrabimus" (Baldini, *Legem Impone Subactis*, p. 175). In fact, no special writings of Clavius remain on the measurement of an area, with the exception of the treatise on isoperimeters (inserted first in the commentary on Sacrobosco and then in the Geometria practica. See F. A. Homann, "Christoph Clavius and the Isoperimetric Problem," *Archivum Historicum Societatis Iesu* (1980): 245–254), and on the quadratic line in the 1589 edition of the commentary on the Elements.

19. "Forte compendium aliquod de his conficiemus" (Baldini, *Legem Impone Subactis*, p. 175). But, as remarked in the text, no mechanical works by Clavius or his disciples survive, although the theory of the centers of gravity was important in their work. Writings of Clavius do not survive even on the Centrobaryca but it is documented that he worked on the argument.

20. Other subjects of the program on which Clavius did not intend to write. This may not be insignificant, intimating something about Clavius's mathematical interests and his instruction in the Academy: his work, as well as that of his direct students in geometry was of a more of the "Archimedean" than the "Apollonian" type. The preeminence of pedagogical motivation in Clavius's activity is confirmed by the fact that practically all his writings that do not correspond to items in the program, were connected with a single circumstance—his role in the Gregorian reform of the calendar. It was

the origin of the Novi calendarii Romani apologia (1588), the Castigatio of Scaliger's criticism of the calendar (1595), the Romani calendarii explicatio (1603), the Responsio to Scaliger (1609), and the Confutatio of G. Germann (1610).

Notes

1. William A. Wallace, *Prelude to Galileo: Essays on Medieval and Sixteenth-Century Sources of Galileo's Thought* (Princeton, 1981); Wallace, *Galileo and his Sources: The Heritage of the Collegio Romano in Galileo's Science* (Princeton, 1984); Wallace, *Galileo, the Jesuits and the Medieval Aristotle* (Brookfield, 1991); Adriano Carugo and Alistair C. Crombie, "The Jesuits and Galileo's Ideas of Science and of Nature," *Annali dell'Instituto e Museo di storia delle scienza di Firenze* 8 (1983): 3–68; C. Dollo, "Galilei e la fisica del Collegio Romano," *Giornale critico della filosofia italiana* 71 (1992): 161–201. On the general aspects of the relations between philosophy and the mathematical sciences in Jesuit culture, see also Peter Dear, "Jesuit Mathematical Science and the Reconstruction of Experience in the Early Seventeenth Century," *Studies in History and Philosophy of Science* 18 (1987): 133–175; Ugo Baldini, *Legem Impone Subactis. Studi su filosofia e scienza dei Gesuiti in Italia, 1540–1632* (Rome, 1992); James M. Lattis, *Between Copernicus and Galileo: Christoph Clavius and the Collapse of Ptolemaic Cosmology* (Chicago, 1994); Rivka Feldhay, *Galileo and the Church* (Cambridge and New York, 1995). For a general bibliography on Jesuit science and philosophy in Italy, see Ugo Baldini, "Die Philosophie und die Wissenschaften im Jesuiteorden," in *Grundriss der Geschichte der Philosophie. Die Philosophie des 17. Jahrhunderts*. Band 1. *Allegemeine Themen. Iberische Halbinsel. Italien*, ed. J.-P. Schobinger (Basel, 1998), esp. pp. 755–769.

2. With respect to the physical aspect, the exceptions involved the possibility of eccentric planetary orbits, the incorruptibility and immutability of the celestial spheres, and some points of contrast between Aristotelian physics and the postulates of Archimedean statics and hydrostatics. With respect to the logical-epistemological aspects, they included the cognitive status of mathematics, the "causal" character of its demonstrations, and its role in the analysis of natural phenomena. These issues have never received a satisfactory treatment. But, for astronomy, see Lattis, *Between Copernicus and Galileo*; M.-P. Lerner, *Le monde des sphères* (Paris, 1996–97) (ad indicem "Clavius"); Ugo Baldini, "Cristoforo Clavio insegnante e teorico di astronomia," in *Saggi sulla cultura della Compagnia di Gesù* (Padua, 2000). For other issues, see Nicholas Jardine, "The Forging of Modern Realism: Clavius and Kepler against the Sceptics," *Studies in History and Philosophy of Science* 10 (1979): 141–173; Carugo and Crombie, "The Jesuits and Galileo's Ideas of Science and Nature"; Dear, "Jesuit Mathematical Science."

3. It is misleading to join together, into something called the "science" of the Collegio Romano, theses in dynamics or kinematics which were part of the course of natural philosophy, the epistemology, and the theory of demonstration usually discussed in the course of logic, and the properly mathematical work—the internal

epistemology of which was somewhat different from the "official" one, namely that of the philosophers. Among at least some of the philosophers and the mathematicians of the college (both in the sixteenth century and after Clavius's death), there raged a debate about the scientific status of the mathematical disciplines. See e.g. G. C. Giacobbe, "Epigoni nel Seicento della Quaestio de Certitudine mathematicarum: Giuseppe Biancani," *Physis* 18 (1976): 5–40; Giacobbe, "Un gesuita progressista nella Quaestio de Certitudine mathematicarum rinascimentale: Benito Pereyra," *Physis* 19 (1977): 151–186.

4. There are monographs on the most prominent of them, including Grienberger and Maelcote (on both of whom see the notes to appendix B). The only exception is Luca Valerio, who, however, left the Society in 1580. See U. Baldini and P. D. Napolitani, "Per una biografia di Luca Valerio. Fonti edite e inedite per una ricostruzione della sua carriera scientifica," *Bollettino di storia delle scienze matematiche* 11 (1991): 3–157.

5. In the Ratio atque institutio studiorum of 1599, the text that defined the program of instruction in the colleges of the Society throughout the 17th and 18th centuries, the program of mathematics is specified thus: [In the second year of the course of philosophy, the professor of mathematics] "explicet in schola tribus circiter horae quadrantibus [every day] Euclidis elementa; in quibus postquam . . . per duos menses versati fuerint, aliquid Geographiae vel Spherae, vel eorum, quae libenter audiri solent, adiungat; idque cum Euclide vel eodem die, vel alternis diebus." (*Monumenta Paedagogica Societatis Iesu*, ed. L. Lukács, Rome, 1965–1992), p. 402. For a general discussion on the role of mathematics in the Ratio, see G. Cosentino, "Le matematiche nella Ratio studiorum della Compagnia di Gesù," *Miscellanea storica ligure*, nuova serie 2 (1970): 171–213. For more specific discussion of the program in mathematics in the Roman College during the second half of the 16th century, see *C. Clavius, Corrispondenza*, ed. U. Baldini and P. Napolitani (Pisa, 1992), I. i. 59–65.

6. For some works, a comparison of the first draft and the printed text can only be indirect and partial. However, it can be accomplished through the commentary on the Sphaera of Sacrobosco, the original version of which (1564) is in Mss. Urb. Lat. 1303 and 1304 of the *Biblioteca Apostolica Vaticana*. (See appendix A.)

7. Four of these senses, including the last, were included in the *Vocabolario degli Accademici della Crusca*, the most authoritative dictionary of the Italian language until the nineteenth century. See e.g. the fourth edition (Florence 1729), volume 1, pp. 22–23.

8. In its formal use, 'academy' designated this second case, to which the definition of the 1599 Ratio refers: "Academiae nomine intelligimus coetum studiosorum, ex omnibus scholasticis delectum, qui . . . conveniunt ut peculiares quasdam habeant exercitationes ad studia pertinentes." See the text in Lukács, *Monumenta*, p. 448. For other documents regarding the academies of the colleges, see ibid. p. 455 and the Index rerum under "academiae."

9. Three main texts connected with the academy specify the number of, and the relations among, the mathematical sciences: Clavius's Prolegomena to his edition of the *Elements* (later reprinted as the general introduction to his *Opera mathematica*); the Apparatus ad mathematicas of Giuseppe Biancani, printed as an appendix to

his *Sphaera mundi* (published in 1620, but written between 1615 and 1617); Paul Guldin's introduction to his *De centro gravitatis trium specierum quantitatis continuae* (Vienna, 1635). The Prolegomena presents two classifications, one Pythagorean and the other, by Geminus, dealing with Proclus's commentary on the first book of Euclid's *Elements*. Biancani's and Guldin's classifications, though faithful in general to the traditional line, are nonetheless original in some aspects.

10. All the sources of information are discussed in Clavius, *Corrispondenza* I. i. 68–69. The academy is now partially dealt with in a book that appeared after this essay was completed (A. Romano, *La contre-réforme mathématique. Constitution et diffusion d'une cultura mathématique Jésuite à la Renaissance* (Rome, 1999).

11. On Torres, see M. Scaduto, "Il matematico Francesco Maurolico e i gesuiti," *Archivum Historicum Societatis Iesu* 18 (1949): 126–141, and the biography and bibliography in *Clavius, Corrispondenza* I. ii. 102.

12. The didactic rules of the order did not mention it (as distinct from those of rhetoric, philosophy, and theology), and it was not included in the inventory of courses in the College. The existence of an advanced course under Torres is attested by the fact that some provinces of the Society asked students of the Spanish professor to be sent as instructors of mathematics in their colleges. One person who almost certainly took the course was Baucek. Another may have been Giovanni Battista Vannino (Forli 1533–Mondovi 1599), who was sent from Rome to Milan in 1575 to teach mathematics in the college of Brera (F. Rurale, *Gesuiti a Milano. Religione e politica nel Cinquecento* (Rome, 1992), p. 143 and p. 170 n. 26). In view of the date of his birth it is almost certain that Vannino was trained in mathematics earlier than 1560 (the last year of Torres's instruction).

13. Baucek (Bausek, Bauzek) was born in Polna (Bohemia) c. 1538 and died in Vienna in 1571. He became a Jesuit in 1556, studied philosophy in the Collegio Romano from 1557 to 1560, and taught mathematics there from 1560 (or 1561) to 1562 (or 1563). In 1563 he was sent to Vienna, where he taught theology. See Sommervogel, *Bibliothèque de la compagnie de Jésus* i. 1062; viii. 1782; see also the index to L. Lukács, *Catalogi personarum et officiorum provinciae Austriae S. I.* (Rome, 1978–1982); *Clavius, Corrispondenza* I. ii. 14.

14. See appendix A.

15. See appendix B. The catalogue of the college for the year 1566 already mentioned "a few students of mathematics distinct from the others" (*Clavius, Corrispondenza*, volume I, p. 43).

16. See the text in Lukács, *Monumenta*, volume VII, pp. 110–115. The full program, relative to the triennial course, is also published in Baldini, *Legem Impone Subactis*, pp. 172–175.

17. Modus quo disciplinae mathematicae possent promoveri; Discursus de modo et via qua Societas Iesu . . . augere hominum de se opinionem . . . brevissime et facillime possit. For the text, see Lukács, *Monumenta*, volume VII, pp. 115–122.

18. The most important restrictions were two. While in the Discursus the annual number of the academicians in mathematics was fixed to ten, the actual number never reached five. Moreover, while Clavius had projected a school for young Jesuits

coming from every Province of the Order, the students were ultimately drawn from the Provinces of Germany and Italy. The reasons for the exclusion of the French and Iberian Provinces are not known. For the latter, the most plausible reason is the lack of interest in the discipline. For France, after 1600, one of the possible reasons was the confidence of the local superiors in their own schools.

19. See the list of participants in appendix B. Attendance was usually for a year, and rarely exceeded two. Thus, it might appear that it was not sufficient to provide a more thorough and complete preparation in the mathematical sciences. However, some students, before or after their formal attendance in the Academy, continued to pursue mathematics while studying philosophy or theology. This was the case for Giovanni Paolo Lembo, one of the principal collaborators of Clavius in the verification of Galileo's observations, of Paul Guldin, and of Gregory of St. Vincent. Moreover, the lectures did not end with the official courses but continued throughout the summer as well—in the period of partial rest that the Jesuit students spent with the professors in the Society's residences in the Roman Hills. A copy of the 1570 edition of Clavius's commentary on Sacrobosco, now at Padua, has this note by a former owner of the copy: "Father C. Clavius began to explain the sphere in Tivoli, on 19 August 1578." (C. Bellinati, "Il Dialogo con le postille autografe di Galileo," in *Novità celesti e crisi del sapere. Atti del convegno internazionale di studi galileiani*, Florence, 1983, pp. 127–128).

20. Grienberger's letter was printed in *Clavius, Corrispondenza* III. i. The notes to these letters (ibid. III. 2) discuss the cases of the above mentioned students.

21. This is evident in Nuncius sydereus collegii Romani, the 1611 lecture in which Maelcote confirmed the observations of Galileo. But it's also true for other lectures and official pronouncements. For example, Grienberger considered Galileo's criticism of Grassi's discussion of the 1618 comet as directed against all the mathematicians of the Roman College. See Baldini, *Legem Impone Subactis*, pp. 194–195.

22. Theorems of Grienberger, Maelcote, and other students are reported in works by Clavius and Villalpando.

23. St. Vincent constitutes a particular case because, while in the Collegio Romano, he was not formally a student of mathematics but of philosophy and theology. However, whatever the reasons for his failure to be assigned to the Academy, it is certain that he attended it during his long sojourn in Rome. (See appendix B.)

24. A formal act suspending the Academy doesn't seem to exist. The courses may have stopped from 1615, if not earlier—the catalogi breves of the college (which indicate the duties of every Jesuit) for the years 1605–1615 appear for the most part to be lost. The mathematicians trained after 1612 followed the advanced courses of Grienberger and Maelcote while studying theology: Adam Schall in 1616–17 during his fourth year, and Paul Guldin between 1609–15, when he was a student of philosophy and moral theology (Rom. 110 fol. 61; Rom. 55 fol. 11). The end of the formal academic course may not be unrelated to the election in 1615 of Muzio Vittelleschi—who opposed to the philosophical implications of the new science—as General. It is also possible that it derived from his predecessor's (C. Acquaviva) alarm by novel ideas propagated by young professors like Biancani and Borri (see G. Camerota's censure of Biancani in Baldini, *Legem Impone Subactis*, pp.

229–232. In his teaching at Mondovì and Milan (from 1607 to 1614), Borri had maintained the nonexistence of the spheres and the fluidity of the heavens. (His 1612 lectures at Milan are in Rome, Biblioteca Nazionale, ms. Fondo Gesuitico 587). In 1614, the senior professors of Milan's college called on Acquaviva to intervene against Borri (see the latter's account in D. M. Gomes dos Santos, "Vicissitudes da obra de Cristóvo Borri," *Anais da Academia Portuguesa da Historia*, s. 2, 3 (1951), p. 143), and the General removed Borri from instruction. For a bibliography on Borri, a missionary in Vietnam until 1624, who left the Order in 1631, see L. Polgár, *Bibliographie sur l'histoire de la Compagnie de Jésus 1901–1980* (Rome, 1981–90), volume III, pp. 325–326); see also Baldini, *Saggi sulla cultura*, pp. 143–144. Perhaps Acquaviva saw in the Academy, which was formerly disengaged from philosophical and theological instruction, a potential contributor to the diffusion of heterodox cosmological theses. But perhaps, more simply, the prejudices against the study of mathematics that existed in certain sectors of the Society, resurfaced after Clavius's death. After 1630, instruction in mathematics in the Roman College was offered conducted by many persons, each for a brief period. Some of them were on inferior scientific level, and could in no way be called professional mathematicians. Others (Grassi, Kircher, P. Casati, G. Ferroni) were better. But it doesn't appear that they were really able to revitalize the school. (Also, the scientific life of the College during the mid seventeenth-century, as distinct from the writing of particular professors, has been little studied.) The qualitative deterioration is confirmed by the fact that the school did not produce qualified instructors (Kircher, Casati, and Ferroni were called to Rome from other provinces of the Society.) Thus a school that had been the origin of almost all the others of the Order came to depend on them for its own continuance.

25. This may seem in conflict with the remark of a figure like Kircher. But the work of the German Jesuit was not important in fundamental research, either in pure mathematics or mathematical physics. For a bibliography of Gottignies and Borgondio, a list of their unpublished works and an overview of the school of mathematics of the Collegio Romano after Grienberger, see Ugo Baldini, "Boscovich e la tradizione gesuitica in filosofia naturale: continuità e cambiamento," *Nuncius* 8 (1992), pp. 27–31, 61–63.

26. This is suggested by the absence of records of Clavius's lectures on some parts of the program. Also, there exists some evidence on students' library borrowings—like some works by Viète—suggesting the utilization of the classics in those parts of the program lacking a manual written for internal consumption.

27. On both, see appendix B.

28. The report to the Cardinal, dated April 24, 1611, was signed by Clavius, Grienbeger, Maelcote, and Lembo. See *Le Opere di Galileo Galilei*, ed. A. Favaro (Florence, 1890–1909), volume 11, pp. 92–93.

29. The rich specialized library, and a considerable collection of instruments, made it possible for the academicians to carry out research on the entire range of the mathematical sciences. I shall return to this subject.

30. The most famous correspondence, between Clavius and Galileo, is neither the fullest nor the most important in illustrating the internal history of the school. This

role must be assigned to the correspondence with A. van Roomen—of which only the letters of the Belgian mathematician to Clavius (19 letters, 1592–1604)—survive. They were published in P. P. Bockstaele, "The Correspondence of Adriaan van Rooman," *Lias* 3 (1976): 85–129, 249–299, and in *Clavius, Corrispondenza*.

31. The relations between Ghetaldi and Viète is well known, but that of Schreck (Terrentius) is not. It is documented in a letter of Magini to Clavius dated November 12, 1603: "I have been visited by a German named Mr. Gio. Terrentio, who has been a good while with Viète, and was still with him when he died, and is said to have all of his writings except his astronomy which remained in the hands of his heirs." (*Clavius, Corrispondenza*, V. i. 90–91). The mention of the unpublished Harmonicon coelestis shows that Magini is referring also to unpublished works. In fact, as may be inferred from later documents, Schreck did not have a copy of at least one other important work by Viète, *De recognitione aequationum*; however the unpublished works of Viète possessed by him and by Ghetaldi were instrumental in diffusing the works of the French mathematician at Rome and in Italy, and perhaps in Germany as well. See *Clavius, Corrispondenza* VI. ii. 43–44 n. 2.

32. The subsequent correspondence of Ghetaldi and the College (published in *Clavius, Corrispondenza*), demonstrates that he was familiar not only with Clavius, Grienberger, and other members of the school, but also with former students of the Academy, such as Luca Valerio. Participation in the Academy's work, particularly in astronomical observations, is documented later for J. Remus Quietanus and A. Argoli.

33. It would suffice to note the presence in his later works of a typical theme of the school: the center of gravity.

34. A typical case is Teodosio Rossi (c. 1565–after 1637), a functionary of the Pontifical Tribunal of the Sacra Rota, author of a work on the duration of daylight, in all latitudes, and on every day of the year, published in 1589 and often reprinted with additions. Going to Prague in 1592 as a member of a Pontifical embassy to the Emperor Rudolph II, Rossi befriended Ursus who gave him a copy of his Fundamentum astronomicum, from which Clavius learned of the Brahe-Wittich formula of prosthaphaeresis. The correspondence between Ursus and Rossi has not survived. Clavius described Rossi's gnomonical instruments in his own works, and the pupil defended the master in his quarrel against Viète over the Gregorian calendar. See *Clavius, Corrispondenza* I. ii. 88–89; III. ii. 24–25 (nn. 1 and 3 to letter 101). Less known is Marcello Francolini, a secular priest who published a book about the astronomical determination of the times of liturgical acts during the day. Clavius thought highly of it and he consulted Francolini on the calendar's reform (M. Francolini, *De tempore horarum canonicarum tractatus* (Rome, 1581), pp. 404–409). Another student was the Roman nobleman Lorenzo Castellani, who financed the printing of Clavius's *Epitome arithmeticae practicae*, translated it into Italian and published it (Aritmetica prattica, Roma 1586). Like Rossi, he, too, defended Clavius against Viète. Among Clavius's non-Italian students the best documented—and more notable—were Ernst von Bayern, who later became the prince-archbishop of Köln and Liège and a central figure in Germany's catholic front, and the Swede Botwid Nericius. On the latter, see Svenskt Biografiskt Lexicon, V. 581–586, and *Clavius, Corrispondenza*, I. ii. 75–77.

35. As far as we know, Clavius first learned on Brahe's research in 1586 or 1587 from B. Scultetus (see *Clavius, Corrispondenza* II. ii. 196 n. 7). More precise knowledge reached him c. 1590 from G. A. Magini, an admirer of the Dane, who often asked Clavius to postpone the composition of the Theoricae planetarum, he had announced, until Brahe published his own observations. Clavius complied but soon became critical of at least one aspect of Brahe's ideas: the measurement assigned by the latter to the apparent diameter of the moon implied the impossibility of a total eclipse of the sun, although the Jesuit had observed one at Coimbra in August of 1560. The need to verify certain measurements forced the group of the Collegio Romano to observe some eclipses of the moon between 1604 and 1610. It is probable that they also checked other theses and results of Brahe, but this is not clearly documented.

36. In those lectures Lembo offered both a theoretical explanation, and a practical description, of the telescope, which surely reflect the discussions and attempts in the Collegio Romano from the middle of 1610. In addition, he mentioned certain facts about the academy's first telescopic observations of Venus—made to verify those of Galileo—which are otherwise unknown.

37. On the chronology and use of these telescopes use see *Clavius, Corrispondenza* VI. ii. 89–90 n. 3. The instruments were dispersed by the end of the eighteenth century, and only a 1575 celestial globe that Clavius built or ordered survived, now preserved in the Biblioteca Nazionale in Rome. The globe is interesting because Clavius represents there the principal constellations with their Copernican longitudes. See Ugo Baldini, "Christoph Clavius and the Scientific Scene in Rome," in *Gregorian Reform of the Calendar*, ed. G. Coyne et al. (Vatican City, 1983), p. 163 n. 1; Ugo Baldini and J. Casanovas, "La sfera celeste di Cristoforo Clavio," in *Osservatorio astronomico di Capodimonte. Almanacco 1996* (Naples, 1996).

38. However, at least while during Clavius's lifetime, the College did not have at its disposal instruments comparable in dimension and accuracy to those of Brahe. This may be inferred for some of Grienberger's letters who, in addition to being a pure mathematician was, together with Lembo, the member of the School most involved in the construction of instruments.

39. The two libraries were separated: that of mathematics was located partly in the room of the professor (hence, while he lived, in that of Clavius), and partly in the "room of mathematics" (a place reserved for the deposit of books and of instruments of the discipline). The other was called "segreta" because only professors and advanced students were admitted (students of the regular courses could only use handbooks and texts kept in other places).

40. A volume of notes of Torres (Vatican Library, ms. Barb. Lat. 304), includes lists of mathematical books of the College and the names of those (some non-Jesuits) who borrowed them. One such person, whom Torres identifies as "Federico" may be F. Commandino, the philologist and mathematician from Urbino whose works were later important for the intellectual formation of Clavius. On Torres's volume see Paul L. Rose, *The Italian Renaissance of Mathematics* (Geneva, 1975), pp. 167–168, 196–198.

41. A notable example is a copy of Copernicus's *De revolutionibus* (now in Rome's Biblioteca Nazionale, 201-39-I-26) with detailed notes in Clavius's handwriting on the trigonometrical part of book I. Equally important is an handwritten note by A. Santini on a copy of Viète's Supplementum geometriae (Bibl. Naz., 8-31-M-12) which appears to have been sent by him to Clavius in 1606. The note, a demonstration of Viète's prop. 19, was later published without attribution by F. van Schooten in his 1659 edition of Viète's works (pp. 252–253, 552). See *Clavius, Corrispondenza* V. ii. 48 n. 12, and VI. ii. 44 n. 4].

42. The Biblioteca Nazionale was established in 1873 on the site of the Roman College's Bibliotheca major. The Jesuit library was its main endowment, but the library was quickly enriched by books of other Roman religious houses. The Jesuit books are usually marked on the frontispiece but, unfortunately, they are mixed with other books as in establishing the Biblioteca Nazionale all old books were divided into sections according to size. A catalogue of the Jesuit library is preserved (J. Diamond, "A Catalogue of the Old Roman College Library and a Reference to Another," *Gregorianum* 32 (1951): 103–114), but this is not definitive, for it includes only the books of the Bibliotheca major—hence the only mathematical books included are those that were discarded from the mathematician's library because technically obsolete, or for other reasons. A comparison of titles quoted by Clavius and Grienberger with those surviving in the Biblioteca Nazionale suggests the dispersal of many books, perhaps during the century between the Society's dissolution in 1773 and the library's takeover by the Italian State in 1873. Some are found in the Biblioteca Vaticana and other Roman libraries, but the majority presumably went into private hands (sometimes reappearing in non-Italian collections). At least some of the other great Jesuit colleges in Italy had a specialized mathematical library. On Ferrara, see *I gesuiti e i loro libri a Ferrara: frontespizi figurati del Seicento*, ed. L. Pepe (Ferrara 1998). For Parma's Biblioteca Palatina, see *Catalogus quadruplex librorum Publici Matheseos Professoris in Universitate Parmensi S. Rocchi Societatis Iesu* (ms. Parmense 1000), probably written at the end of the seventeenth century, listing several hundred volumes.

43. The degree to which musical theory was taught in the Academy and in advanced courses of other colleges of the Society is uncertain. Musical competence emerged in students of the Academy like Biancani (Baldini, *Legem Impone Subactis*, p. 230, p. 243 n. 8), and Clavius also composed sacred music (*Clavius, Corrispondenza* III. ii. 70 n. 22.) Some historians have attributed the latter's competence to the Portuguese school of music of the sixteenth century, but it is not clear whether this is documented from his music or is an hypothesis deduced from the fact that he studied at Coimbra in the years 1556–1560. In the College of Arts at Coimbra no instruction in mathematics or—at least formally—in music, was offered. Another possibility is that Clavius acquired, or expanded, his knowledge of music during the years 1571–72 in the sanctuary of Loreto where, it seems, he was sent as a confessor for the German-speaking pilgrims. (See *Clavius, Corrispondenza* I. i. 45–46.) The sanctuary was in fact the seat of an important tradition of sacred music, which has left copious documentation. (See *Guida degli archivi lauretani I*, ed. F. Grimaldi (Rome, 1985), pp. 345–752.)

44. In appendix C, to illustrate this, I offer the numbers of the points of the program indicated in the text and the corresponding titles of works (or parts of works) of Clavius, with the year of their original edition. The scheme also includes unpublished works which are either preserved in manuscript or lost, as well as works that Clavius declared he intended to write but failed to write.

45. The first part, finished in 1615, was marked by the collaboration of Grienberger and Maelcote (who died in that year, on the eve of the examination of the Copernican doctrine by the Congregation of the Index and the Holy Office). The Belgian Jesuit knew and appreciated Kepler's works, much more than his master or colleague. Maelcote understood the Astronomia nova, and his position in favor of changes in cosmology and in the theory of the planets was more pronounced. See Baldini, *Legem Impone Subactis*, chapter 4. For a bio-bibliography of Maelcote and his relations with Kepler, see *Clavius, Corrispondenza* I. ii. 67–69). O. Grassi, Maelcote's successor as instructor of the public course, was mainly interested in astronomy (and in this he was later joined by C. Scheiner), while Grienberger concentrated on the Academy, directing the studies of relatively "pure" mathematicians such as Guldin and St. Vincent. The formation of all these men, deducible from their works and biographical documents, indicates programmatic readjustments in the Academy. Hitherto, however, the study of them tended to focus on the examination of their published works without reconstructing this developmental phase.

46. An annual inventory of the Jesuit missionaries leaving Lisbon during the early modern period, with the names of the ships and the dates of departure and arrival to Goa, can be found in J. Wicki, "Liste der Jesuiten-Indienfahrer 1541–1758," *Sonderdruck aus Portugiesische Forschungen des Görresgesellschaft* 7 (1967): 252–450. For a discussion on what motivated the Society to send mathematically trained missionaries to Asia much more than to America, see U. Baldini, "As Assistências ibéricas da Companhia de Jesus e a actividade científica nas missões asiáticas," *Revista Portuguesa de Filosofia* 54 (1998): 195–246; Baldini, "The Portuguese Assistancy of the Society of Jesus and Scientific Activities in its Asian Missions until 1640," in *Historia das ciências matemáticas. Portugal e o Oriente* (Lisbon, 2000).

47. On the "Hall of Sphere" see L. Albuquerque, "A 'Aula de Esfera' do colégio de Santo Antão no seculo XVII," *Anais da Academia Portuguesa da Historia*, series 2, 21 (1972): 335–391—which ignores, however, its function in connection to the Collegio Romano and the Asiatic mission—and U. Baldini, "L'insegnamento della matematica nel collegio di S. Antão a Lisbona," in *Saggi sulla cultura della Compagnia di Gesù*. Delgado was the founder of the mathematical school of the Portuguese Jesuits.

48. At present there exists only a list of those missionary-scientists in the Far East who studied in the Academy from the 1570s to the 1640s. See Baldini, *As Assistências*, pp. 208–209; Baldini, The *Portuguese Assistancy*, pp. 84–87.

49. Clavius's interest in the centrobaryca is documented in the first part of his correspondence with Galileo and by his students' letters, from which it appears that he had written (or intended to write) on the topic. See e.g. *Clavius, Corrispondenza* V. i. 114; II 2, n. 2 of letter 43. Similarly, his correspondence with Botwid Nericius, a

Sweed who had been his student in Rome, concerns chiefly topics in statics (*Clavius, Corrispondenza* IV. i. letters 136, 139, 147, 149, 153). However, none of Clavius's known works, either published or in manuscript, specifically treats this topic. For the presence of the theme in the school of the Collegio Romano, see Baldini and Napolitani, "Per una biografia di Luca Valerio," pp. 8–9 and passim.

50. The scholastic distinction between physica and mathematica, present in Renaissance Aristotelianism (and very different from the modern one), has often been discussed, but no exhaustive analysis exists. An essential difference from the modern distinction, particularly relevant for the point under discussion, is that the modern distinction is primarily that of object (namely, between natural events and formal structures), while the medieval-renaissance distinction was primarily ontological, between essential-causal and morphological-quantitative aspects (or levels). From this is derived a distinction in language; in the first case it was qualitative-developmental, in the second it was quantitative-descriptive.

51. Apart from describing the movements of the celestial spheres in terms of typical scholastic distinctions—like that between motus simpliciter and motus per accidens (or secundum quid)—such general absence from Clavius's works has only two notable exceptions. The first—in a less interesting sense because of its commonality and scholastic origin—is the brief analysis of the case of a body falling through a tunnel, which traverses the earth passing through its center. See Clavius, *In Sphaeram Ioannis de Sacro Bosco Commentarius nunc iterum ab ipso auctore recognitus* (Rome, 1581), p. 194. The second—less developed (it is the assertion of a fact as an evidence) but historically more developed—is Clavius's contention, against Earth's rotation, that a stone falling from the top of a ship's mast travels vertically to the deck (ibid., p. 192). While Galileo's contrary use of this example has been often traced back to Bruno's similar one in La cena delle ceneri, historians seem to have missed the fact that Galileo's analysis could be a reaction to the Jesuit's assertion.

52. This lexical circumstance is evident, but its connections to the "scientific revolution" has scarcely been recognized. For the whole of the sixteenth century "mechanica" (a term in the vocabulary of "mathematicians," not "physicists"), denoted that part of mathesis mixta (or media) concerned with simple machines, and not the study of the phenomena of movement. The latter, unlike all other mathematical disciplines, lacked a specific name. It was designated by expressions substituting for a name (de motu, de motu gravium, de motu proiectorum, de impetu, etc.), as happened for all the problematical fields corresponding to quaestiones of natural philosophy. For this reason the linguistic difference expresses a profound fact: the study of motion was not thought of as a discipline—individuated by a term and by peculiar "principles"—but as a certain number of questions internal to the general study of nature. This difference is maintained in the titles of works concerned with the two areas until the early decades of the seventeenth century, when scientific changes slowly resulted in treating static phenomena as limiting cases of the phenomena of motion. Galileo, too, never calls "mechanics" the study of motion. On the contrary, by claiming that the latter was a "new science," he made it clear that he thought it to be something quite different from a generalization of traditional mechanica.

53. "Forte compendium aliquod de his conficiemus." Baldini, *Legem Impone Subactis*, p. 175.

54. To these three classifications a fourth could be added, expounded by Antonio Possevino in book 15 ("De mathematicis") of his *Bibliotheca selecta qua agitur de ratione studiorum* (Rome 1593), which is a synthetic description of the discipline's role within the Jesuit educational system. That its general lines correspond to the others is hardly surprising. Not only was Possevino a Jesuit writing in Rome but, as he himself admitted, his source was Clavius himself.

55. Archivio della Pontificia Università Gregoriana (APUG), Rome, mss. 768, 771–777.

56. Clavius was in close contact with the two chief protagonists of Archimedean statics in sixteenth-century Italy, F. Commandino and G. U Dal Monte. His correspondence also demonstrates that he was familiar with Stevin's work on statics.

57. J. Prado and J. B. Villalpando, *In Ezechielem explanationes et apparatus urbis, ac Templi Hierosolymitani* (Rome, 1596–1604). The three-volume work is known chiefly for its contribution to architectural theories of the late renaissance, but some parts of it are purely scientific. Among other things it includes references to various geometrical results of Grienbeger. For Villalpando, see Polgár, *Bibliographie sur l'histoire de la Compagnie de Jésus*, III. iii, ad indicem, and *Clavius, Corrispondenza* I. ii. 104–105.

58. Prado and Villalpando, *In Ezechielem explanationes et apparatus urbis* III 2, pp. 319–328. See P. Duhem, *Les origines de la statique* (Paris, 1905–06) ii. 115–123; Duhem, *Études sur Leonard de Vinci* (Paris, 1906–13) i. 80–85. The work provided a seminal contribution to animal statics, inaugurating a Jesuit tradition in the field that lasted throughout the seventeenth century. See U. Baldini, "Animal motion before Borelli: 1600–1680," in *Marcello Malpighi: Anatomist and Physician*, ed. D. Bertoloni Meli (Florence, 1997), pp. 221–226. It is worth mentioning that, in discussing the properties of the center of gravity, Villalpando considered the case of a body falling from the moon's sphere to the center of the universe, whether it coincides with that of the Earth or not (III 2, p. 319). His example is not concerned with the speed of that body (thus not with the time required in order to reach that center), but it may have inspired Scheiner's 1614 discussion—who did introduce those elements—which, in turn, originated Galileo's discussion

59. For Grienberger's judgement, see Baldini, *Legem Impone Subactis*, p. 235. The Tyrolian Jesuit identified the earth as a spherical body whose center is suspended in space. By the laws of the centrobaryca it could not oppose any resistance to a rotation around this center, and hence it would also have to rotate because of minimal tangential pressures on the points of its surface. Grienberger asked himself why this would not occur? The problem was not new; what makes it interesting is that in contrast to the "physicists" of the College, the mathematicians considered the absence of an axial rotation of the planet not as a principal, but as a fact that demanded an explanation. Another indication of the advanced use of statics in the Academy is the fact that either Grienberger or a former student of the Academy, G. Biancani, accepted the development of Archimedean hydrostatics proposed by Galileo in the Discorso sopra le cose che stanno in su l'acqua. Grienberger had it defended in an lec-

ture held in the College by the student Girolamo Bardi; see G. Bardi, *Eorum quae vehuntur in aquis experimenta* (Rome, 1614). Biancani wished to insert a summary of in the Aristotelis loca mathematica (1615), but the censors of the Society prohibited its publication. See Baldini, *Legem Impone Subactis*, pp. 232, 244–245 nn. 1–2. As noted above, Galilean hydrostatics made the contrast between the Archimedean laws and the "natural" motion of the Aristotelian tradition explicit.

60. The impression of the role of statics in the development of dynamic (and sometimes cosmological) conceptions, derives in part from discussion of the so-called trepidatio terrae—assuming that the center of gravity of the earth and the universe tend to coincide, every motion of bodies on the surface of the earth displaced its center of gravity so that the latter must continually oscillate around the center of the universe. The question, which had originated in the middle ages from the adoption of Archimedean methods of statics in physical discussions, was conspicuous in Jesuit natural philosophy since the end of the sixteenth century. The most influential discussion was that by Gabriel Vazquez in his *Commentaria et disputationes in Primam secundae Summae Theologiae Sancti Thomae Aquinatis*, disp. lxxxi, ch. 3 (Venice, 1606), volume 3, pp. 464–465. Toward 1615, Guldin began to treat it with mathematical methods, and his example was followed in the schools of Rome and Parma. For some aspects of this discussion see Martha R. Baldwin, "Magnetism and the Anti-Copernican Polemic," *Journal for the History of Astronomy* 16 (1985): 155–174.

61. A possible explanation for this apparent anomaly is that Clavius has written the Algebra—like his other works (see appendix A)—many years earlier, as a manual for the Academy, and when, almost 70 years old, he decided to publish it, he no longer had the energy to rework it and limited himself to partial modification and integrations. Clavius certainly advertised a work on algebra much earlier, and various former students mentioned it in their letters to him, as if a draft of the work existed. The absence of certain recent authors and results in the Algebra was pointed out in a letter from J. G. Brengger to M. Welser dated November 2, 1608, which contains the fullest and most pointed contemporary analysis of the work. See *Clavius, Corrispondenza* V. i. 98–104; VI. ii. 59–64, note.

62. Some of these local traditions had already been introduced before Clavius's death. Among the most noteworthy was that of the province of Germania superior (Bavaria), with exponents like Lantz, Scheiner and Cysat; and, in Italy, that of the Venetian province, connected with the instruction of Biancani in the College of Parma. On the less-well-known Venetian Province, see Baldini, *Legem Impone Subactis*, chapters 10 and 11. The development of a mathematical tradition in the French Assistancy of the Society is the subject of Romano, *La contre-réforme mathématique*. Prior to c. 1610, however, its importance was more didactic than scientific. St. Vincent's school in Bohemia and Belgium obviously originated after he had left Rome, and became established only after 1630. As for the Iberian peninsula, a real Spanish school came into existence only some decades after the start of mathematics courses in Madrid's Collegio Imperial (1627). Delgado's teaching in Lisbon was prior to that, but even here, a scientific tradition, as distinct from merely a didactic one, came much later. For both countries see Baldini, "As Assistêncis." The difference between these schools and the Collegio Romano was not so much an

epistemological one (in view of the common philosophical basis and the uniformitas doctrinae imposed by the Society), as one involving modes of instruction and, even more, direction of research.

63. This is true for both public declarations and published works. As for private convictions, it is certain that Clavius did not doubt the geocentric theory. Yet some contemporaries had the impression that certain mathematicians of the College (Grienberger and Grassi, and even Scheiner), did not reject categorically the physical reality of heliocentrism. Whatever the basis of these impressions (disputable, at least for Scheiner), the obligation to maintain the official position of the Church, and the philosophical and scriptural reasons that made heliocentrism unacceptable, prevented the mathematicians, at least until the time of Boscovich, from expressing their convictions publicly.

64. See Baldini, *Legem Impone Subactis*, chapters 1 and 2; Baldini, *Cristoforo Clavio insegnante e teorico d'astronomia*.

65. See Baldini, *Legem Impone Subactis*, pp. 127–131; Lattis, *Between Copernicus and Galileo*. In addition, while Clavius lived, his prestige prevented his students from showing themselves too modernly inclined, whereas after 1616 the authorities of the Society were careful to prevent the Roman mathematicians from showing themselves less than faithful to tradition. Their silence, however, cannot be taken as indicative of total conformity and lack of personal reflections. Not only Brahe's model was soon adopted (see n. 82), but at least one of them, Lembo, expounded in his 1616–17 course in Lisbon an astronomical system midway between Brahe's and Riccioli's (formulated more than 30 years later). See Baldini, *Saggi sulla cultura*, p. 161.

66. On Clavius's contribution to the development of the formulae, see A. von Braunmühl, *Vorlesungen über Geschichte der Trigonometrie. Erster Teil (*Leipzig, 1900), pp. 189–192, 196–197, 228–230. On his general role as a mathematician see E. Knobloch, "Sur le rôle de Clavius dans l'histoire des mathématiques," in *Christoph Clavius e l'attività scientifica dei Gesuiti nell'età di Galileo* (Rome, 1995).

67. On the tables of Grienberger see *Clavius, Corrispondenza* VI. ii. 11–13, n. 21. The Tyrolian Jesuit also calculated pi to 38 decimals. See C. Grienberger, *Elementa trigonometrica* (Rome, 1630), toward the end of the Proemium.

68. Naturally this does not mean that Clavius (and Commandino, who translated the Conics into Latin), did not master thoroughly, or did not have any interest in, Apollonius's work. The Jesuit tried for a long time to gain access to the Arabic manuscript of Apollonius, owned by the Medici, which included books 5–7 of the work, hoping to have it translated into Latin. See Clavius's letter to B. Vinta dated October 19, 1605, in Corrispondenza V. i. 164 and the notes on it in V. ii. 95. (Such a translation was accomplished only around 1660 by A. Ecchellensis and G. A. Borelli). The letters of his students also show that the study of the Conics had been an important component in their training. However, particularly before 1600, the Archimedean direction of research clearly prevailed in the School.

69. As far as Europe is concerned, students of Clavius were active from Lithuania (Hay and Bosgrave) to Portugal (Delgado, Gibbons, Grienberger, Wremann, Lembo), and from Ireland to Sicily. See appendix B.

70. As is well known, starting with M. Ricci many astronomical observations were made to establish the latitudes of Asian towns, but many others were made for theoretical purposes—not a few in order to check the reliability of the common astronomical tables and, through them, of the astronomical system according to which they had been calculated. Another important subject was magnetic declination, because of the belief that tables of it could be instrumental in measuring longitudes. There might be a connection between the loss of this collection and the nearly total disappearance of Grienberger's vast correspondence—only a fraction of which can be found in the archive of the Pontifical Gregorian University in Rome, ms. 534. It is also possible, though, that some of the observations may be found in some other manuscript of the archive, for which there exists only a summary inventory. Since scientific information sent from the Asian missions came to Europe through Lisbon, they were first consigned to the Jesuits in S. Antão college. Consequently, a search for copies of these texts need to be carried out in Lisbon—in a much more systematic way than had been done in the past—mainly among the Jesuit manuscripts. in the Biblioteca Nacional (still partially unknown), and in the collection "Jésuitas na Asia" of the Biblioteca da Ajuda.

71. See Jardine, "The Forging of Modern Realism"; Carugo and Crombie, "The Jesuits and Galileo's Ideas of Science and of Nature"; Lattis, *Between Copernicus and Galileo*.

72. This issue, too, has been studied almost exclusively in regard to Clavius focusing, in a limited fashion, on two groups of texts written in the early part of his career, between 1570 and 1590: the programmatic documents mentioned earlier, the epistemological parts of the Prolegomena to his commentary on the *Elements* and some additions to the second edition (1581) of his commentary on Sacrobosco.

73. The theme de certitudine was studied in Pereira and Biancani, exponents, respectively, of the position of the philosophers (often inclined to deny mathematics a scientific role, in the Aristotelian-scholastic sense of the term scientia) and of that of the mathematicians. For an analysis (not altogether convincing) of their ideas, see Giacobbe's, "Epigoni nel Seicento della Quaestio de Certitudine mathematicarum" and "Un gesuita progressista nella Quaestio de Certitudine mathematicarum rinascimentale. For a more recent discussion, see P. Mancosu, *Philosophy of Mathematics and Mathematical Practice in the Seventeenth Century* (New York, 1996). The passage from the physical tradition of the Jesuit philosophers to Physico-mathesis is the subject of Dear's "Jesuit Mathematical Science and the Reconstruction of Experience in the Early Seventeenth Century." His analysis is very general and limited to a restricted group of cases, authors and period. The tensions produced within the Society by the emergence of quantitative physics are exemplified by a passage in J. B Villalpando that describes one attitude current among the mathematicians and another among the philosophers: "Qui, cum mathematicis adhaerescant disciplinis, philosophiae insultant, ac nobilissimae scientiae derogant . . . vel contra . . . qui veterem illam philosophorum iactantiam cum rerum plerumque ignoratione coniunctum sectantes, mathematicas disciplinas contemunt, iniuriis lacessunt, aut damnant." (Prado and Villalpando, *In Ezechielem explanationes et apparatus urbis*, volume 2, p. 49) The Spanish Jesuit alludes to these two attitudes in general terms but it is probable that he also had experience of them in the Collegio Romano.

74. Some evidence suggests this for at least the mathematical school of the Venetian province. See Baldini, *Legem Impone Subactis*, chapters 10 and 11. It is worth mentioning that one of the first instances (not only among the Jesuits) in which the term physico-mathesis occurs is in Guldin's *Dissertatio physico-mathematica de motu terrae ex mutatione centri gravitatis ipsius proveniente*, published at Vienna in 1622 but written in Rome in 1618.

75. See appendix A under the year 1576–77.

76. See the chronological list of the works in appendix A.

77. Only a few topics, like statics, eluded Clavius. For many years he also contemplated writing a Compendium, that is, a synthetic text for the entire program of the public course. But this work (which would have been the first complete Jesuit manual of mathematics) was never written.

78. The impulse to write manuals, documented in letters from students to Clavius, is also evident in Grienberger's manuals of geometry and trigonometry and Biancani's *Sphaera mundi*. The latter (written in 1616–1618, published in 1620) introduced an important discontinuity in content, by replacing the geocentric model with that of Brahe, as well as in structure, by discontinuing the tradition of an introduction to astronomy written in the form of a commentary on a classic text.

79. Some academicians later became known as professors, authors, or administrators of the Society. In their case the notes are limited to essential dates, and references to the bibliography. In other cases, a biographical outline has been provided, drawn from information in the archives. The Scot John Hay (1546–1608) was professor of philosophy and an anti-Protestant polemist in Lithuania, France, and Belgium. See *Clavius, Corrispondenza* I. ii. 59–60, which includes a bibliography. For his published works, see Sommervogel, *Bibliothèque de la compagnie de Jésus* iv. 161–166; xii. 216–217, 1106.

80. Bosgrave (Godmanstone, Dorsetshire, c. 1547–Kalisz 1623), later taught mathematics and philosophy in Bohemia and Poland. He was sent on a secret mission to England (1580), discovered and imprisoned and released in 1585 at the request of the Polish King. See *Dictionary of National Biography* V. 420–421; *Clavius, Corrispondenza* I. ii. 20–21; P. Skwarczynski, "Elsinore 1580: John Rogers and James Bosgrave," *Recusant History* 16 (1982): 1–16; Sommervogel, *Bibliothèque de la compagnie de Jésus* i. 1851.

81. Ricci (Castelfidardo 1543–Rome 1613) should not be confused with Matteo Ricci. In 1574 he taught mathematics at the Collegio Romano and after that he was master of novices in the province of Naples and provincial of Sicily. See *Clavius, Corrispondenza* I. ii. 85–86; Sommervogel, *Bibliothèque de la compagnie de Jésus* vi. 1782–84; ix. 805.

82. Fuligatti (Cervia 1550–Siena 1633), friend of Matteo Ricci and the addressee of Ricci's letters from China, taught mathematics in the Collegio Romano in 1586–87 and was superior in the colleges of central Italy. See *Clavius, Corrispondenza* I. ii. 47–49; Sommervogel, *Bibliothèque de la compagnie de Jésus* iii. 1065–1066.

83. Valerio left the Order in 1580. He taught mathematics in the University of Rome and was member of the Lincei. He is the most notable Italian student of

Clavius. For his relations with the latter see Baldini and Napolitani, "Per una biografia di Luca Valerio." The fullest biographies of M. Ricci (1552–1610) listed in Polgár, *Bibliographie sur l'histoire de la Compagnie de Jésus* III. iii. 65–78, frequently ignored the chronology of his studies, and in particular of his training in mathematics. He followed the year of natural philosophy (the second of the philosophical cursus in which the study of mathematics was included) in 1574–75, when the professor dealing with the material was B. Ricci. Hence his assertion that he studied for some years with Clavius (M. Ricci, *Storia dell'introduzione del Cristianesimo in Cine* (Rome, 1942–49), volume III, p. 207) must refer to an attendance at the Academy, in the period 1575–77. In the latter year he left for Lisbon. Little is known about Ferdinando Capece (Naples or Salerno c. 1545–Cluj, Transylvania 1586). He substituted for Clavius for a year in the public course (probably in 1576–1577) and gave a course of philosophy in the Collegio Romano. In 1583 he was invited to Cluj as rector. Biography and bibliography in *Clavius, Corrispondenza* I. i. 66 n. 23. There is no direct proof of his attendance at the Academy, but between 1572 and 1575 he followed the course of philosophy in the College, and the fact that in 1576 Clavius named him as his own substitute suggests that he considered him qualified for the position. Gibbons (Wells, Somerset, c. 1547–Douai 1632) was later professor of philosophy, mathematics, and theology at Bordeaux, Rome, Coimbra and in Belgian colleges. See Sommervogel, *Bibliothèque de la compagnie de Jésus* iii. 1404–1408; xii. 1086; *Dictionary of National Biography* xxi. 264–265; Baldini, *L'insegnamento della matematica*, pp. 137–138; additional bibliography in *Clavius, Corrispondenza* I. ii. 52–53.

84. Bartolomeo Ricci left Rome in the summer of 1576.

85. Regio (or Reggio: Palermo, c. 1545–Palermo 1614) was later a professor of philosophy in the Sicilian colleges and a professor of theology in Vienna; and superior of the Sicilian Province of the Society. See *Clavius, Corrispondenza* I. ii. 83–84; Sommervogel, *Bibliothèque de la compagnie de Jésus* vi. 1591 He studied with Clavius but it is not clear whether this was at Rome, or while Clavius was in Sicily in 1574. See *Clavius, Corrispondenza* IV. ii. 41–42 n. 1.

86. Pistorius (born in Zatec, Bohemia, c. 1553) can be considered the founder of the mathematical tradition in the College at Prague (one of his students was Grienberger: see n. 96). He left the Society in 1595 and nothing is known on his later life. *Clavius, Corrispondenza* II. ii. 51–52 n. 10.

87. De Angelis (Spoleto 1558–Rome 1597), elder brother of Alessandro, taught philosophy and theology in the Collegio Romano (Sommervogel, *Bibliothèque de la compagnie de Jésus* i. 388; *Clavius, Corrispondenza* III. ii. 54 n. 4). Delgado was later the founder of the school of mathematics in the Portuguese province of the Society. Born at Lagos (Algarve) about 1553; Jesuit in 1574; was at Rome between 1576–85. From 1586 to 1590 he held private courses of mathematics in the college of Coimbra, and from 1590 public courses in that of Lisbon, alternating teaching with the role of architect of the Society. He died at Coimbra at 1612. Two of his courses survive in manuscript: one in astronomy (1605–06) and one in judicial astrology (1607). See Albuquerque, "A 'Aula de Esfera' do colégio de Santo Antão, pp. 369–371; Baldini, "L'insegnamento della matematica," pp. 136, 148. He is mentioned in F. Rodrigues, *Historia da Companhia de Jesus na Assistencia de Portugal*

(Porto, 1931–50), II. i. 22, 209 n. 3, 218; II. ii. 13 n. 1, 97–98; IV. i. 403–404. The sources affirm that Delgado studied with Clavius, but this cannot be dated with precision because such study took place in years for which the catalogues of the Collegio Romano are incomplete. Since a catalogue of 1586 states that Delgado had already finished the course in theology, it can be placed in those five years.

88. Jean Deckers (Hazebrouck, Ypres, 1550–Graz 1619) was afterward one of the most important (and controversial) Jesuit students of theoretical chronology. Among the first to antedate Jesus's birth in several years, his ideas got him into trouble and he was not allowed to publish his opus magnum, over which he labored for 30 years. He was also removed from theological instruction because he was favorable to the positions of Molina and Lessius on Divine Grace. He first taught philosophy and theology in Belgium and then appointed chancellor of the university of Graz. For his life see *Clavius, Corrispondenza* I. ii. 31–32; Sommervogel, *Bibliothèque de la compagnie de Jésus* ii. 1870–73; ix. 180; xi. 1876; xii. 426, 1035. For a bibliography, see Polgár, *Bibliographie sur l'histoire de la Compagnie de Jésus* III. i. 557.

89. Alessandro De Angelis (Spoleto 1563–Ferrara 1620), brother of Muzio, taught theology in Milan and Rome before becoming theologian of the Cardinal Legate in Ferrara. His most important work was a book against astrology. Sommervogel, *Bibliothèque de la compagnie de Jésus* ii. 387; viii. 1653; xii, 923; *Clavius, Corrispondenza* III. ii. 60 n. 24; U. Baldini, "The Roman Inquisition's Condemnation of Astrology: Antecedents, reasons and Consequences," in *Church, Censorship and Culture in Early Modern Italy*, ed. G. Fragnito (Cambridge, 2001), p. 96, p. 109 n. 92.

90. Spinola was later one of the Society's martyrs in Japan and was declared blessed by the Catholic Church. Born in Prague in 1564, to a noble family of Genoa, then moving to Naples where he entered the Society. He attended the Academy during a long stay at Rome, in the interim of being transferred from Naples to Milan, where he taught mathematics from 1591–93. His observation of a lunar eclipse (Nagasaki 1612) was later used by Wremann (n. 112) to measure the longitude of that city. He was put to death in Nagasaki in 1622. See Sommervogel, *Bibliothèque de la compagnie de Jésus* vii. 1146–1147; ix. 657; xii. 818, 1228–1229; Polgár, *Bibliographie sur l'histoire de la Compagnie de Jésus* III. iii. 257; *Clavius, Corrispondenza* III. ii. 8 n. 4, 18 n. 7.

91. Alperio was born in Rome (or Subiaco) c. 1566; Jesuit in Rome in 1586 (Ven. 38, folio 36). From 1588 to 1597 he studied philosophy and theology in the Collegio Romano; his status as academician is evident by the fact that in 1599 he substituted for Grienberger in the public instruction, but we have no dates for his attendance. He pursued the curriculum of natural philosophy and mathematics 1589–90 (when Grienberger was professor); thus, his attendance did not begin before late 1590, and terminated before 1597 (in this year he taught Latin grammar in Ancona: Rom. 79, folio 27). He was again at Rome from 1599–1603 (in 1601–02 he was still giving the public course); From 1603 to 1617 he taught philosophy and theology in the College of Parma, where he died on May 29, 1617. His writings do not survive. For an account of his activity in Parma (where he may have held novel positions similar to those of Biancani), see Baldini, *Legem Impone Subactis*, chapters 10–11.

92. In 1591 Grienberger (Hall, Tyrol, 1564–Rome 1636), then professor of mathematics in Vienna, was called to Rome as substitute for Clavius in the public course in mathematics. He remained permanently in Rome, except for two intervals of instruction in Portugal (1599–1602) and Sicily 1607–10. In 1612 he succeeded Clavius as in director of the Academy of mathematics, and was the principal expert of the Society in the revolutionary phase between 1615 and 1633. In 1616 he assisted Bellarmine in formulating the terms of the condemnation of Copernicus on the part of the Congregation of the Index, and in 1620 that of the decree stipulating the corrections of De revolutionibus. This role arouse in him to an internal tension, partly documented in his correspondence (see Baldini, *Legem Impone Subactis*, chapters 5–6). His publications were inferior, both in number and quality, to the scientific proficiency unanimously acknowledged to him by contemporaries. Sommervogel, *Bibliothèque de la compagnie de Jésus* iii. 1810–1812; ix. 440; xii. 1098; *Clavius, Corrispondenza* I. ii. 55–57 (biography and bibliography).

93. Staserio "studet nunc mathematicae" (catalogue of the Collegio Romano, April 1595, Rom. 53 folio 209). A later catalogue will describe him as "Studuit in Societate . . . Mathem. [annum] 1" (Neap. 80 folio 143v). The next year he began the course of theology but continued to attend the Academy. After completing his studies in Rome he was sent as professor of mathematics to the College of Naples, where he remained almost uninterruptedly until his death. On his life (Bari 1565–Naples 1635) see *Clavius, Corrispondenza* I. ii. 99–100; R. Gatto, *Tra scienza e immaginazione*. Le matematiche presso il collegio gesuitico napoletano (1552–1670 ca.) (Florence, 1994), pp. 75–89, 101–113, 150–160, 308–323. A. Giustiniani (Sibenik/Sebenico, Dalmatia, 1568–Perugia 1620), was later professor of mathematics in the Collegio Romano (1599–1600), and superior of various colleges in central Italy. See *Clavius, Corrispondenza* III. ii. 55 n. 5. Giovanni Battista Luca (born in Naples in 1567) was then student of theology in the fourth year; in the same year 1595 he left the Society and nothing is known of his later life. Some letters in the correspondence of Clavius seem to refer to him as an academician (*Clavius, Corrispondenza* III. ii. 59 n. 21).

94. D'Alessandro (Naples 1570–Naples 1651) was later professor and rector of colleges and provincial of Naples and of Sicily. He does not seem to have written any works, and the text of his lectures has not been preserved. See *Clavius, Corrispondenza* III. ii. 61–62 n. 5; Gatto, *Tra scienza e immaginazione*, pp. 76–78 and passim. Janos Nagy (Fogaras, Transylvania, 1571–Trnava 1615), later taught philosophy and mathematics in Graz and Vienna. (*Clavius, Corrispondenza* III. ii. 74–75). Rocchi (Siena 1572–Macao 1605) was sent in 1596 to the missions in Asia and left from Lisbon in 1597. In 1601 he went from Goa to China, and in 1604 to Japan (see *Clavius, Corrispondenza* III. ii. 65 n. 23; Baldini, "The Portuguese Assistancy of the Society of Jesus," p. 84 n. 113). Gibelli (born in 1567) left the Society in 1597 and nothing further is known of him. See *Clavius, Corrispondenza* III. ii. 80–81 n. 10. Cerroni (Rome 1573–Recanati 1631) was afterward professor and superior of the Jesuit Colleges in the Roman province. His writings are not known. (See *Clavius, Corrispondenza* III. ii. 55–56 n. 8). R. Kobenzl (Slovenia 1571–Vienna 1627) taught philosophy and theology in Vienna and Graz and was superior in colleges in the province of Austria. See Lukács, Catalogi personarum et

officiorum provinciae Austriae, ad indicem; *Clavius, Corrispondenza* III. ii n. 5 to letter 127; Sommervogel, *Bibliothèque de la compagnie de Jésus* ii. 1252; ix. 55.

95. Camogli (or Camoggi) is wholly unknown to historians. Born at Genoa c. 1573 he became a Jesuit in 1591 (Med. 47, folio 218). Between 1598 and 1602 he followed the course of theology. From 1603 he was in various colleges in Northern Italy, including those of Milan and Genoa. In 1617–18 he was again in the Collegio Romano as "extraordinarius," but in the catalogue of that year (Rom. 110, folio 75) his name has been deleted. Nothing is known about his life after 1618, except for some letters sent to him by General M. Vitelleschi (until 1632), preserved in ARSI. No documents survive to attest to his mathematical competence.

96. On Biancani, see E. Grillo, "Biancani, Giuseppe," in Dizionario Biografico degli Italiani, 10 (Rome, 1967), pp. 33–35; Giacobbe, "Epigoni nel Seicento della Quaestio de Certitudine mathematicarum"; Baldini, *Legem Impone Subactis*, chapters 6, 10, 11; *Clavius, Corrispondenza* I. ii. 18–19. His presence in the Collegio Romano is documented only for the following academic year, but in 1598–99 he was not included in the catalogue of the Venetian province, while the catalogue of 1599–1600 says that he was studying mathematics at Rome for the second year. Moreover, his correspondence with Clavius, beginning in February of 1598, resumes only in 1603. It is unlikely that Clavius summoned him to Rome after a year and a half, without having had any contact with him in the meantime.

97. Rom 54, folio 77.

98. Some sources attribute the mathematical competence of Sabatino De Ursis to his studies in the Collegio Romano. Since at the beginning of 1600 he was still in Benevento, and in March of 1602 he left Lisbon for India, his studies at Rome must have occurred only in 1600–01, a period for which no catalogues have been preserved. He is one of the most interesting Jesuit mathematicians in Asia in the generation after M. Ricci. Born at Lecce in 1575, he became a Jesuit at Naples in 1597 and then studied at Naples. He left from Lisbon in March of 1602. From 1603 he was at Macao (destined for Japan and then for the China mission). Between 1603–06 he studied theology at Macao (the catalogue for 1604 states that De Ursis "ouvio hum año de mathematica"). From late 1606 or 1607 he was the colleague of M. Ricci in Peking. (Ricci wished to use the scientific competence of De Ursis in order to gain credit among Chinese scholars). In 1617 he was expelled from Peking, and from 1618 was at Macao where he died in April or May of 1620. De Ursis is known above all for his account of the death of M. Ricci (1610), and for his work on the Chinese calendar. See Sommervogel, *Bibliothèque de la compagnie de Jésus* viii. 351–352; xii. 1040; S. Santagata, Istoria della Compagnia di Gesù appartenente al Regno di Napoli, volumes 3–4 (Naples, 1756–57) IV. 177–188; M. Ricci, Opere storiche I. 523 n. 1, 614–620; II. pp. lviii–ix, 340, 483–487; L. Pfister, *Notices biographiques et bibliographiques sur les jésuites de l'ancienne mission de Chine*, I (Shanghai, 1932), pp. 103–106; J. Dehergne, *Répertoire des Jésuites de Chine de 1552 à 1800* (Rome and Paris, 1973), p. 75; P. D'Elia, *Galileo in Cina* (Rome, 1947), pp. 30–31, 71–114.

99. Gennaro (1577–1644) was at Rome, at first with unknown duties then as a student of theology, from 1599 to 1605. From 1604 his name appears in the

correspondence of Clavius, and it appears that he then served as Clavius's secretary. Later he taught moral theology and was superior in various Jesuit residences in southern Italy. He wrote tables on the length of day at various latitudes, for gnomonical and ecclesiastical use, published frequently from 1626. Among his other works the best known is the Saverio orientale, a history of the Asiatic mission of the Society, of which only the first volume was published, that on the Japanese mission before 1600. The Saverio is one of the sources on the beginning of Jesuit cartography on the Japanese archipelago. See *Clavius, Corrispondenza* V. ii. 45–46 n. 2; Sommervogel, *Bibliothèque de la compagnie de Jésus* iii. 1421–1422.

100. Rom. 53 fols 75, 111; Rom. 110, folio 13; Rom. 79, fols 5, 105. Maelcote (Bruxelles 1572–Rome 1615), became a Jesuit at Tournai in 1590. He studied philosophy and theology until 1596, and between 1597–1601 taught arts and cases of conscience in Belgian colleges. In 1601 Clavius summoned him to Rome, where he remained until his death (except for 2 stays in Belgium in 1607–09, and 1612–13, in the second of which he corresponded with Kepler). At Rome he taught for several years the public course of mathematics, and assisted Clavius and Grienberger in instruction in the Academy and in astronomical observations. He is known above all for the Nuncius sidereus Collegii Romani, the lecture held in May of 1611 in honor of Galileo. He published a work on the astrolabe, while a lecture of his on the supernova of 1604 was published in Baldini, *Legem Impone Subactis*, chapter 4. His lectures on Aristotle's De caelo remain unpublished. See Sommervogel, *Bibliothèque de la compagnie de Jésus* v. 281–282; xii. 855; *Biographie Nationale de Belgique* xii. 43–45; *Clavius, Corrispondenza* II. i. 68–69.

101. For their attendance in the Academy see *Clavius, Corrispondenza* I. i. 55 (for the year 1602). Giacomo Fuligatti (Rome 1576–Rome 1653), nephew of Giulio, was later professor and preacher, but he is known above all as the biographer of Bellarmine and Francisco Xavier. (Sommervogel, *Bibliothèque de la compagnie de Jésus* iii. 1064–1065; ix. 384; *Clavius, Corrispondenza* V. ii. 45 n. 5). Giannotti (Correggio 1575 or 1576–Mirandola 1624) was afterward rector of minor residences in the Venetian province of the Society. See *Clavius, Corrispondenza* I. ii. 51–52; Baldini, *Legem Impone Subactis*, p. 447 nn. 112, 115 and passim. His attendance at the Academy is attested only for 1603–04. However, a 1606 catalogue states that he had studied mathematics for two years (Rom. 54, folio 191). Since he was a student of theology from 1604, he probably attended the Academy as early as 1602–03. Figliucci (Siena 1566–Rome 1622) was professor of mathematics at Naples and of cases of conscience in Rome, and rector of various colleges. For his career and scientific activities, see Sommervogel, *Bibliothèque de la compagnie de Jésus* iii. 735–738; ix. 339–340; xii. 458, 1064; *Clavius, Corrispondenza* I. ii. 40–41; Gatto, *Tra scienza e immaginazione*, pp. 37–59, 130–132. Bombino (Cosenza 1576–Mantova 1648) taught rhetoric, philosophy and sacred scripture at Parma and at Rome and was the influential confessor of the Duke of Mantua. In 1627, for reasons that are not clear, he left the Society and entered the Congregation of Somasca (the episode became notorious in view of his celebrity and elevated position in the Jesuit Order). For his works see Sommervogel, *Bibliothèque de la compagnie de Jésus* i. 1682–1684; viii. 1861; xii. 963; for his life *Clavius, Corrispondenza* III. ii. 79 n. 22. Pernato is practically unknown. Born at Novara in 1576 he became a

Jesuit at Rome in 1593 or 1594. Between 1597–1600 he was student of philosophy at the Collegio Romano, and professor of Latin there between 1600 and 1602. From 1602 to 1606 he was student of theology at the Collegio Romano. He taught philosophy at the College in Ancona from 1608 to 1611 and died at Novara in 1614. Nothing is known of his writings. (Rom. 54 fols 2v, 82, 141v, 189v, 289; Rom. 79 folio 147; Rom. 110 folio 26v).

102. Little is known about Marzi. Born in Novara c. 1576 he entered the Society at Rome in 1598. From 1599 to 1603 he studied arts and philosophy in the Collegio Romano, and theology from 1604 to 1608. He taught moral theology and was superior in minor residences of the Society. He died in Novara in 1628. Rom 54 folio 39v; Rom. 169, folio 22; Rom. 79, folio 74.

103. Rom. 78 I, folio 4. Grassi—(Savona 1583–Rome 1654), future professor of mathematics at the College, architect of the Church adjacent to it, and opponent of Galileo in the debate about the final comet of 1618—established contact with Clavius and Grienberger in the previous year when, as a student of natural philosophy, he followed the institutional course in mathematics. All his advanced studies had taken place in the Collegio Romano (he had entered the Society in Rome in 1600). Studies on Grassi are listed in part in Polgár, *Bibliographie sur l'histoire de la Compagnie de Jésus* III. ii. 96, but no full-scale monograph was devoted to him. Pietro Redondi's portrait of him in *Galileo eretico* (Torino, 1983) is debatable. For a biography, see C. Preti's forthcoming article in Dizionario biografico degli italiani. The judgment on his caliber as a scientist is still colored by his polemics with Galileo. For his works see Sommervogel, *Bibliothèque de la compagnie de Jésus* iii. 1684–1686.

104. Rom. 79, folio 216; Rom. 78 I, fols 14v, 31.

105. In the autumn of 1607 Grienberger was called to teach in Sicily; he returned to Rome in October of 1610. At the end of 1606 or the beginning of 1607 Maelcote also left for Belgium. He returned to Rome in 1608 or 1609.

106. Gregory of St. Vincent was the most talented mathematician trained in the Academy in the last years of Clavius. As mentioned above, he was not a formal member, but attended the Academy while a student of philosophy and theology. The chronology of his presence in Rome is not entirely clear. But in 1606 he was already in the Roman novitiate of S. Andrea (Rom. 54, folio 205). He was still in Rome in 1611, present at Maelcote's lecture in honor of Galileo. For a biography see H. van Looy, *Nationaal Biografisch Wordenboeck* 9 (1981), pp. 677–684; see also the bibliography in Polgár, *Bibliographie* III. iii.

107. Aleni, or Alenis, was one of the most influential missionaries/mathematicians trained by Clavius. (See Pfister and Dehergne, ad indicem; Sommervogel, *Bibliothèque de la compagnie de Jésus* i.157–160; P. Pirri in Dizionario biografico degli italiani, ii. 150–152; Polgár, *Bibliographie sur l'histoire de la Compagnie de Jésus* III. i. 138–139). He belonged to the Venetian province of the Society, and studied at the College of Parma. In 1606 or 1607, when he had already been assigned to the Asiatic mission, he was invited to Rome and remained in the Collegio Romano until the second half of 1608. He left Lisbon for Goa in March of 1609. His first known scientific composition is a letter to Magini dated January 1611 on

a lunar eclipse observed near Goa the previous January (A. Favaro, *Carteggio inedito di Ticone Brahe, Givanni Keplero e di altri celebri astronomi . . . con Giovanni Antonio Magini* (Bologna, 1886), 347–349).

108. Wremann (Vremann, Uremann) is one of the least known among the last students of Clavius. Born at Spalato (Split) in 1583, he became a Jesuit at Rome in 1600. Between 1602–07 he studied arts and philosophy at the Collegio Romano (Rom. 79, fols 76, 81, 149v). He had already attended the Academy during his philosophical studies, since in January 1609 he was sufficiently qualified astronomer to correspond with Magini, and assisted Clavius in observations. Assigned to the Asiatic missions, he went to Portugal probably in the same year (1609), but for unknown reason, possibly connected to the difficulties confronted by the Portuguese during the years 1609–12 in sending non-Iberian Jesuits to Asia (E. Lamalle, "La propagande du P. Nicholas Trigault en faveur des missions de Chine (1616)," in *Archivum Historicum Societatis Iesu*, 9 (1940), 78), he left for Goa only in 1615. His activities in Portugal are unknown before 1614 but he probably studied theology. In 1614–15 he offered a private course of mathematics in the College of Lisbon. In 1612 he sent to Grienberger information on a lunar eclipse Aleni had observed in Macao. The letters of Aleni, and those of Wremann to Grienberger, appear to be lost, but the data was published by Riccioli, who probably obtained it from Kircher, in his Astronomia reformata (I 2, p. 106). Wremann arrived at Macao in 1616 and remained there until 1620 or 1621—teaching, among other things, mathematics—when he was sent to the Chinese interior. His ship was lost in dramatic circumstances, which seriously damaged his health. He died after a few month at Nanking (in April of 1620 or 1621). A letter of his to Magini was printed in Favaro, *Carteggio*, pp. 323–325. See also Sommervogel, *Bibliothèque de la compagnie de Jésus* viii. 922; Pfister, *Notices biographiques*; Dehergne, *Répertoire des Jésuites de Chine*, ad indicem; Z. Dadic, "Matematicki tekst splicanina Ivana Vremana," in *Rasprava: Gradja za Povijest Znanosti. Razreda za Matematicke, Fisicke i Technicke Znanosti*, 4 (1983): 1–6; M. Korade, "Rodaci o Hrvatskim Isusovcima iz XVI. i XVII. st.," in *Vela i prinosi*, 15 (1985): 102–105; J. Antolovich, "Hrvatski misionar isusovak, Ivan Vreman," in *Marulic*, 19 (1986), 37–40.

109. Lembo became a Jesuit in Naples in 1600. From 1602 to 1607 he studied philosophy, and then taught Latin grammar, in Naples. Between 1607 and 1611 he was sent to study theology in Rome, with the intention of also enabling him to attend the Academy. He became particularly interested in instruments and constructed the first telescopes for the College. From 1607 to 1614 he filled administrative posts in the College of Naples. In 1614 he was sent as professor of mathematics to the College of Lisbon where he remained until 1617 when, for health reasons, he returned to Naples. His private lectures of 1616–17 (on the sphere, theory of the calendar, hydraulic machines, optics and the theory of the telescope) are preserved at Lisbon (Arquivo Nacional da Torre do Tombo, ms. 1770). He is known above all as one of the co-signers (together with Clavius, Grienberger and Maelcote) of the April 1611 letter to Cardinal Bellarmine on the astronomical observations of Galileo. See P. Pirri, *Archivum Historicum Societatis Iesu*, 11 (1942), pp. 189–193; *Clavius, Corrispondenza* I. ii. 65–66; Gatto, *Tra scienza e immaginazione*, pp. 303–306 and passim.

110. From the 1610–11 catalogue we learn that Guldin (St. Gall 1577–Graz 1643) came to Rome to study mathematics (Rom. 54, folio 259). However, in that year he was not formally a mathematicus, because he followed the course of philosophy. Since he had arrived in Rome in 1609 it is probable that he attended the Academy in the preceding year. This is confirmed from his correspondence with J. R. Ziegler (the editor of Clavius's *Opera mathematica*), which shows that as early as 1609 Guldin was collaborating on the edition (*Clavius, Corrispondenza* VI. ii. 8–9 n. 3). After 1611 he pursued his study of mathematics while following the course of theology, and remained in the College as an extraordinarius until 1618, when he was sent as professor of mathematics to Graz. Except for St. Vincent, he was the most talented mathematician trained in the College in the first part of the seventeenth century. See H. L. L. Busard, "Paul Guldin," in *Dictionary of Scientific Biography*, ed. C. Gillispie, v. 588–589; E. Giusti, *Bonaventura Cavalieri and the Theory of Indivisibles* (Rome, 1980), pp. 55–65, 73–76; E. Ulivi, "Il teorema di Pappo-Guldino. Dimostrazione e attribuzioni," *Bolletino di storia delle scienze matematiche* 2 (1982), 179–201; I. Bulmer-Thomas, "Guldin's theorem or Pappus's?" *Isis* 75 (1984), 348–352; Polgár, *Bibliographie sur l'histoire de la Compagnie de Jésus* III. ii. 108–109; Lukács, Catalogi personarum et officiorum provinciae Austriae, II. 607; Sommervogel, *Bibliothèque de la compagnie de Jésus* iii. 1946–1947.

111. In February of 1612, a month before Clavius's death, Maelcote left for Belgium. He returned to Rome in the autumn of 1613.

Galileo's Jesuit Connections and Their Influence on His Science

William A. Wallace

So much has been made of Galileo's adversarial relationships with the Jesuits that any connections he may have had with the Society of Jesus could easily be presumed to have had a negative influence on his science. This is not the interpretation to be placed on the title of this essay. The word 'connections' is sufficiently neutral to sidestep the problem of personal relationships; whether Galileo liked or did not like the Jesuits at particular periods or throughout his life is not the point at issue. What is intended is the claim that in his long career Galileo had contacts with a number of Jesuits; moreover, some of these contacts, particularly those before 1612, proved remarkably fruitful for the development of the "new sciences" in which Galileo was interested. The connections that developed were intellectual, not personal, and their overall influence on Galileo's science was positive, not negative. Thus, the thesis being advanced goes contrary to a common perception that would vilify all Jesuits with whom Galileo came in contact, picturing them as ill-informed, bad-willed, and otherwise obstructionist in their dealings with the Pisan scientist. Its aim is to show that this is a misapprehension, and that generally the opposite is true. Indeed, it would be fairer to say that Galileo benefited from his Jesuit connections for well over half his life and that at least some of his success as a scientist can be credited to them.

Galileo's first connection with the Jesuits is the most important, since it underlies much of what follows. During the past 25 years there have come to light surprising pieces of evidence that connect Galileo with Jesuit professors at the Collegio Romano around 1588–1591, the period during which he was launching his teaching career at the University of Pisa.[1] Though the discovery is of crucial importance, thus far it is not widely known or appreciated among historians and philosophers of science. It shows that Galileo's early views on scientific method and on the study of motion were not formed exclusively by professors who taught him at Pisa, such as Francesco Buonamici.[2] They were also influenced by those of young Jesuits, colleagues and probably disciples of Christopher Clavius, who were currently teaching logic and natural philosophy in Rome.[3] Not only this, but much of the Jesuit terminology for dealing with these matters was appropriated by Galileo and developed by him as an integral part of the *nuove scienze* he was to elaborate in his later writings. How this came about, and the influence these Jesuits may have had on the "Father of Modern Science," is the principal theme I shall develop in what follows.[4]

The Collegio Romano

The Collegio Romano was founded by St. Ignatius Loyola in 1551. It grew so rapidly that by 1582 it had to move into a new building just completed for it, one still standing in the center of Rome. The early professors at the Collegio were mainly Spaniards, the most influential being Franciscus Toletus, who had studied at Salamanca before becoming a Jesuit, and Benedictus Pererius, a Valencian who was later to make his mark as a Scripture scholar.[5] Both wrote manuals of philosophy that were first published in the 1570s and reprinted often thereafter. Toletus's texts are important because they were supplemented, and improved upon, in the lecture notes of later Jesuits, one set of which was published as Additamenta to Toletus's logic as late as 1597. Pererius's writings are similar, and his textbook on natural philosophy, *De communibus omnium rerum naturalium principiis et affectionibus* (Rome 1576), exerted considerable influence. Less Thomistic than Toletus, Pererius subscribed to a number of Averroist theses, among which was a strongly expressed opposition to the use of mathematics in the study of nature. This would not have endeared him to Clavius, then mathematics professor at the Collegio, and may explain why Pererius was later "promoted" to the Scripture faculty of that institution.

Apart from the textbooks produced by Toletus and Pererius, there is little published information about the materials covered in course work at the Roman College. Fortunately, however, a large number of extant manuscripts contain the lecture notes of later Jesuits there, and these are a rich sources of data on this subject. Many of these are still conserved in the archives of the Collegio, now the Gregorian University, in Rome; others can be found in the Vatican Library and in libraries in Rome, Pistoia, Milan, Bamberg, Überlingen, Vienna, Lisbon, and Coimbra.[6] For present purposes, the notes of Antonius Menu mark the indispensable starting point for the study of influences on Galileo. Menu lectured on natural philosophy and metaphysics from 1577 to 1579, and then again from 1579 to 1582. Menu inaugurated his physics course only one year after Pererius's *De communibus* was published, but at that time he broke radically with the latter's theses. Instead of adopting a conservative Averroist stance, Menu imported into a general Thomistic framework a progressive Aristotelianism that owed much to the Doctores Parisienses and to the fourteenth-century "calculatory" tradition of Oxford and Paris. On this account he was more open to the use of mathematics in physics than was Pererius, and apparently he was acceptable to Clavius on that account.[7]

Many of Menu's ideas in natural philosophy, particularly his teachings on impetus, were taken up by a successor, Paulus Vallius, who taught *De elementis*, a tract on the elements wherein the motion of heavy and light bodies was treated, from 1585 to 1587.[8] Then, in 1587, Vallius began a sequence that was to become quite usual at the Collegio, wherein each professor would take his class through the entire three years of the philosophy cycle. Vallius taught logic in 1587–88, natural philosophy in 1588–89, and metaphysics in 1589–90. Mutius Vitelleschi pursued the same cycle from 1588 to 1591, and Ludovicus Rugerius from 1589 to 1592.[9] Vitelleschi and Rugerius are important because complete sets of their lectures have been preserved, and these are in remarkable continuity with the portions of the courses of Menu and Vallius that are still extant. This is particularly true of most of the matters that show up in three of Galileo's notebooks, about to be discussed. Strong evidence has accumulated, in fact, to show that the contents of all three notebooks were appropriated from the lecture notes of Vallius (and possibly his colleagues) between 1589 and 1591, while Galileo was beginning his own teaching career at Pisa.

Galileo's Pisan Manuscripts

Since the end of the nineteenth century it has been suspected that two of the Pisan manuscripts, one containing questions on logic (ms. 27) and the other questions on the heavens and the elements (ms. 46), were derived, possibly copied by Galileo, from other sources. The editor of the National

Edition of Galileo's works, Antonio Favaro, thought both were student notebooks, the first written at the Monastery of Vallombrosa around 1577 and the second at the University of Pisa in 1584.[10] Favaro regarded the first manuscript as so insignificant that he excluded it from the National Edition; the other two he published, though suspicious of their value because of the interest they manifested in Aristotelian logic and natural philosophy. Subsequent work has shown that Favaro's dating and evaluations were quite mistaken. The two manuscripts just mentioned, and a third (ms. 71) containing Galileo's early treatises on motion, were written in conjunction with his course preparation at Pisa. Apparently he used Jesuit notes to supply the needed background for his own lectures. And that early Pisan period was one of great productivity for Galileo, during which he laid the foundations on which much of his later work would be based.

The dependence of the Pisan manuscripts on Jesuit notes has not been easy to determine, but the following is a sketch of how it was done.[11] I begin with the logical questions (ms. 27), which starts out with a treatise titled *De praecognitionibus et praecognitis* (On Foreknowledges and the Foreknown).[12] The title is not common, but it is obviously part of a commentary on Aristotle's *Posterior Analytics*, the first chapter of which is concerned with this topic. A search through many manuscripts and printed works finally yielded a book whose table of contents lists questions like this, and indeed gives titles that correspond to other tracts in ms. 27—for example, a *Tractatio de instrumentis sciendi* (Treatise on instruments of knowing), which discusses definition, demonstration, resolution, composition, and other topics important for a scientific methodology. The book, it turns out, was printed at Venice in 1597, and its author, Ludovico Carbone, proposes it as Additamenta to the logic text of Toletus, already mentioned.[13] What is truly remarkable is that a line-by-line comparison of it with Galileo's ms. 27 shows so many parallels that either one was copied from the other or both derive from a common source. But the date is very late, 1597, a full six or seven years after mss. 46 and 71 seem to have been written, whereas ms. 27, by all other indications, should have preceded the other two in order of composition.

This puzzle persisted until my further search through Jesuit materials turned up a two-volume logic text published by Vallius at Lyons in 1622. This text also listed long treatises on these very subjects, though the wording was not as close to Galileo's as that found in the Additamenta. The discovery was most important, however, for the preface to Vallius's second volume includes a passage that reads as follows:

About twenty years ago [i.e., around 1602], a certain individual—possessing a doctorate, having published a number of small books, and being otherwise well known—had a book printed at Venice in which he took over and brought out under his own name a good part of what we had composed in our *De scientia* and had taught at one time, thirty-four years before this date [i.e., in 1588], in the Roman *gymnasio*. And having done this, this good man thought so much of other matters we had covered in our lectures that he took from them, and claimed under his own name, a large part of *De syllogismo, De reductione, De praecognitionibus,* and *De instrumentis sciendi,* and proposed these as kinds of *Additamenta* to the logic of Toletus, especially to the books of the *Prior Analytics*. He further saw fit to publish, again under his own name, our *Introductio* to the whole of logic, having changed only the ordering (disordering it, in my judgment), along with the introductions and conclusions. I wish you to know this, my reader, so that, should you see anything in either, you will know the author. I say, "should you see anything in either," for we have so expanded our entire composition that, if you except only the opinions (which once explained we have not changed), hardly anything similar can you see in either. So in those works you have what he took from me, in this what I have prepared more fully and at length.[14]

This piece of information, to be sure, changed the whole picture. Carbone, through his plagiarism, had unwittingly preserved Vallius's logic course as it was offered at the Collegio Romano in 1587–88, known not to have been completed until August of 1588. Galileo, through the good graces of Clavius, obtained a copy of Vallius's lecture notes, and from these wrote out the interesting materials contained in ms. 27. A detailed study of textual correlations between Galileo's manuscript, Carbone's Additamenta, and Vallius's *Logica* of 1622 reveals that Galileo's questions follow the ordering of Vallius's *Logica*, whereas the Additamenta does not.[15] This confirms that Galileo followed the original ordering of Vallius's lectures whereas Carbone did not—precisely the point made by Vallius in the preface cited above.

Galileo's Jesuit Contact: Christopher Clavius

Galileo's first contact with Clavius came in 1587, when he visited Rome, having left his studies of philosophy at Pisa to pursue a career in mathematics.[16] A year earlier he had composed an original treatise, *Theoremata circa centrum gravitatis solidorum*, which he had circulated among prominent mathematicians for their critique. Apparently he left a copy of this with Clavius late in 1587, for there is an interchange of correspondence between them concerning it in 1588.[17] Clavius was impressed by Galileo's work; indeed, he collaborated with Guidobaldo del Monte to secure the young mathematician a teaching position. With regard to the *Theoremata*, however, he had a difficulty: Galileo's logic was not flawless, for it involved a *petitio principii*, i.e., it presupposed the very point it attempted to prove. The coincidence of dates and subject matter—note that this was 1588 and the problem relates to the role of *suppositiones* in demonstration, precisely the matter covered in Vallius's *Logica* and finished in that same year—points to Clavius as the intermediary through whom Galileo gained access to Vallius's lecture notes. The fact that Vallius had distributed them to his class (he mentions this in his preface[18]) and the fact that Carbone had secured a set argue for their availability at precisely the time Galileo would have benefitted from studying them. And if Clavius did Galileo this favor, once the latter saw the thoroughness with which logical questions were treated at the Collegio (perhaps as contrasted with his previous instruction at the University of Pisa[19]) it would have been reasonable for him to seek additional lecture notes on the heavens, the elements, and the motion of heavy and light bodies. These, after all, were topics in which he was greatly interested and on whose mathematical treatment he would soon be (or already was) lecturing at his own university.

In the absence of apodictic proof, this seems the most plausible way to account for Galileo's acquaintance with the works of these Jesuits. And if one peruses carefully their courses in logic and natural philosophy, and then studies Galileo's writings—not only mss. 27, 46, and 71 but most of his treatises down to *Two New Sciences* (1638)—one finds repeated signs of Jesuit influence on Galileo. I will now point out a few of these signs, especially for their ability to cast light on the concept of science that was regulative throughout his later investigations.

Contents of the Notebooks

As I have already intimated, ms. 27 contains a number of references to *suppositiones* and how they are to be employed in scientific reasoning, particularly in a type of argument known as demonstration *ex suppositione*.[20] Related to this kind of reasoning are two additional points. The first has to do with the removal of impediments that prevent generalizing on the basis of such reasoning. Such impediments are mentioned in a marginal insert on a folio of ms. 27. Apart from the fact that this provides an important clue to copying, it points to a problem that was to remain a concern for Galileo to the end of his life.[21] The second is a detailed discussion of the demonstrative *regressus* found in the last question of the same manuscript.[22] This proves to be basic to the logic of discovery and proof that Galileo was henceforth to make his own. How Galileo used suppositions, impediments, and the technique of the *regressus* not only in his study of the heavens but also in his attempts to construct a science of local motion will occupy us later in this essay.

The physical questions of ms. 46 hold less interest for present purposes. Noteworthy is the fact that two of the questions this manuscript contains, one relating to the number and one to the order of the heavenly spheres, are excerpted almost entirely from Clavius's commentary on the *Sfaera* of Sacrobosco.[23] This was the standard astronomy text of the period, and it was probably in Galileo's possession. In fact, in a letter written by Galileo to his father on November 15, 1590, Galileo tells him that the copy of the *Sfeara* he had requested from home had not yet arrived—which fits in well with other evidence that the manuscript was written late in 1590 or early in 1591.[24] Also noteworthy are two expressions that characterize this particular notebook. The first is its references to the Doctores Parisienses, the fourteenth-century thinkers whom Pierre Duhem regarded as the "precursors" of modern science.[25] Their work had earlier impressed Domingo de Soto, the Dominican under whom Toletus had studied at Salamanca, and was also known to Menu, as already noted. The other is an expression used by these Parisian doctors and their predecessors at Oxford, *uniformiter difformis*, which is the Latin term employed by Soto to describe uniform acceleration in free fall. Galileo shows a surprising acquaintance with this terminology, and the Jesuits are likely to have been its source .[26]

The final notebook, ms. 71, contains Galileo's early treatises on motion. This is of interest because it was written at Pisa and contains a reference to experiments made while dropping objects from a high tower there.[27] One of its folios actually cites Girolamo Borro, who taught at Pisa and had published a work in 1575 titled *De motu gravium et levium*, also cited in Jesuit lecture notes. Borro claimed to have dropped a piece of wood and a piece of lead from a second-story window and to have found that the wood always reached the ground before the lead.[28] Apparently Galileo checked out Borro's account. Galileo writes that he dropped a piece of lead and a piece of wood from a high tower and found that the wood moved more swiftly than the lead at the beginning of the motion, but that the lead eventually overtook the wood and then left it far behind. Galileo emphasizes that he performed this experiment many times, and there is reason to believe he did so from the Leaning Tower. His results have been verified for the case where one holds two balls, one in each hand, and leans over the edge of a parapet when releasing them. For some reason, perhaps muscle fatigue that impedes release of the heavier ball or a tendency to pull up on it, the wood starts before the lead and so gets ahead at the beginning of the motion, though the lead quickly catches up.[29]

Galileo at Padua

Galileo moved to the university city of Padua in 1592, and there he spent the next eighteen years, which he later said were the happiest of his life. Galileo was now professor of mathematics at the University of Padua, whose main building, "Il Bo," is still in use today, used partly as an administration and classroom building and partly as a museum. Among the objects preserved there is the cumbersome lectern from which Galileo is said to have lectured. Only a few rooms away is the anatomical theater in which Fabricius of Aquapendente performed his dissections and where William Harvey got his first instruction as a medical student.

Galileo left numerous records of experiments he performed at Padua, mainly with pendulums and inclined planes, which he never mentions in his published writings. Most of these are preserved in ms. 72, several folios of which record experiments that have been dated and analyzed.[30] Diagrams on the folios show the schematic arrangement of the apparatus Galileo used, along with numbers indicating the distances of travel he had either measured, or calculated beforehand, or both. On the basis of his sketches, various attempts have been made to reconstruct his apparatus—basically inclined planes set on a table top, which would allow a ball rolling down the incline from various heights and for various distances to be projected, either horizontally or obliquely, onto a floor or a surface below. Several of the experiments Galileo performed with apparatus such as this have been duplicated within the last two decades. Scholars offer different interpretations of what he was trying to prove with these "table-top" experiments, as they are now called.[31] It seems fairly certain that some were performed to confirm horizontal inertia and uniform acceleration in free fall. Those two factors, taken together, would explain the semi-parabolic path traced by a ball projected horizontally from the table's surface as it made its way to the floor.

Among the manuscripts relating to these experiments are many fragments, written in Latin, wherein Galileo uses scholastic terminology—expressions such as *gradus velocitatis* (degree of velocity) and *momentum velocitatis* (moment of velocity, roughly equivalent to our concept of "velocity at a point")—when analyzing his experimental results. The source of this terminology has thus far eluded scholars. A plausible possibility would be the Jesuits whom he knew at Padua, various philosophers and mathematicians who had been at the Collegio Romano and thus were colleagues or students of Clavius. Two were Menu and Vallius, the former having been at Padua up to 1606. Another was Giuseppe Biancani. Yet another, Andrea Eudaemon, a Greek whose fuller name was Eudaemon-Ioannis.[32] In a codex in the archives of the Collegio Romano is preserved a long *Quaestio de motu proiectorum*, written by Eudaemon in the calculatory manner, which abounds with expressions such as *uniformiter difformis*, to which I have already alluded.[33] Years later, Mario Guiducci would write to Galileo and remind him about this "Father Andrea, the Greek," with whom he had discussed the "ship's mast experiment" during his years at Padua.[34] Still another Jesuit connection was John Shreck, a Swiss who worked with Galileo at Padua and was admitted to the Academy of the Lincei shortly after Galileo. Shreck became a Jesuit, took the name of Terrentius, and later went to China as a missionary, bringing Galileo's science along with him for the instruction of Chinese astronomers. On hearing of Terrentius and his call to the Jesuits, Galileo wrote that he had exchanged one *Compagnia* (the Lincei) for another, the *Compagnia di Gesù*, one to which he acknowledged he "owed much"![35]

By 1609, just before he perfected the telescope, Galileo had completed most of the work on which his *Two New Sciences*, not to be published until some 30 years later, would be based. In fact, a draft of the part of that book titled "De motu accelerato" is still extant, and the manuscript fragment on which it is written is dated by some scholars as from his Paduan period. The draft is difficult to read because the ink has faded and run, but it has been transcribed, and it can be shown to be almost identical with the corresponding passages in *Two New Sciences*.[36] But then, toward the end of that fateful year, Galileo made his telescope and turned it on the heavens, and that was the end of his researches on motion for a good long while. The *Sidereus nuncius* was published in 1610—written in Latin, as its title suggests—and soon Galileo's name and fame had resounded all over Europe.[37] He would leave his humble professorship and travel to Florence to become "mathematician and philosopher" to the Grand Duke of Tuscany, Cosimo II de' Medici, who was quite young and indeed had been Galileo's student not many years before.

Galileo at Florence

Galileo's life at Florence was far different from what it had been at Padua. He was feted and honored, and even enjoyed a triumphant visit back to the Collegio Romano in 1611. The Jesuit astronomers there had built a telescope and, after several efforts, had succeeded in confirming the main results he had presented in his "Sidereal Messenger." Clavius wrote to Galileo, diagraming in the letter the positions he had observed for the satellites of Jupiter. But, while progressive Aristotelians such as the Jesuits endorsed his findings, the conservative Peripatetics in the universities generally opposed them. It is said that his old friend at Padua, Cesare Cremonini, was so unconvinced that he refused even to look through the telescope.[38] Another adversary, Ludovico delle Colombe, attacked Galileo for his views on floating bodies. At the urging of the Grand Duke, Galileo replied to Colombe in writing, and so entered into another phase of his career—the polemical and rhetorical phase—which he would not relinquish until after the disastrous Trial of 1633.

In connection with this *Discourse on Floating Bodies* let us return to Giuseppe Biancani, the second Jesuit Galileo knew in Padua, referred to above. When the Jesuits were expelled from the Venetian republic in 1606 Biancani went to Parma to be professor of mathematics at the university there. Here he published two works: the first brought Clavius's *Sphaera* up to date, incorporating in it the discoveries of Galileo, Kepler, and others, and enthusiastically endorsing the advances being made in astronomy. The second was a treatise on the nature of mathematics, wherein Biancani defended the possibility of a mathematical physics and justified this science using the canons of Aristotle's *Posterior Analytics*.[39] Biancani endorsed Galileo's analysis of flotation as an excellent example of this new type of science. He also defended Galileo's stand regarding mountains on the moon—which elicited a long letter from Galileo to another Jesuit astronomer, Christopher Grienberger, in which Galileo states that he is "infinitely obliged" to Biancani.[40] Unfortunately this student of Clavius got too enthusiastic in Galileo's cause, and his remaining writings were never passed for publication by the censors of his Order.[41]

The remaining controversies in which Galileo got involved during his years at Florence were not so favorable to the Jesuits. It is difficult to explain the change in attitude after 1612, the year in which Clavius died. The first was occasioned by letters on sunspots published by the German Jesuit, Christopher Scheiner, professor at Ingolstadt. Perhaps the fact that this seemed to question Galileo's claim to priority of discovery serves to explain the vehemence of Galileo's reply. But when one studies both of these works, what is remarkable is that both use the same terminology and the same methods of reasoning—a sign of formation in the same methodological tradition—even though they come to quite different conclusions about the nature of sunspots.[42]

The next controversy was the most enduring and had the gravest consequences for Galileo's later life. It was started not by Jesuits but by the Dominicans at Florence, who saw Galileo's commitment to Copernicanism as calling into question the truth of the Scriptures. The Jesuits got involved, however, in the person of Cardinal Robert Bellarmine, who years earlier had taught astronomy at the Collegio and was now charged with preserving orthodoxy in matters of faith.[43] Bellarmine pointed out to Galileo that his arguments in favor of Copernicus were merely hypothetical, and that until he had produced a demonstration of the earth's motion, he should not try to reinterpret the Scriptures. Galileo used this occasion to write his famous *Letter to the Grand Duchess Christina*. In this letter he suggests that he already has at hand "necessary demonstrations" that will prove his point.[44] Less well known is another letter Galileo wrote, this one to Cardinal Alessandro Orsini in Rome on January 8, 1616, in which he sketched such a demonstration—a causal argument based on the tides—that purported to prove the earth's motion.[45]

The interchange with Bellarmine also gave Galileo the opportunity to explain the ways in which he thought *suppositiones* could be used in proofs that are truly scientific, provided that they are not false suppositions but true suppositions that accord with nature itself.[46] His effort in this direction was stalled, however, by a decree of the Holy Office condemning Copernicanism. An injunction was prepared to serve on Galileo should he not acquiesce to the decree and cease teaching the Copernican theory as anything other than a mathematical hypothesis. This proved unnecessary, and Galileo returned from Rome to Florence. On arrival there, he found that he was being calumniated as a heretic who had been forced to abjure in Rome. Galileo quickly wrote to Bellarmine and secured from him a testimonial that such was not the case. A draft of this document has recently been discovered. This contains emendations in Bellarmine's own hand that absolve Galileo not only from a commitment to Copernicanism but also from any other departure from doctrinal orthodoxy, at Rome or any other place where he had been teaching.[47] It provides unexpected evidence that Bellarmine was indeed Galileo's friend during this difficult crisis.

But his troubles were not over—only this time all are agreed that Galileo brought it on himself. In 1618 a series of comets appeared in the heavens and Orazio Grassi, a successor of Clavius as astronomer at the Collegio, gave a series of lectures on them. They were inoffensive, certainly not directed at Galileo. But it happened that one of Galileo's students, Mario Guiducci—who also had studied at the Collegio Romano—had been invited to lecture at the Florentine Academy, and chose comets as his subject. Guiducci's book turned out to be a vicious attack on Grassi. What is incriminating about it is that its draft version still survives, and shows that most of it was written by Galileo![48] Grassi, probably knowing Guiducci, figured that out for himself, and soon composed a counter-reply to the Galileo-Guiducci missive. This, in turn, provoked two more return attacks on Grassi, one by Guiducci and the other by Galileo. That by Guiducci is most interesting, for it is addressed not to Grassi but to Tarquinio Galluzzi, the Jesuit who had been Guiducci's professor of rhetoric at the Collegio.[49] Galileo's reply was much longer in coming, but when it finally appeared, as *Il Saggiatore*, it was dedicated to the newly elected pope, Urban VIII. This too is a masterpiece of polemical and rhetorical literature.[50]

The mention of Urban VIII brings us to Galileo's *Dialogo* on the two chief world systems, published at Florence in 1632, which incurred Urban's displeasure and brought about Galileo's downfall at the hands of the Roman Inquisition. This too is clever in the rhetorical strategies it employs to favor Copernicus over Ptolemy and Aristotle.[51] At its end, Galileo tried to polish up the tidal argument he had sketched to Orsini sixteen years before, although this time he admitted, at least implicitly, that it was not a demonstration. But Urban ordered his trial nonetheless, which took place at the Dominican church of Santa Maria sopra Minerva in Rome. The injunction of 1616, though never served on Galileo, was introduced as evidence of his wrong-doing, but Galileo was able to produce his exoneration from Bellarmine and headed off that tactic. This did not prevent his being convicted as "vehemently suspect of heresy" and condemned to house arrest for the rest of his life. It is often alleged that Grassi was the villain behind Galileo's condemnation, and recently Pietro Redondi has reproduced a document from the files of the Holy Office which, he argues, was Grassi's charge against Galileo.[52] Handwriting analysis has shown, however, that Redondi is mistaken—the document was not written by Grassi—who, in fact, had argued on Galileo's behalf both before and after the trial.[53]

Most of Galileo's house arrest was spent at Arcetri, just outside Florence, and there he set aside his astronomical theorizing and turned once again to the problem of motion. Space in his villa was ample for experimentation, but there is little evidence he did any at this stage. All of his notes and documents from his Paduan days had been conserved, and he apparently reordered and reworked these to produce his final masterpiece. This was published at Leiden in 1638, only four years before his death. Its title shows that he was still intent on "science" and "demonstration," for in translation it reads "Discourses and Demonstrations Pertaining to Two New Sciences Pertaining to Mechanics and Local Motion."[54] One of the sciences was concerned with the strength of materials and the other with local motion. In his treatment of accelerated motion, Galileo opens with the statement we have already seen in manuscript, written many years before, and gives a full account of his many experiments with pendulums. He discusses only one experiment with inclined planes, however, which he uses to prove the times-squared relationship—that distances of travel down an incline will be proportional to the squares of their times—but makes no mention of the tabletop experiments he had performed in 1608 or 1609, some 30 years earlier.[55]

With this, Galileo had completed his work, had secured the necessary demonstration, and had founded the "new science" of mechanics, for which he is justly celebrated as the "Father of Modern Science." Soon afterward he went blind, and a few years later, in 1642, he passed to his reward, fortified by the Sacraments, to contemplate forever the wonders of the heavens whose vision he had opened up with his little telescope.[56] He was buried in the Church of Santa Croce in Florence, first in a side chapel (because of Urban VIII's continued displeasure with him), and later in the main church, where his tomb can be seen today.

Jesuit Influences on Galileo's Science

Did the Jesuits influence Galileo in the development of his science? It is surely arguable that they did, and mainly in two ways.[57] First in a positive way, by providing the notes in logic from which he learned how to construct a valid scientific demonstration, with the type of rigor sought by Aristotle, for that was what was expected of a *scientia* in Galileo's day; and second in a negative and more restrictive way, by keeping him honest as he sought to develop a new science of the heavens based on the supposition that the earth moves with a twofold motion.[58] In conjunction with the first way, the more important for present purposes, its claim does not imply that Galileo's role was merely passive in the learning process. No, he went beyond the materials he had appropriated from Vallius and others, and he was truly a methodological innovator, though he did so within the general context sketched in his early notebooks. In this sense one may argue that there is a substantial element of continuity between the ideal of science (especially the ideal of a mathematical physics) that was taught at the Collegio Romano around 1590 and the ideal of science that was to emerge in Galileo's later writings.[59]

To substantiate this claim let us return to the demonstrative *regressus* as this is explained in Galileo's ms. 27, which in turn was based on Vallius's exposition in his lectures of 1588. To simplify somewhat, the *regressus* is made up of two progressions, one going from effect to cause, the other from cause to effect. It is called a *regressus* because the second progression actually reverses the direction of the first, with effect and cause now being interchanged. The two progressions, moreover, are separated by an intermediate stage during which the investigator passes from grasping the cause in a confused or material way to seeing it distinctly and formally as the proper cause of the particular effect.[60]

A classical example is the way in which one can demonstrate that the moon is a sphere from the fact of its waxing and waning through crescent and gibbous phases. When studying the phases of the moon, a person makes the first *progressus* when he suspects that this phenomenon is caused by the moon's shape; here he is going a posteriori from effect to cause. Then he enters the intermediate stage, where the burden of the examination is to ascertain if the spherical shape really is the cause, which he usually would do by eliminating other possibilities. For example, the moon is illuminated externally, i.e., by the sun; it is seen by us from many different angles; under such circumstances, there is one shape, and only one, that will cause it to exhibit crescent and gibbous phases. When a person has completed the examination in this fashion, he has grasped the cause formally, and can make the second *progressus*, now a priori, from the cause recognized as such, to its proper effect. In other words, because the moon *is* a sphere (which we do *not* see), it waxes and wanes through the phases we *do* see.[61]

Astronomical Demonstrations

With this understanding of the demonstrative *regressus* it becomes a simple matter to identify how Galileo used it in the astronomical demonstrations he originally proposed in his *Sidereus nuncius* and later in his *Dialogo* on the two world systems. The first application I shall discuss is a straightforward analysis based on his observations with the telescope, which led him to affirm that there are mountains on the moon. Here the first progression proceeds from effect to cause in a vague and general way: shadows on the moon's surface suggest that they are the effect of a mountainous terrain. This insight leads directly to the intermediate stage, a period of observational and even experimental activity, to see whether or not this is the proper explanation. (Apparently Galileo constructed a model of the lunar surface, illuminated it in various ways, viewed it from different angles, and finally came to see that mountains are the only plausible explanation.[62]) The final step, the second *progressus*, then affirms that there *are* mountains on the moon (which we do *not* see), and these are the cause of the shadows we *do* see on its surface.[63]

Galileo's discovery of the satellites of Jupiter may be seen as a similar application of the same method. The discovery of "the four Medicean stars" and their changes of place with respect to Jupiter set up the first *progressus*, in which the movements of the newly discovered heavenly bodies are traced "materially" to their being moons of Jupiter. At first this is merely suspected, but the suspicion sets up the second or intermediate stage wherein a detailed examination of the seemingly erratic motions leads to the conviction that they result from the bodies' actually revolving around the planet, at different periods corresponding to their distances from its center. This brings on the second *progressus*, wherein these revolutions are recognized "formally" as the proper cause of the changes of position of the new "stars," with the conclusion further implied that they are actually moons of Jupiter.[64]

A final example is Galileo's observation of Venus and his discovery that it revolves around the sun and not the earth. Again the procedure falls into a similar methodological pattern. The first *progressus*, undoubtedly suggested to him by Copernicus's system, compares the appearances of Venus as seen through the telescope, say, its apparent magnitude and phases, with a likely cause of those appearances: a possible revolution around the sun. The intermediate stage then checks this out, as it were, with more detailed observations and calculations, to ascertain whether such a revolution is formally the cause of the observed appearances. The final step, the second *progressus*, explicitly identifies this cause and from it demonstrates the properties formally connected with it.[65]

All three of these demonstrations belong to the mixed (*scientia mixta*) or intermediate science (*scientia media*) that makes use of physical and mathematical premises to establish its conclusions and so can, with reason, be referred to as a mathematical physics.[66] The physical premises are the more problematic, since they suppose that the appearances seen through the telescope are not optical illusions but represent factual states of affairs. The mathematical premises for the most part are supplied by projective geometry, although they too are based on a supposition: that light rays travel in straight lines and thus that optical phenomena can be analyzed with the aid of geometrical principles. But the remarkable thing is that the conclusions of the arguments just sketched, after initial opposition on the part of some who had difficulty with the optical evidence on which they were based, were accepted in Galileo's day as true demonstrations. Once they were in possession of a good telescope, for example, the Jesuits at the Collegio Romano quickly assented to all of the claims in the *Sidereus nuncius*.[67] And one might add that Galileo's conclusions command assent to the present day, not as mere theories or hypotheses, but as valid demonstrations on which our knowledge of the solar system is still based.[68]

The Study of Motion

Earlier I referred to Galileo's interest in suppositions and impediments to scientific knowing and how the latter can be circumvented through a technique known as demonstration *ex suppositione*. The suppositions involved in the optical demonstrations just explained are relatively simple, and thus are not particularly helpful for illustrating that technique. More to the point is the way in which they can be employed in constructing a science of local motion. This was Galileo's major breakthrough and represented a type of methodological innovation over the account of demonstration appropriated from Vallius in ms. 27. The following is a simplified and partly conjectural account of how he continued to make use of the basic procedure of the demonstrative *regressus* and successfully adapted it to solve the difficult problems associated with a science of local motion.[69]

In general it seems that Galileo preserved the three stages of the *regressus* as already explained, except that rather than have the first stage conclude to a cause "materially" suspected, as stated in ms. 27, he began to think of the cause at the end of this stage as "supposed," that is, taken *ex suppositione*. The second stage for him then consisted of examining all of the relationships between the supposed cause and its effect to see whether the former is both the necessary and the sufficient condition for the latter under appropriate suppositions. Some of these suppositions, to be sure, would be concerned with the removal of impediments, such as friction and resistance to motion, which could be regarded as accidental or adventitious causes that prevent one from arriving at its essential and proper causes. Suppositions such as these then would have to be reasonably justified, either experimentally or by measurement in cases involving physical-mathematical reasoning. If one could conclude this empirical program successfully, then one would have certified the a posteriori part of the reasoning and could proceed with deducing, in a priori fashion, the results the proper cause entails. This could be done in the fashion of a mathematical treatise, especially when the phenomena investigated admit of joint physical-mathematical analysis in the manner associated with the *scientiae mediae*.

Two examples may now serve to illustrate how this type of *regressus* could work for Galileo, the first in the context of the arguments he initially offered in a letter to Cardinal Orsini mentioned above and then later in the *Dialogo*, the second in the similar context of *Two New Sciences*.

The argument for the earth's motion from the tides may be begun, in this view, with the first *progressus* stated in suppositional fashion: if the earth is rotating daily on its axis and revolving annually around the sun, certain tidal variations will be caused in seas on the earth's surface. The intermediate stage that follows this is crucial, for the alleged cause, the earth's motion, is certainly problematical, going as it does against sense experience and the social and religious sentiment of Galileo's day. In his attempts to certify the reasoning Galileo invoked the so-called barge experiments, his observations of the tides, and a variety of secondary or accidental causes (such as the depth of the sea beds and the shape of their boundaries) that might be counted as so many "impediments" that would explain the deviations he encountered from his expected results.[70]

A question that has intrigued Galileo scholars for years is whether or not Galileo himself believed that he had concluded this stage successfully. In the *Letter to the Grand Duchess Christina* he made claims that would induce one to think he felt he had done so, but there are sufficient qualifications to give pause, and one cannot be sure. A reasonable view would be that by 1615 he himself was not certain that he had solved all the difficulties, but was sufficiently confident that they could be solved that he repeatedly used the expression "necessary demonstration" when referring to his proof in the letter. The *Dialogo* was written under such circumstances that Galileo could not boldly claim his tidal argument to be demonstrative, although some theologians who examined the book charged him with this view.[71] Others, including Jesuit scientists of the time, regarded the argument as made *ex suppositione* but as invoking a false cause, just as Galileo had evaluated the principles behind Ptolemaic astronomy.[72]

The last view represents the majority opinion to this day. The *vera causa* of tidal variation is now thought to be the moon's motion and lunar attraction, so that even were the earth at rest there would still be tidal variations. But the important point to note is that Galileo's logical methodology was not defective.[73] Had he been able to show that the earth's motion was a necessary and sufficient condition for the tides to occur, he would have been able to conclude the second *progressus* and would have achieved the necessary demonstration he was seeking. Unlike hypothetico-deductive reasoning, his was not vulnerable to the *fallacia consequentis* and was not defective from the viewpoint of the logic he had appropriated in ms. 27.

The demonstrative force of the reasoning developed in *Two New Sciences* to establish a *nuova scienza* of motion is even more difficult to evaluate. Schematically, however, it can be formulated in a single argument that shows how Galileo may have thought it demonstrative in the light of his suppositional understanding of the *regressus*. This argument applies to a ball projected horizontally from the top of a table and then allowed to fall naturally to the floor. The first *progressus* in this case is again expressed suppositionally: on the supposition that the ball undergoes a uniform horizontal motion as a result of the projection and at the same time undergoes a uniform vertical acceleration during the period of its fall, the ball will follow a semi-parabolic path to the floor. (Other mathematical properties of the resulting motion, such as satisfying the double-distance rule and the times-squared rule, may also be specified, but these are already implied in the parabolic trajectory.)

The intermediate stage here again is the difficult one, and it undoubtedly caused Galileo considerable "agitation of mind." This consists in showing, from a large number of experiments and calculations, that a uniform horizontal motion and a uniform increase in velocity of fall with respect to time is the only way to explain these mathematical properties within the accuracy of the observed results. Apart from the problem posed by precision in measurement, the mental examination involved suppositions about accidental impedimenta, such as friction and resistance, being either eliminated or reduced to the category of adventitious causes that do not alter the "essential character" of the motion.[74]

In the long run Galileo believed that such suppositions are reasonable and that he had concluded this stage successfully, and so could proceed to the second *progressus*. This, in effect, provided him with the principles on which his science of motion could be based: uniform velocity along the horizontal axis and uniform acceleration along the vertical, in the absence of impediments that might perturb the result. Thus he could organize his final treatise along the lines of a Euclidean formal exposition, confident that his empirical foundations could sustain a "new science" of kinematics or dynamics that would be on a par with the science of statics Archimedes had formulated successfully so many centuries earlier. The demonstrations he offered would still satisfy the Aristotelian canons of the *Posterior Analytics*, but they would be physical-mathematical along the lines of the astronomical demonstrations already discussed, only now they invoke the geometry of conic sections rather than the spherical geometry used to explain the appearances of the moon, Jupiter, and Venus.[75]

Admittedly this exposition of Galileo's relationships with the Jesuits has been brief and sketchy, leaving many questions unanswered. But perhaps it serves to show that Galileo's Jesuit connections were not insignificant, that they extended over a considerable period, and that in the long run they bore considerable fruit. To sum up: Galileo's contacts with Clavius surely gave him his start, his borrowing from Vallius provided him with a sound logic of discovery and proof, and his polemics with later Jesuits pushed his genius to the extreme that was needed to found a new and modern science of mathematical physics.

Notes

1. On how this evidence was uncovered, see William A. Wallace, "Galileo's Sources: Manuscripts or Printed Works," in *Print and Culture in the Renaissance*, ed. G. Tyson and S. Wagonheim (Newark, 1986).

2. I say "exclusively" because of the extent to which many of Galileo's ideas derive from the teachings of Buonamici. See Mario Otto Helbing, *La Filosofia di Francesco Buonamici, professore di Galileo a Pisa* (Pisa, 1989).

3. As it turns out, a goodly number of their teachings were in conformity with the views of Buonamici and his colleagues at the University of Pisa. For an overview, see the introduction to William A. Wallace, *Galileo's Logical Treatises* (Dordrecht and Boston, 1992) (a translation of Galileo's ms. 27, henceforth cited as Galileo, *Treatises*). They were also in conformity with the views of Giovan Battista Benedetti, as is explained in Wallace, "Science and Philosophy at the Collegio Romano in the Time of Benedetti," in *Cultura, Scienze e Techniche nella Venezia del Cinquecento, Atti del Convegno Internazionale di Studio "G. B. Benedetti e il suo tempo"* (Venice, 1987) (reprinted in Wallace, *Galileo, the Jesuits, and the Medieval Aristotle* (Aldershot, 1991), henceforth cited as *Jesuits*). For parallel accounts of Galileo's relationships with these Jesuits, though situated in different contexts, see Wallace, "Galileo and the Professors of the Collegio Romano at the End of the Sixteenth Century," in *Galileo Galilei*, ed. P. Poupard (Pittsburgh, 1987); Wallace, "Reinterpreting Galileo on the Basis of His Latin Manuscripts," in *Reinterpreting Galileo*, ed. W. Wallace (Washington, 1986). The *Galileo Galilei* volume appeared first in French (Tournai, 1983) and later in Italian (Rome, 1984).

4. I have already elaborated on this theme in a variety of ways. My most recent studies, which provide good overviews, are "Galileo's Pisan Studies in Science and Phil-

osophy," in *The Cambridge Companion to Galileo*, ed. P. Machamer (Cambridge, 1998), and "Dialectics, Experiments, and Mathematics in Galileo," in *Scientific Controversies*, ed. P. Machamer et al. (New York and Oxford, 2000). For details of the main earlier works to which I refer, in addition to those cited in the previous note, see *Galileo's Early Notebooks: The Physical Questions*, ed. W. Wallace (Notre Dame, 1977), a translation of Galileo's ms. 46, with historical and paleographical commentary, henceforth cited as *Notebooks*; see also *Prelude to Galileo: Essays on Medieval and Sixteenth-Century Sources of Galileo's Thought* (Dordrecht and Boston, 1981), henceforth cited as *Prelude*; *Galileo and His Sources: The Heritage of the Collegio Romano in Galileo's Science* (Princeton, 1984), henceforth cited as *Sources*; *Galileo Galilei, Tractatio de praecognitionibus et praecognitis and Tractatio de demonstratione*, ed. W. Edwards and W. Wallace (Padua, 1988), henceforth cited as *Galileo, Tractationes*; and *Galileo's Logic of Discovery and Proof: The Background, Content, and Use of His Appropriated Treatises on Aristotle's Posterior Analytics* (Dordrecht and Boston, 1992), henceforth cited as *Logic*.

5. For some details on Toletus, see *Notebooks*, pp. 13–14, passim; *Sources*, pp. 10–14; William A. Wallace, "The Early Jesuits and the Heritage of Domingo de Soto," *History and Technology* 4 (1987): 301–320, esp. pp. 302–304 (reprinted in *Jesuits*). On Pererius, see *Notebooks*, pp. 14–15, passim; *Prelude*, pp. 207–209, 255–262, passim; *Jesuits*, essay 6.

6. For listings of the more important manuscripts, see *Sources*, pp. 351–354, and the notes to "The Early Jesuits" (also in *Jesuits*).

7. On Menu, see *Notebooks*, pp. 16–17, passim; *Prelude*, pp. 243–245, passim; *Sources*, pp. 61–63, 150–155, 158–160, 191–196; William A. Wallace, "Aristotelian Influences on Galileo's Thought," in *Aristotelismo Veneto e Scienza Moderna*, volume I, ed. L. Olivieri (Padua, 1983) (reprinted in *Jesuits*).

8. My pre-1988 publications refer to this author as Paolo Valla, since this is the way his name appears in the rotulus of professors teaching at the Collegio Romano. My subsequent publications refer to him as Paulus Vallius, the name he himself used when publishing his *Logica* of 1622; this accords with other spellings of his family name, de Valle or de la Valle, which appear on some of his manuscripts. For information on Vallius, see *Notebooks*, pp. 17–18, passim; *Prelude*, pp. 245–247, passim; *Sources*, pp. 63–66, 168–170, 178–180, 196–199; William A. Wallace, "Randall Redivivus: Galileo and the Paduan Aristotelians," *Journal of the History of Ideas* 49 (1988): 133–149 (reprinted in *Jesuits*).

9. On Vitelleschi, see *Notebooks*, pp. 18–19, passim; *Prelude*, pp. 111–125, 247–249, 289–290, 330–336; *Sources*, pp. 66–68, 155–157, 160–167, 173–178, 180–189, 201–202; "Aristotelian Influences," in *Aristotelismo Veneto*, volume I, pp. 364–367 (also in *Jesuits*); William A. Wallace, "Causes and Forces in Sixteenth-Century Physics," *Isis* 69 (1978): 400–412 (reprinted in *Prelude*). On Rugerius, see *Notebooks*, pp. 19–20 passim; *Prelude*, pp. 249–251, 311–314, 334–336; *Sources*, pp. 69–70, 170–172, 189–191, 199–201.

10. On the dating of the manuscripts, see *Le Opere di Galileo Galilei*, ed. A. Favaro (Florence, 1890–1909), volume IX, pp. 279–282, and volume I, pp. 9–13. This work is henceforth cited as *GG*.

11. For fuller details, see Wallace, "Galileo's Sources: Manuscripts or Printed Works?"

12. For a transcription of the Latin text of this treatise and a commentary, see Galileo, *Tractationes*, pp. 1–30 and 117–172. For my translation of the text, with notes and commentary, see Galileo, *Treatises*, pp. 85–123.

13. On Carbone, see *Sources*, pp. 12–14, 16–23, 89–95, 223–225. See also Galileo, *Tractationes*, pp. xxv–xxxv. The contents of the Additamenta are listed on pp. xxxii–xxxiii. Carbone was not a Jesuit, though he had studied under them.

14. Paulus Vallius, *Logica* (Lyons, 1622), volume II, p. 1. For the Latin text, see *Sources*, p. 19.

15. For a table showing these textual correlations, see *Sources*, p. 51. It also appears in "Randall Redivivus" and in *Jesuits*.

16. On these early contacts, see *Prelude*, pp. 225–228; *Sources*, pp. 91–95.

17. *GG*, volume X, pp. 24–25, 29–30.

18. The passage is cited on p. 18 of *Sources*.

19. Apparently the logic professors at Pisa during Galileo's studies there were much less distinguished than those in natural philosophy. In any event, they left no publications or manuscripts whereby one might judge their competence. See *GG*, volume I, p. 22; Helbing, *La Filosofia di Francesco Buonamici*, pp. 17–28.

20. *Suppositio* is used here in a sense different from that employed in medieval logic, where it is usually applied to terms to indicate how they are to be understood in a proposition. Here it is applied to propositions themselves when these serve as principles in a demonstrative syllogism. The usage is explained in Aristotle's *Posterior Analytics*; for details, see William A. Wallace, "Aristotle and Galileo: The Uses of Hypothesis (*Suppositio*) in Scientific Reasoning," in *Studies in Aristotle*, ed. D. O'Meara (Washington, 1981) (reprinted in *Jesuits*). The expression *ex suppositione* is discussed in some detail in Wallace, "Galileo and Reasoning Ex suppositione: The Methodology of the Two New Sciences," in *Proceedings of the 1974 Biennial Meeting of the Philosophy of Science Association*, ed. R. Cohen et al. (Dordrecht and Boston, 1976) (enlarged and reprinted in *Prelude*).

21. The text itself states that "the existence of the subject of demonstration must be foreknown [at least for its places and times and removing its impediments], in cases where either a property or some other predicate is shown to inhere in it." The passage enclosed in square brackets is a marginal insert. For the text, see Galileo, *Tractationes*, pp. 10; for a translation, see Galileo, *Treatises*, pp. 93 and 113–114.

22. For the Latin text, see "Randall Redivivus," pp. 146–149 (reprinted in *Jesuits* and in Galileo, *Tractationes*; translated in Galileo, *Treatises*).

23. The questions themselves are translated in *Notebooks*. See also pp. 200–207 of *Prelude*. For additional details, see Wallace, "Galileo's Early Arguments for Geocentrism and His Later Rejection of Them," in *Novità Celesti e Crisi del Sapere*, ed. P. Galluzzi (Florence, 1983).

24. The letter is translated on p. 227 of *Prelude*. For the Italian, see *GG*, volume X, pp. 44–45.

25. For a critical appraisal of Duhem's discoveries relating to these Parisian doctors, see William A. Wallace, "Galileo and the Doctores Parisienses," in *New Perspectives on Galileo*, ed. R. Butts and J. Pitt (Dordrecht and Boston, 1978) (enlarged and reprinted in *Prelude*).

26. On the expression *uniformiter difformis* and Soto's use of it, see William A. Wallace, "The Enigma of Domingo de Soto: Uniformiter difformis and Falling Bodies in Late Medieval Physics," *Isis* 59 (1968): 384–401 (reprinted in *Prelude*); Wallace, "Domingo de Soto's 'Laws' of Motion: Text and Context," in *Texts and Contexts in Ancient and Medieval Science*, ed. E. Sylla and M. McVaugh (Leiden, 1997). For additional details, see "The Early Jesuits," pp. 301–320 (also in *Jesuits*); Wallace, "Late Sixteenth-Century Portuguese Manuscripts Relating to Galileo's Early Notebooks," *Revista Portuguesa de Filosofia* 51 (1995): 677–698.

27. For the treatise in which Galileo makes this reference, see *On Motion and On Mechanics*, tr. I. Drabkin and S. Drake (Madison, 1960), pp. 13–114, esp. p. 107.

28. For this passage in Latin, see William A. Wallace, *Causality and Scientific Explanation* (Ann Arbor, 1972, 1974), volume I, p. 238, n. 110; see also volume I, pp. 149–150.

29. For a discussion of this and related experiments, see T. B. Settle, "Galileo and Early Experimentation," in *Springs of Scientific Creativity*, ed. R. Aris et al. (Minneapolis, 1983).

30. For facsimile reproductions of these folios, see Stillman Drake, "Galileo's Notes on Motion Arranged in Probable Order of Composition and Presented in Reduced Facsimile," *Supplementi agli Annali dell'Istituto e Museo di Storia della Scienza di Firenze* 2 (1979).

31. The more significant contributions include the following: S. Drake, "Galileo's Experimental Confirmation of Horizontal Inertia: Unpublished Manuscripts," *Isis* 64 (1973): 291–305; S. Drake and J. H. MacLachlan, "Galileo's Discovery of the Parabolic Trajectory," *Scientific American* 232 (1975): 102–110; R. H. Naylor, "The Evolution of an Experiment: Guidobaldo del Monte and Galileo's Discorsi Demonstration of the Parabolic Trajectory," *Physis* 17 (1974): 323–346; R. H. Naylor, "Galileo's Theory of Projectile Motion," *Isis* 71 (1980): 550–570; R. H. Naylor, "Galileo's Method of Analysis and Synthesis," *Isis* 81 (1990): 695–707; D. K. Hill, "A Note on a Galilean Worksheet," *Isis* 70 (1979): 269–271; D. K. Hill, "Galileo's Work on 116v: A New Analysis," *Isis* 77 (1986): 283–291; D. K. Hill, "Dissecting Trajectories: Galileo's Early Experiments on Projectile Motion and the Law of Fall," *Isis* 79 (1988): 646–668. For a synoptic overview, see W. A. Wallace, *The Modeling of Nature: Philosophy of Science and Philosophy of Nature in Synthesis* (Washington, 1996), pp. 341–350. On the overall significance of this literature to Galileo's logical methodology, see *Logic*, pp. 263–267.

32. For a preliminary account of these authors and their possible influence on Galileo, see *Sources*, pp. 261–280.

33. For a brief account of this manuscript and its teachings, see "The Early Jesuits," pp. 308–311 (also in *Jesuits*).

34. *GG*, volume XIII, p. 209. For details, see *Sources*, pp. 269–270.

35. *GG*, volume XI, pp. 235, 239, 247, 284, 516. Favaro provides biographical data on Schreck (*GG*, volume II, pp. 534–535).

36. The folios, now bound in ms. 71 along with other early materials on motion, are transcribed in *GG*, volume II, pp. 257–266. For a brief description and analysis in light of Galileo's logical methodology, see *Sources*, pp. 272–276.

37. For a new translation of this work by Albert Van Helden, containing an introduction, conclusion, and notes, see *Sidereus nuncius or The Sidereal Messenger* (Chicago and London, 1989). One of its valuable features, from the viewpoint of the present study, concerns the reactions of Jesuit astronomers at the Collegio Romano to Galileo's telescopic discoveries (pp. 109–113).

38. On Cremonini and his relationships with Galileo, see C. B. Schmitt, *Cesare Cremonini: Un aristotelico al tempo di Galileo* (Venice, 1980).

39. The full titles of these works are *Sphaera mundi seu Cosmographia, demonstrativa ac facili methodo tradita, in qua totius mundi fabrica, una cum novis Tychonis, Kepleri, Galilaei, aliorumque astronomorum adinventis continetur. Accessere: I. Brevis introductio ad Geographiam. II. Apparatus ad mathematicarum studium. III. Echometria, idest Geometrica traditio de Echo* (Bologna, 1620) and *Aristotelis loca mathematica ex universis ipsius operibus collecta et explicata. . . Accessere: De natura mathematicarum scientiarum tractatio, atque Clarorum mathematicorum chronologia* (Bologna, 1615).

40. *GG*, volume XI, p. 180.

41. This information was given to me by Ugo Baldini, who has published a lengthy study on the subject: "Una fonte poco utilizzata per la storia intellettuale: Le 'censurae librorum' e 'opinionum' nell'antica Compagnia di Gesù,' *Annali dell'Istituto Storico Italo-Germanico in Trento* 11 (1985): 19–67. For a more recent and comprehensive account of Biancani's battle with the Jesuit censors, see R. J. Blackwell, *Galileo, Bellarmine, and the Bible* (Notre Dame and London, 1991), pp. 148–153.

42. Both were convinced of the existence of sunspots and of the possibility of attaining scientific knowledge of them through a posteriori reasoning—another way of saying that both employed the demonstrative regressus in their investigations. They were both aware, moreover, of the extreme difficulty of this task, and admitted that their arguments were dialectical or at best demonstrative in a negative or indirect way, that is, they could know what sunspots are not rather than what they actually are. Scheiner attempted to model them as little stars (*stelle*), Galileo, with more success, as clouds (*nugole*). For a fuller analysis of their respective views, see *Logic*, pp. 207–211.

43. Much has been written about Bellarmine and his relationships with Galileo. For an even-handed account that does justice to both parties, see Blackwell, *Galileo, Bellarmine, and the Bible*, esp. pp. 29–110.

44. For a detailed analysis of all of Galileo's claims for demonstrative knowledge of the heavens in the letter to the Grand Duchess, see Jean D. Moss, "The Rhetoric of Proof in Galileo's Writings on the Copernican System," in *Reinterpreting Galileo*. See also Moss, "Galileo's Letter to Christina: Some Rhetorical Considerations," *Renaissance Quarterly* 36 (1983): 547–576; Moss, *Novelties in the Heavens: Rhetoric and Science in the Copernican Controversy* (Chicago, 1993).

45. Titled "Discorso del flusso e reflusso del mare," the letter is contained in *GG*, volume V, pp. 377–395. For a translation, see M. A. Finocchiaro, *The Galileo Affair: A Documentary History* (Berkeley and Los Angeles, 1989), pp. 119–133. On the use of causal terminology, see *Sources*, pp. 94–295; William A. Wallace, "The Problem of Causality in Galileo's Science," *Review of Metaphysics* 36 (1983): 607–632, esp. pp. 621–622 (also in *Jesuits*).

46. This is preserved under the title Considerazioni circa l'opinione Copernicana in *GG*, volume V, pp. 349–370. For a translation, see Finocchiaro, *The Galileo Affair*, pp. 70–86.

47. See Ugo Baldini and G. V. Coyne, "The Louvain Lectures (Lectiones Lovanienses) of Bellarmine and the Autograph Copy of his 1616 Declaration to Galileo," in *Studi Galileiani* (Vatican City, 1984), pp. 24–26.

48. The book itself, titled *Discorsi delle comete*, is reprinted in *GG* (volume VI, pp. 37–108). For the evidence of Galileo's hand in its preparation, see Favaro's Avvertimento preceding the document (*GG*, volume VI, pp. 5–12).

49. The reply took the form of a letter published at Florence in 1620. It is reprinted in *GG* (volume VI, pp. 183–196).

50. For a brief summary of its arguments and their relationships to Galileo's logical terminology, see *Sources*, pp. 295–298.

51. See J. D. Moss, "Galileo's Rhetorical Strategies in Defense of Copernicanism," in *Novità celesti e crisi del sapere*. For a logical analysis of the entire Dialogo from the viewpoint of modern logic, see M. A. Finocchiaro, *Galileo and the Art of Reasoning: Rhetorical Foundations of Logic and Scientific Method* (Dordrecht and Boston, 1980). For a complementary analysis based on Galileo's exposition in ms. 27, see William A. Wallace, "Galileo and Aristotle in the Dialogo," *Angelicum* 60 (1983): 311–332 (reprinted in *Jesuits*).

52. This is the main argument of Redondi's book *Galileo eretico* (Turin, 1983), published in English translation as *Galileo Heretic* (Princeton, 1987).

53. For evidence against Redondi's reading of the document, see *I Documenti del processo di Galileo Galilei*, ed. S. Pagano and A. Luciani (Vatican City, 1984), pp. 44–48. For a more appreciative portrayal of Grassi, see P. M. D'Elia, *Galileo in China* (Cambridge, Mass., 1960), pp. 57–58.

54. The Italian reads "*Discorsi e dimostrazioni matematiche intorno a due nuove scienze attenenti alla mecanica e i movimenti locali*" (*GG*, volume VIII, p. 41). In English usage this is now commonly abbreviated to *Two New Sciences*.

55. The accuracy and the probative value of the inclined-plane experiment have been questioned by Alexandre Koyré. Thomas Settle, on the other hand, has duplicated it and argues that it proves all that Galileo claimed for it ("An Experiment in the History of Science," *Science* 133, 1961: 19–23).

56. Galileo's student Vincenzo Viviani, who was with him at his death, described his passing as follows: "After two months of illness that little by little consumed his spirit, on Wednesday the eighth of January in the year of the Incarnation 1642, at four o'clock in the morning, at the age of seventy-seven years, ten months, and twenty days, he returned his soul to his Creator with philosophical and Christian

perseverance. He sent it, as he liked to believe, to enjoy and to gaze more closely on those eternal and changeless marvels he had so eagerly, if impatiently, by means of a fragile instrument, brought closer to our mortal eyes." (*GG*, volume XIX, p. 623) On Galileo's own religious sentiments at the time of his death, see Olaf Pedersen, "Galileo's Religion," in *The Galileo Affair*, ed. G. Coyne et al. (Vatican City, 1985).

57. My reply here is basically the same as the one I offered some years ago to a similar question, "Did Aristotle influence Galileo in the development of his science?" (Wallace, "Aristotelian Influences," p. 350). In that work I considered Galileo's intellectual achievement in two stages, the first before the publication of the Sidereus nuncius in 1610, at which time he was already 46 years of age, and the second after that publication, to the end of his life at the age of 78. The thesis I advanced was that during the first stage Galileo pursued a progressive Aristotelianism, somewhat tempered by his rejection of reactionary teachings with which he came in contact, and that during the second stage, which was dominated by his rhetorical and polemical concerns, he turned the knowledge he had gained against a conservative Aristotelianism then being used to maintain a philosophical and theological status quo.

58. Both points are developed in a different though complementary way in William A. Wallace, "The Problem of Apodictic Proof in Early Seventeenth-Century Mechanics: Galileo, Guevara, and the Jesuits," *Science in Context* 3 (1989): 67–87 (reprinted in *Jesuits*).

59. For details of the Jesuit ideal of science and how it might be realized in a mathematical physics, see *Logic*, pp. 105–114.

60. This is the way the regressus was understood by Vallius and so passed on to Galileo, as explained in "Randall Redivivus," pp. 141–145 (also in *Jesuits*). Randall himself explains the genesis of this methodology in "The Development of Scientific Method in the School of Padua," *Journal of the History of Ideas* 1 (1940): 177–206. Randall's paper was later expanded into a book: *The School of Padua and the Emergence of Modern Science* (Padua, 1961).

61. This is a very abbreviated account of the methodology with which ancient and medieval astronomers came to a correct explanation of the phases and aspects of the moon, as explained in Galileo's *Trattato della Sfaera* (*GG*, volume II, pp. 250–253). For fuller details, see *Logic*, pp. 193–197.

62. Galileo mentions having done this in his Dialogo (*GG*, volume VII, pp. 111–112).

63. For a more complete analysis of this argument, see Logic, pp. 197–201. In the present day most people are convinced that there are mountains on the moon because astronauts have been on the moon and have seen them with their own eyes. This is the equivalent of having sense experience of the mountains, as opposed to having scientific knowledge of their existence. The problem Galileo faced, along with most observers before the age of space exploration, was that of seeing the mountains with "the eye of the mind," that is, demonstrating their existence from the optical effects they produce on the moon's surface. Many philosophers of science now argue that it is impossible to reason apodictically from effect to cause, but this, it would appear, is precisely what the demonstrative regressus enables one to do.

64. For a more complete explanation of this argument, see *Logic*, pp. 201–203. It is not immediately apparent that the "fixed stars" lined up with Jupiter, as Galileo first saw them on January 7, 1610, are actually circling around that planet. Not until January 11 did Galileo have sufficient evidence to complete the regressus and convince himself that they are not fixed stars at all but actually satellites of the planet (*GG*, volume III, part 1, p. 81).

65. Again see *Logic*, pp. 203–207. In this case Galileo was hampered by the fact that, at the time he was making his observations of Jupiter, Venus was in the morning sky and not in a favorable position for viewing. Not until almost a year later did he have sufficient details of Venus's appearances to make the regressus and assure himself (and others) that it was actually rotating around the sun.

66. Jesuit teachings on the mixed sciences are explained on pp. 97–114 of *Logic*. On how mixed sciences were understood within the Aristotelian tradition and also by Galileo, see James G. Lennox, "Aristotle, Galileo, and 'Mixed Sciences,'" in *Reinterpreting Galileo*, ed. W. Wallace (Washington, 1986).

67. *GG*, volume XI, pp. 93–93. Van Helden has translated the document in which they did so in his *Sidereus nuncius* (pp. 111–112).

68. In any elementary textbook on astronomy one will find essentially the same arguments as Galileo's for establishing our basic understanding of the solar system. See, e.g., Otto Struve et al., *Elementary Astronomy*, revised edition (New York, 1959), pp. 74–80, 98–101.

69. A full exposition would require an analysis of Galileo's earlier writings on motion as well as those incorporated in *Two New Sciences* (*Logic*, pp. 238–298). With regard to *Two New Sciences* itself, I have offered alternative analyses of Galileo's methodology in previous writings; see especially *Prelude*, pp. 150–156; *Sources*, pp. 338–347; Galileo, *Tractationes*, pp. lxxxi–lxxxiii.

70. I offer two analyses of this argument in *Logic,* one based on the way it was first presented to Cardinal Orsini and the other on the way it was presented in the Dialogo. In each I make use of Finocchiaro, *Galileo and the Art of Reasoning* (pp. 42–44).

71. Most noteworthy in this connection is the charge of Melchior Inchofer, (*GG*, volume XIX, pp. 349–356, translated in Finocchiaro, *The Galileo Affair*, pp. 262–270).

72. My view of the matter is that Galileo himself realized that the argument from the tides was not demonstrative, even though he still regarded it as persuasive. See William A. Wallace, "Galileo and Aristotle in the Dialogo," pp. 311–332, esp. 327–332 (also in *Jesuits*).

73. Indeed, Bernard Vinaty makes the case that Galileo's argument may still be seen as "not entirely erroneous." See his "Galileo and Copernicus," in *Galileo Galilei*, ed. Poupard, esp. pp. 27–28.

74. Galileo's references to his "agitation of mind" ("post diuturnas agitationes mentis") (*GG*, volume VIII, p. 197) and to the "essential character of naturally accelerated motion" ("cum essentia motus naturalis accelerati congruere confidimus," ibid.) suggest the use of the demonstrative regressus as described by Zabarella. See Galileo, *Tractationes*, pp. lxxxii–lxxxiii, nn. 73–75.

75. As will be seen in the analysis of this argument in *Logic* (pp. 284–295), none of Galileo's demonstrations is based on efficient causality, that is, on a knowledge of the physical causes of uniform motion or of uniformly accelerated motion; rather, they are all based on formal causality, on the kinematical relationships that hold between space, time, and speed as he had determined them from actual experiments (ea quae naturalia experimenta sensui representant) (*GG*, volume VIII, p. 197). The experiments (plural) to which he refers here go far beyond the inclined-plane experiment he describes in *Two New Sciences*; they include also the "table-top" experiments mentioned above. Naylor's tying these experiments in with Galileo's "method of analysis and synthesis," as suggested in the title of his 1990 essay, seems an implicit confirmation of my claims for the use of the demonstrative regressus.

The Partial Transformation of Medieval Cosmology by Jesuits in the Sixteenth and Seventeenth Centuries

Edward Grant

Because the Jesuit Order was formed in 1540 and survived as a vibrant and powerful force until 1773, when it was dissolved in Europe, Jesuit natural philosophers found themselves living in a period of enormous scientific and intellectual change. Founded only three years before the publication of Copernicus's *De revolutionibus orbium coelestium*, the Jesuits had to confront the new science that was emerging from that landmark treatise. In a real sense, they were caught between two intellectual conceptions of the world: the geocentric Aristotelian world view and the new one taking shape around the heliocentric system of Copernicus and the discoveries of Tycho Brahe and Galileo. What was the reaction of Jesuit natural philosophers?

During the sixteenth century, and in the first 60 years of the history of the Jesuit order, Jesuit cosmological opinion was best represented by the Conimbricenses, the Jesuits at the University of Coimbra, Portugal, who wrote commentaries on most of Aristotle's works, and by Christopher Clavius (1537–1612), whose *Commentary on the Sphere of Sacrobosco*, first published in 1570, went through many editions well into the seventeenth century. The works represented by these authors exerted considerable influence on the seventeenth-century Jesuit natural philosophers Francisco de Oviedo (1602–1651), Pedro Hurtado de Mendoza (1578–1651), Bartholomew Amicus (1562–1649), Roderigo de Arriaga (1592–1667), Thomas Compton-Carleton (ca.1591–1666), George de Rhodes (1597–1661), and Melchior Cornaeus (1598–1665), and on the great Jesuit astronomer Giovanni Baptista Riccioli (1598–1671).

Between 1543 and 1611, the most basic concepts of medieval cosmology came under attack. These attacks fall under two categories. In the first category, arguments derived from Copernican astronomy were directed against the medieval belief in the centrality and immobility of the earth. Arguments in the second category were directed against the traditional Aristotelian concept of an incorruptible and unchanging celestial region and against the well-established belief in the existence of hard celestial orbs. These arguments were based on Tycho Brahe's naked-eye observations of the New Star of 1572 and the comet of 1577 and on Galileo's telescopic observations of the planets. For Jesuits, as indeed for all Catholics, attacks against traditional medieval cosmology in the first category were effectively forbidden by the condemnation of the Copernican theory in 1616. Assaults against celestial incorruptibility and hard orbs in the second category were in no way offensive to Church dogma or tradition. Thus, in the first category it was incumbent on Jesuits to uphold traditional Aristotelian doctrine, but in the second they could agree or disagree with traditional views.

In the seventeenth century, the Jesuits seem to have taken the lead in marshalling arguments against the earth's motion in particular and the Copernican system in general.[1] In 1644, Giorgio Polacco of Venice organized 195 *assertiones* against the earth's motion in a book titled *The Catholic Anti-Copernican*.[2] Seven years later, Giovanni Baptista Riccioli made an even greater effort to defend an immobile earth. His treatment of the question of the earth's immobility or mobility in the *New Almagest* of 1651 was probably the lengthiest, most penetrating, and most authoritative analysis made by any author of the sixteenth or the seventeenth century. He seems to have included every known argument for and against the earth's immobility.

But exactly how did Jesuit natural philosophers respond to the challenges of the new cosmology?

The Jesuit Response to the Ideas and Concepts of the New Cosmology

The Earth

The Earth Lies at the Center of the Universe

Drawing on Aristotle, medieval scholastic natural philosophers had proposed positive arguments in favor of the earth's location at the center of the universe. Jesuit authors would continue the tradition. As the most obvious cause of the earth's centrality, Clavius, Conimbricenses, and Bartholomew

Amicus invoked the natural heaviness of the earth.[3] Only by occupying the center of the universe could the earth be fittingly in the lowest place and be most remote from the heavens. The earth remains motionless at the center of the universe because any movement away from the center would be an ascent and contrary to the earth's heaviness.[4] Amicus argued further (*De caelo*, p. 601, column 2) that a stone dropped through a hole imagined to extend from one side of the earth's diameter to the other "would not be moved except to the middle and there it would naturally rest and not proceed beyond except by force."[5] Clavius observed that heavy bodies always fall naturally at equal angles along diameters of the world toward the center of the earth. Because those diameters intersect at the earth's center, the latter is equivalent to the center of the universe.

Elaborating on John of Sacrobosco's *Sphere*, Clavius furnished other arguments in defense of the earth's cosmic centrality. If we were not equidistant from the heavens, but were nearer to one side than to another, the stars nearer to us would seem greater, which is contrary to experience.[6] And if the earth were not in the center, we would not see half the signs of the zodiac at one time, but observe more than half, or less.[7] Moreover, lunar eclipses would not occur if the earth were not at the center of the universe.[8]

For most Jesuits, as for most scholastics, the center of the world was occupied by the earth because the latter was the heaviest and therefore least noble body in the universe. Its ignobility was further manifested by the fact that it was also the most remote body from the heavens, where the noblest bodies in the universe existed. The Copernicans reversed this situation. On the assumption that the Sun was the noblest planet and that it was in the center of the universe, they argued that the center of the world must of necessity be the noblest place.

To defend the earth's centrality, Riccioli presented a daring interpretation.[9] He conceded that in the natural order the center is the noblest place, but not in the supernatural order, where the noblest place is the empyrean sphere, the highest place, and the worst place is the center of the world, the lowest place, where the damned are located. By assuming that in the natural order the center was the noblest place in the world, Riccioli abandoned the long-held medieval view that the center of the physical world was the most ignoble place of all. But which body occupies the center: sun, or earth? In a dramatic turn, Riccioli insists that in the natural order, the sun does not occupy the center because "the earth, with its living things, especially rational animals, is nobler than the sun."[10] Thus did Riccioli abandon a second traditional opinion: that the sun is nobler than the earth. In mid-seventeenth-century scholastic circles, Riccioli's opinions may be construed as radical departures within the framework of a geocentric world view. Despite his departure, Riccioli left no doubt in subsequent discussion, most notably at the conclusion of his arguments based on Sacred Scripture (see next section), that "physical evidence and certain physico-mathematical demonstrations" were against both a diurnally rotating earth and an immobile sun lying at the center of the universe.[11]

Earth Is Immobile at the Center of the Universe

Jesuit opinion was unanimous in defense of the traditional view that the earth lay at the center of the universe.[12] But was it absolutely immobile, or did it perhaps rotate daily on its axis, as Copernicus argued?[13]

During the Middle Ages a number of scholastic authors considered the possible axial rotation of the earth, which was located at the center of the universe.[14] Although none had accepted the real axial rotation of the earth, John Buridan and Nicole Oresme concluded that axial rotation was as astronomically justifiable as the universally accepted alternative. Some of their arguments, especially those that relied on the relativity of motion, also appear in Copernicus's *De revolutionibus*. When the Jesuits first turned their attention to the possibility of the earth's axial rotation, they followed medieval tradition and did not pose the question in terms of the possible axial rotation of the earth; rather, they asked, as did the Coimbra Jesuits, "whether the earth rests in the middle of the world and what is the cause of its immobility;"[15] or they followed Clavius, who simply takes up the problem under the rubric that "the earth is immobile."[16] In his *Commentary on the Sphere of Sacrobosco* (1581), Clavius attacked Copernicus on astronomical and Scriptural grounds.[17] Most Jesuits, however, did not mention Copernicus. The Conimbricenses, for example, did not mention or allude to Copernicus, although the author of the *Commentary on De caelo* cites the same sources for axial rotation as did Copernicus. In the seventeenth century, some Jesuit authors continued to ignore Copernicus,[18] but most who wrote after 1616, the year of the condemnation of the Copernican system, mentioned him—and sometimes Galileo as well.[19]

Of the three motions attributed to the earth in the Copernican system, the daily rotation attracted the most attention and will be my major concern here.[20] Most of the arguments against axial rotation had medieval counterparts, although embellishments and alterations were made. Arguments from economy and simplicity were important and seemed to favor Copernicus and axial rotation. Prima faciae, it seemed plausible that God would have made a world that operated as simply as possible, one in which the small earth would rotate once a day on its axis rather than have the planets cover vast distances in that same time.

The simplicity argument was, however, easily countered. Although the earth is much smaller than the heavens and would seem to be more readily movable, Amicus insisted that the earth's heaviness made it more unsuitable for motion than water, which was less suited for motion than air, which in turn was less suited for motion than fire. It followed that the superior celestial bodies are far better adapted for motion in their places than is the earth in its place.[21] Nature and God would indeed use the shortest and simplest way to achieve a result if the effect could be achieved equally well in other ways. But this would not apply to any motion assigned to the earth, for if the earth moved with a daily motion it would thwart God's intent to create a resting earth to serve as the dwelling place of man and animals. By moving the planets with such speeds, God also shows the magnitude of his power and love for us. After all, we ought not to reject something just because we imagine it to be difficult.[22]

Riccioli was also unimpressed with simplicity arguments. As long as the spheres themselves are capable of enduring great speeds, the latter were of little consequence. Moreover, God or the motive intelligences that move the spheres would have no difficulty in overcoming any resistances, however large, that might arise from the great velocities of these huge orbs. Because the planetary speeds are regulated by celestial intelligences, our senses suffer no ill effects from them.[23]

New Responses to Axial Rotation

Although most of the Jesuit arguments in the seventeenth century had counterparts in the Middle Ages, attempts to repudiate the earth's axial rotation produced responses that were unknown in the Middle Ages. Many of the physical consequences derived from acceptance of the earth's axial rotation were linked to what was often called the "common motion," which assumed that all bodies on and above the earth's surface shared in the earth's rotational motion. Although Ptolemy had already introduced the concept of common motion, only to reject it as an appropriate justification of the earth's daily rotation,[24] Copernicus defended the earth's daily motion in *De revolutionibus* (book 1, chapter 8), declaring that "the motion of falling and rising bodies in the framework of the universe is twofold, being in every case a compound of straight and circular."[25] The "circular" motion was of course the "common motion" that all light and heavy bodies acquired from the circular motion of the earth's daily motion in which they all shared.

Among Jesuit authors, Riccioli was one of the few to contend seriously with this important argument. The "common motion" entered into a variety of contexts. One such context (which finds no counterpart in the Middle Ages, but which was raised by Copernicus himself and falsely ascribed to Ptolemy) asserts that "living creatures and any other loose weights would by no means remain unshaken" if the earth has a daily axial rotation.[26] Scholastic opponents of the Copernicans specified numerous effects that would be obvious to the senses if there really were a daily motion. Among the effects reported by Riccioli were that lead balls would liquefy in the air from the excess heat caused by its synchronous rotation with the earth, that water from the pipes of fountains would rise and gradually dissipate into insensible drops, that clouds would be dissipated into vapor, that the sound of bells would either be dissipated or heard more easily and swiftly toward the west, and that no odors could be perceived from the east (since the air is always carried toward the east, thus preventing odors from reaching us from the opposite direction).[27] Riccioli seems to have found these arguments inconclusive, insofar as he explains that Copernicans rebut them by appeal to the common motion. None of these effects could occur, since all such entities, whether buildings, natural bodies, or sounds, would be moving west to east with the air itself and would thus offer no resistance to it.[28]

Although Riccioli found many of these simplistic arguments of little value against the Copernicans, he did attempt to refute the "common motion" argument—and the axial rotation of the earth—by other kinds of effects derived from the trajectory of cannonballs and the fall of heavy bodies toward the earth.

Tycho Brahe introduced the cannonball into the debate about the earth's axial rotation. If the earth really rotated daily on its axis from west to east, a cannonball shot westward should traverse a readily detectable greater distance than an identical cannonball fired to the east. Observation, however, reveals no such discrepancy. The cannonballs appear to travel approximately equal distances. Tycho concluded that the earth has no axial rotation. In his arguments on this theme, Riccioli sided with Tycho Brahe and against the Copernicans.[29]

Copernicans analyzed every terrestrial motion as if it were compounded of two motions: its own proper motion and the common motion that it shared with the earth and all other objects on earth. They assumed, however, that the two component motions did not interfere with each other, an assumption that Riccioli rejected because of his conviction that different motions in a body interfered with each other. Riccioli believed that every motion of a body supplied a quantity of impetus to it. Thus, if the earth really rotated daily on its axis, its daily motion should affect the impetus which a body, say a cannonball, possesses as it is projected either eastward or westward. A cannonball projected eastward would be moved eastward not only by the explosive power of the cannon but also by the earth's eastward rotational motion. Under these circumstances, these two impetuses would reinforce each other. By contrast, two oppositely directed impetuses would adversely influence a cannonball shot westward: the impulse of the cannonball to follow the earth's eastward rotation would interfere with the impetus driving the cannonball westward and therefore retard it. The results are the opposite of those we would expect from a purely kinematic standpoint. Thus, if the earth really possessed a daily axial rotation, the eastward shot should go considerably farther than the westward shot. Since Riccioli detected no such discrepancies, he argued against the daily rotation.[30]

In medieval parlance, the motion of the cannonball would have been classified as a violent motion. But what of the natural, rectilinear motions of heavy and light bodies? If the earth had a daily rotational motion, Riccioli was convinced, a heavy body could not return to its natural place by the shortest rectilinear path perpendicular to the earth. Instead its path would be a much longer curved trajectory caused by a combination of the body's common rotational motion and its rectilinear motion. Riccioli found this unacceptable. He was sufficiently traditional and Aristotelian to insist that, by their very natures, heavy bodies had to fall toward the earth in straight lines perpendicular to tangents to the earth's surface.[31] Indeed, this is what was repeatedly observed. For Riccioli, who speaks here for all Aristotelian geocentrists, the physical evidence is not simply that of a few sensations and experiences, "but [arises] from the sensation of all [and has been] repeated nearly an infinite number of times." Should it not be "evident to the sense that heavy bodies descend through a straight line," Riccioli concludes, "nothing will be evident to it and the whole of physical science will be destroyed."[32]

Biblical and Theological Arguments

From the standpoint of science and natural philosophy, Jesuits, as we have seen, were deeply involved with the Copernican theory and its challenge to traditional Aristotelian cosmology. But from the time of Christopher Clavius's first edition of his *Commentary on the Sphere of Sacrobosco* (1570), Jesuit authors became equally involved in the theological implications and ramifications of the Copernican theory. Their interest in and their concerns about the Copernican theory intensified in the seventeenth century because of their long relationship with Galileo—originally friendly to about 1616, and then hostile, especially in 1632–33.[33] Indeed, it was a famous Jesuit, Cardinal Robert Bellarmine (1542–1621), who, on February 26, 1616, warned Galileo to "abandon completely the . . . opinion that the sun stands still at the center of the world and the earth moves."[34] Whatever their attitudes toward Galileo, Jesuits were rarely neutral about him.

Even before the condemnation of the Copernican theory in 1616, Sacred Scripture had become a potent weapon in defense of the traditional world view. By the seventeenth century, various biblical passages were cited in support of traditional geocentric cosmology. If Clavius was one of the first Jesuit scientists and natural philosophers to invoke the Bible against the daily rotation, Riccioli was one of the last and perhaps the most thorough.[35] In the course of his discussion, he mentions most, if not all, of the biblical passages that were relevant to the anti-Copernican cause. The Bible contained passages that mentioned one or the other of the two basic conditions that were opposed to the Copernican system: an earth at rest in the center of the universe and a mobile sun that revolved around it. Riccioli divided his Scriptural passages into these two categories, taking up first "The Motion of the Sun from Sacred Scripture" and then "The Rest and Immobility of the Earth from the Sacred Texts."[36]

As far as Riccioli was concerned, "Propositions of Sacred Scripture, in which the motion of the Sun and the immobility of the Earth are asserted, must be accepted literally according to the proper sense."[37] The literal sense of Scripture must prevail, Riccioli insisted, "as long as there is no contradiction [repugnantia] with other propositions of the same Sacred Scripture that are equally or more certain, or [as long as there is no contradiction] with a definition of the Roman Pontiff of the Catholic Church, or with any proposition that is certain and evident by a natural light." In Riccioli's judgment, the numerous propositions of the Bible in support of a stable earth and a moving sun did not violate these conditions.[38]

The Celestial Region

If the Copernican system, with its assumption of the earth's motion and the sun's immobility at the center of the universe, brought theological censure, the new discoveries that altered the perception of the heavens carried no stigma and could be rejected or accepted without fear of theological denunciation. We saw above that the "new discoveries" included the New Star of 1572, the comet of 1577, and Galileo's telescopic discoveries of 1610 and 1611, namely the satellites of Jupiter and the observation of sunspots (the latter discovery also made by others in the same year, one of whom was the Jesuit Christopher Scheiner). The implications of these discoveries were potentially profound. The New Star threatened the venerable and cherished Aristotelian concept of an absolutely unchangeable and incorruptible celestial region; the comet, thought by Tycho to be moving in a circular orbit around the sun, threatened to destroy the widely held view that the planets were carried around by hard celestial orbs. Such hard spheres either would have prevented the comet of 1577 from following its observed path or would have been shattered by its impact.

Hard Orbs and Celestial Incorruptibility

So great were the potential consequences of Tycho Brahe's claim that the New Star of 1572 and the comet of 1577 were celestial phenomena that many, if not most, scholastic natural philosophers sought to deny the celestial locale of those phenomena; if they were celestial phenomena, both of these astronomical events seemed, at first glance, to signify that the celestial region was capable of change and corruptibility. The long-standing medieval tradition of celestial incorruptibility would have to be repudiated. Among natural philosophers of the late sixteenth century and the seventeenth century, Jesuits seemed to have been most receptive to Tycho's claims and to the subsequent discoveries of sunspots in 1611, which seemed to further reinforce Tycho's position on the actuality of celestial change.

The initial reaction of scholastic natural philosophers was to deny the celestial location of the New Star of 1572 and the comet of 1577. The famous Jesuit astronomer Christopher Clavius was one of the first astronomers and natural philosophers, and perhaps the first Jesuit, to adopt Tycho's celestial location for these two astronomical phenomena of the 1570s. He insisted that the new star was in the region of the firmament because it maintained the same distance and relative position with respect to the other fixed stars.[39] Moreover, if the New Star were no further away than the atmosphere, or air, it should have revealed different aspects. None had been observed. Nor indeed could it be in any of the regular planetary orbs, because no astronomer had yet detected any motions that might indicate this. Clavius concluded that it had to be in the most remote parts of the celestial region, that is, in the firmament among the the fixed stars.

But from whence did this new celestial body derive? If it was not a divine supernatural creation, then it must be natural. If the latter, then it was plausible to infer that comets as well as new stars can emerge in the heavens, which "is not a certain fifth element, but a mutable body, although less corruptible than inferior [terrestrial] bodies."[40] Just as Clavius seems on the verge of opting for the corruptibility of the celestial region, he explicitly declines to interpose his opinion, resting content to have demonstrated the celestial location of the new star. Only God, in his judgment, knew the answers to such questions. By accepting a celestial location for the new astronomical phenomena, Clavius took only the first step. He refused to speculate on the corruptibility or incorruptibility of the celestial region.

The assumption of new stars as celestial phenomena posed a major question: How could one preserve the incorruptibility of the heavens while simultaneously accepting the real celestial location of new stars? That all the Jesuits mentioned thus far accepted the celestial location of the new star and comets is in itself noteworthy. Unlike Clavius, however, most of them expressed an opinion as to whether the new star (and comets as well) was a new celestial phenomena and therefore represented a physical change in the heavens that would now have to be considered corruptible; or whether the new star (and comets) represented rearrangements or realignments of already existing bodies, so that the changes were merely accidental and not substantial. The latter approach, conceived as saving celestial incorruptibility, was maintained by a number of Jesuits, including the Coimbra Jesuits, Bartholomew Amicus, and Franciscus de Oviedo. For them the best evidence for celestial incorruptibility continued to be the experience of the ages, which revealed a remarkable constancy in the celestial region.[41]

Amicus describes four representative arguments to illustrate the manner in which this group chose to interpret the new discoveries. All four explanations denied the occurrence of substantial celestial changes.

The first explanation sought to preserve the Aristotelian interpretation that all the seemingly new phenomena are actually sublunar. To achieve this, they attributed the new phenomena to the physical effects of various external causes, such as an impure medium, the extreme distance of the objects and the falsity of the instruments.[42] In general, they were the results of tricks played on our senses.

The second explanation appealed to God's supernatural power. One could readily concede that the newly observed phenomena are in the etherial heaven in both substance and accidents, placed there by a supernatural power.[43] Because of their supernatural origin, the new celestial phenomena should not count as natural celestial alterations. Celestial incorruptibility remained inviolate. Although explanation by miracle was given a strong boost when the Coimbra Jesuits adopted it at the end of the sixteenth century as the "more probable" [verisimilior] interpretation,[44] few scholastics chose to follow them in the seventeenth century. Oviedo informed his readers that his concern for the question of celestial incorruptibility was confined to natural causes since almost all scholars were agreed that God could corrupt the heavens if He wished.[45]

The third explanation was clearly the most important and represents a response against those who located some, or all, comets and new stars above the moon.[46] To counter such claims, Amicus thought it necessary to explain the emergence and disappearance of comets and new stars without the assumption of the generation and corruption of any new celestial substance.[47] In what he regarded as the most plausible response (his fourth argument), Amicus invoked epicycles, suggesting that when three planetary epicycles are aligned in such a way that their denser etherial parts are clustered together the sun would illuminate the etherial cluster and make it appear as a visible new star. As the planets and their epicycles move away from each other, the new star gradually fades.[48]

Another tactic in defense of the traditional position was to draw empirical consequences from a corruptible heaven. On the assumption that fire would form part of a corruptible heaven, Hurtado de Mendoza assumed that moon and fire would oppose each other, such that the stronger of the two would consume all or part of the other in the same manner in which fire consumes the part of the air nearest to it. But we observe nothing to indicate such a struggle.[49] Moreover, if the heavens were corruptible, they would be subject to corruption by some natural agent. Over thousands of years, that natural agent should have acted and corrupted the heavens sufficiently so that they would have lost their ability to govern and perpetuate the world. Again, we observe nothing in support of such a drastic consequence.[50]

Thus was celestial incorruptibility preserved to the satisfaction of Amicus and other scholastic authors. During the course of the third quarter of the seventeenth century, however, a major shift occurred. In that period, at least three Jesuit authors—Riccioli, Cornaeus, and George de Rhodes—abandoned the traditional scholastic belief in celestial incorruptibility. Riccioli, whose views were most widely known, believed that "from its very internal nature, the heaven has the capacity for generation and corruption."[51] Three sources prompted Riccioli to accept celestial corruptibility:

> The authority of Sacred Scripture, the testimony of the Fathers, and the arguments derived from experience concerning spots and torches near the solar disk that were discovered by the telescope and from certain comets that have come into being and passed away above the moon. These changes are more naturally explained by generation and corruption than by other more violent means or by nonviolent miracles.[52]

Of these three sources, Riccioli heeded the Church Fathers most, for it was they who convinced him that the heavens were composed of two elements that were identical with their terrestrial counterparts, namely water and fire, with the former comprising the solid sphere of the fixed stars and the latter comprising the planetary heavens, which Riccioli conceived as a fiery fluid. Because water and fire constituted a vital aspect of terrestrial change, Riccioli, like the Church Fathers he claimed to follow, assumed that they were also involved in celestial generations and corruptions.

Riccioli readily admitted that no genuine evidence or precise arguments could be offered in support of the claim that the heaven of the fixed stars was a congealed watery solid and the heaven of the planets was a fiery fluid.[53] Patristic authorities were, however, at hand. Some of the fathers had held that the heaven consisted of elementary water, others that it was composed of elementary fire.[54] It therefore seemed a good compromise to identify the sphere of the fixed stars as the solid and watery sphere both because the stars themselves remained fixed and unchanging and seemed to enclose the world and because the word 'firmamentum' was used to describe the starry sphere; and to interpret the heaven through which the planets moved as a fiery fluid since the paths of the planets varied.[55]

Riccioli's assumption of a fluid planetary heaven was not of itself a sufficient indication of a belief in celestial corruptibility,[56] but his belief that the heaven actually consisted of two terrestrial elements was. In his chapter on the corruptibility or incorruptibility of the celestial region, which immediately follows the chapter that identifies celestial and terrestrial matter, Riccioli declares the corruptibility of the celestial region. On the basis of his assumption that the heaven of the fixed stars is most probably watery and that the heaven of the planets is fiery, he infers "that from its very internal nature, the heaven has the capacity for generation and corruption."[57] However, Riccioli informs us later that it was not only ideas from the Church Fathers and Scripture that led him to accept celestial corruptibility but also "the arguments derived from experience concerning spots and torches near the solar disk that were discovered by the telescope and from certain comets that have come into being and passed away above the moon." "These changes," he continues, "are more naturally explained by generation and corruption than by other more violent means or by nonviolent miracles."[58]

Though by its elemental nature the heaven is intrinsically corruptible, it is not corruptible by any naturally created external agent. Riccioli regarded the celestial region as "accidentally incorruptible" [per accidens esse incorruptibile] because no natural, external agent could corrupt it.[59] But if its totality was "accidentally incorruptible," the parts of the celestial region were corruptible. Riccioli compared celestial incorruptibility to that incorruptibility which applies to the whole earth and to the totality of air, each of which is really incorruptible as a totality even though its parts suffer continual change.

Only with regard to the empyrean sphere did Riccioli accept the traditional opinion of incorruptibility. That outermost, immobile sphere was, however, invisible, although it was required for the perfection of the universe and for the incorruptibility and eternal well-being of our bodies.[60]

Melchior Cornaeus and Georgius de Rhodes, who both published after Riccioli, reinforced the latter's defense of celestial corruptibility.[61] De Rhodes went beyond Riccioli and argued for the fluidity of the entire heavens, including the sphere of the fixed stars.[62] In other respects, however, he seems to have followed Riccioli closely.

During the seventeenth century, Jesuits led the way in changing scholastic opinion about celestial incorruptibility from what it had been during the period between the Middle Ages and the end of the sixteenth century. Even if the majority of seventeenth-century scholastics retained the traditional opinion (and this is by no means certain), Jesuit scholastics such as Riccioli, Cornaeus, and de Rhodes were prepared to abandon it and concede that substantial generations and corruptions could and did occur in the celestial region. In answering the charge that Aristotle had declared the heavens to be immutable and incorruptible, Cornaeus even declared:

> . . . if Aristotle were alive today and could see the alterations and conflagrations that we now perceive in the sun, he would, without doubt, change his opinion and join us. Surely the same could be said about the planets, of which the Philosopher knew no more than seven. But in our time, through the works of the telescope, which was lacking to him, we know for an absolute certainty that there are more.[63]

A Fluid Heaven and Celestial Corruptibility

Our three Jesuits were agreed on celestial corruptibility because they assumed that the heavens were composed of two or more of the same elements found in the terrestrial region. Did the gradual acceptance of a fluid heaven play a significant role in the abandonment of celestial incorruptibility? Tycho Brahe's claim that the comet of 1577 was moving among the planets clearly implied the nonexistence of solid planetary spheres.[64] For those who accepted comets as supralunar, a gradual but inexorable shift toward a fluid heaven began. But did a fluid heaven imply a corruptible heaven? At least one Jesuit scholastic, Antonio Rubio, in a work published in 1615, expressed the belief that a fluid heaven would have to be corruptible (presumably because of divisibility) and therefore rejected it.[65] But other Jesuits, including Bartholomew Amicus and Franciscus de Oviedo, thought that the solidity or fluidity of the heavens was irrelevant to the issue of incorruptibility. Indeed, Oviedo believed that the heaven was both fluid and incorruptible. For some scholastics, then, fluidity alone did not necessarily entail divisibility. The matter of the heaven might be such that it was only capable of receiving a single form; or celestial matter might be incorruptible by virtue of its form, a form that adhered to its matter so firmly that another could not be received.[66] A seventeenth-century scholastic could therefore accept fluidity and incorruptibility. Although the shift from hard solidity to fluidity was a significant change from the medieval tradition, it was not crucial for the issue of celestial incorruptibility. With this in mind, let us now consider Jesuit opinions on the nature of the heavens: solidly hard, or soft and fluid?

Hard Orbs or Fluid Heaven?

During the late Middle Ages, scholastics devoted no specific *questio* to the hardness or fluidity of the heavens or orbs, from which we may infer that the hardness or softness of the celestial orbs was not judged a significant topic. Some did, however, find occasion to discuss the issue, usually within some other cosmological question. In the thirteenth century most scholastics assumed a fluid heaven, but in the course of the fourteenth century most scholastic natural philosophers opted for hard orbs.[67] By the time Tycho Brahe made his views known, in the late sixteenth century, the hardness theory was dominant. Tycho Brahe challenged and changed the hardness theory for two fundamental reasons: (1) His world system required an intersection between the orbits of Mars and the sun, which would have been impossible if hard spheres existed. (2) By virtue of his own careful observations, Tycho confirmed that the comet of 1577 was moving in the celestial region beyond the moon. He therefore denied the existence of solid, hard celestial orbs, and opted instead for a heavenly region that was composed of a fluid substance.[68] Before Tycho's arguments took hold, belief in the existence of hard, solid spheres was common, at least in the early seventeenth century. But it was not unanimous. Between 1570 and 1572, Robert Bellarmine, the famous Jesuit of the Galileo affair, emphatically rejected hard orbs—indeed orbs of any kind[69]—and insisted that celestial bodies moved freely through a fluid medium, "like birds in the air and fishes in the sea."[70]

In his *Cursus philosophicus* of 1632, Roderigo de Arriaga explained that just a few years earlier celestial incorruptibility and hard solidity "were absolutely beyond controversy."[71] By the time his book appeared, fluid and corruptible heavens had largely replaced the two previously entrenched concepts, and they had done so because of "the diligent observations of certain mathematicians and astronomers, which [observations] were discovered with the aid of new and excellent instruments, especially the telescope. Thus did some [individuals] begin to invert completely the structure of the heavens."[72] Writing before 1661 (the year of his death), George de Rhodes, whose book was published posthumously in 1672, could say "no one now denies the fluidity of the heaven of the planets."[73]

Because of the popularity of Tycho's world system within the Society, Jesuit opinion favored a fluid heaven. Among the few Jesuits who defended the existence of solid orbs were the Conimbricenses, Bartholomew Amicus, and Thomas Compton-Carleton. Jesuit advocates of a fluid heaven included Hurtado de Mendoza, Roderigo de Arriaga, Francisco de Oviedo, Giovanni Baptista Riccioli, Melchior Cornaeus, and George de Rhodes. Some in the latter group, including Hurtado de Mendoza and Riccioli, envisioned a heaven that was essentially fluid in its planetary part but surrounded by a solid, hard sphere of fixed stars. Despite the assumption of one hard enclosing sphere, Hurtado and Riccioli may be appropriately identified with the fluid theorists.

What did Jesuit natural philosophers understand by a "fluid" heaven? In responding to the question "whether the heavens are fluid," Roderigo de Arriaga thought it important to explain what he understood by fluid. It need not be a "watery liquid" [liquor aqueus], for "it suffices if they [the heavens] are easily permeable, much like our air, which is, nevertheless, not called absolutely fluid."[74] Thus, the heavens could range from a liquid to a gas and still be categorized as a fluid. The meaning of fluidity was apparently extended in this manner to avoid the charge that a watery liquid heaven would fall as rain. A vaporized fluid, analogous to air, was more readily conceived to remain in its celestial location. The "fluid" could signify either a liquid or a gaseous state for the heavens. Not many authors bothered to identify their choice.

In the controversy about a hard or a fluid heaven, biblical passages were cited on both sides of the controversy and therefore largely offset each other.[75] They were invoked because Scriptural authority was still thought important. Of these numerous passages, Job 37: 18 served as the most important biblical support for hard orbs. Isaiah 51: 6 was the most frequently cited passage upholding a fluid heaven, insofar as it contained the phrase "quia caeli sicut fumus liquescent" ("because the heavens appear as smoke").[76]

Jesuits who argued against hard orbs and for a fluid heaven relied heavily on Tycho Brahe's interpretation of comets. But they did not embrace his views without hesitation and qualification. Riccioli summarized virtually all the relevant arguments with respect to the formation, the substance, the location, and the distance of comets.[77] Some thought that the comets were below the moon, others that they were above the moon, and others that some comets were below the moon and some above it. Opinions as to the matter from which comets were formed ranged from the sublunar elements in various manifestations to celestial matter, either by means of condensation, by the alteration of parts of the heaven, and even by matter flowing from the sun and the planets.[78] Toward the end of what was surely one of the lengthiest and most detailed studies of comets in the seventeenth century, Riccioli arrived at cautious conclusions that conceded the probability but not the certainty of supralunar comets. Because he was not yet convinced that there had been any absolute demonstration that any comets were above the moon (second conclusion),[79] Riccioli concluded that it was probable that some comets were above the moon and some below. History, he acknowledged, could furnish no information to help determine cometary locations.[80] On this basis, Riccioli argued that free trajectories of comets above the moon, which astronomers had demonstrated, would be incompatible with solid eccentric, concentric, and epicyclic heavens[81]. In a world of solid orbs, Riccioli implied, epicycles would also be required to carry comets. But since comets appear only occasionally, where would the matter come from to form a special epicycle for any particular comet, and from whence would the place appear to accommodate the epicycle? Because no such special adjustments seemed possible or plausible, Riccioli concluded that the free trajectory of comets demonstrates the fluidity of the heavens.

Melchior Cornaeus, who accepted Tycho Brahe's geoheliocentric system, was fully aware that in Tycho's scheme, which departs radically from Aristotelian cosmology, a number of planetary motions are centered on bodies other than the earth. Cornaeus mentioned Mercury and Venus (which moved around the sun as center and were therefore sometimes above and sometimes below it, a state of affairs that was based on Tycho's geoheliocentric system and Galileo's discovery of the phases of Venus[82]), the intersection of the orbits of Mars and the sun (so that Mars is sometimes below the sun, as well as above it[83]), and the four satellites of Jupiter (which are also sometimes above Jupiter and sometimes below it, and sometimes ahead of it and sometimes behind it). And yet all these subsystems also moved around the earth. No arrangement of hard orbs could survive the movement of these subsystems through the heavens. It would be impossible, said Cornaeus, for these celestial bodies to be fixed in a solid, hard heaven.[84]

Riccioli, who had rejected the argument from simplicity in defense of the Copernican system, now sought to invoke it in support of a fluid heaven and against hard orbs. It seemed unlikely, he thought, that the Divine Wisdom would create a vast and complex machinery of orbs to carry around a single planet like Saturn, when He could have done it so easily by the use of a motive Intelligence. Hard orbs appear even more incongruous when one realizes that a planet is like a point with respect to the orb that carries it—indeed it bears a smaller ratio to it than any drop of water to the ocean. Why construct a vast orb to carry a small planet? Thus did Riccioli imply that the Divine Wisdom would have rejected hard orbs and resorted to the simpler expedient of a fluid heaven.[85]

Despite the inexorable, if gradual, abandonment of hard orbs in favor of a fluid heaven, a system of hard orbs had its Jesuit defenders. One of the most prominent was Bartholomew Amicus, who emphasized that the very name *firmamentum*, which applies to the heaven of the fixed stars, implies firmness and solidity. Moreover, a solid body is required to divide the waters from the waters, since a liquid body has no proper boundaries. Without a solid, hard firmament to play this role the waters would mix with the things around them.[86] However, *firmamentum* applies not only to the sphere of the fixed stars but also to all the other heavens and planets. After all, in Genesis 1: 14–17, which Amicus cites, God placed in that very firmament the luminaries he created on the fourth day. Planets and stars were all parts of the firmament.[87]

If the celestial substance were really fluid, the enormous velocities of the gigantic celestial bodies that move through it would seem of necessity to produce a loud noise, especially at the point of impact.[88] Although Amicus did not draw the inference, it followed that, because we do not hear such a sound, the heaven is not of a fluid nature.[89] On a more positive note, Amicus also argued that solid, interconnected, and interrelated orbs conferred more nobility on the heaven than would be the case with stars and planets moving independently through a fluid medium, like fishes through a sea.[90]

For Amicus, the assertion of the liquidity of the firmament was contrary to common sense.[91] But though he was a staunch advocate of solid orbs, Amicus allowed that solidity was not natural to the heaven because the true nature of the heaven was conferred on the first day when God apparently produced a fluid, indeed watery, heaven, which was divided on the second day by the heaven created on that day, namely the solid firmament, which is really the fluid heaven of the first day made hard and solid. The solidity of the firmament was therefore an accidental property of the heaven, secondary to its true and original fluid nature.[92] Amicus distinguished two groups: those who believed that the heavens were naturally and permanently fluid and those who held that the heavens were originally fluid but were made unnaturally solid and hard.

Because the fluidity of the heavens seemed natural in both theories, Amicus concluded that "from authority, from the motions of new stars, and from similar things, which [Christopher] Scheiner reports, it is sufficiently probable that the heavens are fluid. But I do not follow this [opinion], nor do I retreat from ancient opinion without an urgent reason and [also] because solidity [and hardness] conform more to Scripture to which every human intelligence is subjected."[93] Although Amicus thought the fluidity of the heavens improbable on Scriptural grounds, he conceded that the opinions drawn from the scriptures and from the Church Fathers were not so clear or obvious in support of the solidity of the heavens. Moreover, many learned contemporary theologians, philosophers, and astronomers (Amicus called them mathematicians) thought they were fluid. Despite the improbability of a fluid heaven, Amicus concluded that it was by no means theologically "rash" to uphold it.[94]

The theory of fluid heavens did not triumph because of any overwhelming and certain arguments. Indeed, those who abandoned hard orbs in favor of a fluid heaven had to confront the problem of planetary motion directly. What enabled a planet to move in its orbit like a fish in water or a bird in air, as the popular analogies expressed it? For those who assumed not only fluid planetary spheres but also a fluid zone for the fixed stars, there was the additional problem of assigning a motive cause to each of the more than 1,000 visible stars. No longer could they rely on a single hard orb to carry around the fixed stars that had been previously imagined as fixed in their hard sphere like knots in a piece of wood. Although he recognized that if the firmament were solid only one mover would be required to carry all the stars simultaneously, Melchior Cornaeus preferred to believe that God did not create hard orbs but rather assigned one angel to each star. After all, God was not destitute of angels, and a star was not so small that it did not deserve its own motive angel.[95]

It was one thing to assume a fluid heaven, but quite another to provide a causal explanation for the motion of orb-less planets and stars. Kepler had proposed a causal, physical mechanism based on magnetic forces to account for the motions of orb-free planets in his *Astronomia nova* (1609) and *Epitome astronomiae Copenicanae* (1617–1620).[96] Jesuits did not follow such a path. Most Jesuit supporters of a fluid heaven adopted explanations similar to that of Cornaeus and resorted to external intelligences or angels to move the planets and stars. The extent to which intelligences were regarded as celestial movers in the seventeenth century is revealed by Thomas Compton-Carleton's 1649 declaration that this "common" opinion had "come into such use among all so that it is almost a crime to deny it."[97] Whether Jesuits assumed hard orbs or fluid heavens, they adopted the same causal mechanism to account for the motions of celestial bodies: angels and intelligences. Not until Newton published his theory of universal gravitation in 1687 was the issue settled.

Conclusion

Theological constraints—at least after 1616—compelled the Jesuits to reject the earth's daily and annual motions and to assume instead the earth's immobility and centrality. But where theological constraints were absent, as in questions about the hardness or fluidity of the heavens or their corruptibility or incorruptibility, Jesuits offered diverse opinions. Indeed, Jesuits led the way for Aristotelian natural philosophers to adjust to the new, anti-Aristotelian cosmological opinion that followed in the wake of the momentous discoveries by Tycho Brahe and Galileo. Occasionally they went beyond mere adjustment to declare new and bold cosmological ideas, as when Thomas Compton-Carleton proclaimed the existence of an infinite, three-dimensional space, which he identified with God's infinite immensity.[98] By linking God's infinite immensity with infinite space, Compton-Carleton preceded by at least 15 years the quite similar conceptions of Henry More and Isaac Newton.

Where they were reasonably free to react, Jesuits sought to contribute to the new cosmology in the same manner that they had contributed to the other sciences of their day, especially optics and magnetism. Despite the great obstacles they confronted as a result of the condemnation of heliocentrism, they did not wish to jeopardize the respectability they had achieved in science by appearing to be dogmatic traditionalists in cosmology.

Notes

1. On the attitude of Jesuits toward Copernicanism, see chapter 11 of Rivka Feldhay's *Galileo and the Church: Political Inquisition or Critical Dialogue?* (Cambridge, 1995).

2. *Anticopernicus Catholicus seu De terrae statione, et de solis motu contra systema Copernicanum, Catholicae Assertiones* (Venice, 1644).

3. See Christopher Clavius, *In Sphaeram Iohannis de Sacro Bosco Commentarius* (Rome, 1570; many subsequent editions). See p. 215 in the version included in volume 3 of Clavius's *Opera* (1611). On the Conimbricenses, see *Commentarii Collegii Conimbricensis Societatis Iesu In quatuor libros De coelo Aristotelis Stagiritae*, second edition (Lyon, 1598), book 2, chapter 14, quaest 5, article 2, p. 91; see also Bartholomew Amicus, *In Aristotelis libros De caelo et mundo dilucida textus explicatio et disputationes in quibus illustrium scholarum Averrois, D. Thomae, Scoti, et Nominalium sententiae expenduntur earumque tuendarum probabiliores modi afferuntur* (Naples, 1626), p. 289, column 2.

4. Amicus, *De caelo*, p. 601, column 2.

5. In the fourteenth century, Albert of Saxony and Nicole Oresme differed radically with Amicus's interpretation when they argued that a stone falling to the center of the earth would oscillate around the center. See Edward Grant, "In Defense of the Earth's Centrality and Immobility: Scholastic Reaction to Copernicanism in the Seventeenth Century," *Transactions of the American Philosophical Society* 74 (1984), no. 4, p. 56, n. 208.

6. Clavius, "In Sphaeram," in *Opera*, volume III, pp. 66–67.

7. Ibid., p. 67. For Sacrobosco's argument, see *"The Sphere" of Sacrobosco and Its Commentators*, ed. L. Thorndike (Chicago, 1949), p. 84 (Latin), p. 122 (English). Other Jesuits who cited this argument were Bartholomew Amicus (*De caelo*, p. 581, column 1) and Giorgio Polacco (*AntiCopernicus Catholicus*, p. 104, assertio CXC). Galileo also repeats this argument (*Galileo's Early Notebooks: The Physical Questions*, Notre Dame, 1977, p. 72, paragraph 9).

8. Clavius, "In Sphaeram," *Opera*, volume III, p. 70. The same argument appears in Conimbricenses, *De coelo*, book 2, chapter 14, quaest 3 ("Whether the earth is located in the middle of the world and has the same center of gravity and magnitude"), in article 1 ("That the earth is located in the middle of the world," p. 382), and in Amicus, *De caelo*, p. 581, column 1.

9. What follows is based on Grant, "In Defense of the Earth's Centrality," pp. 59–60.

10. Riccioli, *Almagestum novum*, pars posterior, book 9, section 4, p. 469, column 1 (Primum argumentum).

11. Ibid., p. 500, column 2.

12. As to whether the center of the earth that coincides with the center of the world is the earth's center of gravity or its center of magnitude, see Grant, "In Defense of

the Earth's Centrality," *Transactions* 74 (1984): 20–32, where Clavius's ideas play a significant role.

13. The second of the two propositions condemning the Copernican system in 1616 included the earth's diurnal rotation. See Jerome J. Langford, *Galileo, Science and the Church*, revised edition(Ann Arbor, 1971), p. 89. Thus, although Jesuits might have opted for the earth's daily rotation before 1616 (I know of none who did), they could not do so after 1616.

14. In the fourteenth century alone, John of Jandun, John Buridan, Themon Judaeus, Nicole Oresme, and Albert of Saxony discussed the question. Indeed, the responses of Buridan and Oresme have been widely cited in the twentieth century. For translations of their texts, see Edward Grant, *A Source Book in Medieval Science* (Cambridge, Mass., 1974), pp. 500–503 (Buridan) and pp. 503–510 (Oresme).

15. "An terra in medio mundi quiescat et quae nam eius immobilitatis cause sit" (Conimbricenses, *De caelo*, book 2, chapter 14, quaest 5, p. 389). Although the Aristotelian commentaries of the Conimbricenses were published anonymously, the author of the commentary on *De caelo* was Emmanuel de Goes. See Charles Lohr, *Latin Aristotle Commentaries II: Renaissance Authors* (Florence, 1988), pp. 98–100.

16. "Terram esse immobilem" (Clavius, "In Sphaeram," *Opera*, volume III, pp. 105–107).

17. See H. L. L. Busard, "Clavius, Christoph," in *Dictionary of Scientific Biography*, volume III, p. 311. For numerous mentions of Copernicus by Clavius in the latter's Commentary on the Sphere of Sacrobosco, see James M. Lattis, *Between Copernicus and Galileo: Christoph Clavius and the Collapse of Ptolemaic Cosmology* (Chicago and London, 1994), pp. 138–139, 168–169, and elsewhere. In these instances, Clavius invokes the name of Copernicus for astronomical reasons.

18. For example, Pedro Hurtado de Mendoza did not mention Copernicus in his *Universa Philosophia* (Valladolid, 1615), and Roderigo de Arriaga did likewise in his *Cursus philosophicus* (Antwerp, 1632).

19. Bartholomew Amicus, Giovanni Baptista Riccioli, and Melchior Cornaeus not only mentioned Copernicus but also described both sides of the debate. In the end, all acceded to the decrees of the Church and opted for the traditional opinion.

20. In addition to the daily rotation, Copernicus attributed two other motions to the earth: an annual west-to-east motion around the Sun and a slow westward motion around the poles of the ecliptic. The latter was meant to keep the earth's axis fixed in space. See Lattis, *Between Copernicus and Galileo*, p. 169.

21. Amicus, *De caelo*, p. 291, column 2.

22. For these arguments, see Melchior Cornaeus, *Curriculum philosophiae peripateticae* (Herbipoli [Würzburg], 1657), p. 537 (Ad III).

23. Riccioli, *Almagestum novum*, pars posterior, p. 467, column 2.

24. See *Ptolemy's Almagest*, translated and annotated by G. J. Toomer (New York and Berlin, 1984), book 1, chapter 7, pp. 44–45.

25. Nicholas Copernicus, *On the Revolutions* (1543) (Warsaw and London, 1978), p. 16.

26. Ibid., p. 15. (On the falsity of the attribution to Ptolemy, see ibid, note to p. 15, line 17 on 351.) See also Galileo, *Dialogue Concerning the Two Chief World Systems* (Berkeley and Los Angeles, 1962), pp. 481–482. Here I have altered, rearranged, and added to my discussion of this theme on pp. 54–55 of "In Defense of the Earth's Centrality."

27. Riccioli describes these and other effects in *Almagestum novum*, book 9, section 4, chapter 21, p. 424, columns 1–2.

28. Ibid., p. 24, column 2 (argument 15) and p. 474, column 1. Indeed, Riccioli says much the same thing in argument 29 (ibid., p. 475, column 1).

29. See Riccioli, *Almagestum novum*, pars posterior, book 9, section 4, chapter 21. The cannonball arguments appear in arguments 5–9 (pp. 424–428). For the summaries, see ibid., p. 474, columns 1–2 (arguments 16–20).

30. For the details of the arguments, see Grant, "In Defense of the Earth's Centrality," pp. 42–51.

31. See Riccioli, *Almagestum novum*, pars posterior, book 9, section 4, chapter 34, p. 473, column 2 (argument 7). In argument 10 (p. 473) and in argument 5 (p. 422), Riccioli illustrates the curved path traveled by an angel who has a long chain to which a metallic sphere is attached. The angel is holding one end of the chain immobile over the earth and lowering the metallic sphere down toward the earth. Riccioli argues that the weight of the sphere causes it to reach the earth perpendicular to a tangent to the earth's surface. But if the earth were rotating, the path of the chain would not be perpendicular to the earth; it would be curved toward the east. Riccioli concedes that neither hypothesis can be falsified, but it is clear that he believes that the nature of heavy bodies requires a rectilinear path perpendicular to a tangent to the earth's surface. Hence the earth does not rotate.

32. "Certe si non est evidens sensui gravia per rectam lineam descendere, nihil illi evidens erit ac tota scientia physica peribit." (Riccioli, ibid., p. 473, column 1, argument 6) See also, Grant, "In Defense of the Earth's Centrality," p. 40.

33. Finocchiaro argues that "in the earlier phase of the [Galileo] affair climaxing in 1616, Galileo seems to have been attacked by Dominicans and defended by Jesuits, whereas in the later phase, in 1632–1633, it seems that the two religious orders had exchanged roles." (*The Galileo Affair, A Documentary History*, ed. M. Finocchiaro, Berkeley and Los Angeles, 1989, p. 13)

34. For the translation, see ibid., p. 47. Some months later, on May 26, 1616, Bellarmine wrote a certificate to Galileo denying that the latter had "abjured in our hands" or that he had been given "salutary penances" for his alleged abjuration (ibid., p. 53). For a brief account of Cardinal Bellarmine's role in Galileo's encounter with the Inquisition, see Ernan McMullin, ""Bellarmine, Robert," in *Dictionary of Scientific Biography*, volume I, pp. 587–590. Finocchiaro presents a detailed "Chronology of Events" for Galileo's tribulations with the Church during the years 1613–1633 (*The Galileo Affair*, pp. 297–307). For a fine account of Galileo's difficulties, focusing on the years 1616 and 1633, see Feldhay, *Galileo and the Church*, pp. 13–69.

35. See Riccioli, *Almagestum novum*, book 9, section 4 ("De systemate terrae motae"), pp. 479–500. On pp. 496–500, Riccioli reproduces some important documents relevant to the Church's attitude toward the Copernican theory, including the judgment and the abjuration of Galileo.

36. "Solis motus ex Sacra Scriptura" and "Terrae quies et immobilitas ex sacris literis" (Riccioli, ibid., p. 480, columns 1 and 2).

37. "Propositiones Sacrae Scripturae in quibus solis motus et terrae immobilitas asseritur accipiendae sunt ad literam secundum proprium sensum," ibid., p. 494, column 2.

38. These claims are made within the context of a syllogistic "proof" (ibid.).

39. Clavius, "In Sphaeram," *Opera*, volume III, pp. 103–104. Here I draw on Edward Grant, "A New Look at Medieval Cosmology, 1200–1687," Proceedings of the American Philosophical Society 129 (1985), p. 422, where, however, I used Clavius's fourth edition (Lyon, 1593).

40. Clavius, "In Sphaeram," Opera, volume III, p. 105 (p. 211 in 1593 edition). For the Latin passages relevant to the last two notes, see Grant, "A New Look," p. 429, nn. 28, 29.

41. See Conimbricenses, *De caelo*, book 1, chapter 3, quaest 1, p. 66; Amicus, *De caelo*, Tract 5, quaest 1, p. 232, column 2; Franciscus de Oviedo, *Integer cursus philosophicus* (Lyon, 1640), volume I, p. 464, column 1, paragraph 19. We may also include Galileo. (See Wallace, *Galileo's Early Notebooks*, p. 99.)

42. "Primum negando veritatem illarum apparentiarum, sed esse ludificationes sensuum ex variis causis ortas, scilicet medii impuritate, obiectorum distantia, instrumentorum falsitate." (p. 242, column 2). For a description of Galileo's attacks against those who sought to subvert his telescopic discoveries by challenging the validity of the instrument, see *Discoveries and Opinions of Galileo*, tr. S. Drake, New York, 1957, p. 73.

43. "Alterum responsionis genus admittit illas mutationes esse in coelo aethereo non solum secundum accidentia, sed etiam secundum substantiam, id est, at factas non virtute naturali, sed supernaturali ob finem Deo notum, sive ad significandum aliquem magnum effectum." (Amicus, *De Coelo*, p. 243, column 2)

44. "Superest ergo ut verisimilior sit alia opinio omnium ultima quae asserit novam hanc stellam, non physica, sed supernaturali generatione a Deo fuisse procreatam." (Conimbricenses, *De caelo*, book 1, chapter 3, quaest 1, article 4, 1598, p. 71)

45. Oviedo, *Integer cursus philosophicus*, volume I, p. 464, column 2, paragraph 20. Oviedo adds that even angels are incorruptible only by the grace of God. Also in the context of celestial incorruptibility, Galileo observed that "God alone . . . is a completely necessary being" and that "angels and human souls are immortal by divine grace" (Wallace, *Galileo's Early Notebooks*, p. 96).

46. "Tertium genus respondendi est aliorum qui neque omnes cometas dicit esse infra lunam, neque omnes supra lunam, sed aliquos infra aliquos supra." (Amicus, *De caelo* (1626), p. 244, column 2)

47. "Sed ex iis qui ponunt aliquos esse supra lunam vario modo illam novitatem explicant sine nova generatione et corruptione celestis substantiae." (ibid.)

48. How Amicus actually envisioned this configuration is not clear. For more on his approach, see Edward Grant, *Planets, Stars, and Orbs: The Medieval Cosmos 1200–1687* (Cambridge, 1994), pp. 212–214.

49. Hurtado de Mendoza, *Universa Philosophia*, disp. I, sectio 5, p. 367, column 1. For a similar argument, see Oviedo, *Integer cursus philosophicus*, volume I, p. 464, columns 1–2, paragraph 19.

50. "Tertio quia si coelum est corruptibile, ergo ab aliquo agente naturali potest corrumpi, ergo illa potentia esset reducta in actum per tot annorum millia, atque ita coelum non esset aptum ad continentem et perpetuam mundi gubernationem." (Hurtado de Mendoza, *Universa Philosophia*, p. 67, columns 1–2)

51. Riccioli, *Almagestum novum*, pars posterior, book 9, section 1, chapter 6, 238, column 1. On Cornaeus, see *Curriculum philosophiae peripateticae*, p. 489; De Rhodes, *Philosophia peripatetica*, pp. 278–281.

52. Riccioli, *Almagestum novum*, pars posterior, book 9, section 1, chapter 6, p. 237, column 2.

53. Riccioli (ibid., chapter 7, pp. 238–244) considers the question "whether the heavens are solid or whether, indeed, some or all are fluid" ("An caeli solidi sint, an vero fluidi omnes vel aliqui"). At the end of the question, in a "unica conclusio," he declares: "Although it is scarcely evident mathematically or physically, it is much more probable that the heaven of the fixed stars is solid, that of the planets fluid." (p. 244, column 1)

54. Ibid., p. 233, column 2.

55. Ibid., p. 236, columns 1–2.

56. A few Jesuits had argued that the fluidity or solidity of the heaven had no relevance to its corruptibility or incorruptibility. See e.g. Amicus, *De caelo*, (1626), p. 270, column 2; Oviedo, *Integer cursus philosophicus*, volume I, p. 462, paragraph 2. Oviedo actually believed that the heaven was both fluid and incorruptible (ibid., p. 464, column 1, paragraph 17).

57. "Sequitur caelos hosce esse ab intrinseco et natura sua generationis et corruptionis capaces." (Riccioli, *Almagestum novum*, pars posterior, book 9, section 1, chapter 6, p. 38, column 1)

58. Ibid., p. 237, column 2.

59. Ibid., p. 238, column 1.

60. Ibid.

61. See Cornaeus, *Curriculum philosophiae peripateticae*, p. 489. Cornaeus rejects the existence of a celestial ether, or fifth element, and suggests that fire is the most probable matter of the heavens (ibid., pp. 490–491). Cornaeus regarded new stars and sunspots as evidence of celestial corruptibility.

62. De Rhodes, *Philosophia peripatetica*, p. 278, column 1-280, column 1. De Rhodes specifically refutes the explanations that new stars are not "new" but are in the heaven all the time and only seen when they become sufficiently dense (a view attributed to Vallesius) and that new stars are produced by an accidental generation of opacity (which he rightly attributes to Aversa). See ibid., p. 271, column 1.

De Rhodes died in 1661 and his work was first published in 1671; the actual date of composition is not known.

63. "Si Aristoteles hodie viveret et quas modo nos in sole alterationes et conflagrationes deprehendimus, videret absque mutata sententia nobiscum faceret. Idem sane est de planetis quos Philosophus septenis plures non agnoscit. At nos hoc tempore opera telescopii (quo ille caruit) plures omnino esse certo scimus." (Cornaeus, *Curriculum philosophiae peripateticae*, p. 503)

64. Because the parallax of the comets placed them below the fixed stars, one could continue to believe, as did Riccioli, that the fixed stars were embedded in a solid sphere. William H. Donahue holds that the hard sphere of the fixed stars was the last element of the old cosmos to go (*The Dissolution of the Celestial Spheres 1595–1650*, New York, 1981, p. 117).

65. Ibid., p. 105.

66. Oviedo, *Integer cursus philosophicus*, volume I, p. 462, column 1, paragraph 2.

67. See Grant, *Planets, Stars, and Orbs*, p. 342.

68. See Victor E. Thoren, "The Comet of 1577 and Tycho Brahe's System of the World," *Archives Internationales d'Histoire des Sciences* 29 (1979): 53–67; Thoren, *The Lord of Uraniborg: A Biography of Tycho Brahe* (Cambridge, 1990), pp. 256–258.

69. In his Louvain lectures of 1570–1572 (unpublished until 1984), Bellarmine declared that "such complex and extraordinary structures as epicycles and eccentrics are dreamed up so that that even the astrologers are reticient to speak about them." See *The Louvain Lectures (Lectiones Lovanienses) of Bellarmine and the Autograph Copy of his 1616 Declaration to Galileo*, ed. U. Baldini and G. Coyne (Vatican City, 1984), p. 22 (Latin on p. 23). By *astrologi*, Bellarmine clearly means astronomers.

70. ". . . Sed motu proprio sicut aves per aerem, et pisces per aquam" (ibid., p. 19 and p. 38, n. 88). In the fourteenth century, Jean Buridan utilized both metaphors (he rejected them), as did various Jesuits in the seventeenth century (see e.g. Conimbricenses, *De coelo*, book 2, chapter 5, quaest 1, article 1, 1598, p. 246; Clavius, *De sphaera* (1593), p. 515; Amicus, *De caelo* (1626), p. 266, column 1; Arriaga, *Cursus philosophicus*, p. 499, column 2; Oviedo, *Integer cursus philosophicus*, volume I, p. 471, column 2.

71. "Utrumque ante aliquot annos omnino extra controversiam fuerat." (Arriaga, *Cursus philosophicus*, p. 499, column 1)

72. "Propter quorumdam mathematicorum et astronomorum diligentes observationes quas, novis exquisitisque instrumentis adiuti, invenerunt, et praecipue tubi optici subsidio, caelorum structura penitus a nonnullis inverti coepit." (ibid.) Donahue (*Dissolution of the Celestial Spheres*, p. 273) declares that "by the end of the 1620s the debate over the fluidity of the heavens was very nearly concluded."

73. "Prima ergo pars de fluiditate coeli planetarum a nemine nunc negatur." (de Rhodes, *Philosophia peripatetica,* p. 280, column 1)

74. "Tertio suppono, cum quaerimus an caeli sint fluidi non quaeri a nobis an sint quasi quidam liquor aqueus, qui facile labitur; sufficit enim si sint facile permeabiles

ad modum quo est noster aer, qui tamen non vocatur absolute liquor." (Arriaga, *Cursus philosophicus*, p. 499, column 1)

75. Christopher Scheiner cites a large number of scriptural passages in behalf of a corruptible heaven (*Rosa Ursina* [Bracciani, 1630], book 4, chapter 23, pp. 658–659) and also cites from Church Fathers who allegedly assumed a fiery, or fluid, heaven (*Rosa Ursina*, pp. 626–629). For Riccioli's scriptural citations in behalf of hardness, see his *Almagestum novum*, pars posterior, p. 240, column 2; for his citations in favor of fluidity, see ibid., p. 242, column 1. Amicus also cites a number of biblical passages in favor of fluidity (*De caelo*, 1626, p. 272, column 2) and in favor of solid hardness (ibid., p. 278, column 1).

76. The Latin is from the Vulgate.

77. In *Almagestum novum*, book 8, section 1, chapter 23, pp. 117–120. Riccioli cites the opinions of others on the place, parallax, and distances of comets from the earth.

78. See Riccioli, ibid., chapter 13, pp. 57, 58.

79. Under the heading "Conclusiones de distantia et loco cometarum," the second reads: "II. Conclusio. Nullus adhuc cometarum demonstratus est absolute fuisse supra lunam, sed ex hypothesi tantum probabili quidem, sed tamen incerta." (Riccioli, ibid., book 8, chapter 23, p. 119, column 1).

80. "IV. Conclusio. Probabile est aliquos cometas fuisse supra lunam, aliquos vero infra, etiam ex illis de quorum loco ex nuda historia nihil constat." (Riccioli, ibid., p. 119, column 2)

81. Although Riccioli believed in a fluid heaven, he drew the arguments presented here from a variety of sources, not all of which he accepted.

82. The phases of Venus are explicitly mentioned by Amicus (*De caelo*, 1626, p. 273, columns 1–2).

83. Tycho Brahe made this an integral part of his geoheliocentric view in opposition to Copernicus's heliocentric system. To do so, however, he had to abandon planetary spheres. See Thoren, *Lord of Uraniborg*, pp. 254–258.

84. Cornaeus, *Curriculum philosophiae peripateticae*, p. 499. Although Cornaeus does not use the word 'hard' (*durum*), it is clearly implied. Riccioli, who also mentions the satellites of Saturn, explains that the satellites of Jupiter and Saturn make it unfeasible to admit solid, hard orbs because the latter would impede the motions of the satellites. Like Cornaeus, Riccioli does not explicitly mention hard orbs; he speaks only of "the solidity of the heaven" [soliditas celi], but they are surely the subject of his discussion.

85. Here is the text: "Tertium argumentum. Frustra multiplicantur tot orbes reales ac solidi planetarum et motus eorum. Immo non solum frustra, sed cum periculo mutuae collisionis et impedimenti spectata tanta varietate motuum vel certe absque necessitate cogimur imaginationem defatigare in tot realibus ac solidis epicyclis, eccentricis, concentricis, eccentricis epicyclis. . . . Denique incongruum videtur Divinae Sapientiae, ut propter motuum unius planetae, puta Saturni, qui facillime a se vel ab Intelligentia moveri potest, moveatur tanta et tam vasta machina quanta est totum caelum cuiusque planetae, qui comparatus ad suum caelum non est nisi

instar puncti et minor est quam sit gutta respectu oceanis. . . .” (Riccioli, *Almagestum novum*, book 9, section 1, chapter 7,p. 242, column 2, paragraph XV)

86. Amicus, *De caelo*, p. 278, columns 1–2.

87. “Secunda conclusio soliditatem, quam probavimus convenire firmamento, probabile est convenire omnibus caelis etiam planetarum.” (ibid., p. 279, column 2)

88. Ibid., p. 280, column 1.

89. Riccioli (*Almagestum novum*, book 9, section 1, chapter 7, p. 241, columns 1–2) describes the same argument, mentioning that the sounds should be akin to those hissing or whistling sounds that emanate from stones launched in the air by ballistics machines. Riccioli cites counterarguments from Tycho Brahe, Christoph Rothmann, and Francisco de Oviedo. Rothmann denied that such sounds could reach our ears, because of the great distances and the rarity of the celestial ether. Oviedo’s response—predicated on the widely used analogy between the movement of fish in water and that of planets in the heaven—was that, just as there is no sound in the water itself when fish swim through it, there is no sound in the fluid heaven as the planets move through it.

90. “Conf. secundo nam quo corpora sunt superiora eo magis sunt nobiliora et maiori quodam artificio ornata. At hoc artificium magis apparet ponendo multos orbes tum mobiles inter se connexos et ordinate motos . . . quam si ponatur unum liquidum per quod stellae discurrant ut pisces per mare.” (Amicus, *De caelo*, p. 280, column 1)

91. According to Amicus, Tanner had declared that so true was the assertion of the solidity of the firmament that “the opposite [assertion] would be rash [or imprudent]” (“Resp. Tannerus esse ita certam ut opposita sit temeraria”). Amicus then explains that “rashness” (temeraria) is an assertion that is contrary to the common and profane sense of Sacred Scripture and is asserted freely and without good reason. Rather than being “rash” in any theological or Sciptural sense, however, Amicus declares that the assertion of a fluid heaven is simply contrary to common sense. (“Confir. quia temeraria est assertio, quae contra communem scriptorum sacrorum et prophanorum sensum pro libito et sine causa asseritur, ut patet ex explicatione censurae temeritatis. At assertio liquiditatis firmamenti est contra communem sensum et sine ratione pronunciatur.”—Amicus, ibid.)

92. “Firmamentum secundo die productum sola soliditate differt ab eodem producto initio, sed soliditas, cum sit accidens, non variat naturam rerum, ergo neque naturam firmamenti. Si prius erat liquidum ex natura, similiter erit natura liquidum sub soliditate. Hec autem variatio in caelo facta est ob bonum universi. . . .” (Amicus, ibid., p. 281, column 1)

93. “Ex quibus puto satis probabile esse caelo esse fluidos ex auctoritate, et motibus novarum stellarum et similibus, quae affert Scheiner. Sed eam non sequor, ne recedam ab antiquata opinione sine ratione urgente et quia soliditas est magis conformis scripturae cui omnis humana intelligentia subdidebet.” (ibid., p. 282, column 1)

94. “Ego vero in hac diversitate opinionem asserentium caelum esse liquidum existimo esse quidem improbabile, non tamen temerariam. Nam scripturae loca et

Patrum testimonia non ita clare soliditatem caelorum exprimunt, ut interpretationem non admittant ut patet ex iis quae adversarii adducunt. Idque confirmo nam nostre aetate multi sunt ex Theologis, Philosophis, et Mathematicis, multae eruditionis, qui liquiditatem caelo convenire nituntur probare quos non est aequum temeritatis censura notari." (ibid., p. 281, column 1)

95. Cornaeus (*Curriculum philosophiae peripateticae*, p. 500) first raises an objection against himself ("Si firmamentum non est solidum, ergo singulis astris assignandus est angelus motor, qui per liquidum conducat et certo itinera dirigat. Atqui si firmamentum statuamus solidum, unus sufficiet pro omnibus."), then replies: "Concedo sequel. Neque tam parva res est stella ut angeli custodiam non mereatur, neque tam inops angelorum est Deus ut pro omnibus et singulis stellis non sit ei sufficiens eorum copia."

96. Kepler relied on two forces. He assumed a rotation of the sun, which "sends out into space (in the plane of the ecliptic) a motive whirlpool which carries the planets round and impresses on them a circular motion round the Sun; at the same time the planetary magnets, in accordance with a mechanism which has been fully described above, causes the planets to approach and recede from the Sun. As a result of being subjected to this two-fold influence, the planets do not describe circles in the sky, but describe ellipses having the Sun at one of their foci." (Alexandre Koyré, *The Astronomical Revolution, Copernicus—Kepler—Borelli* (Paris and London, 1973; French original, 1961), p. 323)

97. "Communis tamen sententia affirmat moveri ab intelligentijs quod ita iam invaluit apud omnes, ut pene nefas sit id inficiari cui proinde ob tot tamque doctorum hominum auctoritatem subscribo omnesque constanter asserunt non posse motum illum provenire ab intrinseco." (Thomas Compton-Carleton, *Philosophia universa*, Antwerp, 1649, p. 409, column 2)

98. For Compton-Carleton's views, see Grant, *Planets, Stars, and Orbs*, pp. 183–184. Although the Coimbra Jesuits did not go as far as Compton-Carleton, they argued for the existence of an extracosmic imaginary infinite space in which God exists through His immensity. They assumed that although this infinite space is non-dimensional, it is nonetheless real. For a summary of the arguments, see Edward Grant, *Much Ado About Nothing: Theories of Space and Vacuum from the Middle Ages to the Scientific Revolution* (Cambridge, 1981), pp. 160–163.

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Descartes and the Jesuits: Doubt, Novelty, and the Eucharist

Roger Ariew

When the relations between Descartes and the Jesuits are examined, the focus is usually on the Jesuits' condemnations of Cartesianism. Though this is a reasonable and dramatic focus, it tends to distort one's understanding of those relations because it inevitably emphasizes doctrinal elements and obscures pragmatic and pedagogical ones. I wish to investigate the intellectual exchanges between Descartes and the Jesuits, paying special attention to pragmatic and pedagogical factors, though not neglecting doctrinal ones. In particular, I will look at the exchanges between Descartes and a few notable Jesuits in order to understand their multi-faceted relations.

Descartes's Relations with the Jesuits

In the summer of 1640, Descartes told Constantijn Huygens that he was "going to war with the Jesuits."[1] From then on, Descartes fought skirmishes on many fronts with many adversaries—some real and some imagined, some Jesuit and some non-Jesuit. Those many battles and what has been called the "persecution" of the Cartesians are generally well known.[2] Some actions were covert; others were fought openly. After the hostilities precipitated by a Jesuit disputation at Clermont College in Paris in 1640, there were troubles and condemnations among Protestants at Utrecht in 1642 and at Leyden in 1647.[3] The battles continued after Descartes's death in 1650. There were condemnations by Catholics at Louvain in 1662.[4] Descartes's works were put on the Index of Prohibited Books in 1663.[5] The Jesuits held more anti-Cartesian disputations at Clermont in 1665, with some propositions that clearly intended to make Descartes look ridiculous.[6] The fighting intensified with numerous attacks in print.[7] The Cartesians counterattacked with satires[8] and learned essays,[9] and the anti-Cartesians retaliated with their own satires.[10] Ultimately, the dispute spilled into the domains of the king, of the universities, and of the teaching orders: Louis XIV issued an anti-Cartesian edict in 1671[11]; the faculty of arts at Paris tried to condemn Cartesianism in 1671, and succeeded in 1691[12]; there were skirmishes at Angers and Caen during 1675–1678[13]; the Oratorians, attempting to bring their teaching in line with that of the Jesuits, prohibited the teaching of Cartesianism in 1678,[14] and the Jesuits formally condemned it in 1706.[15] Though not the only enemies of Cartesianism, the Jesuits are often thought to have been the fiercest. Francisque Bouillier, in his *Histoire de la philosophie cartésienne*, devoted a whole chapter to them, stating: "Because of the importance of their role in the battles against and in the persecutions of Cartesianism, . . . they deserve a place apart in this history."[16]

Clearly, not all the salvos in the war went in the same direction. After all, Descartes satirized his own Jesuit education in his 1637 *Discourse on Method*, saying that he had attended one of the most famous schools in Europe, but that he had gained nothing from his attempts to become educated: "From school days I had learned that one can imagine nothing so strange and incredible but has been said by some philosopher." Descartes claimed to have found little worthwhile in his Jesuit education; at best, he wrote, "philosophy enables one to talk plausibly on all subjects and win the admiration of people less learned than oneself," but "there is nothing up to now which is not disputed and consequently doubtful" in it.[17] However, Descartes's thoughts about Jesuit education and his relations with them in general were much more complex than his statements in the *Discourse* would lead one to believe. He courted the Jesuits early on, and when he got into trouble with Protestants at Utrecht in 1642 he tried to get the Jesuits to come to his aid.[18] In fact, the Jesuits' role in the persecution seems to have been rather limited; the battles between Descartes and Jesuits do not appear as significant or as numerous as those between Descartes and others.[19] The effect of the Jesuits must be inferred. In order to have enough materials about the Jesuits as persecutors of Descartes, Bouillier had to treat Huet, a non-Jesuit, as a Jesuit.[20]

At times, Descartes displayed a different attitude toward his Jesuit education. In 1638, after the publication of the *Discourse*, Descartes—responding to a request for his opinion about adequate schooling for his correspondent's son—attempted to dissuade the correspondent from sending the boy to school in Holland. According to Descartes, "there is no place on earth where philosophy is better taught than at La Flèche," La Flèche being the Jesuit institution in which he was educated. Descartes gave many reasons for preferring La Flèche. Among them was that "philosophy is taught very poorly here [in Holland]; professors teach only one hour a day, for approximately half the year, without ever dictating any writings, nor completing their courses in a determinate time." And he praised as a beneficial innovation the "equality that the Jesuits maintain among themselves, treating in almost the same fashion the highest born and the least." Most important, he asserted that, though it was "not as if everything taught in philosophy is as true as the Gospels, . . . because philosophy is the key to the other sciences," it was "extremely useful to have studied the whole philosophy curriculum, in the manner it is taught in Jesuit institutions, before undertaking to raise one's mind above pedantry, in order to make oneself wise in the right kind [of philosophy]."[21] Of course, preferring La Flèche to a Dutch university was not the same as giving an unqualified endorsement to it. Still, Descartes's advice in this letter seemed open and frank. His assertions correlated very well with Jesuit education in the seventeenth century. Descartes was right in suggesting that students would have been taught more philosophy, and would have been taught it more rigorously, at La Flèche than at a Dutch university.[22] The equality of treatment practiced by the Jesuits, and referred to by Descartes, appears to be verifiable.[23]

Other letters by Descartes also cast doubts upon literal readings of the more pejorative remarks in the *Discourse*. In June of 1637, Descartes wrote to one of his old teachers, sending him a copy of the newly published *Discourse*. As Descartes put it, he sent the volume as a fruit that belonged to his teacher, "whose first seeds were sown in his mind by him," just as he also owed to those of his teacher's order the little knowledge he had of letters.[24] Descartes did indicate in the letter that he had not kept in touch with his teacher after leaving La Flèche: "I am sure that you would not have retained the names of all the students you had twenty-three or twenty-four years ago, when you taught philosophy at La Flèche, and that I am one of those who have been erased from your memory."[25] He sent copies of the *Discourse* to a great number of people: close friends, the nobility, various intellectuals, and others.[26] Thus, the letter to his teacher was part of Descartes's strategy to promote discussions of his views. And Descartes did request objections from his teacher and from others of his order in the letter: "If, taking the trouble to read this book or have it read by those of your [order] who have the most leisure, and noticing errors in it, which no doubt are numerous, you would do me the favor of telling me of them, and thus of continuing to teach me, I would be extremely grateful."[27]

Descartes thanked his correspondent for having remembered him and for giving his promise to have the book examined and his objections forwarded. He pressed his correspondent to append his own objections, saying that there were no objections whose authority would be greater and none he desired more.[28] He added that no one would seem to have more interest in examining his book than the Jesuits, since he did not see how anyone could continue to teach the subjects treated, such as meteorology, as did most of the Jesuit Colleges, without refuting or following what he had written.[29] However, Descartes also seemed to recognize the reason why Jesuits might not willingly take up his philosophy; he attempted to reply to the difficulty:

Since I know that the principal reason which requires those of your order most carefully to reject all sorts of novelties in matters of philosophy is the fear they have that these reasons would also cause some changes in theology, I want particularly to indicate that there is nothing to worry from this quarter about these things, and that I am able to thank God for the fact that the opinions which have seemed to me most true in physics, when considering natural causes, have always been those which agree best of all with the mysteries of religion.[30]

Descartes was clear that a stumbling block to friendly relations with the Jesuits would have been their distaste of novelty, because of their desire to safeguard theology, and that they would have rightly seen him as offering novelties.

Descartes's request for objections and his sending out copies did not bear much fruit. Early on, he was uncertain whether he would receive a favorable reaction from the Jesuits. He wrote to Huygens:

As for my book, I do not know what opinion the worldly people will have of it; as for the people of the schools, I understand that they are keeping quiet, and that, displeased with not finding anything in it to grasp in order to exercise their arguments, they are content in saying that, if what is contained in it were true, all their philosophy would have to be false.[31]

But he was hopeful; in the same letter he wrote:

I have just received a letter from one of the Jesuits at La Flèche, in which I find as much approbation as I would desire from anyone. Thus far he does not find difficulty with anything I wanted to explain, but only with what I did not want to write; as a result, he takes the occasion to request my physics and my metaphysics with great insistence. And since I understand the communication and union that exists among those of that order, the testimony of one of them alone is enough to allow me to hope that I will have them all on my side.[32]

The two themes that appear to have characterized the Jesuits in Descartes's mind seem to have been their distaste of novelty and their "communication and union." However, Descartes did not characterize the Jesuits as mere dogmatists, as one might have expected when looking at the texts of Jesuit condemnations. Of course, disliking novelty and striving to achieve union have doctrinal consequences, he would have had difficulty completely separating these elements. But disliking novelty seems to have a pragmatic foundation: it is possible to demand the tried and true because it is tried, even if it is not true. And one can affect a union of doctrines for pedagogical purposes.

In a different context, such a division among the three aspects of the dispute between scholastics and Cartesians—pragmatic, pedagogical, and doctrinal—is explicit in the condemnation of Cartesianism by the academic senate of Utrecht in March of 1642. The reasons for condemning Cartesianism shifted from pragmatic to pedagogical and then doctrinal concerns. Of the Utrecht edict, Descartes wrote:

> The professors reject this new philosophy for three reasons. First, it is opposed to the traditional philosophy that universities throughout the world have hitherto taught on the best advice, and it undermines its foundations. Second, it turns away the young from this sound and traditional philosophy and prevents them from reaching the heights of erudition; for once they have begun to rely on the new philosophy and its supposed solutions, they are unable to understand the technical terms commonly used in the books of traditional authors and in the lectures and debates of their professors. And, lastly, various false and absurd opinions either follow from the new philosophy or can be rashly deduced by the young—opinions that are in conflict with other disciplines and faculties and above all with orthodox theology.[33]

To a degree, such a separation among the pragmatic, pedagogical, and doctrinal elements marked the Jesuit context too. I will start by demonstrating that what is often taken as Jesuit dogmatism can be best understood as the consequences of pedagogical decisions and a pragmatic stance, and that Jesuit philosophy was far from monolithic during the seventeenth century. I will then try to show that pragmatic and pedagogical concerns are important for understanding the exchanges between Descartes and the Jesuits, including Bourdin's *Seventh Objections* to Descartes's letters to Mesland and the Jesuits' various condemnations of Cartesianism.

The Jesuits and Thomism

There is a well-known Jesuit penchant for Thomist doctrines. From the start, Ignatius of Loyola urged the Jesuits to follow the doctrines of Thomas Aquinas in theology and those of Aristotle in philosophy: "In theology there should be lectures on the Old and New Testaments and on the scholastic doctrine of Saint Thomas. . . . In logic, natural and moral philosophy, and metaphysics, the doctrine of Aristotle should be followed, as also in the other liberal arts."[34] Such advice often resulted in the Jesuits' offering a Thomist reading of Aristotelian doctrines.

The official Jesuit position was fairly clear. Francisco Borgia, the third general of the Order (1564–1572), cautioned: "Let no one defend or teach anything opposed, detracting, or unfavorable to the faith, in either philosophy or theology. Let no one defend anything against the axioms received by the philosophers. . . . Let no one defend anything against the most common opinions of the philosophers and theologians." Borgia even specified various opinions that Jesuits must sustain, teach, and hold as true, including several propositions concerning man: "The intellective soul is truly the substantial form of the body, according to Aristotle and the true philosophy. The intellective soul is not numerically one in all men, but there is a distinct and proper soul in each man, according to Aristotle and the true philosophy. The intellective soul is immortal, according to Aristotle and the true philosophy. There are not several souls in man, intellective, sensitive, and vegetative souls, and neither are there two kinds of souls in animals, sensitive and vegetative souls, according to Aristotle and the true philosophy."[35] In that litany, "Aristotle and the true philosophy" clearly meant Thomism. In fact, to hold the opinion that there are not several souls in man, as stipulated by Borgia, is to deny a Scotist doctrine on behalf of a Thomist one.

Not all Jesuits agreed that it was a good thing for the Society to choose a single authority, or that Saint Thomas was always the best author to uphold. But with the succession of Claudio Acquaviva as the fifth General of the Society (1581–1615) these issues took on a new vigor. The period was, of course, the one in which the Society reorganized its curriculum. The Jesuits undertook extraordinary pedagogical discussions, which ultimately led to their *ratio studiorum*. In the meanwhile, Acquaviva summarized the points that had to be "observed provisionally with the greatest exactness and most perfect faithfulness." These included an admission that "we do not judge that, in the teaching of scholastic theology we must prohibit the opinion of other authors when they are more probable and more commonly received than those of Saint Thomas." Acquaviva continued: "Yet because his authority, his doctrine, is so sure and most generally approved, the recommendations of our Constitutions require us to follow him *ordinarily*. That is why all his opinions whatever they may be . . . can be defended and should not be abandoned except after lengthy examination and for serious reasons. . . . The primary goal in teaching should be to strengthen the faith and to develop piety. Therefore, no one shall teach anything not in conformity with the Church and received traditions, or that can diminish the vigor of the faith or the ardor of a solid piety."[36] And he reiterated the same points as Borgia: "Let us try, even when there is nothing to fear for faith and piety, to avoid having anyone suspect us of wanting to create something new or teaching a new doctrine. Therefore no one shall defend any opinion that goes against the axioms received in philosophy or in theology, or against that which the majority of competent men would judge is the common sentiment of the theological schools. . . . Let no one adopt new opinions in the questions already treated by other authors; similarly, let no one introduce new questions in the matters related in some way to religion or having some importance, without first consulting the Prefect of studies or the Superior."[37]

Acquaviva's advice, like that of Borgia before him, blurred the lines between theology and philosophy; the requirement to follow Thomas in theology carried with it the advice to follow the axioms and the common sentiment of the theological schools—that is to say, Thomist-inspired axioms and sentiment. However, the reasons why Jesuits followed Thomist theology (and Thomist interpretations of Aristotelian philosophy) and avoided novelties in theology and in philosophy were not dogmatic but prudential. As conservative as the Jesuit practices seem, there was always the possibility that new doctrines might come to be accepted—especially those that did not seem to threaten the faith and those that appeared distant from theological matters. One might therefore have expected rigid adherence to official positions, with respect to doctrines considered dangerous to piety, and some tolerance of doctrines considered non-threatening. It becomes more understandable that an order so outwardly conservative about philosophy and theology, with a pedagogy that rejected novelty, would have been able to produce novel works in meteorology, magnetic theory, geology, and mathematics.[38]

Still, it would be useful to sketch what was at issue in the debates pro and con Thomist philosophy during the first half of the seventeenth century. Among the widely read Jesuit authors at the beginning of the seventeenth century were the Coimbrans and Franciscus Toletus. The Coimbrans (Conimbricenses) were professors at the Colègio das Artes in Coimbra, Portugal, who published a series of encyclopedic commentaries on Aristotle's works between 1592 and 1598[39]; Franciscus Toletus was a professor at the Collegio Romano (1562–1569) who published numerous commentaries on Aristotle's works, including *Logic* (1572), *Physics* (1575), and *De Anima* (1575).[40] In France, non-Jesuit philosophy texts from the same period included those by professors associated with the University of Paris, such as Eustachius a Sancto Paulo[41] and Charles François d'Abra de Raconis.[42] The seventeenth century also saw an enormous growth of philosophy texts in French, written by the tutors of the nobility (often themselves nobles). The movement began in the 1560s with the first French translations of Aristotle's works, then took off in the 1590s with the first French-language commentaries on the *Physics*.[43] Works in this genre included the *Corps de toute la philosophie* by Henry IV's almoner Théophraste Bouju (Paris, 1614) and *Le philosophe français* (Paris, 1643) by the Jesuit René de Ceriziers, who became a secular almoner of the Duc d'Orléans and later counselor to the king.[44] The most reprinted of such works was *Corps de philosophie contenant la logique, la physique, la metaphysique et l'ethique* (1627) by Scipion Dupleix, Cardinal Richelieu's favorite historian.[45]

An initial general characterization of the doctrines to be found in these texts from the first half of the seventeenth century is that the Coimbrans and Toletus leaned toward Thomism, while authors associated with the University of Paris (including Eustachius and de Raconis) did not, preferring many Scotist doctrines.

It is clearly possible to enumerate a number of issues, both major and minor, ranging through the philosophical corpus and theology, about which Scotus had disagreed with Thomas. During the seventeenth century those oppositions were considered significant enough for some authors to write entire books detailing the "two great systems of philosophy"—Thomism and Scotism. Others followed either Thomas or Scotus in their writings; still others attempted to reconcile them. Thus, the categories "Scotist" and "Thomist" are not anachronisms; they were coined by early modern writers themselves, and by focusing on these oppositions we can better appreciate the issues. First, let us attempt to determine what is a Thomist—that is, what the Jesuits supposedly were promoting.

It happens that the modern Catholic Church, under the leadership of Pope Leo XIII (with his 1878 encyclical *Aeterni Patris*) and his successors, promoted Thomism. In 1914, with the approval of Pius X, the Sacred Congregation of Studies attempted to define Thomism through 24 theses that they thought embodied its essentials.[46] Theses 1–6 characterize Thomist metaphysics. All beings are composed of potential and actual principles, except God, who is pure act, utterly simple, and unlimited. He alone exists independently; other beings are composite and limited. Being is not predicated univocally of God and creatures, and divine being is understood by analogy. There are real distinctions between essence and existence and between substance and accidents. Thesis 7 asserts that spiritual creatures are composed of essence, existence, substance, and accident, but not matter and form. Theses 8–14 treat corporeal beings as composite—that is, as constituted of matter and form, neither of which may exist by itself (*per se)*—and as extended in space and subject to quantification. Qantified (or signate) matter is the principle of individuation. A body can be in only one place at a time. There are animate and vegetative souls, which are destroyed at the dissolution of the composite entity. Theses 15–21 deal with humans more specifically. Human souls are capable of existing apart from their bodies, are created by God, are without parts, and cannot be disintegrated naturally (that is, they are immortal). They are the immediate source of life, existence, and perfection in human bodies, and are so united to the body as to be its single substantial form—a thesis we previously encountered with Borgia. The Thomist theses continue by distinguishing the two faculties of the human soul, cognition and volition, from each other, and by distinguishing sensitive knowledge from intellection. They assert that the proper object of the human intellect, in its state of union with a body, is restricted to quiddities (or essences) abstracted from material conditions. Volitions are said to be free. The last three theses concern knowledge of God. Divine existence is neither intuited nor demonstrable a priori; it is capable of demonstration a posteriori. The simplicity of God entails the identity between his essence and his existence. God is creator and first cause of all things in the universe.

Even at this most abstract level, one can make sense of Scotism in opposition to the Thomist theses. Scotism can be thought of as moderate Augustinianism, that is, as a commitment to the doctrine that humans have knowledge of infinite being,[47] possibly leading one to accept Anselm's "ontological" argument—that is, an a priori argument for the existence of God—in some fashion,[48] as self-evident to us, and not, as Thomas would have it,[49] as merely self-evident in itself (against Thomist thesis 22). Scotus, of course, is famous for a "metaphysical" proof for the existence of God and for thinking that Anselm's a priori proof might be acceptable (after being suitably "colored"). Unlike the Thomists, the Scotists held that the proper object of the human intellect is being in general,[50] not the quiddity of material being (against thesis 18).[51] The Scotists also displayed an attachment to the doctrine of God's absolute omnipotence, requiring many propositions thought to infringe too much upon that omnipotence to be rejected or modified. These two tendencies, among others, are at odds with many of the 24 Thomist theses. Scotists would think that the concept of being holds univocally (not analogically) between God and creatures (against thesis 4),[52] that there is only a formal or modal (not a real) distinction between essence and existence and substance and accidents (against theses 3, 5, and 6), that prime matter can subsist independently of form by God's omnipotence (against thesis 9),[53] that a *haecceity*, or form (not signate matter) is the principle of individuation for bodily creatures (against thesis 11),[54] that a body can be in two places at the same time (against thesis 12),[55] and that humans are a composite of plural forms: rational, sensitive, and vegetative souls (against thesis 16).[56] There were, of course, other points of disagreement between Thomists and Scotists, some of which figured in the seventeenth-century debates but no longer were essential to Thomism in 1914. For example, the Thomist theory of place required the immobility of the universe as a whole as the frame of reference for motion,[57] whereas for the Scotists space was radically relative, with no absolute frame of reference for motion.[58] Similarly, Thomists thought that without motion there would be no time,[59] whereas Scotists thought that time was independent of motion.[60]

It would be fairly simple to show that Parisian scholastics (that is, non-Jesuits) in the first half of the seventeenth century accepted the Scotist view of each of the above disputed theses. For example, on the question of whether the proper object of the human intellect, that which is studied by the science of metaphysics, is the quiddity of material being (with the intellect proceeding up the hierarchy of beings ultimately by analogy alone), or whether it is being in general, Eustachius of Sancto Paulo sided, for the most part, with Scotus.[61] Without referring to any particular authority, Eustachius rejected the Thomist position that the object of metaphysics is predicated being and accepted the Scotist position that the object of metaphysics is being, common to God and created things, as the standard view. Eustachius also defended the proposition that God's essence cannot be conceived except as existing,[62] and he asserted that we can form concepts of God's essence in this life.[63] Eustachius, like Scotus and against Thomas, accepted a third distinction beyond real and rational, arguing that there are three kinds of distinctions: real, rational, and another he called *a natura rei*, which he further subdivided into formal, modal, and potential.[64] He also held that matter can exist independent of form: "Although matter cannot be produced nor annihilated by any natural agent, God can create or annihilate it. . . . God can strip naked all forms, substantial and accidental, from matter, or create it naked, without form, ex nihilo, and allow it to subsist by its own power in such a state."[65] Moreover, he thought that humans are a composite of plural forms not a single substantial form (a debated proposition, as we have seen).[66] Eustachius argued for the Scotist doctrine that a form, not signate matter, is the principle of individuation.[67] On the theory of place, Eustachius again sided with Scotus: external and internal place are relations between the containing and contained bodies, and two places are the same only by equivalence, not in relation to a fixed reference frame.[68] Moreover, after maintaining that two bodies can be in one place by divine virtue, Eustachius argued that there is no incompatibility involved in one body's existing in several places.[69] On the theory of time, Eustachius argued for what may have been the successor to the Scotist line: time is divisible into real time and imaginary time, where imaginary time is that which precedes the creation of the world.[70] (And of course, imaginary time would be independent of bodies and their motions.)

Eustachius was not alone in maintaining Scotist doctrines in seventeenth-century France. What has been said about him could, on the whole, be repeated for others, including Abra de Raconis and Scipion Dupleix. Here I wish to reexamine the Jesuits' well-known penchant for Thomism and to ask how much Scotism could be found in Jesuit philosophy. It seems fairly clear that, with few exceptions, early Iberian and Roman Jesuits, such as the Conimbricenses and Toletus, remained generally faithful to Thomas.[71] One can document their allegiance to Thomist theory of matter, form, place, and time. For example, when Toletus discussed the question of whether prime matter is a substance, he detailed both Scotus's affirmative reply to the question and Thomas's negative answer—that prime matter is pure potency—in order to side with the latter. Toletus then discussed whether matter can exist without form. He referred to Thomas's denial of such a possibility, since it would imply a contradiction, and to Scotus's doctrine that it can be done by supernatural means. He concluded by agreeing with Thomas that there cannot be any matter in act without a form, arguing against Scotus that matter in itself is imperfect.[72] Similarly, Toletus agreed with Thomas on the question of the plurality of forms,[73] also taking Thomas's side against Scotus on the question of the immobility of place.[74] He also argued a Thomist line that if there is no motion then there is no generation or time.[75] On the other hand, Toletus disagreed with Thomas about the real distinction between essence and existence and thought that a form, not quantified matter, is the principle of individuation.

Later Jesuits rejected the Thomist position on all these topics, opting for Scotist ones. Writing in 1643, the French Jesuit René de Ceriziers argued that there can be no form without matter and no matter without form by natural means. But, he added, "one must not deny that God can conserve matter without any form, since these are two beings that can be distinguished, which no more depend upon one another than accident upon substance, the former being separated from the latter in the Eucharist."[76] De Ceriziers further disputed the Aristotelian (and indirectly Thomist) view of time: "Aristotle claims that time is the number of motion or of its parts, insofar as they succeed one another. Now it is certain that time is a work of our mind, since we construct a separated quantity from a continuous one, naming it the number of motion, that is, of the parts that we designate in it."[77] Another French Jesuit, Pierre Gautruche, in a work approved by the Order, argued *contra Thomistas* about prime matter.[78] On the question of the plurality of forms, he even identified a position against the reality of partial forms as the one held by Thomas, by Francisco Suárez, and by the Conimbricenses,[79] but sided with Scotus.[80] Gautruche also rejected the Thomist doctrine of place, including the doctrine that the universe cannot move as a whole.[81] Hence, for of a variety of reasons, the Jesuit penchant for Thomist philosophy seems not to have lasted a full century.

The initial generalization should therefore be limited. Perhaps only early (Iberian and Roman) Jesuits were Thomist-leaning, but later (French) Jesuits were not.[82] However, even this conclusion should be qualified. When reading Suarez's extremely influential *Disputationes Metaphysicae*, one is struck by the fact that the great Jesuit metaphysician generally proceeded by considering issues in the light of his predecessors, especially Thomas and Scotus. Indeed, Suárez sided with Scotus almost as often as he did with Thomas—and not infrequently took a direction that was his own. Even when siding with Thomas or Scotus, however, Suarez modified their doctrines significantly. He accepted analogical predication, siding with Thomas,[83] but thought that a concept of being can be found which is strictly unitary,[84] thus adopting Scotus's position on this issue: "the proper and adequate formal concept of being as such is one." Suárez added that this was the common opinion, defended by "Scotus and all his disciples." [85] Conversely, Suárez accepted the Scotist doctrine of matter's existing without form by divine power,[86] but sided with Thomas on the plurality of forms.[87] Likewise, he argued, against Thomas and with Scotus, that the principle of individuation is a form[88] (though he rejected Scotus's doctrine of the *haecceitas* as formally distinct).[89] Most important, he argued against Thomas that there is a third distinction other than real and rational.[90] He disputed the Thomist doctrine of a real distinction between essence and existence (calling it a distinction of reason with a basis in things) and between substance and accidents (though he rejected the Scotist formal distinction for a modal distinction).[91] Suárez, an important early Iberian Jesuit, was almost as much a Scotist as a Thomist.

Clearly, then, the official endorsement of Thomas by various Generals of the Jesuits appears to have had little effect—or if it did, it did not last very long. It would seem that the official adoption of Thomism did not effect the desired tranquillity—the preservation of the faith—with which nothing should have interfered. In part that might have been because the support for Thomism was a rather pragmatic and pedagogical decision, not a dogmatic one. And once one recognizes the lack of firm philosophical dogma among the Jesuits, one can pay more attention to other elements in Jesuit intellectual relations. A good example can be found in the exchanges between Bourdin and Descartes.

Descartes and Bourdin

On June 30 and July 1, 1640, Pierre Bourdin, the professor of mathematics at Clermont, the Jesuit college in Paris, organized a public disputation in which his student defended several theses, including three articles concerning Descartes's theory of subtle matter, reflection, and refraction. Bourdin composed a preface to the theses—styled a *velitatio* (skirmish)—which he delivered himself. Marin Mersenne, who attended the disputation, not only defended Descartes but also apparently chastised Bourdin for publicly attacking Descartes without sending the latter his objections. Mersenne then forwarded the *velitatio* to Descartes, with the three articles concerning Descartes's doctrines, as if they came from Bourdin himself.[92]

Descartes responded on July 22, thanking Mersenne for the affection he had shown him in "the dispute against the theses of the Jesuits." He informed Mersenne that he had written to the Rector of Clermont requesting he send him their objections against what he has written, "for he does not want to have any dealings with any of them in particular, except insofar as it would be attested to by the order as a whole."[93] Descartes further complained that the *velitatio* was "written with the intent to obscure rather than to illuminate the truth."[94] At that point, Descartes announced he was going to war with the Jesuits, adding: "Their mathematician of Paris has publicly refuted my *Dioptrics* in his theses—about which I have written to his Superior, in order to engage the whole order in this dispute."[95]

It is important to note that Descartes thought of Bourdin's objections as those of the Jesuits, in keeping with his general opinion that the Jesuits normally acted as a corporate body—that the opinion of one was likely to reflect the opinion of all them:

> But since [Bourdin] is a member of a society which is very famous for its learning and piety, and whose members are all in such close union with each other that it is rare that anything is done by one of them which is not approved by all, I confess that I did not only "beg" but also "insistently demand" that some members of the society should examine what I had written and be kind enough to point out to me anything which departed from the truth.[96]

Descartes did not regard Bourdin's initial attack as a solitary gesture; rather, he acted as if he had just received the answer he had been waiting for, concerning whether the Jesuits would support him.[97] He even came to believe that the appearance of Bourdin's attack as that of a solitary agent acting on his own was itself a matter of conspiracy: "Having recognized, in P. Bourdin's action as well as in the actions of several others, that there are many who speak of me disparagingly, and that, having no means to harm me by the power of their reasons, they have undertaken to do so by the multitude of their voices, I do not wish to address myself to any of them in particular, which would be an infinite and impossible task."[98] Descartes seemed to think that if real fault had been found with his doctrines the Jesuits would have given their reasons officially, instead of allowing members, such as Bourdin, to appear to act as individuals.[99]

The Bourdin affair degenerated further, with Descartes referring to Bourdin's objections as *cavillations*.[100] "The cavils of Père Bourdin have resolved me to arm myself from now on, as much as I can, with the authority of others, since the truth is so little appreciated alone."[101] The period was a particularly difficult one for Descartes, since he was about to publish his *Meditations*—his great work on metaphysics, only sketched in the *Discourse*, which was certain to lead him into greater controversies. It was in the summer of 1640 that Mersenne sent the *Meditations* to various savants, soliciting objections that would be published with the *Meditations*. Indeed, Descartes expected a set of objections from Bourdin himself. Bourdin wrote the *Seventh Set of Objections*, which was not received by Descartes in time for the first printing of the *Meditations* and *Objections and Replies* but which made the second printing. The exchange was not successful. Descartes complained bitterly about Bourdin and dismissed his objections as silly or misguided in a letter published with the *Seventh Replies* to Jacques Dinet, Provincial of the Jesuits for the Ile de France. However, Bourdin's criticisms, though verbose, were far from silly. Aside from his exchanges with Descartes, Bourdin does not generally strike one as misguided, and his views cannot even be described as very conservative.

Bourdin (born in 1595, a year before Descartes) became a professor of humanities at La Flèche in 1618, just after Descartes left. Having left in 1623, he returned as a professor of rhetoric in 1633, and he taught mathematics in the following year. In 1635 he was sent to Clermont (later known as the Collège Louis-le-Grand), where he stayed until his death in 1653. By 1640, when he debated with Descartes, Bourdin had already published three books: a *Geometry* following Euclid, another *Geometry*,[102] and a *Cours de mathématique*.[103] A few years later he published an *Introduction to Mathematics*.[104] Bourdin's mathematics, like that of most of his confreres, had a practical bent, as is evidenced by the aforementioned books[105] and by two posthumous publications: *L'architecture militaire ou l'art de fortifier les places regulières et irregulières* and *Le dessein ou la perspective militaire*.[106]

In his *Cours de mathématique*, Bourdin did not shy away from discussing the Copernican system. As was quite common among Jesuits, he treated it as a hypothesis, along with the Tychonic system, taking an instrumentalist line on the status of such hypotheses (again, as was common in mathematical works):

> Since it can happen that the earth, the sun, and such parts can be disposed in various fashions and still all these appearances remain, and can be well explained, astronomers use various means of ordering and disposing the world, each constructing his own hypothesis, according to whether he judges it to be easiest, or following some new remarks he makes, seeking nothing other than its usefulness in explaining the appearances of the world.[107]

The instrumentalist preamble of the *Cours de mathématique* was followed by a section on the hypothesis of the ancients (that is, homocentric spheres, plus epicycles, plus solid eccentrics),[108] a section on the Copernican hypothesis (which referred to sunspots as stars revolving around the sun[109]), and a section on the Tychonic hypothesis (which mentioned Galileo's discovery of the moons of Jupiter).[110] Despite his instrumentalism, Bourdin seems to have preferred the Tychonic system, calling it "the one in fashion today, having been sketched by Martianus Capella and polished and completed not long ago by Tycho Brahe, that excellent mathematician."[111]

There is another reason for thinking that Bourdin followed the fashion for the Tychonic system. In his one public departure from the realm of mathematics as defined in the seventeenth century into that of physics and cosmology, Bourdin gave arguments and sketched doctrines that were compatible only with the Tychonic system. Bourdin's cosmological work consisted of a single volume binding together two small treatises on the same general subject: *Sol flamma* and *Aphorismi analogici*.[112] In those works Bourdin argued that the sun is a blazing fire—a position inconsistent with the Aristotelian theory of the heavens, as Bourdin knew quite well,[113] and one supported by such innovators as Descartes.[114] Bourdin's basic argument was that the sun is a body on which there are sunspots and small torches, as the telescope rendered evident. Thus, the sun is corruptible matter—not incorruptible ether, as Aristotle would have it.[115] In the

Aphorismi analogici, such considerations compelled Bourdin to adopt a Tychonic cosmology. There he moved from an explanation of sunspots on analogy with foam bubbling up from the sea, to there being three regions of stars and planets, to magnetic phenomena affecting both the earth and the heavens.[116] But he rejected the Copernican hypothesis, claiming that the earth stays still.[117]

From Bourdin's writings, then, it would have been difficult to infer his becoming a dogmatic opponent of Descartes. Yet Descartes treated Bourdin as an unworthy critic, insulting him and evading his objections: "What he does is to take fragments from my Meditations and ineptly piece them together so as to make a mask which will not so much cover as distort my features."[118] Descartes compared Bourdin's reasoning to that of a child: "I am amazed that his ingenuity has been unable to devise anything more plausible or subtle. I am also amazed that he has the leisure to produce such a verbose refutation of an opinion which is so absurd that it would not even strike a seven-year-old child as plausible."[119] He sneered at Bourdin: "He is foisting on me, good-natured fellow that he is, a piece of reasoning that is worthy of himself alone," and "he finally reaches a conclusion which is wholly true when he says that in all these matters he has 'merely displayed his weakness of mind.'"[120] Descartes overlaid his insults with the suggestion that Bourdin was not actually inept, but just pretended to be so—that he was playing the clown: ". . . it is embarrassing to see a Reverend Father so obsessed with the desire to quibble that he is driven to play the buffoon. In presenting himself as hesitant, slow, and of meager intellect, he seems eager to imitate not so much the clowns of Roman comedy like Epidicus and Parmenon as the cheap comedian of the modern stage who aims to attempt to raise a laugh by his own ineptitude."[121] Ultimately, Descartes called Bourdin a liar:

> The conclusion, unless I am wholly ignorant of what is meant by the verb 'to lie', is that he is inexcusably lying—saying what he does not believe and knows to be false. Although I am very reluctant to use such a distasteful term, the defense of the truth I have undertaken requires of me that I should not refuse to call something by the proper word, when my critic is so unashamedly and openly guilty of the deed. Throughout this whole discussion he does virtually nothing else but repeat this foolish lie in a hundred different ways, and try to persuade and bludgeon the reader into accepting it.[122]

Descartes treated Bourdin roughly, and perhaps Bourdin merited the treatment. Part of the problem with the *Seventh Objections* was Bourdin's writing his objections in a dialogue form and his penchant for rhetorical flourishes. The decision proved disastrous, as Descartes had the last word, and he undercut Bourdin's objections by interspersing his own replies within Bourdin's dialogue form, making these *Objections and Replies* extremely difficult to read. Bourdin's lengthy objections also suffered because Descartes mustered his considerable rhetorical skills in his even longer replies. Descartes admitted that in his dealings with Bourdin he was sometimes not sure he had understood the thrust of his interlocutor's objections. In a revealing passage, Descartes wrote to Mersenne: "I wish to believe that Father Bourdin did not understand my demonstration," but that does not prevent his objections from "containing cavils that were not merely invented through ignorance, but because of some subtlety that I do not understand."[123] Still, the overall structure of Bourdin's attack on Descartes is fairly clear.

Bourdin's objections were all directed against Descartes's method of doubt, and clearly he hoped to derail Descartes's enterprise from the start. His strategy was to show that the method failed either because it was untrue to itself, and smuggled in various principles, or because, if the method did not smuggle anything in, it went nowhere. Bourdin alleged that doubt was itself a principle; therefore, the method smuggled in various principles.[124] Moreover, he argued that the principles Descartes smuggled in were defective in several ways. Descartes's principles were not as certain as the common principles denied by the method of doubt:

> Let me come to your maxim "If something appears certain to someone who is in doubt whether he is dreaming or awake, then it is certain—indeed so certain that it can be laid down as a basic principle of a scientific and metaphysical system of the highest certainty and exactness." You have not at any point managed to make me consider this maxim to be as certain as the proposition that two and three make five.[125]

And he tried to show that the principles smuggled in were not as worthy or as certain as the common principles ruled out by the method:

> You promise us that you will establish by strong arguments that the human soul is not corporeal but wholly spiritual; yet if you have presupposed as the basic premiss of your proofs the maxim "Thinking is a property of the mind, or of a wholly spiritual and incorporeal thing," will it not seem that you have presupposed, in slightly different words, the very result that was originally in question?[126]

Bourdin even supported his complaint by showing that it was not merely a hypothetical case, but that there were philosophers who held that thinking is a property of the body, so that their position cannot have been ruled out without a substantive principle.[127]

With the second horn of the dilemma, Bourdin tried to show that the method produced nothing or that it proved too much.[128] Bourdin noted that, in fact, the method could not produce anything, as it rejected all means of argumentation and any major premise whatever: "The method is faulty in the implements it uses, for as long as it destroys the old without providing any replacements, it has no implements at all. . . . If you propose any syllogism, it will be scared of the major premise, whatever it may be."[129] More generally, Bourdin argued, the method was quixotic and imprudent:

> The method goes astray by being excessive. That is, it attempts more than the laws of prudence demand of it, more, indeed, than any mortal demands. . . . You will not find anyone up until now who has been dissatisfied if propositions like "God exists and the world is governed by him," or "The souls of men are spiritual and immortal," are known with as much certainty as "Two and three make five," or "I have a head and a body."[130]

Whatever Descartes may have thought about Bourdin's criticism, at least Bourdin's attack was consistent with Jesuit pedagogical practice. By restricting himself to a critique of Descartes's method, Bourdin did not have to engage any particular doctrinal point. Instead, he emphasized the difficulty that Jesuits would have with any method that espoused skepticism, even if only as a preliminary step.

One of the more revealing exchanges between Descartes and Bourdin occurred over the latter's querying the meaning of Descartes's rule that what has the least appearance of doubt must be held as false. He gave three interpretations of the rule: when we are searching for what is certain we (1) must not in any way rely on what is certain, (2) must reject things that are certain to the extent that we make no use of them and consider them nonexistent, and (3) must reject them in such a way that we assume that they are in fact nonexistent or that their opposite truly obtains.[131] Bourdin said that the first interpretation of the rule is valid and "commonly received by all philosophers," that the second is legitimate, certain, and "familiar even to the least novice," but that the third is "invalid and opposite to sound philosophy."[132]

Descartes took offense and asserted that the third interpretation is so unbelievable that no person with good sense would have accepted it, and that Bourdin took it up only because he wanted those who had not read his *Meditations* to believe that Descartes held this ridiculous opinion.[133] He thought that Bourdin called the first two interpretations "familiar even to the least novice" in order to persuade those who had read his works that there was nothing important there. He rejected the critique, but he also said: "I would certainly not argue with the last statement. For I have never sought any praise for the novelty of my opinions."[134]

Descartes's reply involved a delicate subject that, although not directly raised by Bourdin, must have been a major worry for Descartes at the time. Descartes was attacked for the novelty of his opinions; this was the subject of the condemnation of his works by the Academic Senate of Utrecht in 1642. Descartes dealt with the issue in his *Letter to Dinet*, where he denied the novelty of his opinions:

> It may hardly seem likely that one person has managed to see more than hundreds of thousands of highly intelligent men who have followed the opinions that are commonly accepted in the Schools. Well-trodden and familiar pathways are always safer than new and unknown ones, and this maxim is particularly relevant because of theology. For the experience of many years has taught us that the traditional and common philosophy is consistent with theology, but it is uncertain whether this will be true of the new philosophy. For this reason some people maintain that the new philosophy should be prohibited and suppressed at the earliest opportunity, in case it should attract large numbers of inexperienced people who are avid for novelty, and thus gradually spread and gain momentum, disturbing the peace and tranquillity of the Schools and the universities and even bringing new heresies into the Church.[135]

According to Descartes, the solution to this problem—a solution he himself recognized as paradoxical—was that all of Peripatetic philosophy, insofar as it is different from other philosophies, was new, and that his philosophy was ancient. In fact, with respect to the principles of his philosophy, Descartes claimed that he accepted only those "which in the past have always been common ground among all philosophers without exception, and which are therefore the most ancient of all." And since what he deduced from these principles was contained in them, the truths deduced were equally ancient. The principles of the prevalent philosophy were new when Aristotle invented them, and they should not be considered better now than they were then. Besides, "everything deduced from them is controversial and liable to be changed by individual philosophers, depending on the fashion in the Schools, and hence it is exceedingly new, since it is still being revised every day."[136]

Descartes's defense might have seemed unconvincing. He did not say how he knew that all philosophers generally accepted his principles and why he thought that his principles were the most ancient of all. But it can be shown that his reply was not constructed after the fact or just to satisfy the Magistrates of Utrecht. Descartes had already attempted on several occasions to avoid having his philosophy called novel. For example, in a 1638 letter to Père Etienne Noël, Descartes had written: "I know that the principal reason which requires those of your order most carefully to reject all sorts of *novelties* in matters of philosophy is the fear they have that these reasons would also cause some changes in theology."[137] Similarly, in the Dedicatory Letter to the Deans and Doctors of the Sorbonne, published with the *Meditations* in 1641, Descartes had rejected the judgment that his method was novel.[138] Thus, Descartes was not unaware of the potential risk his philosophy ran by being associated with novelty. Even though it did not resolve all the difficulties, Descartes's reply to Bourdin put into relief the element most necessary for understanding his defense against novelty. Descartes's philosophy is ancient because it is true, and one can understand that it is true because it is innate with us; thus, one can recognize its great age as soon as one becomes aware of its truth.[139] This may have been Descartes's strongest and only defense against the charge of novelty, but it was a weak defense that ultimately failed to convince anybody.

Descartes maintained such defense in his later works, elements of which even made their way into one of his replies to the question of the novelty of the *cogito*. He wrote to Mesland:

> I am much obliged to you for informing me of the passages in Saint Augustine that can help in authorizing my opinions. Some other friends of mine have already done something similar. And I take great satisfaction in the fact that my thoughts agree with those of so sainted and excellent a person. But I am not at all of the habit of thought of those who desire that their opinions appear new. On the contrary, I accommodate mine to those of others insofar as truth allows me to do so.[140]

One does not have to delve too deeply into the *Principles of Philosophy* to understand that its point of view was consistent with such a strategy. Part of Descartes's task in the *Principles* was to deny that his principles were novel, or that they are "opposed to the traditional philosophy universities throughout the world have hitherto taught." Indeed, article 200 in part IV of *Principles* began:

> There are no principles in this treatise that are not accepted by all men; this philosophy is not new, but is the most ancient and most common of all. . . . But I likewise desire that it should be observed that although I have here tried to give an explanation of the whole nature of material things, I have nevertheless made use

of no principle that has not been approved by Aristotle and by all the other philosophers of every time; so that this philosophy, instead of being new, is the most ancient and common of all.

These issues were also raised in the preface to the *Principles*, though Descartes seems to have attempted to have it both ways:

The . . . reason that proves the clarity of these principles is that they have been known from all time and even received as true and indubitable by all men. . . . But although all the truths I place in my Principles have been known from all time and by everyone, nevertheless there has never yet been anyone, as far as I know, who has recognized them as the principles of philosophy, that is to say, as principles from which may be derived a knowledge of all things that are in the world; that is why it here remains to me to prove that they are such.[141]

The Jesuit and Other Condemnations of Descartes

Descartes began a correspondence with the Jesuit Denis Mesland after the latter posed him some questions and informed him that he had written an abridgment of the *Meditations* that would be accessible to students.[142] Descartes was delighted and resolved to satisfy Mesland's questions "most frankly, without dissimulating anything of my thoughts."[143] There followed some important discussions on such metaphysical and theological topics as free will and the sacrament of the Eucharist.[144] The correspondence ended when Mesland left La Flèche to become a missionary in the New World.

A number of writers have thought that Mesland's exile to the New World was some kind of punishment. Bouillier asserted: "A small time after this letter [on transubstantiation], Father Mesland was sent to the missions to tend to the savages, perhaps because of his overly ardent taste for the new philosophy."[145] And Richard Watson related that "the exchange of letters [between Descartes and Mesland] began in 1644 and was terminated abruptly in 1646 when, as extreme discipline for his commerce with Descartes, Mesland was banished to Canada."[146] Watson even asked "Why was Mesland dealt with so severely?" and answered "Undoubtedly it was for the same reasons that led Descartes to drop his guard to make some tentative proposals about Cartesian theology himself." The issue of transubstantiation was crucial.[147] It is improbable that Mesland was being disciplined by the Jesuits for his commerce with Descartes. We cannot be sure, of course, but we can surmise that being sent to the missions was not a punishment but a reward for a Jesuit in the seventeenth century. Rochemonteix stated (though without giving any documentation) that Mesland had requested the assignment.[148] Moreover, the length of Mesland's stay in the New World (some 26–28 years, 22–24 years after Descartes's death) is evidence against the thought that Mesland was being punished.[149] More important is the thought that a Jesuit teaching at La Flèche would have been writing an abridgment of the *Meditations* fit for teaching at a Jesuit college.

As the seventeenth century wore on, however, the Jesuits became increasingly anti-Cartesian, as did many others in the teaching orders. A summary of a disputation by the Jesuits of Clermont College during 1665 gives a general assessment of the doctrinal difficulties associated with Cartesianism:

> To say no more, the Cartesian hypothesis must be distasteful to mathematics, philosophy, and theology. To philosophy because it overthrows all its principles and ideas which commonsense has accepted for centuries; to mathematics, because it is applied to the explanation of natural things, which are of another kind, not without great disturbance of order; to theology, because it seems to follow from the hypothesis that (i) too much is attributed to the fortuitous concourse of corpuscles, which favors the atheist; (ii) there is no necessity to allow a substantial form in man, which favors the impious and dissolute; (iii) there can be no conversion of bread and wine in the Eucharist into the blood and body of Christ, nor can it be determined what is destroyed in that conversion, which favors heretics.[150]

The summary is broken down into three main categories. The first, the complaint already issued at Utrecht, is the rejection of any novel philosophy. As we have seen, Descartes attempted to defend himself against that charge by arguing (unsuccessfully) that his philosophy was actually the oldest of all philosophies.[151] The second refers to the scholastic doctrine of the classification of the sciences. The claim is that mathematics should be subalternated to physics and not vice-versa, as with Descartes. The third is itself divided into three parts, all concerning the relations between philosophy and theology. Cartesian philosophy is unfairly linked with atomism, and the standard complaint against atomism is issued against it.[152] The disputants also object that man's substantial form is not necessary, something Descartes himself complained about with respect to Regius's exposition of his philosophy.[153] At last, we come to the issue of the Eucharist, which seems to have been the focus of opposition to Cartesianism in the second half of the seventeenth century. It was the issue to which Louis XIV's edict referred; it was alleged to be the cause of Descartes's works being placed on the Index; and it was specifically cited as a ground for condemnation at Louvain, along with a few other difficulties.

The 1662 condemnation at Louvain (which, according to Victor Cousin, was instigated by Jesuits) listed five difficulties with Cartesian doctrine: the definition of substance, the rejection of substantial forms or real accidents, extension as an essential attribute of substance, the indefinite extension of the world, and the plurality of worlds.[154] These five difficulties were heard again and again throughout the seventeenth century. The Jesuits condemned the following related propositions, but again, they were not they only ones who had difficulty with these Cartesian conclusions: that animals are mere automata deprived of all knowledge and sensation; that there are no substantial forms of bodies in matter; that there are no absolute accidents; that the essence of matter or of body consists in its actual and external extension, and in itself the extension of the world is indefinite; that there can be only one world; and that the compenetration of bodies properly speaking and place void of all bodies imply a contradiction.[155]

Cartesians were not alone in being censured for holding doctrines inconsistent with various Church dogmas, or for attempting to limit God's absolute omnipotence. Most of the difficulties with Cartesianism in the seventeenth century were faced by Aristotelianism four centuries earlier. Among the propositions condemned at the University of Paris in 1277 were some that appeared threatening to the Eucharist. Thus, prohibited were such propositions as "to make an accident exist without a subject has the nature of an impossibility implying a contradiction" and "God cannot make an accident exist without subject or make more than one dimension exist simultaneously."[156] Also condemned in 1277 were numerous propositions thought to infringe upon God's absolute omnipotence—for example, "The first cause cannot make more than one world" and "God could not move the heavens in a straight line, the reason being that he would leave a vacuum,"[157] the latter proposition being widely interpreted as a prohibition of the impossibility of void. Moreover, in 1624 the University of Paris and the Parliament prohibited the denial of substantial forms by some anti-Aristotelians on the ground that holding an atomist philosophy would have been inconsistent with giving an intelligible explanation of transubstantiation.[158] Cartesians and other anti-Aristotelians, therefore, were not being singled out, in the second half of the seventeenth century, in this respect. It was a common tactic much earlier to claim that a particular philosophical view was incapable of accommodating the Eucharist. Scipion Dupleix, for one, had argued that Thomists could not explain the Eucharist if they denied that matter can be without form[159] and that, supernaturally, two bodies can be in the same place.[160] Similarly, the possibility of void was argued on the model of transubstantiation. Théophraste Bouju, in his *Corps de Philosophie*, asserted the impossibility of internal place or space to be void of all bodies "except that God by his absolute power can give subsistence to quantity as he does, in the Holy Eucharist, to the species of bread and wine which remain after transubstantiation."[161] Even Gassendi, in 1624, having accepted the seemingly innocuous doctrine that "the essence of quantity is nothing but its external extension,"[162] felt compelled to point out that his doctrine had negative consequences for the sacrament of the Eucharist and took steps to reaffirm his orthodoxy: "To continue, let us now turn our attention to the famous difficulty concerning the essence of quantity. Our philosophers explain it so well that nothing could be more obscure, though nothing would seem to be more obvious than quantity. However, I must confess that the mystery of the Eucharist, as our faith conceives it, may cause some difficulty in this matter."[163]

By 1691, when the University of Paris finally condemned Cartesianism, the focus was no longer on the first set of Cartesian doctrines as such. Much of the edict was devoted to the condemnation of the Cartesian method of doubt, with the following propositions prohibited:

> 1. One must rid oneself of all kinds of prejudices and doubt everything before being certain of any knowledge. 2. One must doubt whether there is a God until one has a clear and distinct knowledge of it. 3. We do not know whether God did not create us such that we are always deceived in the very things that appear the clearest. 4. As a philosopher, one must not develop fully the unfortunate consequences that an opinion might have for faith, even when the opinion appears incompatible with faith; notwithstanding this, one must stop at that opinion, if it is evident.[164]

Similarly, when in 1706 the general of the Jesuits condemned 30 Cartesian propositions, he did not fail to include some against Descartes's method of doubt. Prohibited were the following propositions:

> 1. The human mind can and must doubt everything except that it thinks and consequently that it exists. 2. Of the remainder, one can have certain and reasoned knowledge only after having known clearly and distinctly that God exists, that he is supremely good, infallible, and incapable of inducing our minds into error. 3. Before having knowledge of the existence of God, each person could and should always remain in doubt about whether the nature, with which one has been created, is not such that it is mistaken about the judgments that appear most certain and evident to it. 4. Our minds, to the extent that they are finite, cannot know

anything certain about the infinite; consequently, we should never make it the object of our discussions. 5. Beyond divine faith, no one can be certain that bodies exist—not even one's own body.[165]

Thus, Descartes's method of doubt officially became a target of criticism. The view is captured nicely by the comment of the Jesuit René Rapin, echoing Bourdin's preoccupation with hyperbolic doubt, though attempting to say something positive about Descartes: "In truth, Descartes teaches one to doubt too much, and that is not a good model for minds who are naturally credulous; but, in the end, he is more original than the others."[166]

Conclusion

There is no doubt that during the seventeenth century some Jesuits became enemies of Cartesian philosophy and science. Various official condemnations of Cartesianism can attest to this, though these were not as frequent as might have been expected. It is equally true that some Jesuits (as well as some non-Jesuits) rejected Cartesian philosophy on doctrinal grounds. Debates over the explanation of transubstantiation in the mystery of the Eucharist can attest to this. Yet there were also Jesuits who were advocates of Cartesian philosophy and science. The greatest problem Jesuits in general (though not exclusively) had with Cartesian philosophy and science was not doctrinal but pedagogical and pragmatic. During the sixteenth and seventeenth centuries, the Jesuits were involved in a massive reorganization of teaching at the collegiate level. Their new pedagogy required an effort in communication and in the maintenance of unity in order to ensure that their curriculum was followed rigorously everywhere. It also required the teaching of what was tried and true; that is, it viewed novelty with suspicion, especially with respect to the portions of doctrine closest to theology, such as metaphysics and natural philosophy. Even if Descartes's doctrines did not oppose those held by the Jesuits, his philosophy simply could not have failed to clash with other Jesuit intellectual characteristics. Descartes was seen to be offering a novel philosophy; even worse, his philosophy was seen to be based on a method that espoused initial doubt. Although the Jesuits tolerated the infiltration of certain novel doctrines, they could not accept a method of doubt or skepticism as a heuristic. This is amply demonstrated by the dispute between Descartes and Bourdin and by subsequent Jesuit condemnations of Cartesianism.

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Notes

1. *Oeuvres de Descartes*, ed. C. Adam and P. Tannery (Paris, 1964–1974), volume III, p. 103. English translations of Descartes's works are from *The Philosophical Writings of Descartes*, ed. J. Cottingham et al. (Cambridge, 1985) or are my own.

2. See Trevor McClaughlin, "Censorship and Defenders of the Cartesian Faith in Mid-Seventeenth Century France," *Journal of the History of Ideas* 40 (1979): 563–581. Also see, in general, Francisque Bouillier, *Histoire de la Philosophie cartésienne* (1868).

3. See *La Querelle d'Utrecht* (Paris, 1988) and *Descartes and the Dutch* (Carbondale, 1992).

4. Charles Duplessis d'Argentré, *Collectio judiciorum de novis erroribus* (Paris, 1736), volume III, part ii, pp. 303–304.

5. Francisque Bouillier, *Histoire de la Philosophie cartésienne*, volume I, pp. 446–447.

6. Ludovicus Prou, *De Hypothesi Cartesiana positiones physico mathematica* (Clermont, 1665). Writing to Boyle, Oldenburg talks about two anti-Cartesian disputations at Paris at Clermont in 1665, giving the text of the first. In the first, Descartes is made to look ridiculous because of his doctrine's absurd (actually non-Cartesian) consequences. The summation is interesting, though, and a very early treatment of the kinds of charges against Descartes that will be lodged later, generally reflecting the objections from Louvain. The second disputation is about comets (as made up of different stars). See *The Correspondence of Henry Oldenburg*, ed. A. Hall and M. Hall (Madison and London, 1965–86), volume II, pp. 430–435. I am indebted to Mordechai Feingold for this reference.

7. See e.g. Louis de la Ville [Louis le Valois], *Sentimens de Monsieur Descartes touchant l'essence et es proprietez du corps opposez à la Doctrine de l'Eglise, et conforme aux erreurs de Calvin sur le sujet de l'Eucharistie* (Paris, 1680). But see also Jean Vincent, *Discussio peripatetica in qua philosophiae cartesianae principia* (Toulouse, 1677); Jean-Baptiste de la Grange, *Les principes de la philosophie contre les nouveaux philosophes, Descartes, Rohault, Regius, Gassendi, le P. Maignan, etc.* (Paris, 1682); Pierre Daniel Huet, *Censura philosophiae cartesianae* (Paris, 1689); Jean Duhamel, *Reflexions critiques sur le système cartesien de la philosophie de mr. Régis* (Paris, 1692).

8. See "Arret burlesque," in *Oeuvres de Boileau*, ed. Saint-Marc (1747), volume III, pp. 150–153; *Corpus 20/21* (1992): 231–240.

9. [Antoine Arnauld?], "Plusieurs raisons pour empecher la censure ou la condemnation de la philosophie de Descartes," in *Oeuvres de Boileau*, ed. Saint-Marc, volume III, pp. 117–141 (reprinted by Victor Cousin in *Fragments Philosophiques pour servir à l'histoire de la philosophie*, Paris, 1866). See also Pierre Bayle, *Recueil de quelques pièces curieuses concernant la philosophie de Monsieur Descartes* (Amsterdam, 1684).

10. Gabriel Daniel, *Voyage du monde de Descartes* (Paris, 1690); M. G. de L'A. [Pierre Daniel Huet], *Nouveaux mémoires pour servir à l'histoire du cartésianisme* (n.p., 1692); Gabriel Daniel, *Nouvelles difficultés proposées par un péripatéticien à l'auteur du "Voyage du monde de Descartes"* (Paris, 1693).

11. Bouillier, *Histoire de la Philosophie cartésienne*, volume I, p. 469.

12. Duplessis d'Argentré, *Collectio judiciorum de novis erroribus tomus tertium*, volume I, p. 149.

13. For an account of the events at Angers, see François Babin, *Journal ou relation fidele de tout ce qui s'est passé dans l'université d'Angers au sujet de la philosophie de Des Carthes en l'execution des ordres du Roy pendant les années 1675, 1676, 1677, et 1678* (Angers, 1679).

14. "Concordat entre les Jesuites et les Peres de l'Oratoire, Actes de la Sixiéme Assemblée, September 1678," in Bayle, *Recueil de quelques pièces curieuses concernant la philosophie de Monsieur Descartes*, pp. 11–12.

15. Camille de Rochemonteix, *Un Collège de Jésuites aux 17e et 18e siècles: Le Collège d'Henry IV à la Flèche* (Le Mans, 1899), volume IV, pp. 89–93. For full texts of the documents cited in notes 10–14, see Roger Ariew, "Quelques condamnations du cartésianisme: 1662–1706," *Archives de Philosophie* 57 (1994): 1–6. The condemnation was widespread; there was even a lengthy discussion of it in the correspondence between Leibniz and the Jesuit B. Des Bosses. See G. W. Leibniz, *Die philosophischen Schriften*, ed. C. Gerhardt (Hildesheim, 1978), volume II, pp. 311–507.

16. Bouillier, *Histoire de la Philosophie cartésienne*, volume I, p. 571.

17. *Oeuvres de Descartes*, volume VI, pp. 5–9, 16. Also: ". . . as for the sciences, inasmuch as they borrow their principles from philosophy . . . no solid building could have been constructed on such shaky foundations."

18. See letter to Dinet, *Oeuvres de Descartes*, volume VII, pp. 563–603, especially the end of the letter (p. 582ff.).

19. Arnauld and Baillet believed that the Jesuits (or one Jesuit: Fabri) caused Descartes's works to be put on the Index. See Bouillier, *Histoire de la Philosophie cartésienne*, volume I, pp. 466–467. See also the anonymous Plusieurs raisons pour empêcher la censure ou la condemnation de la philosophie de Descartes, reprinted by Victor Cousin. Cousin claims to have evidence that the treatise was written by Arnauld. In any case, whoever wrote the treatise clearly blamed the Jesuits for using the Descartes affair in order to stir up troubles against Jansenists (such as Arnauld).

20. Bouillier, *Histoire de la Philosophie cartésienne*, volume I, chapter 28. Huet was certainly a friend of the Jesuits. Victor Cousin also thought the Jesuits were behind the Cartesians' persecution from 1663 to 1706, but he had to treat the University of Louvain and non-Jesuit professors such as Plempius as pawns of the Jesuits, in order to make his point. The Jesuits' involvement might have been genuine, but it was certainly indirect.

21. *Oeuvres de Descartes,* volume II, pp. 377–378.

22. On La Flèche and its curriculum, see Rochemonteix, *Un Collège de Jésuites aux 17e et 18e siècles*. For a more popular exposition of the same materials, see J. Sirven, *Les années d'apprentissage de Descartes* (Paris, 1928). On other Jesuit colleges, see William Wallace, *Galileo and His Sources: The Heritage of the Collegio Romano in Galileo's Science* (Princeton, 1984); François de Dainville, *L'Education des Jésuites* (Paris, 1978); Lawrence W. B. Brockliss, *French Higher Education in the Seventeenth and Eighteenth Centuries: A Cultural History* (Oxford, 1987).

23. Rochemonteix, *Un Collège de Jésuites aux 17e et 18e siècles*, volume II, pp. 25–27.

24. *Oeuvres de Descartes,* volume I, p. 383.

25. Ibid. One can guess from this sentence that the recipient of the letter is Père Etienne Noël, Descartes's repetitor in philosophy, who was Rector of La Flèche in 1637. See G. Rodis-Lewis, "Descartes et les mathématiques au collège," in *Le Discours et sa Méthode* (Paris, 1988), p. 190n; see also her "Descartes aurait-il eu un professeur nominaliste?" and "Quelques questions disputées sur la jeunesse de Descartes," in *Idées et Verités Eternelles chez Descartes* (Paris, 1985). Later, Noël derived some acclaim for his work on the vacuum, defending a scholastic-Cartesian point of view.

26. See e.g. the letter in *Oeuvres de Descartes,* volume I, p. 387, in which Descartes indicated that, of the three copies of the Discourse enclosed, one was for the recipient of the letter, another for Cardinal Richelieu, and the third for the king.

27. *Oeuvres de Descartes,* volume I, p. 383.

28. Ibid., pp. 454–456. In the letter to Dinet, Descartes stated: "Having attempted to write a philosophy, I know that your Society alone, more than any other, can make it succeed or fail." (*Oeuvres de Descartes*, volume IV, p. 159)

29. Ibid. Descartes repeated this in a letter to Dinet (*Oeuvres de Descartes*, volume VII, p. 573).

30. *Oeuvres de Descartes*, volume I, pp. 455–456. See also p. 564.

31. *Oeuvres de Descartes,* volume II, p. 48.

32. Ibid., p. 50.

33. *Oeuvres de Descartes,* volume VII, p. 592.

34. St. Ignatius of Loyola, *The Constitutions of the Society of Jesus* (St. Louis, 1970), pp. 220–221.

35. Bibliothèque Nationale, ms. fond Latin, n. 10989, fol. 87, as transcribed in Rochemonteix, *Un Collège de Jésuites aux 17e et 18e siècles*, volume I, pp. 4n–6n.

For a complete translation of the letter, see Roger Ariew, *Descartes and the Last Scholastics* (Ithaca, 1999), pp. 13–15.

36. Bibliothèque Nationale, ms. fonds latins, n. 10989, as transcribed in Rochemonteix, *Un Collège de Jésuites aux 17e et 18e siècles*, volume IV, pp. 11n–12n.

37. Ibid.

38. John Heilbron, *Electricity in the 17th and 18th Centuries: A Study in Early Modern Physics* (Berkeley, 1979).

39. See C. H. Lohr, "Renaissance Latin Aristotle Commentaries: Authors C," *Renaissance Quarterly* 28 (1975), pp. 717–720. Chief among the Coimbrans was Petrus Fonseca, who separately published an influential commentary on Aristotle's Metaphysics.

40. See Lohr, "Authors So–Z," *Renaissance Quarterly* 35 (1982), pp. 199–201. Descartes remembered having read the Coimbrans and Toletus in his youth (*Oeuvres de Descartes,* volume III, p. 185). Other influential Jesuits who published textbooks for the collegiate curriculum included Rodericus Arriaga, Christopher Clavius, and Antonio Rubius.

41. Eustachius a Sancto Paulo (Asseline) entered the Feuillants, a Cistercian order, in 1605, and was a professor of theology at the Sorbonne. His *Summa philosophica quadripartita de rebus dialecticis, moralibus, physicis, et metaphysicis*, first published in 1609, was published again and again until 1648. See Lohr, "Authors D–F," *Renaissance Quarterly* 29 (1976), pp. 725–726.

42. Charles d'Abra de Raconis, born a Calvinist, converted to Catholicism. He taught philosophy at the Collège des Grassins and the Collège du Plessis in Paris. He then held a chair of theology at the Collège de Navarre, also in Paris. He published his *Summa totius philosophiae* in 1617, republishing it in parts and expanding it numerous times up to 1651. See Lohr, "Renaissance Latin Aristotle Commentaries: Authors A–B," *Studies in the Renaissance* 21 (1974), pp. 235–236. Professors at the University of Paris who wrote philosophy texts included J.-C. Frey, François le Rees, Jacques du Chevreul, and Jean Crassot.

43. See Ann Blair, *The Theater of Nature: Jean Bodin and Renaissance Science* (Princeton, 1997), pp. 46–49.

44. De Ceriziers left the order in 1641, just before the publication of *Le philosophe français*. Philosophy textbooks in French language included François de Gravelle's *Abrégé de la philosophie* (Paris, 1601) and Léonard Marandé's *Abrégé curieux de toute la philosophie* (Paris, 1642).

45. There were more than 20 editions of Dupleix's *Physique* in various incarnations during the first half of the seventeenth century. Cf. E. Faye, "Le corps de philosophie de Scipion Dupleix et l'arbre cartésien des sciences," *Corpus* 2 (1986): 7–15. The various parts of the Corps de Philosophie have been republished recently: *Logique* (Paris, 1984); *Physique* (Paris, 1990); *Metaphysique* (Paris, 1992); *Ethique* (1994). Other French textbooks included *Philosophie mise en francois et divisee en trois parties, scavoir, elements de la logique, la physique ou science naturelle, l'ethyque ou science morale* (1644) by the Protestant Pierre du Moulin, whose logic text was also translated into English.

46. Sacra Studiorum Congregatio, "Theses quaedam, in doctrina Sancti Thomae Aquinatis contentae, et a philosophiae magistris propositae, adprobantur," *Acta Apostolicae Sedis* 6 (1914): 383–386.

47. He also attempted to avoid the extreme Augustinianism of Henry of Ghent.

48. Scotus, *Opus Oxoniense*, I, dist. 2, quaest. 1 and elsewhere.

49. Cf. Aquinas, *Summa Theologiae*, I, quaest. 2, art. 1.

50. Scotus, *Opus Oxoniense* I, dist. 3, quaest. 3.

51. Aquinas, *Summa Theologiae* I, quaest. 84, art. 7.

52. Scotus, *Opus Oxoniense*, II, dist. 3, quaest. 2.

53. Ibid., dist. 12, quaest. 1.

54. Ibid., dist. 3, quaest. 6.

55. Scotus, *Quaestiones quodlibetales*, quaest. 10, art. 2.

56. Scotus, *Opus Oxoniense*, IV, dist. 11, quaest. 3.

57. Aquinas, *In octo libros De physico auditu sive physicorum Aristotelis commentaria*, IV, lectio 8.

58. Scotus, *Quaestiones Quodlibetales*, quaest. XII.

59. Aquinas, *In octo libros De physico auditu sive physicorum Aristotelis commentaria*, IV, lectio 16–17.

60. Scotus, *Quaestiones Quodlibetales*, quaest. XI.

61. Eustachius, *Summa*, Metaphysica, Praef. quaest, 2, p. 1.

62. Ibid., Pars II, Disp. II, quaest. 4, p. 24.

63. Eustachius, *Summa*, Metaphysica, Pars IV, Disp. III, quaest. 1, p. 71. Eustachius continued, however, by denying that we can demonstrate God's existence a priori, since God is not known to us per se nota (quaest. 2, pp. 73–74). He also sided with Thomas about what is said about God and creatures being said analogically, not synonymously (ibid., p. 15).

64. Eustachius, *Summa*, Metaphysica, Pars III, disp. 3, quaest. 5–8, pp. 52–55.

65. Physica, Part I, disp. II, q. IV: Quaenam sint praecipua proprietatis materiae, in *Summa philosophica quadripartita*, pp. 16–17.

66. Eustachius, *Summa*, Physica, Pars III, tract. I, disp. 1, quaest. 6, pp. 174–175.

67. Eustachius, *Summa*, metaphysica, tractatus de proprietatibus entis, disp. 2, quaest. 4, pp. 38–39. See also de Raconis, *Summa*, Metaphysica, tract. 4, sec. 2, p. 4, brevis appendix, pp. 76–78, and Dupleix, *La Metaphysique* (Paris, 1610), p. 235.

68. Eustachius, *Summa philosophica quadripartita*, Physics, tract. III, 2nd disp., quaest. 1, Quid sit locus, pp. 56–58. Eustachius also developed, very briefly, some odd views about the place of the ultimate sphere. The place of the outermost sphere is internal place or space and external, but imaginary place (*Summa philosophica quadripartita*, Physics, tract. III, 2nd disp., quaest. 2, Quotuplex sit locus, pp. 58–59). For more on imaginary place, see Edward Grant, *Much Ado About Nothing* (Cambridge, 1981), chapters 6 and 7. For more on internal and external place, see Grant, chapter 2.

69. Eustachius, *Summa*, Physica, pars 1, tract. 3, disp. 2, quaest. 3, p. 59. See also de Raconis, *Summa*, Physica, tract. 2, quaest. 1 and 2, esp. pp. 207, 216, and Dupleix, *La physique*, pp. 261–262.

70. Eustachius, *Summa*, Physica, tract III, quaest. 2, pp. 63–64. See also Dupleix, *La physique*, pp. 299–303.

71. However, since they did not write commentaries on Aristotle's Metaphysics, this conclusion cannot extend over all the Thomist theses. A fuller treatment of this issue would require a survey of Petrus Fonseca's Commentary on Aristotle's Metaphysics and Toletus's Commentary on Thomas's *Summa Theologicae*.

72. Quaest. XIII: An materia sit substantia. Toletus Physica, fol. 34 verso. Théophraste Bouju also followed the Thomist line about the reality prime matter. See Bouju, *Corps de toute la Philosophie*, volume I, pp. 315–316, 319–320, 322, 326–327, 329–331.

73. Toletus, *Commentaria una cum quaestionibus in tres libros Aristotelis de Anima* (Cologne, 1615), II, cap. 3, quaest. 7.

74. Toletus, *Physica* IV, quaest. V: An locus sit immobilis, fol. 120r–121r. Cf. Edward Grant, "Place and Space in Medieval Physical Thought," in *Motion and Time, Space and Matter*, ed. P. Machamer and R. Turnbull (Columbus, 1976).

75. Toletus, *Physica*, IIII, quaest. 12, fol. 142v–143v.

76. De Ceriziers, *Le philosophe français*, volume II, pp. 51–52.

77. Ibid., p. 100.

78. See Gautruche, *Philosophiae ac Mathematicae*, volume 2, Physica Universalis, p. 27. For more on Gautruche, see Lawrence Brockliss, "The Scientific Revolution in France," in *The Scientific Revolution in National Context*, ed. R. Porter and M. Teich (Cambridge, 1992); "Pierre Gautruche et l'enseignement de la philosophie de la nature dans les collèges jésuites français vers 1650," in *Les Jésuites à la Renaissance*, ed. L. Giard (Paris, 1995).

79. Gautruche, *Philosophiae ac mathematicae*, Physica, p. 40

80. Ibid., p. 41.

81. *Philosophiae ac mathematicae*, volume II, p. 331.

82. As late as 1651, one could still find "materia prima potest naturaliter esse sine omni forma" among the "Propositiones aliquot, quae in scholis Societatis non sunt docendae," "Ordinatio pro Studiis Superioribus ex Deputatione, quae de illis habita est in Congregatione nona Generali, a R. P. N. Francisco Piccolomineo ad Provincias missa a 1651," in *Ratio Studiorum*, ed. G. Pachtler (reprint: Osnabrück, 1968), volume III, p. 90. Note the change from Thomism even here. What should not be taught is that prime matter can naturally exist without a form. Thomas would have gone further and refused to allow that prime matter can exist without a form supernaturally. This is what the Dominican Antoine Goudin explains: "The whole world agrees that matter cannot exist naturally without form because by itself either it has no existence or its existence is dependent on form. But it could be asked whether God could create matter without a form by means of his omnipotence. Scotus affirms this, as do some authors outside the school of Saint Thomas; Saint Thomas

and all the Thomists deny it . . . Conclusion. It seems that this cannot be done—matter existing without form—even by means of God's absolute power. So says Saint Thomas (III quodlib. art 1). God himself cannot make something be and not be. He cannot make something that implies a contradiction, and consequently he cannot make matter without form." A. Goudin, *Philosophie suivant les principes de Saint Thomas* (1668) (Paris, 1864), volume II, p. 117; art 4, p. 131.

83. Suarez, *Disputationes Metaphysicae* (Hildesheim, Olms, 1998), disp. 28, sec. 3, no. 2.

84. Ibid., disp. 2, sec. 3, no. 7.

85. Ibid., disp. 2, sec. 1, no. 9.

86. Ibid., disp. 34, sec. 5, no. 36.

87. Ibid., disp. 15, sec 10, no. 61.

88. Ibid., disp. 5, sec. 2, nos. 8–9.

89. Ibid., disp. 5, sec. 6, no. 15.

90. Ibid., disp. 7, sec. 1, no. 16.

91. Ibid., disp. 31, sec. 1, no. 3, though Suarez did reject the Scotist formal distinction for his own modal distinction; when he rejects the real distinction between essence and existence, he calls it a distinction of reason with a basis in things.

92. Baillet, *Vie de Descartes*, volume II, p. 73. On a couple of occasions, Descartes asked Mersenne to tell him whether the velitatio was given to him by Bourdin, so that Descartes might judge whether Bourdin acted in good faith. See e.g. *Oeuvres de Descartes,* volume III, p. 162. Descartes gave a summary of the events in the letter to Dinet (*Oeuvres de Descartes,* volume VII, pp. 566–572).

93. *Oeuvres de Descartes,* volume III, p. 94.

94. Ibid. In another letter, Descartes told Mersenne that he was shocked by the velitatio, for Bourdin did not have a single objection to anything Descartes had written, but rather attacked doctrines Descartes did not hold (*Oeuvres de Descartes,* volume III, pp. 127–128). In his Replies to the Seventh Objections, Descartes said of Bourdin: "When, some eighteen months ago, I saw a preliminary attack of his against me which, in my judgement, did not attempt to discover the truth but foisted on me views which I had never written or thought, I did not hide the fact that I would in future regard anything which he as an individual produced as unworthy of a reply." (*Oeuvres de Descartes,* volume VII, p. 452)

95. *Oeuvres de Descartes,* volume III, p. 103.

96. *Oeuvres de Descartes,* volume VII, p. 452.

97. Baillet said that he was mistaken in this (*Vie de Descartes*, volume II, pp. 73–74). Descartes repeated the passage from his letter to Mersenne in his Seventh Replies (*Oeuvres de Descartes,* volume VII, pp. 452–453).

98. *Oeuvres de Descartes,* volume III, p. 161.

99. In the Seventh Replies, Descartes said the following of Bourdin's Objections: "Now I would take the same view of the present essay, and believe that it was written at the instigation of the Society as a whole, if only I were certain that it

contained no quibbles or sophisms or abuse or empty verbiage." (*Oeuvres de Descartes,* volume VII, p. 453)

100. That is, "quibbles" or "cavils." See *Oeuvres de Descartes,* volume III, pp. 163, 184, and 250, for example.

101. Ibid., p. 184.

102. *Prima geometriae elementa* (Paris, 1639),divided into geometria speculativa, geometria practica, notae geometrica, and aditus in arithmetica; *Geometria, nova methodo* (Paris, 1640).

103. *Le cours de mathématique*, third edition (Paris, 1661). I include this work among those published by Bourdin on or before 1640 because an anonymous 1645 work was identified as a revised edition; the 1645 work contains plates dated 1631. Thus 1631 is probably the date of the first edition, with printings in 1640 and 1641. See P. J. Jones, "The identity of the Author of a Hitherto Anonymous Work," *Scripta Mathematica* 13 (1947): 119–120.

104. *L'introduction à la mathématique contenant les coignaissances, et pratiques necéssaires à ceux qui commencent d'apprendre les mathématiques. Le tout tiré des élémens d'Euclide rengez et demonstrez d'une façon plus briève, et plus facile que l'ordinaire* (Paris, 1643), Part I: géometrie; II: géometrie de raison; III: abrégé de l'arithmétique.

105. Bourdin's *Cours de mathématique* also contains materials on fortifications, terrain, military architecture, cosmography, and the use of a terrestrial globe.

106. Both were published in Paris in 1655.

107. *Cours de mathématique*, p. 124.

108. Ibid., p. 126.

109. Ibid., p. 128. Sunspots had been widely interpreted in France as small planets going around the sun. See Frederic J. Baumgartner, "Sunspots or Sun's planets: Jean Tarde and the Sunspot Controversy of the Early Seventeenth Century," *Journal for the History of Astronomy* 18 (1987): 44–54.

110. *Cours de mathématique*, p. 130. In the section on optics, there was even a reference to the telescope (p. 176). Bourdin's optics was rudimentary; he discussed reflection, saying that the angle of incidence equals the angle of reflection, and refraction, saying that refraction bends light toward the normal when it goes from a rarer to a denser medium, but he did not give the Snell-Descartes sine law (pp. 156–186).

111. *Cours de mathématique*, p. 130.

112. *Sol flamma sive tractatus de sole, ut flamma est, eiusque pabulo sol exurens montes, et radios igneos exsufflans Eccles. 43 . Aphorismi analogici parvi mundi ad magnum magni ad parvuum* (Paris, 1646).

113. Ibid., p. 1; "Auctores, et argumenta sententia negantis [Aristoteles]," pp. 1–3.

114. Bourdin even referred to Descartes as someone who holds the position: "novissime a Renatus des Cartes solem docet esse flammam," *Sol flamma*, p. 5. This seems to have been the only reference to Descartes in Bourdin's published works (other than in the Seventh Objections). The author to whom Bourdin was most indebted

was Christopher Scheiner, the Jesuit astronomer; there were references to Scheiner's 1630 Rosa Ursina in almost every chapter.

115. *Sol flamma*, "sol est corpus; in quo sunt eiusmodi maculae, et faculae, ut patet ex telescopio, et parallaxi, quae docet haec omnia non distare a sole; ergo sol est corruptibilis," 7–9; "atqui sol paret flamma (ut patet rescipiendi per telescopium; quo, ut docet Scheiner lib. 2 Rosa Ursina, cap. 4. deprehenduntur in sole multa flammae signa)," pp. 14–16.

116. *Aphorismi analogici*, Explicantur maculae solis exemplo spumarum maris, pp. 44–46; Distinguuntur stellae et planetae in tres partes seu regiones, pp. 49–50; De influxu magnetico mundi tum caelesti tum terrestri, pp. 50–52; De terminis fluxus magnetici mundi, pp. 52–53.

117. *Aphorismi analogici*, Terra quies probatur primo, pp. 65–66. The cosmology of three heavens seems to have been widely accepted by the Jesuits by the 1640s. In a thesis by Jean Tournemine, a student at La Flèche, in 1642, we are told that "Apostolic authority teaches us that there are three heavens. The first is that of the planets, whose substance is fluid, as shown by astronomical observations; the second is the firmament, a solid body as its name indicates; and the third is the empyrean, where all species of stars are to be distinguished." Joannes Tournemyne (La Flèche, 1642), as edited in Rochemonteix, *Un Collège de Jésuites aux 17e et 18e siècles*, volume IV, pp. 365–368. One can find a similar theory in Guillelmus de la Vigne's thesis from the Jesuit college at Caen, Collège du Mont, 1666 (Caen ms. 468). The reason why this theory of the heavens seems to be Tychonic is that solidity is attributed to the firmament, or the outer-most heavenly body, containing the fluid universe of the planets.

118. *Oeuvres de Descartes,* volume VII, p. 454. For an account of Descartes's evasions, see Roger Ariew, "Sur les Septièmes Réponses," in *Descartes*, ed. J.-L. Marion and J.-M. Beyssade (Paris, 1994), pp. 123–141.

119. *Oeuvres de Descartes,* volume VII, p. 466. A later comparison is with a three-year-old: "A three year old child could supply the answer to this" (ibid., p. 514).

120. Ibid., pp. 474 and 477. Also: "These comments are amusing enough, if only because they would be so inappropriate if they were intended to be serious." (p. 511) "Having asked this utterly absurd question. . . ." (ibid., p. 524)

121. Ibid., pp. 492–493. Also: "[A]s my critic here jeeringly and impertinently suggests." (p. 491). And My critic continues to play his comic role outstandingly well when he tells the story of the peasant. But what is most laughable here is that he thinks the story applies to my words, when in fact it applies only to his own." (p. 510). Also: "There is much here that deserves to be laughed at now and for ever more, but rather than point this out I prefer to respect the actor's costume that my critic has assumed; and indeed I do not think it is right for me to spend all this time laughing at such ill-considered comments." (p. 517).

122. Ibid., p. 525.

123. *Oeuvres de Descartes,* volume III, pp. 249–250.

124. *Oeuvres de Descartes,* volume VII, p. 532; also pp. 469, 504.

125. Ibid., p. 457. Similarly, p. 471.

126. Ibid., pp. 489–490. Similarly, pp. 494–495.

127. Ibid., p. 490.

128. Ibid., pp. 527–528.

129. Ibid., pp. 528–529; also pp. 529–530.

130. Ibid., p. 530.

131. Ibid., pp. 462–463.

132. Ibid., pp. 462–463.

133. Ibid., p. 464.

134. Ibid., p. 464.

135. Ibid., pp. 578–579.

136. Ibid., p. 580. See also Ibid., p. 581: "Again, there is no need to fear that my opinions will disturb the peace of the Schools. On the contrary, philosophers already take sides against each other on so many controversies that they could hardly be more at war than they are now."

137. October 1637, *Oeuvres de Descartes,* volume I, pp. 455–456. Compare with the letter to Dinet, *Oeuvres de Descartes,* volume VII, p. 581: "As far as theology is concerned, since one truth can never be in conflict with another, it would be impious to fear that any truths discovered in philosophy could be in conflict with the truths of faith. Indeed, I insist that there is nothing relating to religion which cannot be equally well or even better explained by means of my principles than can be done by means of those which are commonly accepted."

138. *Oeuvres de Descartes,* volume VII, p. 3: "And finally, I was strongly pressed to undertake this task by several people who knew that I had developed a method for resolving certain difficulties in the sciences—not a new method (for nothing is older than the truth), but one which they had seen me use with some success in other areas; and I therefore thought it my duty to make some attempt to apply it to the matter in hand."

139. Ibid., p. 464.

140. To Mesland, May 2, 1644, *Oeuvres de Descartes,* volume IV, p. 113.

141. *Oeuvres de Descartes,* volume IXb, pp. 10–11.

142. *Oeuvres de Descartes,* volume IV, pp. 111, 120, 122. Descartes's correspondence with the Jesuits can considered as three separate series of letters, each spanning a couple of years. First are the four letters to Jesuits at La Flèche in 1637 and 1638—possibly Noël, George Fournier, and Antoine Vatier—requesting comments about his newly published Discourse on Method. Second is the series written from 1640 to 1642, dealing with Descartes's "war with the Jesuits," that is, the Bourdin affair, and culminating with the letter to Dinet. I have already discussed the first two sets of letters. Third is the set of letters from 1644 to 1646, predominantly involving Denis Mesland, but also including others such as Etienne Charlet, Noël, Jacques Grandamy, and the now-friendly Bourdin. For most of these letters, Descartes's editor Claude Clerselier does not provide the name of the correspondent or a date for the letter, identifing them simply as "A un reuerend Pere Iesuite."

143. *Oeuvres de Descartes,* volume IV, p. 122.

144. For more on the exchange between Descartes and Mesland on the Eucharist, see chapter 7 of Ariew, *Descartes and the Last Scholastics*.

145. Bouillier, *Histoire de la Philosophie cartésienne*, volume I, p. 451. A marginal note on the manuscript copy of the letter to Mesland makes the same point: "Ce Pere fut relegué en Canada, ou il est mort, à cause de la trop grande relation qu'il auoit avec Mr Des Cartes." See *Oeuvres de Descartes,* volume IV, p. 345.

146. Richard A. Watson, *The Breakdown of Cartesian Metaphysics* (Atlantic Highlands, 1987), p. 156. Watson adds that Mesland "died on the Canadian mission in 1672 without, as far as is known, inquiring further into transubstantiation."

147. Ibid., p. 156.

148. Rochemonteix, *Un Collège de Jésuites*, volume IV, p. 78.

149. For details about Mesland's stay in the New World—in Martinique and Santa Fe (now Bogota) of Nouvelle-Grenade (now Colombia), not Canada—see *Oeuvres de Descartes,* volume IV, p. 669, and Leslie Armour, "Le cartésianisme au Québec," *Archives de Philosophie* 51(1988): 1–12. Both provide basic data to counter the standard misinformation about Mesland (especially that of the Bibliothèque de la Compagnie de Jésus which confuses Denis Mesland with Pierre Mesland, who also taught at La Flèche and who died before the exchange of letters with Descartes).

150. *The Correspondence of Henry Oldenburg*, volume II, p. 435.

151. See Ariew, "Sur les Septièmes Réponses," pp. 123–140. See also de la Grange, *Les principes de la philosophie contre le nouveaux philosophe*, volume I, pp. 1–2: "It is not necessary to enter very far into the details of the propositions taught by Descartes to know that it is with good reason that His Majesty, who applies himself toward maintaining the peace in the Church, as well as toward upholding the interests of the Crown, has not long ago prohibited the teaching of this author's opinions in his kingdom. It is enough to understand that his principles ruin a good part of theology by destroying completely the common philosophy that Catholic theologians have in some fashion blessed by the use they have made of it up to now in explaining many of the mysteries of the faith, as well as in responding to the sophisms of the heretics. One need only hear Descartes explain the greatest mysteries of the faith in a completely novel manner, and assert that all Catholic theologians have been mistaken until now, to become convinced that, even if his doctrine is not wrong, at least it is dangerous, and that professors of philosophy are completely wrong in teaching it to young people, of whom it is appropriate not to inspire the love of novelty and distaste for the old doctrine."

152. The same accusation can be found in Goudin, *Philosophie suivant les principes de Saint Thomas*, volume II, p. 16, art. 3: Des principes des choses suivant Leucippe, Democrite et Descartes, and art 4: Exposé de la doctrine de Descartes sur les principes. 1. Opinion de Descartes sur les principes des choses 2. Les molecules de Descartes ne peuvent être les principes des choses.

153. Letter to Regius, mid December 1641, *Oeuvres de Descartes,* volume III, pp. 460–462 and Letter to Dinet, *Oeuvres de Descartes,* volume VII, pp. 585–586.

154. "Quelques condamnations du cartésianisme: 1662–1706," p. 3.

155. Ibid., p. 6.

156. See propositions 196–199 (originally 138–140) in P. Mandonnet, *Siger de Brabant et l'averroisme latin au XIIIme siècle* (Louvain, 1908), pp. 175–191.

157. Propositions 27 (34) and 66 (49) respectively. Also proposition 190 (201): "That he who generates the world in its totality posits a vacuum, because place necessarily precedes that which is generated in it; and so before the generation of the world that would have been a place with nothing in it, which is a vacuum."

158. For more on what is clearly an important event in the first half of the seventeenth century, See Daniel Garber, "Descartes, the Aristotelians and the Revolution that Did Not Happen in 1637," *Monist* 71 (1988): 471–486.

159. Scipion Dupleix, *La Physique*, pp. 131–132.

160. Ibid, pp. 261–262.

161. Bouju, *Corps de toute la philosophie*, p. 469.

162. Pierre Gassendi, *Exercitationes Paradoxicae Adversus Aristoteleos*, 1624, II, exer. 3, art 10: Quantitatis essentiam esse extensionem externam. Let us recall that Mersenne also advised Descartes not to publish the end of Replies IV to Arnauld, dealing with the Eucharist; Descartes accepted his advice for the first edition (Paris, 1641), but published the full text a year later, in the second edition (Amsterdam, 1642).

163. Ibid., II, exer. 3, art. 11: Species Eucharisticas non item fore Fides nos Orthodoxa docet.

164. Duplessis d'Argentré, *Collectio judiciorum de novis erroribus* (Paris, 1736), volume III, pt. I, p. 149. The rest of the Paris condemnation contained the prohibition of the important Cartesian proposition, "The matter of bodies is nothing other than their extension and one cannot be without the other." It also contained the prohibition of several propositions not normally associated with Cartesianism: "6. One must reject all the reasons the theologians and the philosophers have used until now (with Saint Thomas) to demonstrate the existence of God. 7. Faith, hope and charity and generally all the supernatural habits are nothing spiritual distinct from the soul, as the natural habits are nothing spiritual distinct from mind and will. 8. All the actions of the infidels are sins. 9. The state of pure nature is impossible. 10. The invincible ignorance of natural right does not excuse sin. 11. One is free, provided that one acts with judgment and with full knowledge, even when one acts necessarily."

165. "Prohibited propositions by Michel-Angelo Tamburini, General of the order in 1706," in Rochemonteix, *Un Collège de Jésuites aux 17e et 18e siècles*, volume IV, pp. 89n–90n.

166. René Rapin, "Reflexions sur la philosophie," in *Oeuvres* (Paris, 1725), p. 366.

Giovanni Battista Riccioli and the Science of His Time

Alfredo Dinis

Some Misconceptions about Jesuit Science

I have argued elsewhere that, until recently, scholars, with few exceptions, held a seriously misguided view about the Jesuit tradition in theology, philosophy, and science during the early modern period.[1] It was assumed that the Jesuits were constrained by their main disciplinary documents—such as the *Constitutions*, the *Ratio Studiorum*, the decrees of the General Congregations, and the official letters of the Superiors Generals—to practice, in a monolithic, rigid, and uncritical way, absolute obedience to the Aristotelian-Thomist tradition as well as to the official teaching of the Catholic Church. As guardians of Catholic orthodoxy, they were said to have sacrificed everything—reason and truth included—to attain this goal, reacting against innovation as a matter of principle. This view is still endorsed by some scholars.[2]

Such a view has often been applied to Giovanni Battista Riccioli. Various scholars believed that, although in the dispute over Copernicanism Riccioli was personally convinced that the official positions of Catholic theologians were untenable, he kept his own views private and mentioned in his works only official opinions, as if he fully agreed with them. Depicted as "a spokesman for the Society of Jesus"[3] who was asked by his superiors to upheld a wicked cause, Riccioli was accused of behaving like "a bad advocate"[4] who acted by commission rather than by conviction and who did not make a real effort to argue convincingly against the Copernican views, as if "he had become an enthusiastic admirer of them."[5] I hope to demonstrate that such a negative estimation of Riccioli as a man who sacrificed reason to faith and obedience cannot be fully substantiated. Riccioli has also been accused of working on behalf on the Inquisition,[6] though in fact he was always in trouble with that institution. Indeed, Riccioli's position on the Copernican system was far more complicated than most scholars assumed.

The general misconception about the Jesuits' lack of freedom in their search for truth is often based on an uncritical reading of the documents of the Order and on unwillingness to recognize that a considerable gap existed between the official appeals to orthodoxy and actual Jesuit intellectual practices. The cultural situation of the Society of Jesus in the sixteenth and seventeenth centuries was far more complex (and richer) than a superficial analysis can reveal.[7] True, both the *Constitutions* and the *Ratio* strongly admonish members against embracing new opinions.[8] This, however, remained an ideal; it was never fully attained. In fact, even the *Constitutions* allowed the possibility of legitimate divergence of opinions. Ignatius of Loyola sometimes instructed his followers in terms such as these: "We all must, *as much as possible*, have the same feelings and use the same language."[9] The expression "as much as possible" was also used in at least two other sections of the *Constitutions*.[10] Moreover, the very fact that both the Superiors Generals and the General Congregations frequently demanded uniformity of doctrine is indicative of the difficulty in enforcing it.[11] In a paper published in 1985, Ugo Baldini described this situation as a "continuous tension between personal and even innovative research, on the one hand, and a doctrine that was considered true and biding, on the other."[12] Such a tension, he continues, was not constant. "In problematic areas, and in different times, the tension varied in its degrees of intensity, having reached its peak when confronted with innovative external ideas, such as the Galilean science, Cartesianism and Enlightenment."[13] Baldini also distinguished between the attitude of the mathematicians, which tended to be more innovative, and that of the theologians, which tended to be more conservative.[14] More recently, Marcus Hellyer expressed similar views, pointing out that "from the earliest days of the Order's teaching enterprise, there was a tension between allowing professors a certain degree of freedom in their choice of philosophical and theological opinions and controlling the diverse traditions inherent in Renaissance Aristotelianism in order to maintain uniformity in the Society's enterprise."[15] Hence, although it is true that the history of the Jesuits' contribution to modern science would have been quite different had it not been hampered by official censorship, many Jesuits still managed to keep abreast of contemporary scientific research, even when they appear to have been under pressure from their Superiors—as in the case of Riccioli.

Riccioli's Contribution to Science

A Personal and Free Option for Science

After his ordination in 1628, and after his request to be sent to the missions was rejected, Riccioli was asked by General Muzio Vitelleschi to teach philosophy.[16] Between 1629 and 1631 he taught logic in Parma, performing some "rudimentary experiments" with falling bodies.[17] He tried to determine the increment of their speed, and arrived at the series 1, 3, 9, 27. At the request of his confrere Niccolo Cabeo, Riccioli, assisted by Daniel Bartoli, verified the isochronism of the pendulum. In 1632 Riccioli became a member of a group charged with the formation of younger Jesuits. There is no evidence that he performed any experiments during this year; however, in view of his continued interest in scientific matters, such as astronomy, this is highly probable. During the academic year 1633–34 he taught logic and mathematics in Mantua, performing further experiments on the isochronism of the pendulum with Cabeo. In 1635 he returned to Parma for a year. There, while teaching theology, he carried out his first important observation of the moon.[18] In 1636 Riccioli was sent to Bologna, remaining there for several years as a theology professor. In a letter sent to Athanasius Kircher on December 22, 1646, Riccioli described himself as a theologian, but he reiterated his unwavering interest in astronomy ever since his student days, when he studied mathematics under Biancani. Furthermore, although his superiors, and even his students, had asked him to write and publish on theology, he refused and not only managed to be exempted from such a charge but was also allowed to devote himself to astronomy for two years. In fact, Riccioli argued, while there were many Jesuits publishing on theology already, only few worked in astronomy, an area in which he had already accumulated a great amount of data. He concluded by saying that he really felt more committed to astronomy than to theology.[19] Eventually his superiors asked him to carry on his research in astronomy, as he reveals in *Astronomiae reformatae* (1665): "We are devoted to these studies to the glory of God, first by request, and then by explicit order of the superiors."[20] This was probably the passage that gave rise to the charge that Riccioli's astronomical works were commissioned with the aim of refuting the heliocentric system. However, as Riccioli himself stated in his *Almagestum novum* (1651), his scientific interests were long-standing: "I could never extinguish the enthusiasm for astronomy once it arose in me."[21]

Riccioli's Multi-Faceted Scientific Activity

Although Riccioli conceived the *Almagestum* as an encyclopedic work, he did not intend it to be a mere collection of material culled from published books. He incorporated his own observations, together with new theorems, problems, and tables,[22] intending to revise and correct the astronomical views of Ptolemy and others in order "to sharpen their acuteness . . . to remove the remaining imperfections through their refinement and improvement, and to determine which of them may certainly be removed, and which may not, and have therefore to be tolerated."[23] He also conceived the *Almagestum* in such a way that it might assist those who did not own the chief scientific books already published.[24] Thus, the book is a careful and critical analysis of existing material. (Riccioli was aware that many subjects in astronomy were in need of revision.[25])

In his research, Riccioli dealt not only with astronomy but also with other mathematical sciences, including arithmetic, geometry, optics, gnomonics, geography, and chronology.[26] And although his books on geography and chronology were eventually published separately, they exhibit everywhere a holistic view of knowledge that also encompassed philosophy and theology. This unified view is crucial to an understanding of his critique of the Copernican system.

To facilitate his astronomical research, Riccioli built an observatory in the College of St. Lucia which, according to an unpublished account of his life and work, housed many instruments for astronomical observations—including telescopes, quadrants, sextants, and other traditional instruments—and was occasionally visited by foreigner researchers.[27] Riccioli announced that a treatise on the construction of scientific instruments, the *Liber organicus*, would be included in the projected second volume of the *Almagestum*, which was never published.

Riccioli's research was aided by a voluminous correspondence with such like-minded savants as Hevelius, Huygens, Cassini, and Kircher. The subject matter of this correspondence was not limited to astronomy; it included geography as well, for Riccioli was cognizant of the need to incorporate geographical data in astronomical research. His geographical work was published in 1661 in the *Geographiae et hydrographiae reformatae*, considered one of the best studies on the subject in its time. (It was reprinted posthumously in 1672.) Here too Riccioli insisted that he had not simply collected data but that he also had corrected numerous errors committed by previous geographers. De Dainville praised Riccioli's remarkable accuracy in his tables of latitude.[28] Guillaume de L'Isle drew and published a plan of Italy based on Riccioli's cosmography, and as late as 1756 the participants in a meeting of the Royal Society still quoted Riccioli on this subject.[29]

Riccioli's Epistemology

Truth

Riccioli opposed the revival of skepticism supported by the likes of Gassendi and Mersenne. Indeed, he firmly intended to separate "the certain from the probable" [certa interim a probabilib. discernendo][30] and "the certain from the uncertain" [conclusiones nonnullae statuuntur quibus certa ab incertis hactenus discernuntur],[31] to seek truth irrespective of its source, and to change his mind on any subject when convincing evidence was produced. Truth, he wrote in the preface to the *Almagestum*, "is the only thing that I have proposed myself before God to seek."[32] Thus, mentioning Tycho's astronomical observations, he insisted that he was not prejudiced by any authority, but only by the love of the truth. He added: "One ought to choose the position considered by all to be nearer the truth, so that truth may prevail among us. To achieve this goal, we should devote the best of our energies to revise [all previous] observations."[33] Some still question Riccioli's sincerity on searching the truth. I propose that, as a matter of principle, and taking into account his life and work as a whole, his words ought to be taken at face value.

Evidence

Riccioli distinguished four degrees of evidence in the natural sciences: metaphysical, mathematical, physical, and moral. Both metaphysics and mathematics, which were based on self-evident first principles, shared the highest degree of certitude. They had no need of confirmation through observation or experiment. On the other hand, physical evidence provided by the senses had to conform to the axioms of both metaphysics and mathematics. This kind of evidence was the basis of his strong realism. It showed "the way natural beings and causes are and work." Finally, moral evidence, or prudent judgement, was subordinated to the principles of both physics and metaphysics.[34]

Riccioli paid little attention to mathematical evidence, though he was aware that the topic had been the subject of a passionate debate between Benedict Pereira and Clavius.[35] As one scholar summarized it, the main issues raised by this debate were as follows: "(a) Does mathematics fit the definition of Aristotelian science or does it fall short of it? This problem led in turn to a careful analysis of mathematical demonstrations. And (b) if the certainty of mathematics cannot be argued by appealing to its logical structure, on what other grounds can we justify it?" Riccioli followed the opinion of his mentor Biancani, who believed that mathematical evidence, being free from the deceit of the senses, was clearly superior to physical evidence. "We should not be surprised," he argued, "if not only arithmetic and geometry, which are free from the fickleness of matter, but also mathematical and physical sciences, to which our senses are subordinated, give us a greater degree of certainty than physics only."[36] In the unpublished *Primum mobile reformatum* he further defined mathematics as "the discipline by *antonomasia* for the demonstrative evidence it communicates to those sciences dealing with terminated quantity as such."[37]

The epistemological statute of mathematics was equally important for the sciences that had mathematical structure, such as physics and astronomy. The more the natural sciences were based on mathematics, the more they could be considered sources of reliable evidence. Thus Riccioli believed that astronomy, as a physico-mathematical science, "is subordinated to physics in that it considers the changes in the heavens and the stars and the variety of their accidents, such as shape, color, light, shadow, place, order, distance and motion. But it is even more subordinated to mathematics, which does not consider the above accidents as natural affections or from any other point of view, but only in as much as they fall under terminated quantity, be it continuous or discrete, permanent or successive."[38] During the seventeenth century the term "physico-mathematics" became quite common, appearing in numerous titles of books, including some by Jesuits.[39] Both Clavius and Biancani had claimed that physics needed mathematics, whereas those two disciplines had hitherto been considered independent of each other. According to Baldini, the Jesuits found it particularly difficult to overcome this separation and move from "the medieval mathesis mixta" to "the physico-mathesis in the Galilean and Newtonian sense"[40] (which, by the middle of the seventeenth century, had become the common approach to the study of nature). Peter Dear notes that "'Physico-mathematics' simultaneously exploited and overrode the standard scholastic disciplinary division between physics and mathematics: it advocated mathematics as a tool for the creation of genuine physical knowledge, but did so by means of the Aristotelian characterizations of their subject matters." Dear attributes this to the "increasingly ambitious claims of mathematicians in the few decades of the century."[41] Riccioli inherited such ambition. In the *Almagestum*: he proclaimed: "We will proceed from the following experiments, not by way of likely conjectures but according to infallible physico-mathematical science, to certain conclusions."[42] Accordingly, in the *Almagestum* Riccioli claimed to have proposed a physico-mathematical argument against the motion of the earth, an argument which he claimed was definitive.[43]

Riccioli did not ignore the debate over the epistemological, ontological, or even the theological status of the mathematical representations of the universe. He followed a traditional distinction, deriving from Pythagoras, between knowledge based on discrete quantities (arithmetic) and that based on continuous ones (geometry). He claimed that both God's knowledge and that of angels was based on relations between abstract and discrete quantities. However, in geometry he followed the old tradition of "saving the appearances," thus embracing an instrumentalist view. He considered geometrical representation of celestial motions only an instrumental device, useful for human calculations, with no ontological significance. Both in the *Almagestum* and in the *Astronomiae*, he maintained that, though the planetary motions appeared to be irregular both in speed and in the shape of their orbits, God accommodated them to human capacity, and it was for this reason alone that, in his view, they could be represented as if planets moved along an ellipse. In fact they did not. "In this," he explained, "we disagree with the more recent astronomers, for whereas we consider the elliptical orbit of planets as a mere hypothesis, useful for calculations, they think that such an orbit is the real trajectory along which planets move."[44] Evidently, here Riccioli was thinking of Kepler. His views on this matter may appear paradoxical at first sight. Since in fact geometry does not abstract from matter as much as arithmetic does, the former ought to give us a more direct picture of the world than the latter. Riccioli denied this because he considered geometry to be more influenced by the fallibility of the senses than arithmetic. Moreover, he might have been unwilling to attribute to God and the angels—spiritual beings—a knowledge that was too near to material bodies. On the other hand, he often supported a kind of naive empiricism, insisting that the senses invariably give us a true picture of the world; for this reason, he thought that all physical sciences ought to be based on sense data. Though Heilbron has recently argued that Riccioli had the opportunity to prove the reality of the elliptical orbits of planets on the basis of solar observations that he, Cassini, and Grimaldi carried out in St. Petronius's Church,[45] it is not clear whether Riccioli changed his mind. Riccioli´s ambiguity on this matter is evident. To understand his views on this important issue, we must take into account that he often mentions geometry in a fictional way when criticizing Kepler's theory of planetary motions (a theory based on the sun's magnetic attraction), which he could not accept. Moreover, his geometrical fictionalism was also in agreement with the position of the theologians who had condemned Galileo—a condemnation he wholeheartedly supported. This does not mean that Riccioli never doubted the condemnation of the heliocentric hypothesis. Any certainty based on faith is compatible with doubts on the psychological, philosophical, and scientific levels, since matters of faith are never *completely* demonstrable either philosophically or scientifically.

Reason and the Senses

Riccioli preferred to endorse the centrality of sense data in the Aristotelian tradition, as we have seen. Let us see how they relate to reason. "By themselves," he argued, "the senses, if correctly applied, almost always represent the object as it is in reality."[46] As a consequence, he could claim that the sphere of the fixed stars, the comets, and other celestial bodies were really moving around a motionless earth, because such was the immediate evidence of the senses. "What is against physical evidence acquired through the senses," he insisted, "is not more likely [to be real than that which agrees with the senses]. Such [agreement with the senses] is the case of the daily motion of comets and of the other celestial bodies."[47] And, in discussing the inequality of the tropical year, he argued that "having considered this question, not on the basis of any authority, but rather of reason, I think that the inequality of the tropical year is not totally improbable; but I consider as its eternal physical equality according to the senses much more probable."[48] Thus, reason, although it was epistemologically more trustworthy than the senses, could be subordinated to them in some cases. This thesis, of course, was very useful in combating the Copernican system.

Riccioli noted, however, that the senses may deceive us, and that therefore the evidence of certain sense data ought to be checked against the evidence of other sense data. Some sensations cannot in fact be taken as physical evidence when they are dismissed by other sensations. Thus, a stick that appears to be broken when half immersed in water is an optical illusion, as can be confirmed by taking it out of the water. We experience a similar illusion in the case of the trajectory of a descending body that has been thrown perpendicularly in the air inside a moving ship. Seen from inside the ship, the body's trajectory appears to be rectilinear. Seen from outside, it appears curvilinear.[49]

In the case of a persisting doubt regarding which of two or more conflicting sense data should be preferred, one had to appeal to the evidence of higher principles, such as reason, faith, metaphysics, mathematics, or any other science based on mathematics.[50] Thus, a complex interplay between reason, authority, and the senses was established. "First the senses find 'a posteriori' what is near the truth. Reason however, considering the causes, finds and establishes what is correct." At first sight, reason seems to have the last word. In Riccioli's mind, however, reason was not wholly independent of the senses. As a matter of fact, it required confirmation by them, at least whenever this was possible. "If reason first finds what is correct," Riccioli maintained, "this must then be confirmed by the senses." Riccioli tried to hold a balanced view, and he thought that "we ought not to attribute excessive importance either to reason, as Pythagoras did, or to the senses, a view of Aristoxenius."[51] Thus, he rejected unconditionally Ptolemy's statement that *sensus dat propinquum, ratio autem exactum*. He seems to have applied Ptolemy's statement only to cases in which the results of repeated experiments were not always exactly the same, only nearly the same. In such cases, he thought, "reason needs to correct, or complement, the senses whenever they cannot produce the same certainty."[52]

It is my conviction that Riccioli's unsystematic and at times contradictory method of dealing with the role of reason and the senses in determining evidence and the certainty of human knowledge, reveals one of the most characteristic aspects of his position in the context of the science of his time. He was deeply affected by a process of transition from an old to a new world view, a transition which he only partially comprehended. Like many of his contemporaries, both Jesuits and non-Jesuits, he maintained simultaneously old and new elements, which often contradicted each other. Though it is improbable that he was entirely unaware of this fact, he may well have failed to realize some of the contradictions. This is why his epistemological views cannot be simply understood as if he had been a dogmatic Aristotelian, incapable of grasping the spirit of the scientific revolution, or as if he had been a convinced Galilean, willing to break with the Aristotelian tradition but not able to do it and express his views freely.

Probability

In his attempts to settle scientific controversies, Riccioli was aware that he sometimes could only think in terms of probabilities, a common practice among Jesuits and other contemporary mathematicians. This is hardly surprising. Many traditional views underwent profound transformations, and there were often competing explanations for the same phenomena.[53] Riccioli believed that the interplay between reason and the senses determined different degrees of probability and certainty.

The interplay between probability and evidence was also a subtle one. "The probability of an opinion remains," said Riccioli, "as long as the opposite is not evidently known." On the other hand, an opinion was not to be dismissed simply because the opposite was possible and even apparently supported by some evidence. Thus, when the motion of the sun is observed, "one is not allowed to say that either mathematically or metaphysically speaking, it is not impossible for human senses to be wrong" and thus pretend to falsify the sense evidence that the sun is moving. "This is not the philosophical approach of a physicist, neither does it allow one to argue *a possibile ad esse*."[54] Once again, Riccioli insisted that heliocentrism had no evidentiary support.

In the presence of two opposite and equally probable views based on both reason and the evidence the senses, Riccioli was convinced that authority alone could settle the question. "In any controversy in which reasons favoring opposite sides are of equal evidence," he argued, "we should only choose that position which is favored by authority."[55] This was the case in the polemic over the Copernican system, and Riccioli tried to justify the intervention of religious authority on this matter. In fact, he believed that, especially in that dispute, the principles of the Catholic faith provided "certainty without evidence."[56] Here, theology provided the solution of a mathematically and physically undecidable question. For Riccioli this was a conclusion he could hardly avoid, given his religious formation and the absence of a definite proof of the heliocentric system.

Riccioli's Criticism of the Copernican System

There are contrasting opinions on Riccioli's attitude toward the debate on heliocentrism. Many of them are prejudiced and one-sided. Moreover, they fail to discern that Riccioli's initial tolerance in the Galilean affair gave way to a more rigid attitude. In fact, while he was preparing the publication of the *Almagestum*, his attitude toward the Copernican system was still moderate. Then a request for a summary of his work came from Rome: "Let Fr. Riccioli send to Rome that part of his work, in which he describes his own inventions, so that it may become known what in them is new and better than the work of so many distinguished masters, such as Tycho, Kepler and Lansberg, who dedicated their whole lives to the same subject, with the support of emperors and kings; and which instruments and method have been used in the observation of the motion of the heavenly bodies."[57] This was apparently a request for information, but Riccioli suspected that it might be something more menacing. He soon decided to ask Kircher's help in order to get permission for publication.[58] He answered the letter from Rome by describing his work in great detail. He also pronounced his views on the work of contemporary astronomers, including a few Copernicans: "My advice has been not to condemn or suppress the astronomy of Tycho, Longomontanus, Kepler, Lansberg, Boulliau, Wendelin, and similar [authors], but rather to collect in a single book elements from [the works of] these and others, who have in some way contributed to astronomy, together with their sufficient foundations up to the first principles, in order to reconcile what can be reconciled, and to criticize what cannot be reconciled, stating the reasons on either side, so that anyone can follow the hypothesis he likes."[59] Remarkably, he mention neither the censorship of Copernicus's *De Revolutionibus* nor the condemnation of Galileo, but the expression "and similar" undoubtedly applied to both Copernicus and Galileo, whose names he considered prudent to omit.

Riccioli's attitude toward Copernicus was not only tolerant but admiring. In the *Almagestum* he exclaimed that Copernicus's greatness "has never been sufficiently appreciated nor will it be."[60] On the other hand, he interpreted the cardinals' decree condemning Galileo in the same flexible way, although some authors viewed this interpretation as full of ambiguities:

> The sacred Congregation of Cardinals, taken apart from the Supreme Pontiff, does not make propositions to be of faith, even though it actually happened to define them to be of faith, or the contrary ones heretical. Wherefore, since no definition upon this matter has as yet been issued by the Supreme Pontiff, nor by any council directed and approved by him, it is not yet of faith that the sun moves and the earth stands still, by force of the decree of the Congregation; but at most, and alone, by force of the Sacred Scripture, to those to whom it is morally evident that God has revealed it. Nevertheless, Catholics are bound, in prudence and obedience, at least so far as not to teach the contrary. But this subtlety of theology I have treated in my treatise *De Fide.*[61]

Riccioli's final sentence, noting that a theological subtlety was involved in the above text, was interpreted by Delambre "as if [Riccioli] repented of what he had just written."[62] However, as De Morgan rightly pointed out, in the traditional use of the word, subtlety "is a distinction which requires thought and explanation: all knowledge swarms with subtleties."[63] This accords with the sense that Riccioli gave that word in other contexts. In fact, regarding Copernicus he wrote: "We have not yet exhausted the full profundities of the Copernican hypothesis, for the deeper one digs into it, the more ingenious and valuable the *subtleties* one may unearth."[64]

Riccioli's text deserves a more detailed analysis, as it may at first sight appear to be rather ambiguous and even to lend some support to Delambre's interpretation. We need to take into account that Riccioli expresses his opinion on the cardinals' decree from more than one point of view. In fact, when he first affirms that "the Sacred Congregation of Cardinals, taken apart from the Supreme Pontiff, does not make propositions to be of faith" he is simply issuing an objective judgement from a strictly juridical point of view, not expressing a personal and subjective opinion. Since the condition for a proposition to be declared either heretical or orthodox was not met, the only strictly logical conclusion to be drawn was that "it is not yet of faith that the sun moves and the earth stands still." This is a strictly objective argument, and no other (subjective) interpretation can be made. It weakens, of course, the importance of the cardinal's decree, but it does not necessarily favor the Copernican hypothesis. (Later, however, Riccioli gave a more radical interpretation of the juridical force of the cardinals' decree.) Riccioli then invokes the Bible as the only source of a possible moral—and not scientific—condemnation of heliocentrism. But even here he seems to accept that biblical evidence may not convince everybody. Finally, Riccioli invokes human prudence, and he practically repeats what Cardinal Bellarmine had recommended to Galileo on the occasion of his first trial: "at least" he ought not to teach as true a system that was contrary to the traditional view.

It is worth noting that the decree introduces a distinction between the thesis of the immobility of the sun and that of the mobility of the earth—the former being considered "absurd, false in philosophy, and formally heretical" and the latter "likewise absurd, philosophically false and theologically at least an error of faith."[65] It is not clear why such a distinction was made, and most commentators did not attribute any significance to it. Nevertheless a controversy developed on the interpretation of the decree on this point. Thus, Mersenne denied that the Copernican hypothesis had been condemned as heretical by the Catholic Church, while Pierre Gassendi did not consider the condemnation as "an article of faith."[66] Among the Jesuits, Riccioli appeared the most tolerant. Baltasar Teles considered the thesis concerning the earth's mobility heretical, and Nicolaus Serarius concurred. For both Pineda and Lorini it was an "absurd falsity." Kircher regarded the thesis as "dangerous in faith"—ostensibly a less severe judgement. Only Melchior Inchofer seems to have taken into account the cardinals' distinction between the thesis regarding the immobility of the sun and that of the mobility of the earth. As to the former, he cited the authority of the Church Fathers, who, in his opinion, unanimously agreed on the sun's motion. Inchofer also considered its circularity as a matter *de fide*. As to the earth, he expressed his opinion only in probabilistic terms: "That the earth is motionless in the center of the world is most probably *de fide*."[67] Riccioli immediately tried to weaken Inchofer's opinion: "I say *de fide* at least indirectly, since from its opposite something contrary to faith would follow, namely the falsity of those biblical statements that mention the sun's motion and the earth' stability."[68] Having referred to these and other similar views, Riccioli expressed his rather ambiguous opinion: In fact, he declared, he did not want either to add to or to exclude anything from the cardinals' decision, having decided to subscribe to it, as it had been issued, most prudently and on the basis of right reasons.[69]

Talking of "right reasons," Riccioli may have been thinking of his own long and detailed discussion of the Copernican hypothesis. He enumerated and minutely analyzed 49 proofs favoring it and 77 against it. The former were mainly based on simplicity and economy of motions, on proportions and symmetry, on the nature of heavenly and terrestrial bodies, and on common sense. To dismiss the Copernican argumentation, Riccioli introduced purpose and sense experience, which were especially important from the Aristotelian and the theological points of view. Moreover, he accused the Copernicans of basing their argumentation on rhetoric, sophistry, and dubious experiments. As to the anti-Copernican proofs, they were mainly based on the Aristotelian classification of motions and associated concepts, such as gravity and levity. Among these proofs, Riccioli extensively developed his own "physico-mathematical argument," which instigated a violent controversy. It gave Riccioli an opportunity to comment once again on the cardinals' decree, though in more radical terms. After discussing the pros and cons of the Copernican system, Riccioli drew what he called "rational conclusions"—that is, conclusions that did not take into account either the Bible or the Church's authority.

First: "Taking into account the celestial phenomena alone, they are saved with astronomical and mathematical precision in both hypotheses, that of the immobility of the earth and that of its daily and annual motion. So far, no proof based on celestial phenomena has been produced, which can demonstrate either the truth or the falsity of any of the hypotheses."[70] Riccioli then concluded that the Copernican system ought to be seen as a mere hypothesis, although he neglected to draw a similar conclusion as to the geocentric system. Next, he claimed that his physico-mathematical proof favored geocentrism, rather than heliocentrism.[71] The third conclusion stated that "taking into account physical evidence alone (which in physical questions is the only acceptable evidence), there are some physical proofs that provide evidence for the immobility of the earth, none for its motion."[72] These proofs were mostly based on falling bodies and cannonballs. Riccioli claimed that astronomers could rely on physical evidence provided by the senses, whenever such an evidence was not mathematically shown to be an illusion—as in the case of falling bodies.

Riccioli then moved on to the realm of probabilities. His fourth conclusion stated that "if we ignore the demonstrative and evident proofs, and consider only those that have in themselves a mere probability, then we shall find several in favor of both hypotheses. They are so many and of such a kind that with some ability, the intellect can be inclined towards one or the other hypothesis." He added, however, that this situation changes "when both sacred authority and Divine Scriptures are taken into account."[73] By "demonstrative and evident proofs" Riccioli can only mean the several versions he developed for his (worthless) physico-mathematical argument.

From the second and third conclusions Riccioli drew a fifth one, which he considered his "main conclusion": "On the basis of reason alone, and of the intrinsic value of the proofs, and ignoring all authorities, the hypothesis that assumes the immobility of the earth is, absolutely speaking, to be declared true; and the hypothesis that assumes the motion of the earth, be it only daily or both daily and annual, is to be declared false and repugnant on the basis not only of physical but also of physico-mathematical demonstrations."[74] Once again, Riccioli was establishing the whole weight of a rational demonstration upon his own extremely weak proof.

In the sixth conclusion Riccioli argued that "to either prove or disprove any of the above mentioned hypotheses on the basis of the proofs so far well devised, expertise in physics and theology is not sufficient, unless one has a considerable knowledge of astronomy and is familiar with geometry, arithmetic, and mathematics."[75] In practical terms, this was self-serving, though Riccioli's words could also be taken as favoring Copernicus, also a clergyman and a mathematician. At the same time, Riccioli criticized many Copernicans who could not claim to possess theological expertise. Finally, Riccioli asserted, not without some irony, that a definite conclusion ought to be drawn from all that he had said before: "It is only fair that from now on the supporters of the Copernican hypothesis—should any be left!—recognize that both theologians and churchmen have enough expertise to produce a judgement on these hypotheses; and that the Copernican hypothesis is to be dismissed, not only for the great reverence towards the ecclesiastical decrees, and because it is incompatible with the Sacred Scriptures, but also on the basis of a deeper analysis of both hypotheses and of the reasons deduced from them with the greatest care."[76] Unfortunately, this "greatest care" was of no value at all, and therefore Riccioli had no real arguments to support the geocentric system other than the Bible and the authority of the Church. Later, in the *Astronomiae*, Riccioli put forth a more fundamentalist view, arguing that "the motion of the sun and the immobility of the earth are to be affirmed on the basis of the authority of the Holy

Scripture alone, even if both hypotheses were equally favored by the natural light [of reason]."[77] This may seem to indicate that he recognized the weakness of his physico-mathematical argument and decided to increase the weight of both biblical and ecclesiastical authority. But this was not the case, for by the time he published the *Astronomiae* Riccioli was about to become involved in a controversy over just such an argument. In any event, he reverted back to the discussion on biblical hermeneutics, which was, at least officially, the ultimate basis of the Church's position. In fact, the Church based its decision on a literal interpretation of the Bible, and the issue was a matter of controversy since the time of Copernicus.[78] Galileo wrote extensively on the matter, and Riccioli could not ignore it either.

The anti-Copernican view was theologically based on a literal interpretation of various biblical passages that affirmed the stability of the earth and the mobility of the sun. Such passages were well known to all participants in the controversy, but they were not always interpreted in the same sense. The anti-Copernicans preferred the literal interpretation, citing the Council of Trent.[79] As a matter of fact, there were traditionally four different senses in which the Bible could be interpreted: literal, metaphorical, moral, and eschatological. As such, the Council did not privilege literal meaning. Riccioli, however, thought, like many others, that the literal interpretation ought to be preferred in the first place as a matter of principle. The only approved exceptions were those in which a literal interpretation contradicted revealed truth, tradition, pontifical definition, and the natural light of reason[80] or led to absurdities.[81] Since, in his view, none of these conditions were met in the controversy over the Copernican system, Riccioli concluded that "the propositions of the Holy Scripture which affirm that the sun moves and the earth stands still are to be interpreted in a literal and proper sense."[82] Riccioli, just like his opponents, cited Augustine extensively to support his views. Augustine, however, could be used with an equal success by both sides.[83]

Another controversial topic in biblical interpretation was the "principle of accommodation." It was also invoked by both sides to support their opposite theses. This hermeneutical principle allowed metaphorical interpretation of biblical passages where the Holy Spirit might have accommodated the discourse to the capacity of common people. In Riccioli's words, the question was "whether the biblical passages on the motion of the sun and the stability of the earth are to be literally interpreted, or rather metaphorically, according to the common sense of people, that is, as dealing with mere appearances."[84] Following Bellarmine's opinion in his letter to Foscarini, Riccioli argued that he was ready to interpret metaphorically such passages, provided that a conclusive proof of the motion of the earth was produced. And, he added, not only had this not been done before; he himself had shown how the stability of the earth could be proved by reason alone! Once again he alluded to his inconclusive "physico-mathematical proof."

The fundamental purpose of the Bible was yet another point of controversy. The Copernicans claimed that the Holy Ghost had never intended to instruct mankind on matters of science. Galileo quoted Cardinal Baronius as having said that the Bible teaches "how to go to heaven, not how the heavens go."[85] This was certainly a difficult point for the anti-Copernicans, but not for Riccioli. He tackled the difficulty by dividing it into two related questions: "whether Holy Scriptures contains teaching on physics and astronomy" and "whether the statements on the motion of the sun and the stability of the earth that we find in the Sacred Scriptures are related to questions of faith and religion."[86] Although they were two separate questions, the second clearly was formulated to counteract the impression that might be caused by a negative answer to the first question—and it had to do with the text of the decree of the Council of Trent cited above. On the other hand, Riccioli was in a position to make a distinction between two different senses of the first question, and therefore to give an answer of the "yes and no" kind. "To that question," he wrote, "I answer with a distinction. I concede that the main purpose of the Holy Scripture is not to instruct people on issues purely related either to physics, mathematics and to natural and civil history, or to the other natural arts and faculties." This *concedo* was, of course, only the first part of the answer. Riccioli immediately attempted to regain what he had conceded: "I deny however that the same Scripture does not teach some issues related to the natural sciences and faculties, as part of the foundation of some doctrines, both in ethics and in matters connected with eternal salvation, or aiming to illustrate divine omnipotence, wisdom, providence, etc."[87] This answered the second question, although Riccioli made a further distinction between biblical statements that were directly related to faith and those whose relation to faith was indirect. He included astronomical matters in the latter group, but then, to counteract the impression that they were not very important, he cited St. Paul as saying in his epistle to the Romans that people may come to believe in God through the harmony and beauty of the world. This position was rather weak in defending geocentrism, since the Copernicans agreed that God was to be praised through the enquiry into the nature of the universe. Thus, the issue remained unresolved.

The Radicalization of Riccioli's Position

As I suggested earlier, in order to fully understand Riccioli's views on the Copernican controversy one must recognize that they evolved and became more extreme. As I noted, there was no trace of a dramatic predicament in Riccioli's response to the Roman request of information, even though it was written after Galileo's condemnation. Grant's opinion that there was a real dilemma for "those Scholastics who believed that the Copernican theory was more appropriate, or at least no worse, than the various contemporary geocentric systems [and] where also compelled to repudiate the Copernican system for theological reasons" cannot be fully applied to Riccioli, although Grant thought that Riccioli himself "may have embodied this very dilemma."[88] There is in fact no evidence for this. Riccioli's growing intolerance toward heliocentrism is more likely to have resulted from certain events that occurred after the publication of his *Almagestum*.

Even before the book was printed, some disciples of Galileo expressed their outrage. For example, on April 13, 1647, Evangelista Torricelli wrote to V. Renieri about the frontispiece of Riccioli's book in the following terms: "What an impudent set! They want to make complete fools of us in every area of knowledge! You just read the frontispiece here enclosed and then forget about astronomy."[89] But the criticism of the Copernicans was not what really troubled Riccioli at the time. He was afflicted with something more serious. In 1662, he completed a theological treatise on the immaculate conception of the Virgin Mary, which he considered one of his best works. Although the manuscript was censored and approved by three Roman Jesuits, the Dominican Inquisitors strongly opposed publication. Riccioli then asked various people, including Cassini and especially Daniel Bartoli—a Jesuit lecturing at the Roman College—to intercede on his behalf before the Superior General, the cardinals, and even the pope so that he could print the book. Between 1665 and 1671, a year before his death, Riccioli and Bartoli exchanged numerous letters dealing with the issue. Bartoli's letters reveal both the strong influence of the Dominicans on the decisions of the Inquisition, and their equally strong opposition to the Jesuits: "The friars," he wrote, "are willingly listened to and believed, especially when they are against us, as if they think they get indulgences by beating us."[90]

Despite these problems with the Inquisition, Riccioli's views on the juridical authority of the cardinals´s decree condemning Galileo became, paradoxically, more conservative and rigid. In fact, fifteen years after the publication of the *Almagestum* a violent controversy erupted between Riccioli, Giovanni Alfonso Borelli, and Stefano degli Angeli over Riccioli's physico-mathematical argument against the motion of the earth, which gave birth to several treatises.[91] Riccioli, attacked personally, reacted angrily, perceptibly hardening his conservative view of the heliocentric system. This is evident in his renewed discussion of the juridical value of the cardinals' decree. In 1665 Adrien Auzout claimed that some Jesuits, including Fabri,[92] Grimaldi, and Riccioli, did not, contrary to the cardinals' decree, consider the earth's motion either absurd or false in philosophy.[93] Riccioli retorted in his *Apologia pro argumento physicomathematico contra systema Copernicanum*, insisting that, as far as he and Grimaldi were concerned, Auzout's remarks were untrue: "We say that it is false that either myself or Grimaldi have ever expressed the opinion that the motion of the earth and the stability of the sun are not absurd and false in philosophy."[94] The main intention of the cardinals, he was certain, was "to condemn the opinion of the motion of the earth, and of the immobility of the sun, as heretical, since it contradicts the Holy Scripture literally interpreted."[95] Thus, Riccioli went beyond the decree itself—and even beyond his former views—in considering the motion of the earth to be heretical, a position not taken by the cardinals. Riccioli further claimed that the condemnation of heliocentrism by the cardinals and by theologians more generally was absolute and not merely provisional or only for the time being [dicimus tam Eminentis. Cardinales, quam Theologos Qualificatores S. Congreg. Inquis. absolute, et non tantum provisionaliter, seu pro hunc temporis, tulisse dictas censuras supponentes pro certo nunquam posse demonstrari contrarium], since the condemnation took it for granted that heliocentrism could never be proved.[96]

Riccioli's position becomes clearer once we recognize his concern, already expressed in the *Almagestum*, that any additional bolstering of heliocentrism augured pernicious theological consequences. Thus, when addressing the Copernicans' interpretation of Church documents, he argued that if they were "allowed the freedom with which they interpret the ecclesiastical decrees" one "might fear that such a freedom would not be limited to astronomy and natural philosophy, but would touch the holiest dogmas; it is therefore important to keep the rule of interpreting all sacred texts in their literal meaning. In the case of the motion of the earth, we have no need to put this rule aside."[97] Here biblical hermeneutics and ecclesiastical decrees are strangely put on the same level. Indeed, the cardinals' text was the source of this hermeneutical problem, as it stated that both the motion of the earth and the stability of the sun contradicted the Holy Scriptures—based, of course, on a literal interpretation. Thus, weakening the juridical force of the ecclesiastical decree automatically cast doubt on its content, and Riccioli believed that there was no alternative but to consider biblical and ecclesiastical texts as equivalent.

I have already suggested that Riccioli's attitude is rather paradoxical, for when Degli Angeli attacked his physico-mathematical argument, Riccioli was quite distraught over the Inquisition's refusal to allow him to publish his treatise on the Virgin Mary. Why, then, did he defend the cardinals' decree so vehemently? Could his radical reaction to both Auzout and Degli Angeli be understood as a ploy to elicit a more positive attitude from the Roman inquisitors by so vehemently supporting the condemnation of Galileo? This cannot be ruled out, for Riccioli considered his treatise on the Virgin Mary to be his best work, and he had no qualms about supporting the Inquisition. But Riccioli was also stung by Degli Angeli's attacks on his stature as a scientist and a philosopher, and he reacted more emotionally than rationally.[98] Whatever the reasons for Riccioli's angry reaction, it is clear that in his last years his opinions on heliocentrism became more and more rigid. Only by taking this progression into account can one see Riccioli's position as coherent and sincere, even if not always rational.[99]

The Importance of Riccioli's Work: A Reassessment

Notwithstanding the sobering message of Thomas Kuhn's book *The Structure of Scientific Revolutions*, it seems that many historians and philosophers of science are still struggling with an obsolete historiography of science and are unable to go beyond what Charles Schmitt called "the precursor approach."[100] As Ivana Gambaro put it, "a wrong and widespread conviction has developed, as if progress was attained in an easy and almost linear way, and those who did not immediately accept novelties were isolated individuals who remained outside the line—supposedly unique—of evolution, being unable both to understand novelties and to work in science."[101] On the other hand, Schmitt insisted that the scientific work of early modern mathematicians ought not to be separated from its wider cultural context, as if external elements were irrelevant in the development of science.[102] When applied to Riccioli, such an approach requires that one consider the entire context of his life—his being a Jesuit and a theologian as well as a philosopher and a mathematician—when evaluating his scientific contribution. There is no indication that these several identities conflicted with each other in a fundamental way. I believe this to be consistent with the tension between individual Jesuits and the Order and with the tension within the individuals. Conversely, although Riccioli had a holistic approach to the study of nature, he was well aware of the autonomy of the various fields of research. Thus, he did not endorse the mathematical views of the likes of Kircher, Lana Terzi, Schott, and Bettini, who occasionally engaged in "mystical speculation on numbers."[103] On the other hand, he maintained that natural phenomena possessed their own autonomy, and, although as a theologian he viewed the universe as a magnificent creation of God, he repeated time and again in his books that "we ought not to multiply miracles without necessity."[104] It was in this sense that he did not accept, for example, the opinion of those who explained the tides as caused by angels, "first of all because it makes use of an artifice without necessity, only to avoid the trouble of searching for its causes in nature herself" [primo quia recurrit ad machinam sine necessitate, aut prae taedio inquirendi in natura propriam causam].[105]

I mentioned above that when Riccioli is cited in studies of history of science, especially in the field of astronomy, he is mainly referred to as the author of the *Almagestum*, a work usually described as an encyclopedic compilation.[106] However, several scholars have began a process of re-evaluation. Some have described Riccioli as one of the most learned astronomers of his time, and as having contributed much not only to astronomy but also to geography and chronology.[107] Koyré has attempted to repair Riccioli's negative reputation.[108] Biagi has emphasized Riccioli's flexible attitude on astronomical issues.[109] Hall has opined that Riccioli's work was of high professional quality.[110] A study of the correspondence between Riccioli and Kircher enabled Maccagni to conclude that "Riccioli's image is clearly that of a scholar, deeply and continuously busy with concrete research, a serious and able researcher . . . very much updated as to the developments of the different disciplines."[111] This seems to be also Heilbron's view in a recent work.[112]

Riccioli's views on the Copernican system and related controversies are still a matter of debate. Many believe that neither Riccioli nor others who publicly opposed heliocentrism were expressing their true opinions. I have tried to show that, at least for Riccioli, such an approach may be misleading. In a recent study, Brandmüller and Greipl presented more properly the complexity of contemporary cultural situation when pointing out that Riccioli "had shown his openness towards Copernicus and Galileo, without however abandoning the view that their theories were mere hypotheses," and that "this was neither a sign of duplicity, nor the manifestation of a hypocritical conformity [but rather] a sign of the awareness of the scientific-theoretical problems, an awareness that had been made more clear by Riccioli's philosophical and theological expertise."[113]

Riccioli's specific contributions to the development of modern science include measuring a terrestrial degree and the earth's radius,[114] determining the proportions of land and sea in the northern hemisphere, observing a double star, observing the surface and libration of the moon (which made Grimaldi's accurate lunar maps possible), establishing a new lunar nomenclature, contributing to the measurement of astronomical distances and of the apparent diameter of planets, compiling astronomical tables of planetary motions, studying the pendulum, and experimentally determining the acceleration rate of falling bodies. However, such an evaluation of Riccioli's work is inadequate. Those favoring the "precursor approach" could easily dismiss such "contributions" as insignificant. Pingré claimed that Riccioli's tables of planetary motions, published in the *Astronomia*, were seldom used[115]; De Dainville stated that they were actually used for decades.[116] Such a "technical approach" fails to appreciate Riccioli's work within the context of his time. When Louis XIV awarded Riccioli a prize,[117] it was not to reward him for any specific scientific contributions but to recognize all his activities and their relevance to contemporary culture.

Undoubtedly, Riccioli enjoyed great prestige and great opposition, both in Italy and abroad, not only as a man of encyclopedic knowledge but also as someone who could understand and discuss all the relevant issues in cosmology, observational astronomy, and geography of the time.

Notes

1. Alfredo Dinis, The Cosmology of Giovanni Battista Riccioli (1598–1671), Ph.D. dissertation, Cambridge University, 1989; "Os Jesuítas e a liberdade de investigação," *Brotéria* 131 (1990): 416–423; "Tradição e Transição no Curso Conimbricense," *Revista Portuguesa de Filosofia* 47 (1991): 535–560; "Giovanni Battista Riccioli crítico de Galileu," ibid. 54 (1998): 163–193; "Was Riccioli a Secret Copernican?" in *Giambattista Riccioli e il Merito Scientifico dei Gesuiti nell'Età Barocca*, ed. M. Borgato (Florence, 2002).

2. See A. Fabroni, *Vitae Italorum doctrina excellentium qui saeculis XVII et XVIII floruerunt* (Pisa, 1778), volume II, pp. 359–378; Jean Baptiste Delambre, *Histoire de l'Astronomie Moderne* (Paris, 1821); John L. Heilbron, *Electricity in the 17th and 18th Centuries* (Berkeley and Los Angeles, 1982), p. 96; William B. Ashworth. "Catholicism and Early Modern Science," in *God and Nature*, ed. D. Lindberg and R. Numbers (Berkeley and Los Angeles, 1986), pp. 155–156.

3. See Dorothy Stimson. *The Gradual Acceptance of the Copernican Theory of the Universe* (New York, 1917).

4. Delambre, *Histoire de l'Astronomie Moderne*, volume II, p. 275.

5. "The case of Father Giovanni Battista Riccioli was particularly strange. He had been especially charged by the order with the task of scientifically refuting the Copernican theories; but, in the course of his studies, he had become such an enthusiastic admirer of them that, although for the sake of appearances, he attacked them with all the arguments at his command, he nevertheless described them as the 'finest, simplest and best.' It was, therefore, inevitable that such unbecoming language should bring upon him severe censure from the authorities of the order." Renee Fulop-Miller, *The Power and Secret of the Jesuits* (New York, 1930), p. 403.

6. See Paolo Galluzzi, "Galileo contro Copernico," *Annali dell'Istituto e Museo di Storia dell Scienza di Firenze* 2 (1977), pp. 95–96.

7. Ugo Baldini has pointed out some differences and tensions among the Jesuits, including that between Thomism (realist) and Occamism (nominalist) and that between Aristotelian cosmology and mechanics and the new Galilean approach. See Baldini, "Una fonte poco utilizzata per la storia intellettuale: le 'censure librorum' e 'opinionum' nell'antica Compagnia di Gesù," *Annali dell'Istituto di Storia Italo-Germanico di Trento* 11 (1985), pp. 38–39.

8. *Constitutions* III. i. 18; cf. *Constitutions* IV. v. 4; IV. xiv. 1. See also L. Lukács, *Monumenta Paedagogica Societatis Iesu V. Ratio atque Institutio Studiorum Societatis Iesu (1586, 1591, 1599)* (Rome, 1986), pp. 21, 316, 380.

9. *Constitutions* III. i. 18 (emphasis added).

10. *Constitutions* VIII. i. 8; X. ix.

11. The Commentarii Colleggii Conimbricensis Societatis Iesu, published by Coimbra Jesuits toward the end of the sixteenth century, strongly endorse the Aristotelian tradition. However, there is ambiguity in the discussions of certain themes, of the use of a probabilistic approach, and even of the endorsement of non-

Aristotelian notions, such as the impetus theory. See A. Dinis, "Tradição e transição no Curso Conimbricense," *Revista Portuguesa de Filosofia* 47 (1991): 535–560.

12. Baldini, "Una fonte poco utilizzata," p. 20.

13. Ugo Baldini, *Legem Impone Subactis* (Rome, 1992); Marcus Hellyer, "'Because the Authority of My Superiors Commands': Censorship, Physics and the German Jesuits," *Early Science and Medicine* 2 (1996), pp. 321–322. Both titles are somewhat misleading, for, as both authors acknowledge, the weight of authority never succeeded in attaining uniformity of doctrine.

14. Baldini, *Legem Impone Subactis*, p. 39.

15. Hellyer discusses at length the complex situation of Jesuit censorship. He argues that, from the outset, the work of Jesuit scholars "was marked by the constant tension between the need to preserve uniformity in philosophy and the impulse to grant professors considerable liberty in their teaching and writing." Marcus Hellyer, The Last Aristotelians: The Transformation of Jesuit Physics in Germany, 1630–1773, Ph.D. dissertation, University of California, San Diego, 1998, p. 30.

16. See Riccioli's letter to General Vitelleschi of June 16, 1628, in Archivum Historicum Societatis Iesu (hereafter ARSI), Fondo Gesuitico (hereafter FG) 738, Indipetae vii. 227.

17. Riccioli, *Almagestum novum* (Bologna, 1651), volume II, p. 386.

18. Ibid., volume I, p. 209.

19. Ivana Gambaro, *Astronomia e Tecniche di Ricerca nelle Lettere di G.B. Riccioli ad A. Kircher* (Genoa, 1989), p. 79.

20. Riccioli, *Astronomiae reformatae tomi duo* (Bologna, 1665), p. xi; *Almagestum novum*, volume I, p. xviii.

21. Riccioli, *Almagestum novum*, volume I, p. xvii.

22. The full title of the work is *Almagestum novum astronomiam veterem novamque complectens observationibus aliorum, et propriis novisque theorematibus, problematibus, ac tabulis promotam, in tres tomos distributam*. See also volume II, p. 325.

23. Riccioli, *Almagestum novum*, volume I, pp. xvi–xviii. Later he claimed to have proposed more than 320 corrections of other authors (Riccioli, *Astronomiae reformatae*, preface, p. xii).

24. M. Manfredi, *Argomento fisico-matematico* (Bologna, 1668), p. 29.

25. Riccioli, *Almagestum novum*, volume I, p. xiii.

26. Ibid., p. 2.

27. "Informazione dello stato del Collegio di Santa Lucia di Bologna data dall'anno 1560 fino al presente del 1673," ARSI, FG, B: 112, volume I, pp. 159–160.

28. Daniel argued that Fontenelle credited G. De L'Isle with correcting the dimensions of the Mediterranean Sea and of the Asia in his 1669 charts—something that Riccioli had already done earlier. C. Daniel. "La Géographie dans les Collèges des Jésuites aux XVII et XVIII siècles," *Études*, sixth series, 3 (1879), pp. 808–809.

29. Howard B. Adelmann, *The Correspondence of Marcello Malpighi* (Ithaca, 1975), volume II, p. 439. Baldini argued that the *Geographiae* was the most complete seventeenth-century work in the field. Ugo Baldini, "L'attività scientifica nel primo settecento," in *Scienza e Tecnica nella Cultura e nella Società dal Rinascimento ad Oggi*, ed. G. Michelle (Turin, 1980), volume III, p. 522.

30. Riccioli, Responsio, in Gambaro, *Astronomia e Tecniche di Ricerca*, p. 70.

31. Riccioli, *Astronomiae reformatae*, p. i.

32. Riccioli, *Almagestum novum*, volume I, p. xix.

33. Ibid., p. 248.

34. Riccioli, *Almagestum novum*, volume II, p. 419.

35. Paolo Mancosu, *Philosophy of Mathematics and Mathematical Practice in the Seventeenth Century* (Oxford, 1996), p. 10.

36. Riccioli, *Almagestum novum*, volume I, p. ii.

37. "Mathesis . . . significat disciplinam, antonomastice tamen propter evidentiam demonstrationum tribuitur scientiae, quae versatur circa quantitatem terminatam, ut talem." University Library of Bologne, ms. 1, p. 286.

38. Riccioli, *Almagestum novum*, volume I, p. 2.

39. For example, A. Kircher, *Ars magnesia, hoc est, disquisitio bipartite-empirica seu experimentalis, physico-mathematica de natura, viribus, et prodigiosis effectibus magnetis* (1631); Francesco Maria Grimaldi, *Physico-mathesis de lumine* (1665).

40. Baldini, *Legem Impone Subactis*, p. 52.

41. Peter Dear, *Discipline and Experience: The Mathematical Way in the Scientific Revolution* (Chicago, 1995), p. 168.

42. Riccioli, *Almagestum novum*, volume I, p. 383.

43. Dear (*Discipline and Experience*, p. 172) argues that Paul Guldin's *Dissertatio physico-mathematica de motu terrae* (1622) was the first Jesuit publication to use this term. However, Baldini (*Legem Impone Subactis*, p. 62, n. 27) doubts whether Guldin used it in the sense that became common by the middle of the seventeenth century.

44. Riccioli, *Astronomiae reformatae*, p. v.

45. According to Heilbron, "their combined observations fill about twenty-five pages, at fifteen observations per page." Further: "One of the most useful results of these systematic observations was Riccioli's conversion to Kepler's approach to planetary orbits. Riccioli could not resist Cassini's demonstrations when confirmed by his own laborious measurements. He accordingly bisected the eccentricity and calculated elliptically in his updated Almagest of 1665, to which he gave the Cassini-like title Astronomy restored; and no doubt he would have put all the planets around the sun had holy writ and papal edict not abundantly proved that God was not a Copernican." John L. Heilbron, *The Sun in the Church: Cathedrals as Solar Observatories* (Cambridge, Mass., 1999), p. 122.

46. Riccioli, *Almagestum novum*, volume II, p. 419 and passim. He often mentioned sense experience as the foundation "cui Physica scientia superstruere debet

suos discursus" (ibid., p. 314) and, indeed, as the foundation of all the natural sciences (ibid., p. 340).

47. Ibid., p. 326.

48. Riccioli, *Almagestum novum*, volume I, pp. 174–175.

49. Riccioli, *Almagestum novum*, volume II, p. 419. The case of the trajectory of a descending body thrown in the air inside a ship was often used by the anti-Copernicans to prove their case. If the earth moved, they claimed, that trajectory would be curvilinear inside the boat. In fact, the body would fall behind, due to the earth's daily motion. They never accepted the Copernicans' explanation based on the principle of inertia, according to which the motion of the descending body shared in the motion of the boat. This argument was similar to the "tower argument." Riccioli too was unable to accept the principle of inertia.

50. Ibid.

51. Riccioli, *Almagestum novum*, volume I, p. 530.

52. Manfredi, *Argomento fisicomatematico*, p. 5.

53. On the probabilistic approach of the early modern scientists, see Benjamin Nelson, "Probabilists, anti-probabilists and the quest for certitude in the 16th and 17th centuries," In *Proceedings of the Xth International Congress of the History of Science* (Paris, 1965). See also J. Dorling, Mid-Seventeenth-Century Arguments For and Against Copernicanism: A Probabilistic Appraisal . . . (unpublished).

54. Manfredi, *Argomento fisicomatematico*, p. 33.

55. Riccioli, *Astronomiae reformatae*, p. 86.

56. Riccioli, *Almagestum novum*, volume II, p. 419. I do not see any basis for a claim that Riccioli applied to the natural sciences the much-maligned Jesuits doctrine of moral probabilism. See Ashworth, "Catholicism and early modern science," p. 157.

57. Gambaro, *Astronomia e Tecniche di Ricerca*, p. 40.

58. Michael John Gorman (The Scientific Counter-Revolution: Mathematics, Natural Philosophy and Experimentalism in Jesuit Culture, Ph.D. dissertation, European University Institute, Florence, 1998) has suggested, on the basis of the handwriting, that the text was written by Kircher. The text was forwarded by the General Curia in Rome. Though it is unsigned, it may not be by Kircher; Baldini ("La formazione scientifica di Giovanni Battista Riccioli," in *Copernico e la Questione Copernicana in Italia*, ed. L. Pepe, Florence, 1996, pp. 123–182) dismisses that possibility.

59. Gambaro, *Astronomia e Tecniche di Ricerca*, p. 70.

60. Riccioli, *Almagestum novum*, volume II, p. 309. Here, Riccioli repeated what another anti-Copernican, Clavius, had written in his *Sphaera*, referring to him as "that most excellent geometer who, in our time, has put astronomy on its feet again and who will, in recognition thereof, be celebrated and admired by all posterity as Ptolomey's equal" (cited in Pierre Duhem, *To Save the Phenomena*, Chicago, 1969, p. 93). And Riccioli appears to have been ambiguous regarding Kepler. Although he rejected the latter's theory of planetary motions, Kepler is numbered among the great mathematicians listed in the beginning of the first volume of the Almagestum,

where he is described as "a most shrewd mathematician, a man of a most passionate talent, and a most sharp examiner of astronomical subtleties."

61. "Sacra Congregatio Cardinalium, seorsim sumpta a Summo Pontifice, non facit propositiones de Fide etiamsi eas definiat esse de Fide, aut oppositas esse haereticas. Quare cum nondum de hac re prodierit definitio Summi Pontificis, aut Concilii ab eo directi, vel approbati, nondum est de Fide Solem moveri, et Terram stare, vi Decreti praecise illius Congregationis; sed ad summum, et solum vi Sacrae Scripturae apud eos, quibus est evidens moraliter, Deum ita revelasse: Omnes tamen Catholici ex virtute tum Prudentiae, tum Obedientiae obligamur ad tenendum, quod illa Congregatio decrevit, et saltem ad non docendam absolute oppositum: Sed de hac subtilitate Theologica egi ex professo in Tractatu de Fide, ubi de Regula Fidei." Riccioli, *Almagestum novum*, volume I, p. 52.

62. Delambre, *Histoire de l'Astronomie Moderne*, volume II, p. 277.

63. Augustus De Morgan, "Notes on the Anti-Galilean Copernicans," in *Companion to the Almanac* (London, 1855), p. 4.

64. "Nondum totum Copernicanae hypotheseos profundum exhausimus: quantoque altius in eam descenditur, eo plus ingenii ac pretiosae *subtilitatis* defodere licet." (Riccioli, *Almagestum novum*, volume II, p. 304; emphasis added) In a similar manner Riccioli wrote that "something more subtle is needed to convert the solar hour in equatorial degrees" (*Almagestum novum*, volume I, p. 177). The same sense of the word can be found in Tycho Brahe's statements—for example, "to measure or demonstrate phenomena that are removed from the Earth, requires a great subtlety" (cited by Riccioli, *Almagestum novum*, volume II, p. 72).

65. Cited by Riccioli, *Almagestum novum*, volume II, p. 498.

66. Riccioli, *Almagestum novum*, volume II, p. 495.

67. Ibid.

68. "De fide inquam, saltem indirectè, quatenus ex eius opposito sequitur aliquid contrarium fidei, videlicet falsa esse loca Scripturae Solis motum, et Terrae stabilitatem asserentia." (ibid.)

69. "Ego quidem addere aut detrahere non audeo censurae in hanc opinionem latae à Sacra Congregatione Cardinalium, quam censuram paulò infra referem, sed eidem prorsus subscribo, tanquam prudentissime et iustissimis de causis prolatae." (ibid., p. 496)

70. Ibid., p. 478.

71. As I argued in "The Cosmology of Giovanni Battista Riccioli," this strange proof is of no objective value. The proof is based on a sentence in Galileo's *Dialogue* about the speed of a stone falling from the top of a tower: "The true and real motion of the stone is never accelerated at all, but is always equable and uniform." (*Dialogue Concerning the Two Chief World Systems*, Berkeley and Los Angeles, 1967, p. 166) Galileo called this sentence "a third marvel" as well as a "curiosity" [bizarria] but later explained that he never intended to speak seriously and was only joking. The issue had consequences for the debate on heliocentrism: Riccioli, taking Galileo's words at face value, promptly demonstrated that a falling stone is indeed accelerated, and became convinced that he had won the debate.

72. Riccioli, *Almagestum novum*, volume II, p. 478.

73. Ibid.

74. Ibid.

75. Ibid.

76. Ibid., p. 479.

77. Riccioli, *Astronomiae reformatae*, p. 86.

78. G. Rheticus, *Treatise on Holy Scripture and the Motion of the Earth* (Oxford, 1984).

79. In its fourth session (April 8, 1546), the Council declared that in matters of faith and morals none should "twist the sense of the Holy Scripture against the meaning that has been held by our Holy Mother Church, whose duty is to judge of the true sense and interpretation of the Holy Scriptures; nor shall anyone dare to interpret these Scriptures contrary to the unanimous consensus of the Fathers, even if such an interpretation has never been brought to light." (H. Denzinger, *Enchiridion Symbolorum, Definitionum et Declarationum de Rebus Fidei et Morum*, eleventh edition, Freiburg, 1911, p. 366)

80. Riccioli, *Almagestum novum*, volume II, p. 491. See also *Astronomiae reformatae*, p. 89.

81. Riccioli, *Almagestum novum*, volume II, p. 493.

82. Ibid.

83. Dinis, "Os comentários De Genesi de S. Agostinho e a polémica Copernicana," *Revista Portuguesa de Filosofia* 44 (1988): 39–61.

84. Riccioli, *Almagestum novum*, volume II, p. 491.

85. Galileo, "Letter to Grand Duchess Christina," in *Le Opere di Galileo Galilei*, ed. A. Favaro (reprint: Florence, 1964–1968), volume V, p. 284. See also pp. 317–319, 332–333.

86. Riccioli, *Almagestum novum*, volume II, p. 490.

87. Ibid.

88. Edward Grant, "In defense of the Earth's centrality and immobility: Scholastic reaction to Copernicanism in the Seventeenth-century," *Transactions of the American Philosophical Society* 74 (1984), pp. 13–14.

89. The rudeness of Torricelli's remarks can only be conveyed in the original: "Ecco qua questa razza sfrontatona che ci vuol far restare tutti coglioni in ogni sorta di professione. V.P. lega l'incluso frontespicio e poi abbandoni affatto l'astronomia." (cited in *Edizione Nazionale delle Opere dei Discepoli di Galileo*, ed. P. Galluzzi, Florence, 1976, p. 358)

90. "I Frati sono sentiti e creduti, e contra noi credutissimi, e volentieri, perchè v'è indulgenza al bastonarci." (Biblioteca Comunale dell'Archiginnasio," Bologna, ms. 1,546)

91. Giovanni Alfonso Borelli, *De vi percussionis et motionibus naturalibus a gravitate pendentibus* (Bologna, 1667); *Risposte . . . alle considerazioni fatte sopra alcuni luoghi del suo libro della forza della percossa* (Messina, 1668); M. Manfredi,

Argomento fisico-matematico (Bologna, 1668); Stefano Degli Angeli, *Considerazioni sopra la forza di alcune ragionifisicomattematiche addotte dal M.R.P. Gio. Battista Riccioli* (Venice, 1667); *Seconde Considerazioni sopra la forza dell'argomento fisicomatemático* (Padua, 1668); *Terze considerazioni sopra una lettera del Molto Illustre, et Eccellentissimo Signor Gio. Alfonso Borelli* (Venice, 1668); *Quarte considerazioni sopra la confermazione d'una sentenza del Sig. Gio. Alfonso Borelli* (Padua, 1669); D. Zerilli, *Confermazione d'una sentenza* (Naples, 1668); Riccioli, *Apología pro argomento physicomathematico contra sistema Copernicanum* (Bologna, 1669).

92. Fabri interpreted the cardinals' decree as provisional and capable of being changed when a definite proof for the motion of the Earth is found. See Riccioli, *Geographiae et hydrographiae reformatae* (Bologna, 1661), p. 49. He further argued that, should that ever happen, the literal interpretation of certain biblical passages mentioning the motion of the sun would have to be reinterpreted. That was Bellarmine's position too. See *The Louvain Lectures (Lectiones Lovanienses) of Bellarmine and the Autograph Copy of His 1616 Declaration to Galileo* (Vatican City, 1984), p. 20.

93. Adrien Auzout, *Lettre à Monsieur Abbè Charles sur le "Ragguaglio di nuove osservazioni, etc." da Giuseppe Campani* (Paris, 1665).

94. Riccioli, *Apologia*, pp. 104. In a letter to Malpighi, Auzout complained that Riccioli had completely misunderstood him (Adelmann, *The Correspondence of Marcello Malpighi*, volume I, p. 419).

95. Riccioli, *Argomento*, pp. 104.

96. Riccioli, *Apologia*, pp. 104. Notwithstanding this unequivocal statement, J. Brucker (*La Compagnie de Jésus*, Paris, 1919, p. 495) maintained, wrongly, that Riccioli took the cardinal's decree only as provisional: "Chose à remarquer, Riccioli ne regarde pas l'arrêt du Saint Office, qu'il soutient, come un decrét final, irrévocable du Saint Siège."

97. Riccioli, *Almagestum novum*, volume I, p. 52.

98. Confidential reports often described Riccioli's morose temperament as "sanguine" (six times), "fiery" (twice), "choleric," "melancholic," and "phlegmatic" (once each) . These character traits were exacerbated by Riccioli's chronic poor health. His health was said to be "weak" in 1639 (ARSI, Ven. 39, II: 310), "frail" in 1649 (ARSI, Ven. 40: 94v), and "crippled" from 1651 on (Ven. 39: 178; Ven. 41: 9, 205; Ven. 42: 9).

99. "Riccioli's New Almagestum would make little sense if he were not sincere." (Ashworth, "Catholicism and early modern science," p. 159)

100. Charles Schmitt, "A fresh look at mechanics in 16th-century Italy," *Studies in History and Philosophy of Science* 1 (1970), p. 170.

101. Gambaro, *Astronomia e Tecniche di Ricerca*, p. 5.

102. "Galileo's interests in literature, Kepler's in magic, and Newton's in biblical chronology were as much a part of their lives as the science for which they are remembered." (Schmitt, "A fresh look at mechanics," p. 159)

103. According to Koyré (cited in *De la Mystique à la Science*, ed. P. Redondi, Paris, 1986, p. xxii), both E. Burt and E. Strong, unlike L. Brunschwicg, failed to distinguish between two trends within modern mathematical Neoplationism, "that of the mystical speculations on numbers, and that of mathematical science."

104. Riccioli, *Almagestum novum*, volume II, p. 210 and passim.

105. Ibid., p. 375.

106. See e.g. Fabroni, *Vitae Italorum*, volume 2; Delambre, *Histoire de l'Astronomie Moderne*, volume 2; P. Larousse, "Riccioli," in *Grand Dictionnaire Universel du XIX* Siècle, volume XIII, p. 1177; C. Littrow, cited in J. Schreiber, "Jesuit astronomy," *Popular Astronomy* 11 (1904), p. 110; W. Brandmüller and E. Greipl, *Copernico, Galileo e la Chiesa* (Florence, 1992), p. 26.

107. C. M. Pillet, Biographie Universelle, volume XXXV, pp. 564–565. See also Brucker, *La Compagnie de Jésus*, pp. 489–496; Grant McColley, "Scheiner and the decline of neo-aristotelianism," *Isis* 33 (1947): 63–69.

108. Alexander Koyré, "An experiment on measure," *Proceedings of the American Philosophical Society* 97 (1953), p. 229.

109. *Scienziati del Seicento*, ed. M. Biagi and B. Basile (Milan, 1980), p. lxv.

110. A. R. Hall, *The Revolution in Science* (Harlow, 1983), pp. 27–28.

111. Gambaro, *Astronomia e Tecniche di Ricerca*, p. 6.

112. Heilbron, *The Sun in the Church*.

113. Brandmüller and Greipl, *Copernico, Galileo e la Chiesa*, p. 26.

114. On the evaluation of Riccioli's method to measure the earth's radius, see J. S. Bailly, *Histoire de l'Astronomie Moderne* (Paris, 1779), volume II, pp. 341–342.

115. A. G. Pingré, *Annales Astronomiques du XVII siècle* (Paris, 1901), volume IV, p. 446.

116. F. De Dainville, *La Géographie des Humanistes* (Paris, 1940), p. 446.

117. "Informazione dello stato del Collegio di Santa Lucia," cited above.

Scientific Spectacle in Baroque Rome: Athanasius Kircher and the Roman College Museum

Paula Findlen

In the middle of the seventeenth century, the most famous museum in Italy was the gallery at the Roman College. (See figure 1.) Filled with magic lanterns, distorting mirrors, automata, mummies, exotic animals, mythical creatures (giants, sirens, unicorns), and numerous Egyptian and Chinese artifacts, the museum fulfilled its claim to be a microcosm of the world. The gallery, as Zakiya Hanafi has observed, was "the exquisite fruit of an extraordinary mind, one nourished and developed to the speculative heights of its contemporary culture."[1] Founded by Athanasius Kircher (1602–1680), professor of mathematics at the Roman College, widely acknowledged as one of the most brilliant polymaths in an encyclopedic age, the museum was a congregating point for the godly, the learned, and the curious who passed through the Eternal City. Aspiring Jesuits, members of other religious orders such as the Minims, German princes, and Catholic laymen attended Kircher's lectures on natural philosophy and toured his museum; increasingly they were joined by significant numbers of Protestant virtuosi (most notably members of the Royal Society) who came to Rome to meet the "master of one hundred arts," see his fabled collection, and debate the finer points of various theories about the natural world.

Kircher's accomplishments in the study of ancient and universal languages, archeology, astronomy, magnetism, and Chinese and Egyptian culture were greatly facilitated by his collections of scientific and ethnographic rarities, which remained in the hands of the Roman College well into the nineteenth century.[2] Situated at the symbolic and geographic center of the Catholic world, Kircher's museum was a showpiece for the Jesuit order. "No foreign visitor who has not seen the museum of the Roman College can claim that he has truly been in Rome," boasted Kircher.[3] By all accounts,

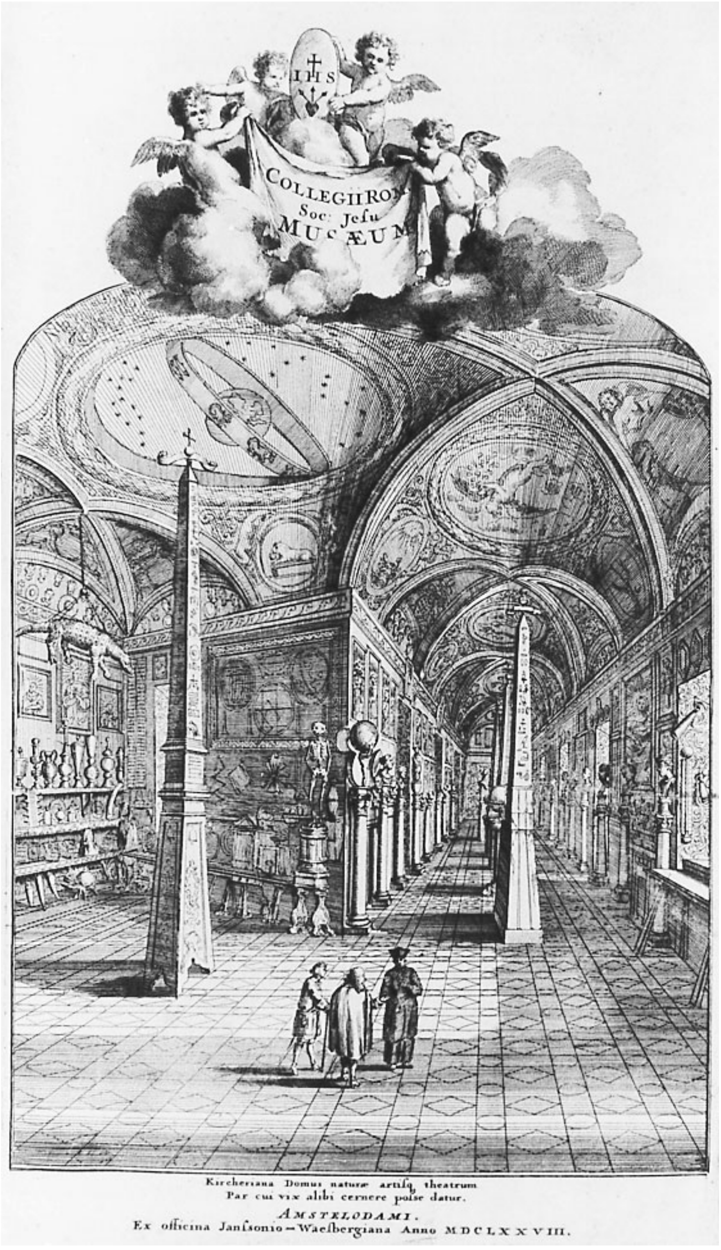

Figure 1
The Roman College museum, 1678. Source: Giorgio de Sepi, *Romani Collegii Societatis Iesu Musaeum Celeberrimum* (Amsterdam, 1678). Courtesy of Special Collections, University of Chicago Library.

Kircher seems to have begun his collection in the late 1630s in his quarters at the Collegio Romano. With the addition of the Roman patrician Alfonso Donnino's collection in 1651, the Jesuits moved the museum from Kircher's private quarters to a 300-foot exhibit hall with three side galleries, in acknowledgment of the collection's new public status. It soon became one of the primary cultural centers of Baroque Rome, and one of the most important centers of scientific learning in the Catholic world.

Kircher's museum was noteworthy but by no means unique. By the late sixteenth century, collecting had become a central feature of urban life and elite culture. From the lavish court collections in Florence, Mantua, Ferrara, and Urbino, to the studios of late Renaissance humanists, to the theaters of nature created by doctors and apothecaries, Italian patricians perceived the possession of a museum to be integral to the formation of their identity.[4] Nowhere was the relationship between collecting and patrician identity made more visible than in Baroque Rome. While Bologna boasted the museum of the senator Ferdinando Cospi, agent to the Medici, and Milan housed the gallery of Kircher's friend, the cleric Manfredo Settala, Rome, a city than many considered one vast museum, contained a seemingly endless array of collections. The social dynamic of the city's elite, heightened by the expansion of the papal court in the late sixteenth and early seventeenth centuries, fostered a competitive ethos of display. Papal nephews such as Francesco Barberini and Flavio Chigi amassed great quantities of books, paintings, and curiosities, and cardinals competed with each other to make their palaces the most sumptuous in the city by filling them with objects and inviting nobles and foreigners to view them. Well-connected nobles such as Cassiano dal Pozzo, the foremost art collector in Rome, and Federico Cesi, prince of the Accademia de' Lincei, moved within the orbit of the papal court, assisting the collecting efforts of patrons such as Barberini and establishing their own museums.[5] Rome, by the time Kircher arrived in 1633, was a city of collectors, and therefore eminently receptive to the philosophical spectacles that he created.

Within this dense network of museums, the Catholic Church played a prominent role as facilitator of such activities. Collecting enhanced the perception of the Catholic Church as an institution with immense material resources at its disposal. In the sixteenth century, learned naturalists and antiquarians had flocked to the Vatican mineralogical museum run by the papal physician Michele Mercati (1541–1593). Under the patronage of several popes, most notably Gregory XIII and Sixtus V, Mercati supervised the botanical garden, oversaw the sculpture collections in the Belvedere and created a *metallotheca* (mineralogical collection) within the walls of the Vatican that rivaled the theaters of nature owned by well-known collectors such as the Bolognese naturalist Ulisse Aldrovandi and the Veronese apothecary Francesco Calzolari.[6] At the papal court, Mercati was surrounded by scholars such as the papal physicians Andrea Cesalpino and Andrea Bacci who undoubtedly exchanged specimens and made observations for their natural histories in this setting. Mercati's *metallotheca* became an important center for scientific learning in Rome. Here in 1581 the architect Camillo Agrippa demonstrated before Gregory XIII his model of an apparatus to transport the Vatican obelisk, repositioned in front of Saint Peter's in 1586.[7] Thus, when the Rector of the Roman College and the Father General of the Society of Jesus chose to establish a museum in which papal interests, civic display, and scientific culture met, and to appoint Kircher as its curator, they drew explicitly on the model established by Mercati in the previous century. Yet at the same time they presented the Jesuits as caretakers of the material abundance of the overseas missions and as interpreters of the most difficult problems of knowledge of the day.

While consciously making the success of the museum a Roman project, Kircher also made sure that it reflected the specific contributions of his order to the world of knowledge, culture, and faith. The museum was a part of a complex theological and educational program that put science, and all forms of learning, in the service of God. The artifacts it displayed reflected the fruits of the Catholic reformation of knowledge in the post-Tridentine era, when the Jesuits could rightfully claim to have been instrumental in making Catholicism a global faith. Kircher's museum demonstrated the Church's and the Society's ability to reconstitute the Christian imperium.[8] Its placement within the Roman College, the premier educational institution of the order, reinforced the idea that, if Rome was the center of the world, the Society of Jesus was the intellectual epicenter.

In Kircher's day, as Steven Harris observes, the Jesuits were prominent in three main contexts: educational institutions, courts, and missions.[9] The contents and uses of his collection brought together these different worlds. By relating the presence of the museum to his teaching duties, Kircher set the stage for the more widespread appearance of scientific collections in the

Jesuit colleges. Disciples such as Gaspar Schott and Francesco Lana Terzi helped regional colleges establish museums for the instruction of their students in imitation of the one in Rome.[10] But natural philosophy was not simply a subject for seminarians who saw it as preparation for the more heady contemplation of theology. It also played an important role in the education of the nobles who studied at the Jesuit colleges.[11] Enhancing the museum through gifts of numerous princely patrons, Kircher made his museum a by-product of European court culture, a manifestation of the cultural strength of the Habsburg emperors and Baroque popes whose portraits lined the walls of the vestibule to the gallery. Less obviously, it also testified to the close ties between Jesuit scholars and the Baroque courtiers who studied in the Jesuit colleges and visited their museums.

When recalling the organization of the portrait gallery that greeted visitors at the entrance to the museum, we should not forget the commemoration of prominent missionaries such as the astronomer Adam Schall. His portrait (adjacent to that of Christopher Clavius, one of Kircher's predecessors in the teaching of mathematics at the Roman College) evoked the connections between the scientific, collecting, and missionary activities of the Jesuit order.[12] Although Kircher himself was never able to persuade the Father General to send him to China or Egypt, as he had hoped early in his career, his circumstances allowed him to train missionary-scholars who relayed the fruits of their travels to him, and to interview Jesuit missionaries reporting to Rome. The results of this work were made manifest in publications such as his *Egyptian Oedipus* (1652–1654) and *China Illustrated* (1677) and in the quantity of non-European artifacts in the museum. Through the accumulation of objects and publications, Kircher emerged as the embodiment of a new form of expertise—not the "on-site" knowledge of the traveler but the more synthetic knowledge of the collector whose wisdom surpassed the abilities of any one individual. The strength of these two categories within the Society of Jesus suggests their complementary functions.[13] It is hardly surprising that a religious order which produced the prototype of the professional traveler, the missionary, should also have facilitated the work of one of Europe's greatest collectors, who used the information accumulated by his fellow Jesuits to create a new encyclopedia of knowledge.

More than any other religious group, the Jesuits were acutely aware of the importance of collecting as a tool of religious and cultural accommodation.

The curiosity and sense of wonder that led men to describe, depict, and possess the unknown coordinated well with the religious impulse to familiarize the unknown for purposes of assimilation and conversion. Following the guidelines set out by Loyola, Jesuit missionaries provided detailed reports to Rome of each region's flora and fauna, along with its customs, politics, and religious rituals. By the seventeenth century, missionaries such as Johannes Terentius in China reported regularly to collectors such as Kircher: "Climates, stones, plants, animals, men, customs, and institutions—he examined all of these and found out the special qualities of each."[14] At the center of this powerful information network lay the Roman College museum. As the main pedagogical organ of the Society of Jesus, the Roman College trained missionaries, teachers, and laymen in preparation for a life of service. Well-known professors such as Kircher enjoyed an unusual degree of access to the political, religious, and intellectual elite. Training collectors of scientific data and corresponding with Europe's leading scholars and cultivating patrons, Kircher was uniquely situated to receive the curiosities of the world and put them on display in his museum.

Kircher's story not only sheds light on his own circumstances and on the formation of a remarkable museum; it also illuminates the importance of his religious order to early modern scientific culture. The Jesuits are one of the most important and understudied groups of scholars active during the scientific revolution.[15] Through their vast networks and proliferation of education institutions, the Jesuits rightfully may claim to have developed one of the largest and most influential scientific communities in early modern Europe. Kircher certainly was not a typical Jesuit nor even a typical Catholic. He enjoyed privileges unavailable to ordinary members of his order, most important a great deal of latitude in his pursuit of highly unorthodox intellectual interests. Yet his prominence within the Jesuit educational system and the visibility of his museum provide us with a particularly interesting case study in the relations between Catholicism and early modern science. If Kircher was not typical, he certainly was exemplary of the tendency among Jesuit scholars to accommodate new ways of thinking alongside the old in the hope of reconciliation. In this respect, his museum served another important function: it was a meeting ground for different visions of the world, as much as it also expressed Kircher's unique outlook on the state of knowledge.

"In This Theater of the City and the World"

Baroque Rome was a city of spectacles, and few spectacles were more alluring than Kircher's museum. Set against the backdrop of magnificently decorated churches such as the Gesù and the recently completed Saint Peter's, and the piazzas decorated by Borromini and Bernini, the museum was yet another product of the peculiar combination of urban and religious renewal that characterized Baroque Rome. Though the objects that made up the scientific core of the museum belonged to Kircher, the museum did not officially come into existence until the donation of Donnino's art and antiquities collection in 1651. Donnino, secretary to the Popolo Romano, presented the Jesuit order with his collection in exchange for a permanent berth in the order's newest and grandest church, San Ignazio. He cited his "singular affection toward the Company of Jesus and the desire for public good, promoting the study of letters and physical and antiquarian erudition" as the reasons that motivated his gift.[16] The decision of the Father General of the Society of Jesus and the Rector of the Roman College to accept this proposition surely indicates their understanding of the system of exchange at work in such transactions. In a city in which the various religious orders competed for the attention of patrons, the Jesuits needed to encourage such donations in order to foster stronger ties with the lay members of the ruling elite.

The museum, as Kircher constantly reminded his readers and correspondents, was not only a *theatrum mundi*; it was also an urban theater. In any other city this phrase would have been relatively insignificant, but, despite the attempts of Luther and his followers to affix the label "Babylon" to Rome, it was still *caput mundi*, the "head of the world," to most visitors. Under popes such as Urban VIII (1623–1644) and Alexander VII (1655–1667), this term took on new meaning.[17] Continuing the policies of urban expansion and renewal begun under earlier popes, both contributed substantially to the reconstruction and embellishment of the city; in addition, they supported a court rivaled in size and magnificence only by Versailles. Thus, when Kircher designated the museum a "theater of the city and the world," he imagined it as a space containing in microcosm the nodal point of the Catholic universe.

Within Rome, Kircher competed with other spectacles to gain the attention of local patricians and foreign visitors. While Bernini staged elaborate plays and pageants in the courtyard of the Palazzo Barberini, and Giulio Rospigliosi (the future Clement IX) wrote the text for the operas to fill them, Kircher invented his own form of theater in the museum. Consider two different gifts offered in homage to Christina of Sweden shortly after her arrival in Rome in December of 1655. From the pen of the talented Rospigliosi came an opera—*Human Life, or the Triumph of Piety* (1656)—allegorically praising her decision to convert to Catholicism as a story of the struggle between virtue and vice. Christina enjoyed its performance at the Palazzo Barberini on January 31, 1656. Earlier that day, she made a second visit to the Roman College to see its collections. Her tour of the museum and her attendance at the opera represented two ends of a spectrum of public events in which she participated. Christina's stay in Rome commenced with a series of careful planned visits to the most noteworthy sites of the city. Of her conversion, one contemporary wrote: "The Amphitheater will be Rome, the Spectators will be the Universe."[18] The inclusion of the Roman College museum in this itinerary, particularly on the same day as Christina's appearance at the Palazzo Barberini, was indicative of its high status among the papal courtiers who guided her through the Eternal City. Like Piazza del Popolo (her first point of entrance into the city) and the Palazzo Barberini, the Roman College was designated as one of the "theaters" in which the newly converted queen should be displayed.

The Roman College museum was the logical terminus for a distinguished visitor who prided herself on her erudition and who embraced the Catholic world as a place in which a new synthesis of knowledge could occur. Kircher and his colleagues were well aware of the ritual significance of the event and prepared carefully for Christina's arrival. During her first visit (January 18), the Jesuits embellished the entire college with emblems, epigrams, and inscriptions, particularly ones commemorating "celebrated heroines." As the centerpiece of this spectacle, Christina was elevated onto an ecclesiastical throne [baldacchino] created specially for the occasion, just as she received the most strategically located seat at the opera. Whereas the activities organized in honor of Christina on January 18 celebrated her conversion, the events of January 31 introduced her to the intellectual resources of the Roman College. During the second visit, Christina toured the sacristy, the library, the pharmacy, and the museum—the most important sites of knowledge and display within the Roman College.[19]

Ushered into the Roman College, Christina received a complete tour of the museum. Kircher demonstrated his choicest experiments to the royal visitor and explained his mechanical inventions. He had anticipated her visit for several months. In October of 1655 he requested a stipend from the Vatican librarian, Lucas Holstenius, in order to prepare a description of "some of the machines in my Gallery" for the queen.[20] By the time the Swedish ex-monarch arrived, everything in the museum was in order so that Kircher could demonstrate his inventions and experiments. Through such demonstrations, he underscored the power of orthodox knowledge, which succeeded where unorthodox experiments—for example, Paracelsian alchemical transmutations—failed. Christina particularly admired the magnetic clocks and was treated to a display of Kircher's most celebrated "Hermetic experiment," the famous "vegetable palingenesis" that recapitulated the myth of the Phoenix.[21] For this particular visitor, the experiment had added significance, since Christina herself was a sort of Phoenix: a Protestant monarch transformed into a Catholic. She also was particularly interested in alchemical transmutations. Having recently taken the name Alexandra as part of her entry into the church, she indeed had renewed her identity.

At the end of the tour, Kircher presented Christina with two gifts. The first was an Arabic translation of the Psalms of David with an index to passages on Solomon's Temple and Moses's Tabernacle, both in reference to the house of wisdom Christina had come to Rome to build. Like Kircher and Alexander VII (elected pope shortly before the queen's arrival) Christina came to Rome to fulfill the destiny portended in the historic ruins of the papal city. She was the new Isis, consort of Osiris, whom Kircher identified as Alexander VII, and patron of Hermes, Kircher's chosen persona.[22] No doubt Kircher saw her as the living embodiment of the statues of Minerva and Isis displayed in the main corridor of the museum; standing before these ancient images, Christina became the latest incarnation of the transcendent figure of female wisdom. Kircher's second gift elaborated on this message. It was a miniature obelisk bearing the following inscription in 33 languages: "Great Christina, Isis Reborn, erects, delivers and consecrates this Obelisk on which the secret marks of Ancient Egypt are inscribed."[23] While Christina's contact with Alexander VII legitimated her new identity as Alexandra, her meetings with Kircher cemented her image as Isis. Thus, the museum was the space in which the allegorical re-enactment of the mythical encounter between Isis and Hermes occurred.

In many respects, the appearance of Christina of Sweden in the Roman College museum represented the culmination of Kircher's efforts to make it the center of Baroque Rome, and by extension the center of the entire Catholic world. Christina was not a typical visitor. Like Alexander VII and the Holy Roman Emperors Ferdinand III and Leopold I, she was the sort of patron whose presence in the museum activated all of its symbolic import. She was proof positive of the living presence of "Egyptian" wisdom, Kircher's metaphor for the hieroglyphic and symbolic knowledge that he collected and interpreted, in Rome. By making the visit to the Roman College museum part of her ceremonial entrance into Rome and accepting the gifts bestowed on her by Kircher, Christina legitimated the forms of knowledge displayed in the museum and validated Kircher's role as the interpretor of arcana. That same year, Kircher's *Ecstatic Voyage* (1656), a dialogue on Tychonic astronomy written in the form of a dream, appeared with a dedication to Christina. Throughout the next two decades, the Jesuit philosopher and the royal convert continued their intermittent contact. Kircher attempted to decipher the inscriptions on a magical sword allegedly belonging to her father, Gustavus Adolphus, and probably shared several evenings with Christina contemplating the heavens in the observatory she built in her palace. From the queen, Kircher received an alleged unicorn's horn, actually the bone of a walrus, to put in his museum. They kept themselves informed of each other's activities through a common circle of acquaintances interested in the occult sciences.[24]

While the death of Alexander VII in 1667 and Christina's increased alienation from the Catholic church probably weakened their formal ties, in the symbolic universe of the Roman College museum, as illustrated in the 1678 catalogue by Giorgio de Sepi and in Kircher's numerous publications on hieroglyphic wisdom, they remained forever joined. The 1656 encounter between a German Jesuit and a Protestant queen, both at the vanguard of the esoteric learning cultivated by Baroque scholars, symbolized the possibility that universal wisdom, and the spiritual and political harmony that accompanied it, might finally be achieved. From Kircher's perspective, his museum, rather than the rooms in which the Peace of Westphalia had been ratified in 1648, was the site best suited to the universal restoration of order in the world. "Unity is the Essence of God," he wrote in his *Egyptian*

Oedipus, and this principle underlay all the activities conducted in the museum.[25] Among its many functions, the Roman College museum advertised the strength of the Society of Jesus in effecting this remarkable union of religion, politics, and philosophy.

As Christina toured the Roman College museum, she must have been impressed with the numerous artifacts in the collection which reinforced the messages of spiritual strength and renewal that Kircher subsequently personalized for her in his gifts. Certainly the first sight to catch her attention, and that of every other visitor, were the five miniature obelisks, exaggerated to gargantuan proportions in De Sepi's frontispiece since their recent rediscovery confirms that the largest was no more than four feet tall.[26] The obelisks that Kircher invented for Christina and the Holy Roman Emperor Ferdinand III were the fruits of his systematic study of the ancient obelisks in Rome whose restoration and interpretation occupied several papacies. De Sepi compared the obelisks to the trophies of Hercules, earned by Kircher through his labors in the republic of letters. They contributed more to his fame than any other artifact in the museum.

When Kircher chose to make five miniature obelisks the centerpiece of the Roman College museum, he underscored the strong connections between collecting, hermetic philosophy and the imperial visions of Catholicism. Consecrated with a cross and a ball, the symbols of Catholic *imperium*, the obelisks represented the fusion of pagan and Christian culture in Rome, and the conjunction of the urban and imperial ambitions of the early modern papacy. Just as the Emperor Augustus had proclaimed his conquest of Egypt through the transportation and erection of the obelisks in ancient Rome, the papacy publicized its spiritual conquest of the pagan world, ancient as well as modern, through the triumphal display of the remaining obelisks. From the 1580s onward, the obelisks were systematically restored and christianized by a succession of popes.[27] Kircher's patrons—Urban VIII, Innocent X and Alexander VII—all shared this interest. With the increased success of missionary orders such as the Jesuits in converting peoples of the Americas and Asia to Catholicism, and the renewed political strength of the papacy, the obelisks symbolized the success of the post-Tridentine church and glorified the activities of individual popes who presented themselves as sacred monarchs.

Kircher's presence in Rome was closely linked to the revived interest in hieroglyphics at the papal court. Mercati in the late sixteenth century despaired at understanding the meaning of the hieroglyphs, but Kircher's fame rested on his ability to recover their secrets. His position at the Roman College was due primarily to his abilities in languages rather than to his skill in mathematics and the invention of mechanical devices. "Kircher splendor of our centuries and interpreter of sixteen languages," wrote Joannes Vondelius. Giacomo Scafili called him "the oracle of languages," while his assistant De Sepi dubbed him the "restorer and interpretor of the Egyptian obelisks."[28] The French savant Nicolas Claude Fabri de Peiresc, who observed Kircher's linguistic abilities during the German Jesuit's stay at the college in Avignon, recommended him to Cardinal Francesco Barberini as someone worthy of bringing to Rome. The papal nephew responded by arranging for Kircher to replace Christopher Scheiner as professor of mathematics at the Roman College. Kircher's primary responsibilities, however, did not concern instruction but the translation and publication of a Coptic vocabulary that Pietro della Valle had brought back from Egypt and the "exposition of those obelisks."[29] Barberini also retained Kircher as a consultant on his project to erect an obelisk, found in the ruins of the Circus Varianus, in the gardens of his family palace, and encouraged him to translate the hieroglyphs engraved on the four obelisks that Sixtus V had erected in the 1580s.

By the 1650s Kircher had cemented his reputation as the only scholar in Europe capable of translating the hieroglyphs.[30] Works such as his *Coptic Forerunner* (1636), *Egyptian Language Restored* (1643), and *Egyptian Oedipus*, a vast moral and philosophical epic on the significance of Egypt as the archetype of the Catholic world, publicized his activities. For Kircher, the obelisks, and the hieroglyphs inscribed on them, represented the purest form of truth. Drawing on hermetic and Neoplatonic texts, Kircher posited that the symbolic language of the Egyptians represented the closest remaining approximation of Adamic language. As Piero Valeriano observed in his influential *Hieroglyphica* (1556), "to speak hieroglyphically is nothing else but to disclose the [true] nature of things divine and humane."[31] The prominent display of five obelisks in the Roman College museum emphasized Kircher's unique abilities to master the secrets of language which, in turn, unfolded the original plan of the universe.

Kircher's desire to possess the secrets of language was part of his larger attempt to make the connections between the spiritual and the material manifest. Understanding the hieroglyphs was the first step in reconstructing a Christian philosophy of nature inspired by the *Corpus Hermeticum*. Kircher's numerous scholarly correspondents never ceased to remind him of the importance of his task. "Already time and blight have almost consumed the Hieroglyphs and no less destroyed the emblems," wrote Joannes Vondelius. "The lack of foreign languages slowly obfuscates our intellect and deprives us of knowledge."[32] Kircher's interpretation of the obelisks of Rome represented the most publicized aspect of the campaign to restore *prisca sapientia* as part of the restoration of faith.

Kircher's role in the excavation and restoration of the obelisks began under Urban VIII and his nephew Francesco Barberini and expanded during the papacies of Innocent X and Alexander VII. As Innocent X put it, Kircher's task was to interpret the obelisks and their inscriptions "so that those who are amazed by the bulk of this great obelisk may come, through your endeavors, to understand the secret meaning of its inscriptions."[33] With the help of assistants such as Gaspar Schott and Giuseffo Petrucci, Kircher participated in the successful restoration of the obelisk of the Emperor Caracalla, placed atop Bernini's fountain in Piazza Navona in 1651, and the obelisk erected on Bernini's elephant in front of Santa Maria sopra Minerva for Alexander VII in 1667. Both events resulted in the publication of two further examples of Kircher's interpretative virtuosity: the *Pamphilian Obelisk* (1650) and the *Egyptian Obelisks* (1666). Similarly the Roman College museum became another place in which to memorialize the archeology of the past conducted in Baroque Rome. Kircher, as his disciple Schott wrote in the preface to the *Egyptian Oedipus*, had become the "Oedipus of the Obelisks," the arch-interpretor of the hidden messages that antiquity had left behind.[34]

Kircher linked the recovery of *prisca sapientia* to the strength of the post-Tridentine church and the prominence of the Jesuits in creating a new intellectual order. The preface to his *Egyptian Obelisks*, for example, contained a poem that explained the combination of Bernini's elephant, the Egyptian obelisk, and the Chigi stars (Alexander VII's family crest) in front of Santa Maria sopra Minerva as a representation of "the Pontiff's might spread over the Earth." Kircher himself underscored this point in his autobiography, where he described his desire to make the Alexandrian obelisk "conspicuous in both the City and the World."[35] Such messages reinforced the image of the Catholic Church presented by other publicists. As Daniello Bartoli, Kircher's colleague at the Roman College, wrote in 1663, "there will not remain a span of earth not subject to the Monarchy of the Church, where it did not possess a span one hundred years ago."[36] The possession of the obelisks in Rome, and the knowledge they contained, became the philosophical equivalent of the battle for souls being conducted throughout the world.

Just as each obelisk was an "eternal monument to the eternal city," Kircher conceived of the Roman College museum as an "ornament to the eternal city."[37] The museum recreated the monuments of the city in accordance with the principles of harmony and order espoused by its creator. The five miniature obelisks reminded visitors of Kircher's unique role in the iconography of papal power. They reinforced the analogy between the museum and the papal empire as microcosm and macrocosm. De Sepi described the museum in the following terms, drawing heavily on theatrical metaphor: "And thus this is the Stage for the Obelisks which Kircher exhibits to the scholarly world in this Theater of the City and the World under three Pontiffs."[38] The museum was a theater which captured all drama of Baroque Rome, and Kircher was the director who cast Christina as his heroine and Alexander VII as the hero of the play whose action unfolded in the contemplation of his objects.

Kircher's fascination with the image of his museum as a "theater of the city and the world" was not confined only to the presentation of the obelisks. Writing to the Danzig astronomer Johann Hevelius, Kircher assured him that sending a copy of his *Selenographia* (1647) to Rome was the best way to publicize its virtues. "[W]hen seen in this theater of the world, your work was eagerly promoted by men of high distinction."[39] Kircher's museum as one of the primary locations in which scholarly reputations were made. In his correspondence with princely patrons, he expanded this metaphor to encompass more political connotations. Writing to Duke August of Brunswick-Lüneberg in 1659, Kircher affirmed, "my Gallery or Museum is visited by all the nations of the world and a prince cannot become better known 'in this theater of the world' than have his likeness here." By January of 1660, Kircher assured his Protestant patron that the portrait would be displayed "in the prime spot in my Museum." Six months later, when the portrait finally arrived, Kircher wrote that it would be shown "in this Theater of the City and the World . . . as an example, and truly to the praise and glory of Your Most Serene Highness."[40] Just as Kircher claimed to magnify the reputation of scholars through discussion of their work in his museum, he also presented himself as a collector capable of increasing the might of princes whose virtues otherwise would be obscured.

As Marc Fumaroli suggests, Kircher typified the attitude of many Jesuit scholars who envisioned "Catholic culture as a 'Theater of Memory' and the city of Rome as the *mis en scène* of this 'Theater.'"[41] By assembling the portraits of all the rulers, Catholic as well as Protestant, known for their patronage of learning, Kircher transformed the museum into a political theater that linked the wisdom of the hieroglyphs with the learning of Europe's leading natural philosophers and the power of its most successful princes. Rome, as Kircher constantly suggested, was the one setting in which all of these different activities came together. And his museum was the site of this sublime synthesis.

Displaying Catholic Knowledge

As Gioseffo Petrucci commented in his *Apologetic Forerunner to Kircherian Studies* (1677), Kircher was the centerpiece of the "great Theater of Knowledge," the Baroque encyclopedia.[42] The metaphor of the theater, which described the museum as a microcosm of Rome, also encompassed the intellectual dimensions of Kircher's activities. Kircher's saw all of nature as a spectacle to be brought into his museum. Publications such as his *Subterranean World* (1664–65) and *Great Art of Light and Shadow* (1646) presented nature as a constantly unfolding drama. The *Subterranean World* revealed the hidden secrets of the earth and portrayed Kircher as the principal actor in a heroic adventure that commenced with his observation of the eruptions of Etna and Vesuvius in 1637–38, and ended with his complete understanding of the hidden forces that governed the natural world. The *Great Art of Light and Shadow* displayed Kircher's ability to harness the forces of nature in order to create new forms of representation, highlighting Kircher's role as Baroque magus producing spectacles that evidenced his mastery over nature. Nature, as he wrote in the preface to this work, was the "sensory Theater of the world."[43] He stood in its midst in order to observe and then replicate what he saw.

While highlighting the role of the Roman College museum as a form of urban spectacle, Kircher also publicized its philosophical function. As one of the most celebrated spaces of learning in the Catholic world, the museum offered Kircher a location in which to display the artifacts that made up his encyclopedia. The Roman College museum was a visualization of Kircher's metaphysical system—an "illustrated encyclopedia."[44] Through the juxtaposition of nature and art, pagan and Christian, ancient and modern, Kircher illuminated archetypes, those universal symbols of shared wisdom that linked all civilizations and cultures. His goal was nothing less than complete knowledge. This personal vision accorded well with the goals of his superiors. The objects in his collection, and the publications resulting from their contemplation, strengthened the Church's claim that the condemnation of Galileo in 1633 had not impeded the progress of science in Catholic lands. The popularity of collections such as the Roman College museum, filled with the most controversial phenomena and up-to-date scientific instruments, suggests that Catholic scholars, led by Jesuits such as Kircher, had simply found a different venue in which to pursue their studies of nature.

While the condemnation of Galileo certainly did not halt scientific investigation in Italy, it forced many natural philosophers within orders to declare themselves in favor of various scientific orthodoxies connected to the Aristotelian world view that the decision of the Holy Office had reaffirmed. Kircher, who had been decidedly ambivalent about the work of Galileo before 1633, informed friends such as Peiresc of the problems of reconciling Copernicanism with Christianity. In subsequent decades, he reinforced this message by publishing numerous works in defense of key Aristotelian tenets, while connecting them quite frequently to less orthodox philosophies that interested him. The abundance of objects in the Roman College museum and the success with which Kircher and his assistants manipulated them to produce an up-to-date account of the natural world that conformed to the dictates of faith became one of the most celebrated attempts to synthesize traditional natural philosophy and the new experimental philosophy.

Kircher's commitment to the Aristotelian world view mandated by the Catholic Church, to a certain degree, shaped his image of nature. As the apostles of the new scientific order in Baroque Rome, Jesuit scholars upheld their order's commitment to a Christianized Aristotelianism embodied in the writings of Aquinas, while exploring the possibilities of Neoplatonism, natural magic, and even atomism until it was condemned by the order. Kircher's museum was filled with objects that reinforced sound Aristotelian principles such as the impossibility of a vacuum or perpetual motion. (See figures 2 and 3.) Like many writers of traditional textbooks on natural philosophy,

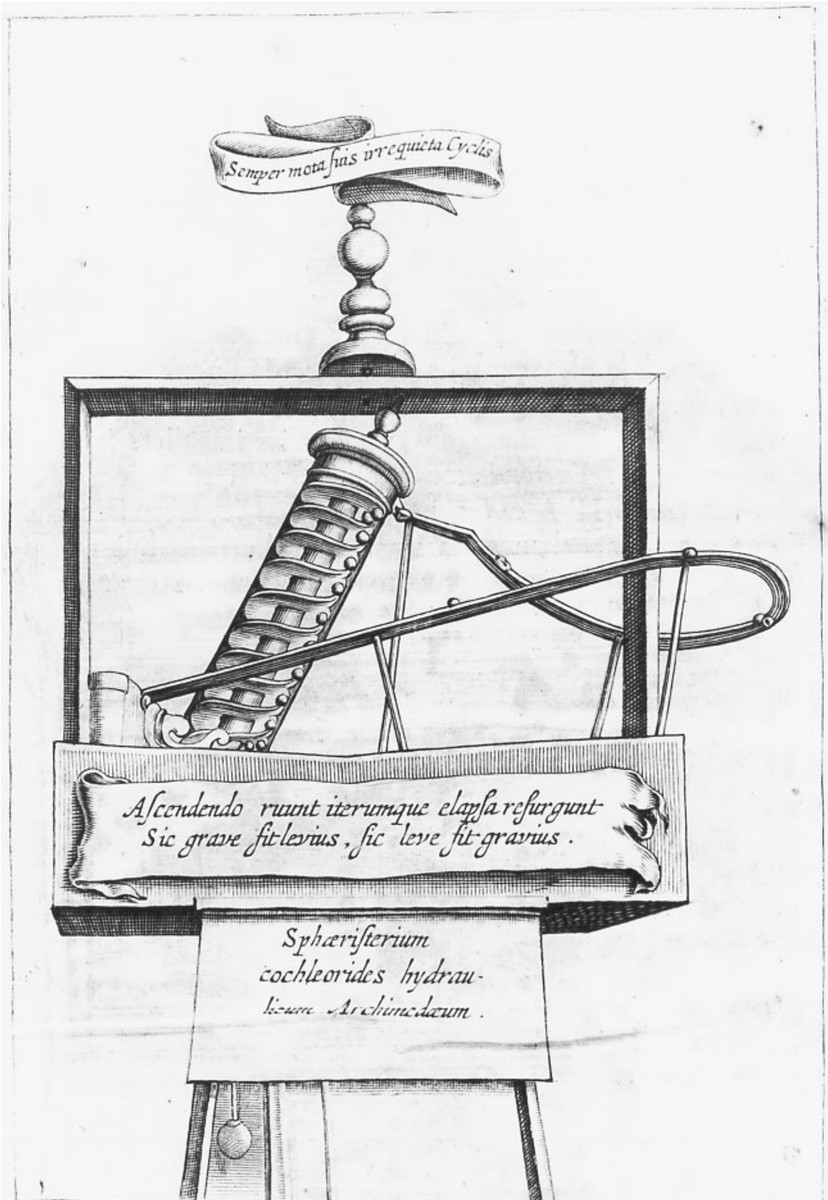

Figure 2
Perpetual motion machine. Source: Giorgio de Sepi, *Romani Collegii Societatis Iesu Musaeum Celeberrimum* (Amsterdam, 1678). Courtesy of Elmer Belt Library of Vinciana, University of California, Los Angeles.

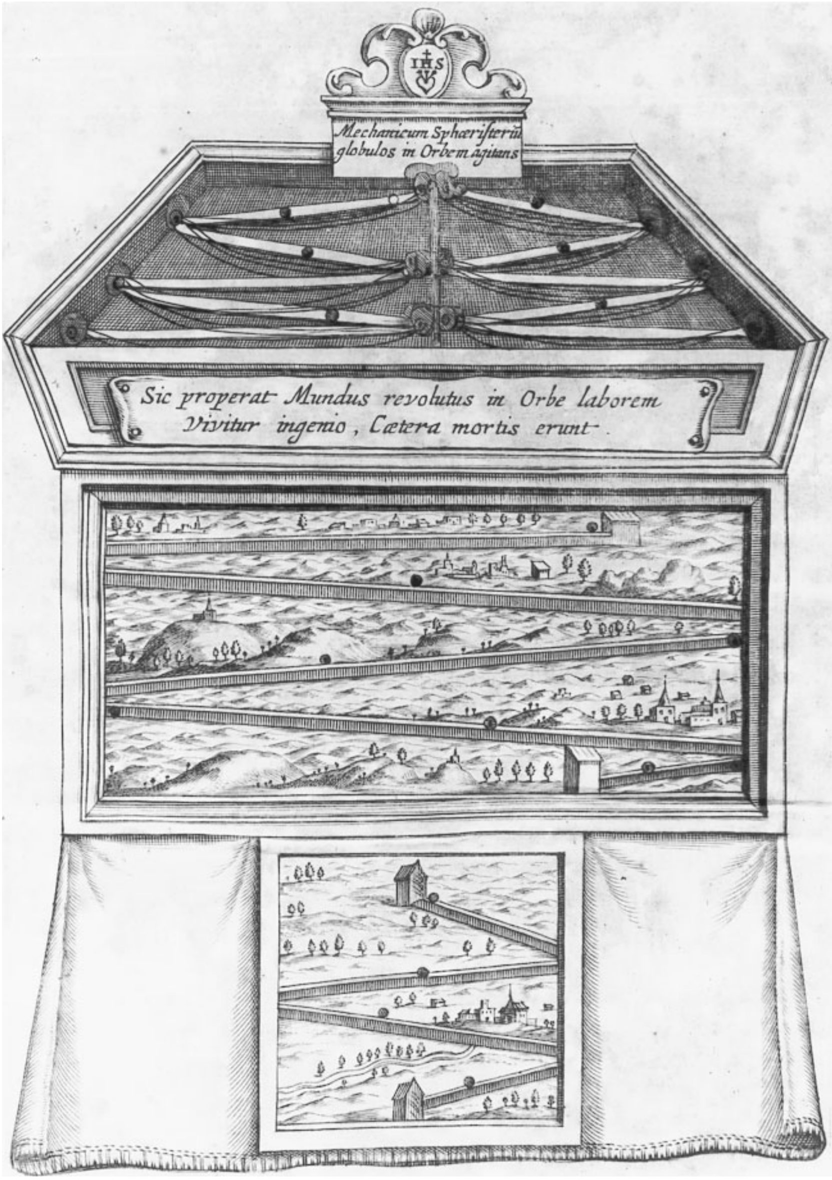

Figure 3
Perpetual motion machine. Source: Giorgio de Sepi, *Romani Collegii Societatis Iesu Musaeum Celeberrimum* (Amsterdam, 1678). Courtesy of Elmer Belt Library of Vinciana, University of California, Los Angeles.

he viewed ancient knowledge as the authoritative framework for science.[45] Yet Aristotelianism was only one of several ancient philosophies which Jesuit natural philosophers espoused. Baroque Aristotelianism, of which Kircher was a sublime example, brought the syncretic tendencies of Renaissance philosophy to their logical conclusion.[46] It measured the teachings of Aristotle against a vaster field of ancient, pristine truths held up to the mirror of experience. Nurtured on the classics and educated within an order that valued syncretism as a tool of conversion, Kircher perceived the past as capable of accommodating everything that the present and future state of knowledge offered. His museum was a monument to this sort of learning.

While the synthesis that Kircher effected in the Roman College museum occurred in the name of Aristotle, it nonetheless was a prime example of the crumbling of this great edifice of knowledge. A delightful, alarmingly heterodox intellectual product that occasionally alarmed the Jesuit censors, it was a cornucopia of ideas and information that threatened to overflow at any moment. The endless parade of novelties and antiquities that filled the museum, and Kircher's books, underscored the fact that the world was infinitely vaster and more complex than Aristotle had ever imagined. So many things yet to be understood or explained. Subsumed within a religious framework that gave his philosophy conceptual clarity, "to the greater glory of God," Kircher's investigations of the natural world struggled to find connections between the old and the new. Since Kircher's philosophical insights were rarely the fruits of personal travel and exploration, but the product of studying objects in proximity to each other, he eschewed expertise in any single domain of knowledge for a kind of comparative nirvana, as he toured the world from his museum by looking at what entered into it.

As Charles Schmitt notes, by the end of the Renaissance, Aristotelianism had become a porous sponge that absorbed a variety of different philosophies. Not least of these were hermeticism and natural magic.[47] They appeared in the pedagogical programs instituted in the Jesuit classrooms and in the research of scholars such as Kircher. Natural philosophers who had begun with a quest for the authentic Aristotle, as a means of reviving his philosophy of nature, subsequently reinvented Aristotle in light of the alternative natural philosophies that the wholesale excavation of antiquity had brought to light. The *Ratio studiorum* (1599) reflected these modifications. Advising the professor of philosophy on how to teach his subject, the Society of Jesus counseled, "In matters of any importance let him not depart from Aristotle unless something occurs which is foreign to doctrine or which academies everywhere approve of: much more so if it is opposed to orthodox faith."[48] Thus the Jesuits advocated a philosophical orthodoxy that allowed ample room for other forms of knowledge to enter, either for reasons of faith or due to the consensus of the community of Catholic natural philosophers.

Kircher's confidence in his own interpretive abilities knew virtually no bounds. When Peiresc suggested to Cassiano dal Pozzo that he feared Kircher might "do violence to the authority of the ancients," he reflected a certain conservatism toward the Jesuit's intellectual program that lacked the rigor of the careful antiquarian and philological scholarship that he admired.[49] Had Peiresc lived to see the publication of the *Egyptian Oedipus*, his worst fears would have been confirmed. Kircher advertised the three-volume tome as containing "Egyptian wisdom, Phoenician theology, Chaldean astrology, Hebrew Kabbala, Persian magic, Pythagorean mathematics, Greek theosophy, Mythology, Arabic alchemy, and Latin philology."[50] By the time Kircher completed his collecting of knowledge, very little of traditional knowledge remained and the new sciences of erudition were transformed into a dazzling display of intellectual pyrotechnics. What neither traditional Aristotelians, nor seventeenth-century antiquarians appreciated about Kircher was his desire to combine their approach to learning with esoteric philosophies and experimental practices and a newly reinvigorated empiricism that made gathering new knowledge as important as the act of interpretation.

For Kircher it was what lay behind Aristotle as much as beyond him that mattered. Kircher extended his chronological reach, moving ever backwards to the original source of wisdom which lay in such texts as the *Corpus Hermeticum*. As Cesare Vasoli comments in his study of seventeenth-century encyclopedism, "The task of the Catholic scholar thus seemed to consist of making one's way through the encyclopedic 'forest' of mysteries, secrets and 'sympathetic' virtues of the world, in search of a sort of archetypal language that collected, at its font, an unmoving, unchanging truth, beyond the flow of cultures, doctrines and civilizations."[51] Kircher's interest in hermeticism led him not only to the hieroglyphs but also to view nature as hieroglyphic.[52] Just as the juxtaposition of different scripts—the Egyptian hieroglyphs and Chinese scrolls in his museum—allowed visitors to see the "essential" characteristics of language, the collection of diverse natural objects allowed viewers to discern the pattern of nature. Fossils, for example, demonstrated the ability of nature to produce the same image in several places.[53] In Kircher's interpretation, inspecting the actual object confirmed the traditional view of fossils as mysteriously figured stones, "jokes of nature," because this supported his synthesis of Aristotelian and hermetic learning. Highlighting the "prodigies of nature"—a category that encompassed the novelties of the New World as well as fabulous creatures of myth and legend—Kircher presented nature as an object of wonder; this served to reinforce its divine status and underscored its inherent spectacularity.[54] In contradiction to Francis Bacon's view, for some Jesuits the evidence of the senses did not initially topple the ancients, though it might lead them to a different appreciation of their work. The material culture of knowledge revealed God's hidden truths by making them visually evident. Seeing was an act of faith, even through the lens of a microscope.

While agreeing with Aristotle that wisdom consisted of universal truths, Kircher differed sharply in his criteria for establishing knowledge and understanding its purpose. The primary function of Kircher's encyclopedia lay in the identification of signs. A symbol, he posited, "leads our mind through a kind of similitude to an understanding of something very different from the things which offer themselves to our external senses; whose property is to be hidden under the veil of obscurity."[55] The system of correspondences that linked these signs formed, as Kircher's colleague Bartoli put it, "the philosophy of nature, as if nature had written, almost in a cipher, her precepts everywhere."[56] Not unlike Paracelsus's doctrine of signatures, which Kircher roundly condemned as a good Catholic, or Marsilio Ficino's astral magic, his *ars signata* presented nature as a divinely encoded structure that only a Catholic natural philosopher could read properly.[57] The difficulty of reading the book of nature became the ultimate test of faith.

Kircher's guidelines on these matters were noted by disciples such as the Danish anatomist Nicolaus Steno, who copied the following passage from Kircher's *Lodestone or the Magnetic Art* (1641) into his commonplace book in 1659: "Only he whom God and nature have ordained for it should be regarded as fitted and destined for this study."[58] Steno's subsequent conversion to Catholicism made his notation of these words particularly meaningful. Once within the fold of the Catholic Church, Steno devoted less time to anatomies and the mathematical study of nature and produced an emblematic treatise that had strong affinities with the more mystical and allegorical speculations of Kircher. As William Ashworth has observed, the Jesuits were among the leading proponents of the emblematic world view.[59] Kircher's strong interest in the occult sciences and symbolic forms of knowledge made him the prototype of this sort of natural philosopher. Under his direction, the Roman College museum attracted the attention of scholars from all over Europe intent on elaborating the hieroglyph of nature. To invoke a favorite metaphor of Kircher and his contemporaries, the museum was "Ariadne's thread" that led the faithful out of the labyrinth.[60] What seemed confusing or impenetrable in the world might be clarifying in the museum.

The objects in Kircher's museum reflected the emphasis which he placed on symbolic knowledge and universal correspondences. Besides hieroglyphs, magnetism was the other subject that greatly preoccupied Kircher. His first publication, written before his arrival in Rome, was on the *Magnetic Art* (1631). This was followed by the *Lodestone or the Magnetic Art* and the *Magnetic Kingdom of Nature* (1667). Many of his other treatises, for example, the *Subterranean World*, included a discussion of this phenomenon.[61] Like the hieroglyph, magnetism expressed a tangible reality as well as being a metaphor for all natural operations. It emblematized Kircher's fusion of the traditions of hermeticism with those of natural magic. "The world is bound in secret knots," proclaimed the frontispiece of his *Magnetic Kingdom of Nature*. Magnetism was the golden chain, to invoke a metaphor used frequently by the sixteenth-century magus Giovan Battista Della Porta and resuscitated by Kircher, that linked together all segments of the universe. It was proof positive that the *ars analogica* was a divine and not a human invention, written by God as directly into nature.

Examples of magnetic virtue were scattered throughout the museum. "Species of sympathetic matter," probably heliotropic plants out of which Kircher created vegetable clocks, decorated the windowsills. The cobra's stone, the quintessential missionary artifact and a celebrated example of sympathetic magic through its ability to draw forth poison from a wound, was proudly displayed. Each object lent credence to Kircher's belief that the world was governed by mysterious forces whose actions unfolded the pattern of the universe. "The virtues of all natural things imitate the power of the lodestone," wrote Kircher.[62] At the heart of the museum lay the lodestone itself, which De Sepi identified as "the center of the Kircherian Museum."[63] A tiny object, proportionately overwhelmed by all the machines and other large artifacts that more immediately caught the attention of visitors, it nonetheless was the key to the museum. Embedded within various mechanical devices that demonstrated the occult powers of the lodestone, it literally put the collection in motion. Magnetism, as Kircher wrote, was the "path to the treasure of the entire world, the only guide and key to all motion whatsoever."[64] This was only one of many instances in which Kircher extended Della Porta's definition of natural magic as the "practical part of Natural Philosophy."[65]

Many of the demonstrations in the Roman College museum came directly from the pages of popular textbooks of natural magic. Figures such as the medieval philosopher Roger Bacon and his Renaissance counterparts, Girolamo Cardano, Della Porta and Tommaso Campanella, were the source of Kircher's inspiration. They also were the object of his severest criticisms. Kircher assiduously recreated the most famous experiments from works such as Della Porta's *Natural Magic* (1558), not only to test their verity but also to expose their natural and human rather than supernatural origins, continuing a line of thought first evidenced in Renaissance naturalism. Ancient tales of miraculous feats of technology such as Architas's flying dove, Daedalus's talking statue, and Archimedes's burning mirror all came under his scrutiny, since they occupied a canonical place in the natural magic tradition.[66] While Kircher celebrated the dove of Architas as an example of the power of magnetism (figure 4) and exalted Daedalus as his precursor in the creation of automata such as the famous "Delphic Oracle" and the talking devil which he proudly displayed in the museum, he reproved Cardano and Della Porta for claiming to exceed Archimedes's alleged feat of igniting ships at 150 paces when Kircher had not been able to create a parabolic mirror that burned even at that distance.[67] Like the alchemists who claimed to have produced the philosopher's stone, Renaissance magi frequently presented their experiments as evidence of unparalleled powers. Instead Kircher saw natural magic as a tradition that bridged ancient and contemporary traditions of science through its respect for authority, its insistence on demonstration and its exaltation of man's ability to harness nature's powers. He proposed an alternative definition of natural magic that celebrated human skill while defining its limits.

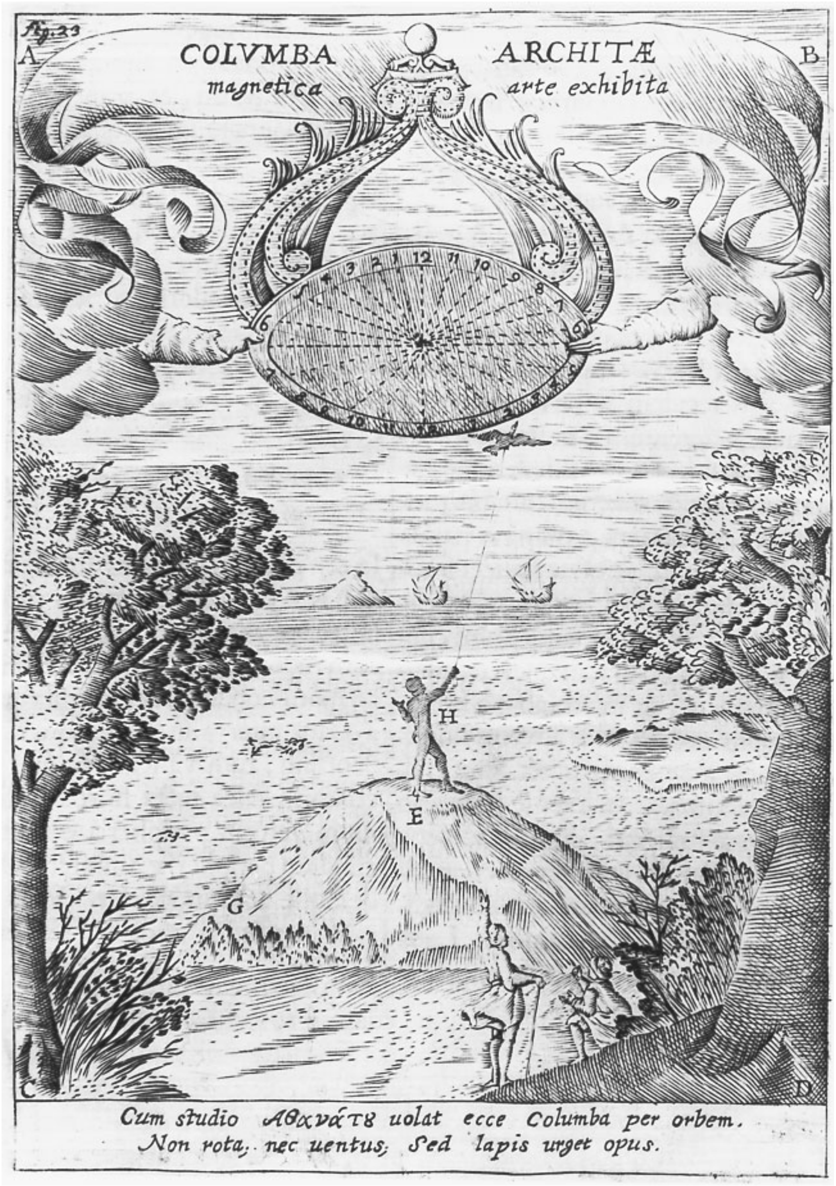

Figure 4
The dove of Architas. Source: Giorgio de Sepi, *Romani Collegii Societatis Iesu Musaeum Celeberrimum* (Amsterdam, 1678). Courtesy of Elmer Belt Library of Vinciana, University of California, Los Angeles.

Through a systematic examination of the experimental corpus canonized in the works of Cardano and Della Porta, Kircher participated in the process of resuscitating natural magic as a Christian art. Castigating Della Porta as a "seller of miracles," Kircher reproduced one experiment after another from the *Natural Magic* in order to deflate his predecessor's reputation.[68] Della Porta presented his optical illusions as experiments that unleashed hidden powers, distorting, transforming and multiplying images of the viewers who gazed upon them; Kircher created a similar set of mirrors to prove how easy it was to fool the ignorant into believing that this was a supernatural occurrence. Della Porta offered his readers potions that metamorphosed men into beasts, inducing an artificial form of madness; Kircher countered that such transformations lay in the mind rather than in the eye of the beholder.[69] (See figure 5.) In contrast to these failed experiments, however, lay his success in replicating many of the more mundane natural effects that Della Porta highlighted. Like the Renaissance magus, Kircher firmly believed in the metamorphic potential of nature; many exhibits in the museum illustrated the abilities of nature to constantly transform itself.[70] As part of his commitment to the preservation of Aristotelian philosophy, Kircher assiduously tested reports on the spontaneous generation of living creatures. In his *Subterranean World*, for example, he affirmed Della Porta's conclusion that bees generated spontaneously from the dung of oxen.[71] In this instance, upholding Aristotelian philosophy and Christianizing natural magic converged.

Natural magic played an increasingly important role in the seventeenth-century curriculum of the Jesuit colleges.[72] Despite the appearance of Della Porta's works on the Jesuit's internal Index of Prohibited Books, and the 1651 proclamation that key tenets of natural magic such as action at a distance should not be taught, a significant portion of the community of Jesuit philosophers—for example, Niccolò Cabeo, Kircher, Schott, and Lana Terzi—made natural magic an important part of the teaching of physics.[73] In his *Universal Magic of Nature and Art* (1657–1669), for example, Schott described the "lessons on artificial magic" which Kircher taught in the Roman College museum to students and visitors.[74] Understanding magic represented an important step in arriving at a more complete understanding of nature. It also proved to be an effective tool with which to imprint moral lessons on the minds of viewers. Missionaries trained at the Jesuit colleges transported crude versions of Kircher's demonstrations—particularly

Figure 5
Della Porta's metamorphosis. Source: Gioseffo Petrucci, *Prodomo apologetico alli studi chircheriani* (Amsterdam, 1677). Courtesy of Bancroft Library, University of California, Berkeley.

lodestones, clocks and optical games—all over the world, using them as proof of the superior powers of Catholic priests over native shamans.[75] Despite Kircher's repeated criticisms of Della Porta as a magus who derived his stature by playing on the fear and ignorance of others, in practice, he, like many of the Jesuits missionaries, seemed to reaffirm rather than undermine Della Porta's faith in the power of natural magic. While naturalizing magic for an educated audience, Kircher continued to point out how easily it amazed the uninitiated.[76] This sort of insight founds its practical uses in the Jesuit missionaries' appreciation of the magical qualities of seemingly mundane objects, such as books and images, as effective tools of conversion. Undoubtedly many of the fathers in the field recalled their own wonder at Kircher's "miraculous book," an early example of pop-up art (figure 6), when they observed the reactions of people unfamiliar with the physical properties of books.[77] Thus the scientific lessons learned at the Roman College could translate into practices employed by Jesuits missionaries all over the world, a natural philosophy for an evangelical faith.

Back in Rome, Kircher's exhibits transformed the technology of natural magic into moral artifacts. Natural philosophy, as the *Constitutiones* drafted by Loyola in 1556 reminded their readers, was worth studying because it would "dispose the mind for theology."[78] Acting literally on this principle, Kircher infused religious messages into many of his demonstrations. Many of his exhibits shared common features with medieval morality plays and popular broadsheets that visually summarized the most important features of Catholic theology. The famous magic lantern which he claimed as his own invention (despite its discussion by Della Porta and other magi) provided viewers with a visual synopsis of the life of Christ and allegorical images of Death, no doubt to remind them that they should give themselves over to God while there was still time. (See figure 7.) Similarly Kircher christianized Della Porta's optical experiments by having them spell out edifying messages: Christ's message of redemption and of course the motto of the Society of Jesus. (See figure 8.) He constructed a turning wheel that depicted the passions of Christ and an optical experiment that recreated the Resurrection by making an image of Christ appear to float in midair.[79] Technology, as Kircher wrote in his description of one of his most prized automata, the talking devil, was a "mechanical hieroglyph," as capable of recording the messages of its creators as the Egyptian obelisks that occupied so much of his intellectual energy.[80]

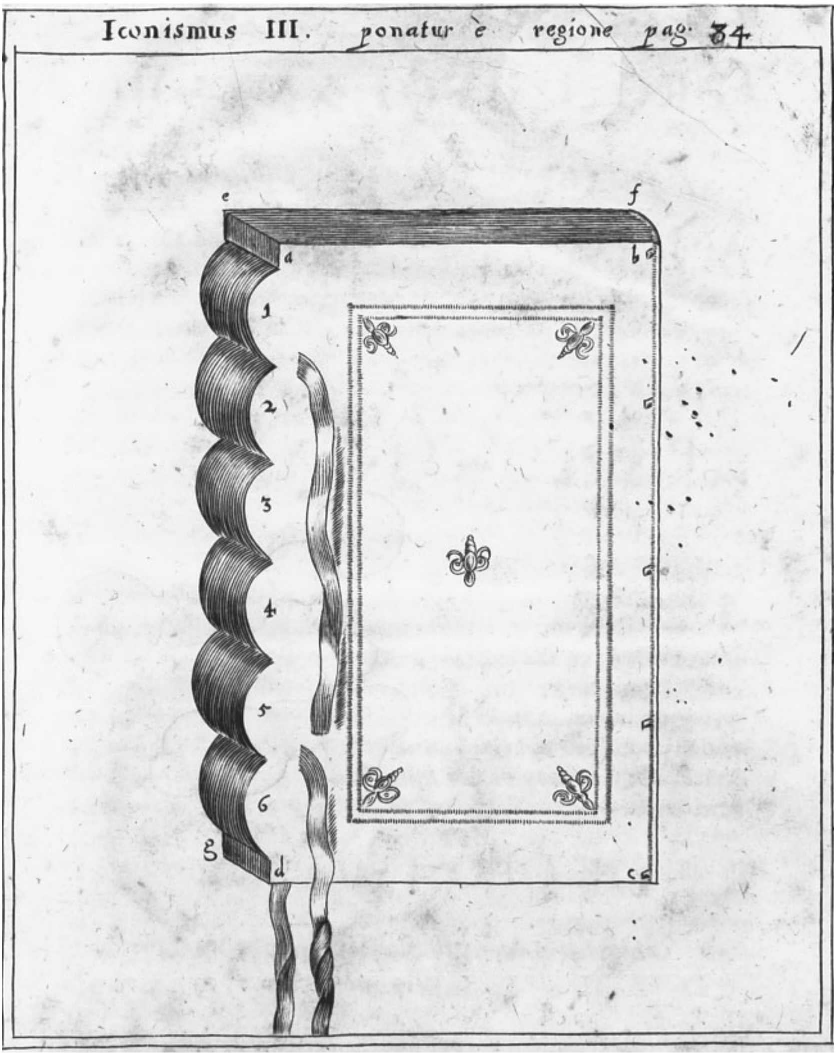

Figure 6
Magic book. Source: Gaspar Schott, *Ioco seriorum naturae et artis, sive magiae naturalis centuriae tres* (Würzburg, 1666). Courtesy of Bancroft Library, University of California, Berkeley.

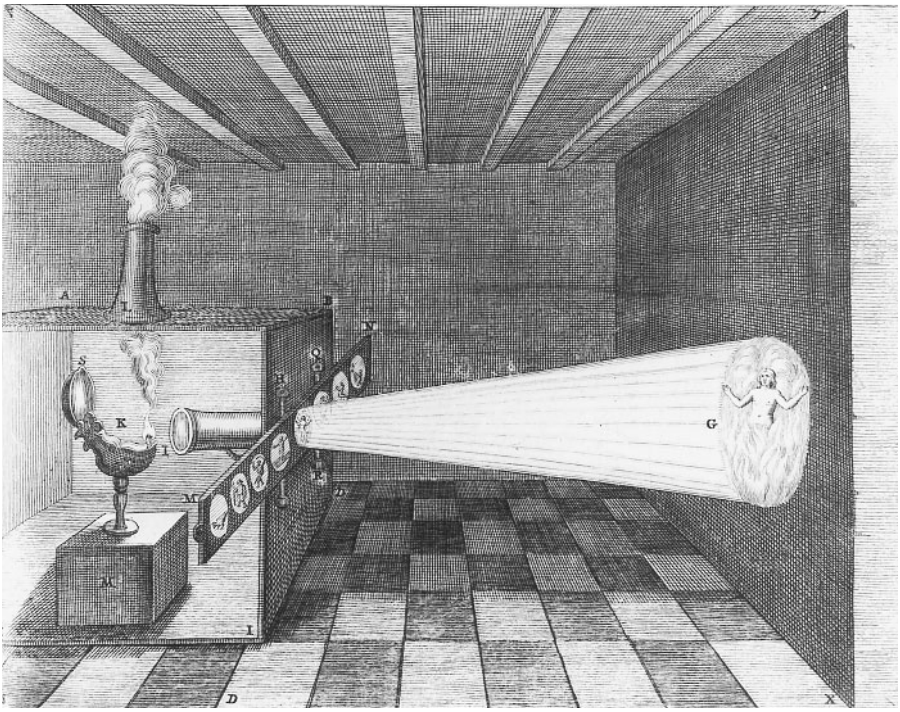

Figure 7
Magic lantern. Source: Giorgio de Sepi, *Romani Collegii Societatis Iesu Musaeum Celeberrimum* (Amsterdam, 1678). Courtesy of Elmer Belt Library of Vinciana, University of California, Los Angeles.

Just as Kircher reinvented natural magic by bringing its materials into the Roman College museum, he also redefined the purpose of other suspect philosophies by putting their artifacts to different uses. The Roman College museum contained many of the best objects produced by experimental philosophers, and reaffirmed the centrality of instruments to mid-seventeenth-century science. Galileo's telescope and microscope (improved by the Jesuit instrument makers), the natural paradoxes that confounded the Accademia dei Lincei, and the air pumps, barometers, and thermoscopes prized by the Royal Society and the Accademia del Cimento all found a place in the gallery.[81] Kircher's encyclopedic definition of knowledge made it impossible to exclude objects simply because their inventor was not Catholic or their canonical use ran counter to prevailing orthodoxies. Like the Jesuit encyclopedias that juxtaposed the conclusions of Cardano and

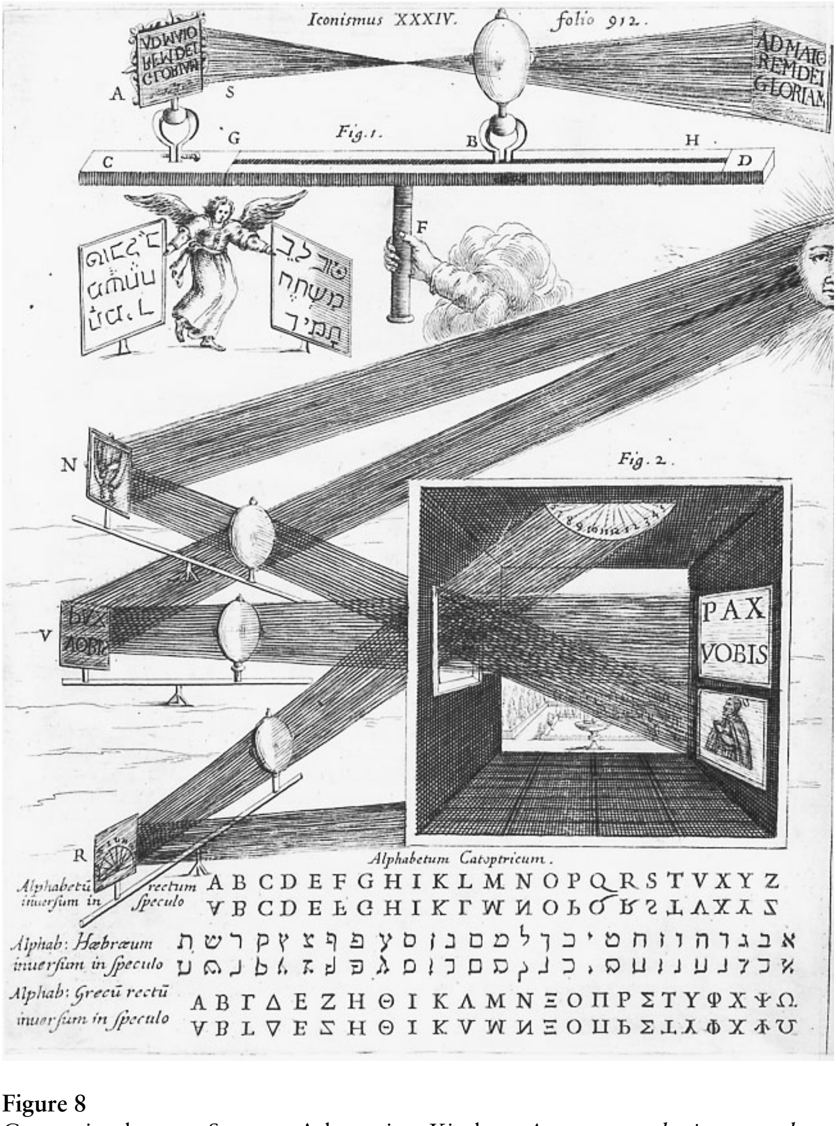

Figure 8
Catoptric theater. Source: Athanasius Kircher, *Ars magna lucis et umbrae* (Amsterdam, 1671). Courtesy of Bancroft Library, University of California, Berkeley.

Della Porta to those of Bacon and Boyle, his museum collected all the materials that the seventeenth-century community of philosophers offered. Through their display and manipulation, Kircher developed his conclusions about their proper significance. In doing so, he hoped to convince his contemporaries who rejected the authority of the ancients that traditional natural philosophy, as reconstituted by the Jesuits, could accommodate many of the techniques and findings of the new experimental philosophy.

In his *Experimental Kircherian Physiology* (1675), containing 300 of Kircher's most successful experiments, Johann Koestler described his master as "the prodigious miracle of our age who has excited the admiration of the whole world by innumerable experiments on which he has based his universal sciences."[82] Like the Renaissance naturalists who strove to revive Aristotle's empirical program through the collection of data, or the members of the Royal Society who derived their Baconian "matters of fact" from the contemplation of objects, Jesuit natural philosophers increasingly incorporated material culture into their scientific activities. In many respects, the Jesuits were uniquely situated to undertake such an enterprise. The importance of observation in Jesuit missionary culture contributed to its appearance in the Jesuit colleges, where prospective missionaries and teachers trained. In the Roman College museum, the artifacts that accompanied missionary reports to Rome and the artifacts of experiment found common ground. All were subjected to similarly intensive investigation, for Jesuit scholars, like many of their contemporaries, were also in the process of determining the criteria for good knowledge.

In presenting his museum as the material embodiment of his philosophical principles, Kircher participated in the scientific culture of demonstration that was emerging throughout Europe. Like many seventeenth-century natural philosophers, he realized that it was not enough to prove or deny a physical proposition through recourse to logic. The first and final point of rebuttal lay in the "sense experiences" that objects yielded. As his protégé Petrucci explained, Kircher did not wish to be one of those "unexperimented persons who asserts too easily the belief that they have seen [something] with their own eyes."[83] This was a principle that Kircher reaffirmed constantly. He wrote in his *Lodestone or the Magnetic Art*: "I have introduced nothing, however small, into this book which could not be, so far as lies within my power, personally tested and established."[84] Thus, the artifacts in the Roman College museum served two purposes: they supported the tenets which Kircher upheld, and they denied the validity of philosophical positions which he deemed suspect.

Kircher's demonstrations publicly strengthened the official Catholic position on a wide range of scientific theories, even if they privately undermined the whole point of the enterprise by constantly emphasizing the importance of kinds of learning that increasingly rejected an Aristotelian world view. In Kircher's museum, one could explore the power of machines to remake knowledge without endangering one's immortal soul. While accepting the idea that knowledge had to be tested by philosophers in public demonstrations, Kircher rejected the notion that tradition would falter before the evidence of the senses; a new procedure, in other words, did not always lead to new knowledge. Where nature was ambiguous, as often occurred in such trials, God was decisive.[85] Kircher's air pump, for example, existed to demonstrate the fallibility of this quintessentially anti-Aristotelian instrument. Its inability to create a vacuum lent further weight to the truths of Aristotelian physics. Similarly, perpetual motion machines gave testimony to the impossibility of infinite movement. "Kircher exhibits different experiments on perpetual motion in his museum, which he reproves rather than assists," wrote De Sepi.[86] Kircher capitalized on the fascination with Torricelli's tube not to affirm the presence of a vacuum in an inverted tube, which he did not believe existed, but to introduce visitors to the fascinating properties of mercury. (Schott, for example, invited readers to witness the "miraculous motion of mercury exhibited" in the Roman College museum.[87]) Through the constant production of spectacle, Kircher attempted to revive support for ancient views of nature by demonstrating that understanding nature was not a simple task and that nature's complexity might better be captured in the esoteric writings of antiquity than in the transparency of an experiment. And, as Kircher often reminded his readers, most experiments were not self-evident.

When the community of naturalists seemed on the verge of proclaiming a new theory about fossils, Kircher rose to the challenge. Like the lodestone, fossils were a central feature of his claim that the universe was bound together by unseen forces; their ability to mimic flora and fauna provided incontrovertible proof of nature's occult powers. Conducting numerous tests to prove the existence of the *vis spermatica*, the universal generative principle that spread nature's seed throughout the world, Kircher presented fossils as a product of the lapidifying juices that coursed through the veins of the earth in search of something to resemble. Unable to experimentally reproduce a fossil, he settled instead for a series of demonstrations that exhibited nature's ability to spontaneously form images, calcifying urine, producing samples of his famous *arbor metallica*, performing "crystallogenesis," and mixing chemicals to produce a marbling effect in stone.[88] By analogy, Kircher argued, fossils were sublime examples of nature's aesthetic powers. He knew well the research of friends such as Steno, who argued that fossils were the calcified remains of something that was once living. But such knowledge did not diminish his belief that the lapidifying juices that might encase a shark's tooth in stone could also produce images of Christ on the cross, entire cities, exotic animals, and just about anything else that the active forces of Nature cared to create in stone.

Kircher's commitment to these principles ensured his prominence within the debates about spontaneous generation. When the Tuscan naturalist Francesco Redi launched his attack on the idea of spontaneous generation, describing the generative parts of insects with the aid of a microscope, Kircher observed "subterranean animals" under his own microscope in order to contradict his rival.[89] He further entertained visitors with demonstrations designed to invalidate Redi's findings at the Medici court. Schott recalled one experiment in which "herbs and flowers [were] artificially produced in a glass vial" as further proof that the Aristotelian understanding of nature could survive the onslaught of the new philosophy.[90] In Jesuit hands, the instruments that lent authority to the claims of the new science became tools with which to reinsert doubts about the validity of new ideas. By appropriating the tools and techniques of their adversaries, Jesuit natural philosophers reminded their audience that experimental knowledge was a universally valid approach to learning that complicated the debates about how to interpret nature before it might clarify them.

Despite Kircher's attempts to make his museum the embodiment of Catholic orthodoxy, in the end his desire to accommodate all aspects of natural philosophy undermined the ostensible premise of his encyclopedia, and it is not clear how strongly committed he was to the more conservative views of the Catholic Church. The inclusion of hermetic, magical, and pagan artifacts rendered the museum suspect in the eyes of contemporaries intent on restoring Catholic natural philosophy to its pristine state. Yet another group found Kircher's perpetual fascination with experimental philosophy problematic because, like the missionaries who occasionally went native, he seemed too sympathetic to and even admiring of the ideas he criticized. The decision to make the lodestone the symbolic center of the museum is a case in point. While lodestones embodied Kircher's contention that the world was ruled by occult forces, in a different context they were central to the argument for heliocentrism, a position antithetical to the teachings of the Society of Jesus.[91] Kircher, an avid reader of Gilbert and Kepler, knew this well. The lodestone embodied the paradoxical attractiveness of the new philosophy, even for the most tradition-bound Aristotelians, and its presence in the Roman College museum highlighted all the difficulties that the synthesis of the new learning and the old entailed. Rather than refuse to display this contentious object, Kircher made it the central spectacle of his museum, just as he, like many Catholic astronomers, had armillary spheres that demonstrated the Copernican system. However much Kircher attempted to shape the interpretation of the lodestone to conform with the teachings of the Catholic Church, he implicitly allowed viewers to form their own opinions by encouraging them to see knowledge as something demonstrable. Certainly the number of natural philosophers willing to communicate with Kircher, despite their strong differences of opinion on the most basic scientific principles, suggests that many contemporaries viewed the Roman College museum as a laboratory of knowledge whose value lay beyond the interpretations Kircher imposed on his artifacts, in the objects themselves.

Ultimately, Kircher's decision to present his findings as a form of experimental knowledge undermined the strengths of his claims. Initially the desire to experiment gave him added status within the community of natural philosophers. Writing to Benedict de Spinoza in 1665, Henry Oldenburg argued that Kircher deserved more credit than he often was given. His attempts to utilize the technique of the new science set him apart from the other peripatetics. "I have turned over part of Kircher's *Subterranen World*," he wrote, "and all his arguments and theories are no credit to his wit, yet the observations and experiments there presented to us speak well for the author's diligence and for his wish to stand high in the opinion of philosophers." One month later, Oldenburg revised his opinion. Attempting to replicate the findings reported by Kircher, he wrote to Boyle that the "very first Experiment singled out by us out of Kircher" had failed, "and yt 'tis likely the next will doe so too."[92] Once other natural philosophers discovered that they could not reproduce the results of Kircher's experiments, his credibility was seriously damaged. Jesuit experiments often succeeded in Jesuit colleges and other Catholic centers of learning but nowhere else, but this was also true of many experiments made by the same Royal Society members who censured Kircher's work while waiting avidly for each book to appear. When Petrucci reported that Kircher had experimented successfully with the cobra's stone in 1663 "in the presence of many Fathers and most learned men" and then had his results confirmed by the physicians at the imperial court in Vienna, he defined the parameters of the Catholic scientific community.[93] Unable to persuade members of the Accademia del Cimento and the Royal Society that he had proved his point, Kircher contented himself with the fact that he had made Catholic knowledge experimental. He had founded no new science that conformed to the principles set forth in the writings of Bacon, Galileo, and Descartes, but within his own natural philosophical tradition he was the "Hercules . . . among writers," the creator of an infinite number of new sciences that contributed to the perfection of knowledge.[94]

Nobles, Philosophers, and Missionaries

While Kircher's natural philosophy evoked a variety of reactions from his contemporaries, from admiration to skepticism, they universally praised his skill as a cultural broker. Francesco Redi described him as the "most celebrated man of letters in Europe," and many perceived him to be the "arbiter and dictator of all arts and sciences."[95] As curator of the Roman College museum, Kircher occupied a unique position in his world. The growing popularity of the museum and his tireless efforts to promote his work through a steady stream of publications contributed to his reputation as a man who seemed to know absolutely everything. "The marvels that you deigned to show me in your most curious Gallery," wrote Filippo Sbarra, "confirmed that esteem that I had formed of your profound genius from reports of [your] fame."[96] By the 1660s he had become one of the most important members of the republic of letters. Travel guides increasingly directed visitors to Kircher when they came to Rome. "Does the conference of learned persons please you?" wrote Jacob Spon. "See Father Kircher for unknown languages and mathematics."[97]

The popularity of the Roman College museum often made it difficult for Kircher to fulfill his obligations at the college, though he eventually had no official teaching obligations since custodianship of the museum and his endless research projects occupied all of his time. In 1675 he complained to Hieronymus Langenmantel: "At the time of Jubilee, a great multitude of visitors, dignitaries of all types, and learned men come to me without intermission daily to see my museum. I am so held up by dealing with them that I scarcely have time, not only for my studies, but even for my normal spiritual duties."[98] Correspondents besieged Kircher with requests to visit his museum or to admit their friends, family, and patrons when they came to Rome. From Florence, Filippo Nardi wrote that to see the Roman College museum was his "greatest desire." Baldassar Sozzifanti, whose brother was the rector of the Jesuit College in Siena, recalled how lucky he was to have seen "your noble, ingenious and famous Gallery in Rome."[99] Cesare Paleari requested that his patron, Signor Lazzaro of Corfu, "be introduced to your famous Museum" and shown the sites of Rome.[100] In accordance with the civil norms of early modern society, visitors presented such letters of introduction at the entrance to the museum, where Kircher and his assistants determined whether the bearers were worthy of admission. (See figure 9.) Though not evident in the illustration of the museum, which places Kircher and his visitors in the middle of the museum, a gate that "prohibited free access" physically barred visitors from entering unannounced. As Filippo Bonanni remarked, "only from time to time were locals as well as foreigners . . . allowed in."[101]

Kircher measured his success not only by the number of visitors who came to the gallery and subsequently praised its contents in their reports but also by the quantity of letters addressed to him in Rome. The "reciprocal commerce of letters" was a defining aspect of his identity as a philosopher and collector.[102] Among the artifacts worthy of mention in the Roman College museum, De Sepi noted the presence of twelve volumes of correspondence: ". . . twelve folio Tomes of Letters are contained in the Kircherian Museum, collected for forty years." These letters, De Sepi assured his readers, came not only from "Pontiffs, Emperors, Cardinals and Imperial Princes but also learned Philosophers, Mathematicians and Physicians throughout the entire world" who wrote "in various languages." Like the portrait gallery, the inscriptions publicizing the gifts of important patrons, and the catoptric device containing "the effigies of various Patrons

Figure 9
Kircher greeting visitors. Source: Giorgio de Sepi, *Romani Collegii Societatis Iesu Musaeum Celeberrimum* (Amsterdam, 1678). Courtesy of Elmer Belt Library of Vinciana, University of California, Los Angeles.

positioned upside down . . . flying in midair," Kircher's collection of letters paid tribute to his fame within the world of learning.[103] They remain the best source for understanding his position in the philosophical community at the height of the scientific revolution.

The Roman College museum and the world Kircher created around it was a microcosm of the social universe inhabited by the Jesuits. From his letters as well as his publications, we gain a fairly precise idea of the audience which natural philosophers within the Society of Jesus addressed. As Kircher wrote in his *Magnetic Kingdom of Nature*, he intended his experiments for the "investigation of the learned," the "admiration of the ignorant and uncultured," and the "relaxation of Princes and Magnates." Elsewhere he referred to his natural philosophy as "exhibited in the Republic of Letters."[104] These different purposes underscored not only the complexity of his task but also his social astuteness. Unwilling to limit his audience, Kircher created scientific spectacles designed to please everyone. For scholars, he offered the pursuit of knowledge; for princes, an approved pastime to fill their leisure. For the curious patricians who secured the appropriate letters of introduction, Kircher promised a display that would satisfy the most theatrical sensibilities. The ability to anticipate the demands of his audience and the generosity with which he cited the work of his contemporaries made him one of the most successful natural philosophers of the seventeenth century. In 1662 he wrote to Raffaello Maffei: "As everyone knows, I exalt my friends and place them in the public light of the world so that everyone may recognize their merits in having communicated to me so many beautiful things."[105] Praising everyone and offending no one, Kircher made the Jesuit philosophy of accommodation a social as well as a scientific principle.

Kircher was well equipped to engage the attention of his chosen audience. His education within the Jesuit college system not only prepared him for a life of religious service but also gave him the social skills to interact with the upper classes. Like his colleague Emanuele Tesauro, who made courtly etiquette an ethical norm for the Society of Jesus in his *Moral Philosophy* (1670), or his friend Bartoli whose *Recreation of the Learned Man* (1659) presented science as patrician pastime, Kircher was well versed in the gentlemanly arts of conduct. Schott, for example, recalled a performance at the Roman College in which Kircher displayed his ability as a swordsman.[106] Gassendi and Daniel Georg Morhof praised him as a model of civil scholarship and encouraged other philosophers to emulate him.

Adept at dissembling as well as at display, Kircher collected patrons with the same facility with which he acquired artifacts.

Kircher counted the leading political, intellectual, and religious figures of Baroque Europe among his correspondents. The succession of princes, nobles, and patricians who visited the museum and wrote to Kircher enhanced the status of the Roman College as a political theater. Most Catholic princes and several potential converts (including Christina of Sweden, the Landgrave Friedrich of Hesse-Darmstadt, and the Prince of Tunisia) sent him letters, stipends, and gifts. German princes such as Duke August of Brunswick-Lüneberg entrusted their sons to Kircher's care, even though they were Protestant. And in 1664 the Elector of Hanover, Ernst August, and his wife Sophie Elizabeth, arrived.[107] Such occasions, as we already have seen in the case of Queen Christina, were opportunities to present science as a noble pursuit. In 1676, for example, the "Prince of Neoburgo" arrived with twenty courtiers at the Roman College, where he subsequently enjoyed an afternoon of music and the spectacles that "various telescopes" and the famous magic lantern provided.[108] Kircher's success with princes earned him the admiration of various courtiers. Imperial confessors, court physicians, philosophers, mathematicians, and antiquarians in cities such as Vienna and Florence kept him informed of the activities of their mutual patrons and encouraged him to pursue subjects that would please their employers.

Kircher's lavished the most attention on the Habsburg emperors, Duke August, the Medici, and the succession of Italian nobles who ascended to the papacy. The shifting political climate often determined the extent of his loyalties. When the Holy Roman Empire was in chaos and the imperial succession uncertain, he declared his allegiance to the Barberini, dedicating his *Coptic Forerunner* to the papal nephew Francesco. Perhaps Urban VIII was one of the first dignitaries to see Kircher's nascent collection when he visited the Roman College in 1640.[109] With the decline of the Barberini after the death of Urban VIII in 1642 and the growing strength of the Habsburgs at the end of the Thirty Years' War, Kircher turned his attentions to Ferdinand III, dedicating several treatises to him.[110] Indeed, the entire Habsburg family and the most prominent scholars at the imperial court in Vienna (most notably the Bohemian philosopher Marcus Marci of Kronland[111]) became patrons of the *Egyptian Oedipus* when Kircher chose to dedicate it section by section.

The Medici proved to be such disappointing patrons that Kircher did not even dedicate his *Etruscan Voyage* to them, preferring instead to offer it as gift to Duke August. During the 1650s and the 1660s, Kircher enjoyed the attentions of the Grand Duke of Tuscany, Ferdinando II and his brother Leopoldo. Leopoldo visited the museum twice and sent Kircher a copy of the Accademia del Cimento's *Essays* (1667). In 1661, Ferdinando II personally showed Kircher the sights of Tuscany during a two-week trip. Kircher responded with gifts of books and letters of fulsome praise.[112] Despite such a promising beginning, the Jesuit collector soon turned his attention back to his German patrons. Committed to supporting natural philosophers at home (such as Redi, whose attitude toward Kircher was decidedly ambivalent), the Medici had no interest in becoming Kircher's official sponsors.

By the 1660s the Roman College museum had become as much a tribute to Habsburg rule as to the papal *renovatio*. The Habsburg family crest was scattered liberally throughout the museum, embedded in optical illusions and magnetic clocks and in publications such as the *Great Art of Light and Shadow*. With the succession of Leopold I in 1658, Kircher redoubled his efforts to secure patronage in Vienna. Petrucci observed: "Since Father Kircher is greatly obliged to the Imperial Majesty for many titles, he does not neglect the opportunity to deliver those signs of devotion that are owed to the most munificent patrons."[113] Knowing Leopold I's proclivities for cryptograms and ciphers, Kircher directed at least three treatises on artificial languages to him. In 1673, he described the emperor as the "Archetype of every orthodox Monarch."[114] As his father had done previously, Leopold I responded by subsidizing the cost of Kircher's publications and increasing his annuity.[115] Despite his great distance from the imperial court, Kircher had become its pre-eminent philosopher.

Leopold I was not the only patron for whom Kircher tailored his studies. The prevailing intellectual passions among the nobility determined the majority of his projects. Hieroglyphic and emblematic studies were a standard feature of the education which young patricians received at the Jesuit colleges, an extension of the humanist education program that was courtly in origin. The *Ratio studiorum* encouraged professors of rhetoric to teach "hieroglyphics, Pythagorean symbols, apothegms, adages, emblems, and enigmas." Students who graduated from the Jesuit colleges knew how to "compose emblems," to "make or solve enigmas," and, above all, to "exercise themselves in invention."[116] They were the perfect audience for Kircher's highly rhetorical presentation of nature in the Roman College museum.

Noble knowledge appeared in many different shapes and forms.[117] Gifts of asbestos, copies of technological wonders such as Kircher's *arca musurgica* and *arca glottotatica*, and an endless stream of publications flowed out of the Roman College museum in response to the demands of patrons. In return, Kircher received portraits, medals, and exotica such as the amber-encased lizard Duke August presented to him in 1659.[118] In certain instances, Kircher chose to take his experimental program to his patrons rather than have them visit his museum. Many of the acoustic experiments recorded in his *New Way of Making Sound* (1673) were conducted in "princely palaces" rather than the Roman College; this made the science of sound a literally noble pursuit.[119]

Artificial and universal languages greatly interested Baroque rulers. Not only Leopold I, but numerous princes begged Kircher for his secrets. In the case of Duke August this subject was the common ground for the initiation of their relationship, since the German prince had written a cryptography in 1624. Kircher presented treatises such as the *New Polygraphy* (1663) as works written exclusively for princes. Readers exclaimed over their utility for "wandering Nobles and curious Princes" or, as the Spanish philosopher Juan Caramuel y Lobkowitz put it, "all Princes and lovers of curious doctrines."[120] The letter that accompanied the presentation of the *New Polygraphy* to Leopoldo de' Medici, for example, assured him that the "artificial secret of languages" had been "communicated to no one until now except His Majesty the Emperor, my most August Patron, and to the most Serene Archduke Leopold, likewise a great promoter of my studies."[121] Communication, as Kircher tactfully recognized when he presented his artificial language as inspired by a conversation with Ferdinand III, was the prerogative of princes, and the laboratory of eloquence he created in the Roman College museum was designed to attract their attention.

Kircher's interest in the art of communication was emblematic of the role he played within the republic of letters. He positioned himself at the center of a vast epistolary network that spanned the length and breadth of the learned world. In many respects, Kircher owed his entry into this community to his association with Peiresc, one of the preeminent brokers of the early seventeenth century. During his stay in Avignon, Peiresc introduced him to scholars such as Gassendi. When Kircher arrived in Rome in 1633, Peiresc's friends and associates helped him establish himself at the papal court. Peiresc's connections to this world were powerful enough that he convinced the Jesuits to accord Kircher special status. He informed Cassiano dal Pozzo in 1636: "I am writing to the most Reverend Father General of the Jesuits . . . to help the studies of the Reverend Father Athanasius Kircher, so that he may pursue his other, more important works."[122] Soon after, Kircher was relieved of his teaching duties. While the Roman College provided a home for Kircher, Peiresc never ceased to remind his protégé of the debt that he owed to the republic of letters. It was a lesson that Kircher learned well. Patrons made his publications financially possible and allowed Kircher to present his museum as an extension of court culture. But the community of scholars provided the materials for books and exhibits, and arbitrated their success and failure.

Corresponding with members of the Royal Society, the Accademia del Cimento, the Paris Academy of Sciences, and the Academy for the Curious of Nature, Kircher presented the Society of Jesus as the Roman equivalent of the leading scientific societies. As a client of dal Pozzo and Barberini, two members of the now defunct Accademia dei Lincei, he imagined his museum as the replacement for Federico Cesi's *studio*, where Roman virtuosi had congregated. In essence, the Jesuit colleges provided a version of the "colonies" which the Linceans proposed opening, with Rome as their center. While the Linceans had been relatively unsuccessful in establishing an international correspondence, Kircher soon had scholars writing to him from every corner of the world. In this capacity, Kircher was the Oldenburg of Rome and his publications were the Jesuits' version of the *Philosophical Transactions*. No topic of conversation was neglected. With Christoph Scheiner he discussed the condemnation of Galileo; with Caramuel and Leibniz he discussed his work on artificial languages. With his fellow cleric and collector Manfredo Settala he exchanged ideas about the construction of parabolic mirrors. Scholars of the occult sciences openly embraced him, introducing themselves one by one. In 1644 Caramuel wrote: "If all friends are in common, you are mine, Athanasius, since I am a good and faithful friend of your Marci."[123] Even philosophers such as Redi, Torricelli, and Huygens, who laughed at Kircher's more tradition-bound conclusions behind his back, took him seriously as a communicator, if not always as a critical consumer of knowledge. Redi dedicated his *Experiments on*

Diverse Natural Things, Particularly Those That Come from the Indies (1671) to Kircher.[124]

Such was Kircher's stature by the 1660s that younger scholars wrote to him in search of mentorship. Leibniz (who would eventually join the ranks of skeptical readers of Kircher's books) initially wrote to Rome in 1670 as an admirer of the vistas that Kircher had opened up. Corresponding with Kircher and his disciple Lana Terzi, he felt, was one of the important steps he made in developing a scientific correspondence. Leibniz wrote in 1673: "Thus I established a partly oral and partly written commerce with a few of the distinguished geniuses of our time, among whom I can name the Gentlemen of the French and English Societies for the Curious, Father Kircher, Boyle, and a great number of others." Twenty years later, he still advertised the "commerce of letters" he had enjoyed with Kircher.[125]

Leibniz's estimation of Kircher as the unofficial secretary of the Jesuit scientific community accords well with the opinions held by members of the leading scientific societies. In 1667, Oldenburg informed Boyle that the Jesuits had offered "to procure for the Royal Society a correspondency all over the world by means of missionaries."[126] Although he did not mention Kircher explicitly in this communication, it is hard to imagine any other Jesuit capable of making such an offer. While Kircher believed that confessional differences in no way impeded the scholarly exchange of information, Oldenburg was highly skeptical that Catholic natural philosophers would freely do anything for heretics. As a result, the offer fell on deaf ears. In contrast, Kircher more readily convinced the German physicians who started the Academy for the Curious of Nature to enter into such an exchange. Philipp Jacob Sachs informed Oldenburg in 1671: "In a letter from Rome, F[ather] Athanasius Kircher has promised that he will arrange for the Italians to undertake a correspondence about scientific questions with us, whence I don't doubt a great flow of advantages to our Academy, if this promise is kept in fact by one who is as German in trustworthiness as in his birth."[127] Writing letters and receiving visitors, Kircher fulfilled the ideal of service that the Society of Jesus demanded, securing the position of the Roman College as a center for scientific communication and scholarly exchange.

The increased arrival of visitors to the Roman College museum further enhanced the epistolary network Kircher had created. As Leibniz observed, the commerce of letters was part of a larger commerce of words. Disciples such as Petrucci happily recalled the many years of "learned conferences" that they had enjoyed with Kircher.[128] Often Kircher was the only philosopher whom virtuosi noted meeting during their stay in Rome. Jesuits at the various national colleges in Rome finessed introductions for scholars. Through connections at the English College, John Evelyn met Kircher in 1644. Paolo Boccone, botanist to the Grand Duke of Tuscany, encountered him in 1678. Robert Southwell, later president of the Royal Society, informed Boyle in 1661: "Father Kircher is my particular friend and I visit him and his gallery frequently." He further confirmed Kircher's image as a man versed in the art of civil conversation, adding that the Jesuit was "very easy to communicate whatever he knows; doing it as it were, by a maxim he has."[129]

The skills with which Kircher impressed visiting philosophers were nurtured in his correspondence with missionaries, a global model for the republic of letters formed in Europe. Kircher's letters reached Jesuits in Tunisia, Syria, China, the Philippines, Mexico, and Chile.[130] Having once aspired to become a missionary, Kircher often expressed envy of those in the field. To Adam Schall in China, he praised his "labors in the vineyard of Christ."[131] Others were singled out for the specific contributions they made to his projects. The *Magnetic Kingdom of Nature* was dedicated to the Mexican priest and mathematician Alejandro Fabián. The preface to the *Subterranean World* began with an encomium of Ferdinand III, Leopold I, Duke August, the Archbishop of Tyrol, and several German electors, but it ended with praise for Jesuits in Hungary and the Indies whose communications had made Kircher's study of nature more geographically comprehensive than any done by secular philosophers.[132] Kircher also acknowledged the importance of missionaries in helping him collect astronomical observations, just as he thanked astronomers in Europe such as Cassini, Riccioli, and Hevelius. From Chile, Nicolaus Mascardus commented on "the wonder of the Southern skies and the beauty of stars and planets unknown in Europe"; in Peru, Joannes Ramon de Coninck recorded the path of a comet.[133] Just as the Jesuit colleges provided the institutional base for the formation of a society of Catholic philosophers, the missionary reports fulfilled the Baconian ideal of a continuous, indiscriminate gathering of facts. The best and most interesting "facts" found their way into Kircher's museum and his publications.

Kircher's greatest missionary project was his study of China. Through his missionary contacts, he obtained a complete transcription of the Sino-Syrian monument, important evidence in the debates over the origin of Christianity in China. Nearly all the material published in his *China Illustrated* was from missionaries' reports. In the preface, he thanked Martin Martini and Michael Boim, both missionary-authors of important works on China, as well as Adam Schall, Johannes Grueber, Albert de D'Orville, Henry Roth, and the Procurator of Japan, Filippo Marino. Boim, Grueber, and Roth personally delivered precious manuscripts to Rome. D'Orville, who once had supplied Kircher with samples of the precious cobra's stone, died en route. "If anything worthy of the Christian Republic is found in these pages," he concluded with heartfelt sentiment, "I want to give these priests the credit."[134] The missionaries arriving in Rome added yet another dimension to the civil society of conversation that Kircher cultivated: they provided tangible proof that the world was an exotic and mysterious place, filled with undiscovered curiosities, just as Kircher's publications promised. Grueber and Roth stayed on in Rome to help Kircher complete his work during 1666. By the time they left, they enjoyed the status of minor celebrities, traveling to various European courts and publicizing their involvement in Kircher's latest project along the way.[135]

Kircher extended his participation in the missionary culture of observation by instructing pupils in techniques that he perceived to be particularly useful for honing their observational skills. He praised Martini, "my former pupil in mathematics [who] communicated to me many things, his keen insight having been well trained for this by his mathematical studies." Students often received parting words of advice in the form of letters to carry with them on their journey. ". . . I always bring with me that . . . most esteemed letter of my most beloved Master in Rome, as the dearest thing to me, carrying it with me to the end of this Barbaric and entirely unknown Country, situated beyond the Andes," wrote Mascardus. Mascardus further reassured Kircher that he was "always searching for a way to better accomplish and satisfy the obligations and promises made to Your Reverence before my departure."[136] Studying with Kircher, seeing his museum, and reading his books helped to prepare missionaries for their encounter with the unknown. "Here in Manila . . . I see many marvels which Your Reverence narrated in your books," wrote Giovanni Montel in 1654, despite the fact that Kircher himself never set foot outside of Europe.[137]

Kircher's fascination with missionary culture was directly connected to its importance to the continued health of the Roman College museum.

Through missionaries, chocolate, chili peppers, iguanas, armadillos, and other exotic items prized by the European elites arrived in Rome. Kircher frequently reminded correspondents of the authority he claimed in this area. When Raffaello Maffei sent him a few natural objects, he magnanimously replied that they were so wonderful "that there is no longer need to go to the Indies to observe the prodigious effects of nature."[138] The Grand Duke of Tuscany and Manfredo Settala were particularly impressed with Kircher's knowledge of China, and they eagerly requested any news that he could offer.[139] By publicizing his contact with missionaries, Kircher further secured his position as a broker between the information-gathering networks within the Society of Jesus and the circulation of knowledge in the republic of letters.

In 1666, acting on behalf a certain father at the Jesuit mission in Puebla, Kircher negotiated the presentation of "certain stuff from New Spain" to Alexander VII's nephew, Flavio Chigi:

> Having been informed by me that already almost two years have passed since Your Eminence desired some rare and exquisite things from the new world to enrich your most noble gallery, he responded that he was indescribably content with this news and that he was confused, not knowing what worthy thing he could find to bestow upon a person as dignified and eminent as the nephew of the pope; hence he immediately sent people to the most remote and foreign countries of that new world to acquire a good quantity of the most marvelous things that they can find.[140]

Kircher's intervention accomplished three goals: it offered a priest in New Spain contact with Rome, provided a Roman noble with novelties that connected him to the Americas, and allowed Kircher to demonstrate how efficiently he controlled these channels of communication (thus further ingratiating himself with a important patron). Just as the gift of a miniature obelisk to Queen Christina was a product of Kircher's unique investment in the world of learning, the presentation of missionary artifacts testified to the power and the privileges that came from Kircher's status as the most famous Jesuit natural philosopher in Baroque Europe.

Conclusion

Given the extent to which the scientific culture of the Roman College museum was bound to the activities of its creator, the Society of Jesus found it difficult to maintain the Roman College museum as a center of learning after Kircher's death in 1680. Despite Kircher's attempts to improve the museum in the 1670s, his failing health and his decision to prioritize the publishing of his works over the maintenance of the gallery precipitated its decline. Within a decade, little was left of the museum's splendors. When Maximilian Misson saw it in 1687, he commented on its demise: "Father Kircher's Cabinet in the Roman College was formerly one of the most curious in Europe, but it has been very much mangl'd and dismember'd: yet there remains still a considerable collection of natural Rarities, with several mechanical Engines." By the time Leibniz arrived in Rome in 1689, shortly after the death of Christina of Sweden, the museum was in danger of disappearing.[141]

Upon Kircher's death, custody of the museum was placed in the hands of his assistant—probably De Sepi, author of the *Most Celebrated Museum of the Roman College* (1678). If it was De Sepi, he proved unequal to the task. His successor, the Jesuit naturalist Filippo Bonanni, wrote: "After this [father] left Rome, the key to the Gate fell into the hands of many and various inexperts [were] introduced here at the slightest instance, secular people of every condition. In short time, the machines made by Father Kircher became weakened and broken, and many things were taken." Only four of the obelisks remained. By 1698, when Bonanni was appointed custodian, the museum "seemed a Cadaver of the Gallery celebrated until that time." Rather than being the pride of the Society of Jesus, the museum had become an embarrassment. With some indignation, Bonanni remarked: "Foreigners enticed by its fame felted cheated when they were admitted and I often heard many persons of note say that it was not decorous of the Company [of Jesus] and the Roman College to show it. Many in the know rightfully blamed [them for] the betrayal and ingratitude shown towards the defunct Benefactors."[142]

Bonanni, a well-known collector in his own right and a vocal champion of Aristotelian natural philosophy, immediately set about restoring the museum. The corridor was enclosed, fifteen leaded windows were added, the ceiling of the main hall was painted, and sixty cupboards and fifteen chests were placed in two adjacent rooms. In 1702, Bonanni persuaded Clement XI to enact legislation granting a permanent stipend to the museum so that its survival would not depend solely on the generosity of individuals. Furthermore, "entrance to any person whatsoever was closed . . . so that in future years they could neither destroy that which had been built nor alienate what the Roman College had acquired."[143] At the encouragement of Monsignor Giovanni Ciampini, Bonanni composed a new catalogue, *Kircherian Museum* (1709), to publicize the revival of the museum. As other projects, such as Bonanni's unfinished *Library of Jesuit Authors* indicate, his task was to restore the Society of Jesus to its former intellectual glory.[144]

The Roman College museum reopened with great fanfare. In 1718, Clement XI visited the museum, and Bonanni immediately led him to his portrait, now displacing the images of Alexander VII and Leopold I. For several decades, at least, the perpetuity of the museum was assured.

Fathers Orazio Borgondio Bresciano (1725–1741), Contuccio Contucci di Montepulciano (1741–1761), and Anton Maria Ambrogi (1761–1772) succeeded Bonanni as custodians. During this period, the Marchese Alessandro Capponi and King August of Poland made donations to the museum. Other scholars revived some of Kircher's work; for example, Johannes Laurentius Draganich published a *Treatise on Subterranean Animals and Insects Excerpted from the Works of the Reverend Father Athanasius Kircher, S. J.* (1741). In 1773, Giovanni Antonio Battarra reissued Bonanni's catalogue, with emendations, as a *History of Natural Things . . . in the Kircherian Museum*.

Not coincidentally, the renewal of interest in the Roman College museum during the late eighteenth century occurred in 1773, the same year that the Society of Jesus was suppressed. While the papacy wondered what should be done with the gallery, Bonanni's exhibits were dismantled and the objects dispersed throughout Rome. They returned briefly to the Roman College after the restoration of the Society in 1814, but they did not remain in the hands of the Catholic Church for long. In 1870 the Italian government confiscated the remnants of Kircher's museum in one of its efforts to create a cultural patrimony to enrich the identity of the new nation. Today fragments of the Roman College museum can be found in various museums around Rome[145]; however, the museum itself, as Kircher and his contemporaries imagined it, exists only in Kircher's manuscripts and published works, though it has recently been reconstructed for a temporary exhibit in Rome.

Collecting was an important cultural strategy for Baroque philosophers and an integral part of the intellectual revival of the Catholic world in the wake of the Reformation. The Roman College museum was one of the important settings from which the Jesuits staked their claim to be participants in the new scientific culture of the seventeenth century. Some years ago, William Ashworth suggested that "the very factors that made the Society such a successful religious order, and set it apart from all others, also figured strongly in Jesuit scientific work, isolating it irretrievably from the main currents of the scientific revolution."[146] Yet a close inspection of the activities at the Roman College museum does not bear out this assertion, and increasingly we must consider how much scientific societies learned and benefited from the Jesuits' idea of intellectual community and transmission of knowledge. Though Kircher interpreted the natural world in a manner alien to the sensibilities of philosophers who accorded religion a less intimate role in knowledge, or whose religious image of the world was not Catholic, he nonetheless exemplified the extent to which Baroque scientific culture accommodated the new within the framework of the old, and put it all on display.[147] Attuned to the latest techniques employed by proponents of the new experimental philosophy and eager to incorporate them into his own work, Kircher reflected the resiliency of traditional learning at a moment when it seemed an unlikely source for new insights. As an admirer of the new scientific societies, a friend of leading natural philosophers, and a client of multiple patrons, he was an astute observer of the transformation of the mid-seventeenth-century philosophical community, and he was eager to contribute to the growing appetite for new kinds of knowledge.

Kircher's numerous published works and his voluminous correspondence are largely unread and unappreciated today, and they are filled with what we, like Huygens, might describe as "nothing but a heap of unreasonable stuff." Nonetheless, they are a treasure trove for anyone seeking to reconstruct the global shape of knowledge in the seventeenth century. Neither Kircher nor his order was solely responsible for this change, but they were crucial to its realization.[148]

Acknowledgments

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Notes

1. Zakiya Hanafi, *The Monster in the Machine: Magic, Medicine, and the Marvelous in the Time of the Scientific Revolution* (Durham, 2000), p. 70. For a more detail discussion of the material culture of Kircher's museum, see *Athanasius Kircher: Il museo del mondo*, ed. E. Lo Sardo (Rome, 2001).

2. The main studies of Kircher that I have drawn upon in this essay are the following: P. Conor Reilly, *Athanasius Kircher S. J.: Master of a Hundred Arts* (Wiesbaden, 1974); Valerio Rivosecchi, *Esotismo in Roma barocca: Studi sul Padre Kircher* (Rome, 1982); *Enciclopedismo in Roma barocca: Athanasius Kircher e il Museo del Collegio Romano tra Wunderkammer e museo scientifico*, ed. M. Casciato et al. (Venice, 1986); "Athanasius Kircher und seine Beziehungen zum gelehrten Europa seiner Zeit," in *Wolfenbüttler Arbeit zur Barockforschung*, ed. J. Fletcher (Wiesbaden, 1988); Dino Pastine, *La nascita dell'idolatria: l'Oriente religioso di Athanasius Kircher* (Florence, 1978). The most interesting contextualization of Kircher's work remains that on pp. 311–345, 419–450 of R. J. W. Evans, *The Making of the Habsburg Monarchy 1550–1700: An Interpretation* (Oxford, 1979). For a basic introduction to Kircher, see the following: Joscelyn Godwin, *Athanasius Kircher: A Renaissance Man and the Quest for Lost Knowledge* (London, 1979); Eugenio Lo Sardo, *Iconismi e mirabilia da Athanasius Kircher* (Rome, 1999); Ingrid Rowland, *Ecstatic Journey* (Chicago, 2000); *The Great Art of Knowing: The Baroque Encyclopedia of Athanasius Kircher*, ed. D. Stolzenberg (Stanford, 2001).

3. Pontificia Università Gregoriana (hereafter PUG), Kircher, ms. 560 (VI), f. 111 (Rome, October 23, 1671), in Rivosecchi, *Esotismo in Roma barocca*, p. 141. See also ms. 559 (V), f. 140 (Rome, October 17, 1670).

4. For a discussion of the broader significance of collecting to early modern culture, see Paula Findlen, "The Museum: Its Classical Etymology and Renaissance Genealogy," *Journal of the History of Collecting* 1 (1989): 59–78; Findlen, *Possessing Nature*; Oliver Impey and Aarthur MacGregor, eds., *The Origins of Museums: The Cabinet of Curiosities in Sixteenth- and Seventeenth-Century Europe* (Oxford, 1985); Adalgisa Lugli, *Naturalia et mirabilia: Il collezionismo enciclopedico nelle Wunderkammern d'Europa* (Milan, 1983); Giuseppe Olmi, *L'inventario del mondo. Catalogazione della natura e luoghi del sapere nella prima età moderna* (Bologna, 1992); Krzysztof Pomian, *Collectionneurs, amateurs et curieux. Paris, Venise: XVIe–XVIIIe siècle* (Paris, 1987); Julius von Schlosser, *Die Kunst- und Wunderkammern der Spätrenaissance* (Leipzig, 1908).

5. For a survey of museums in seventeenth-century Rome (which, interestingly, does not include Kircher's museum), see Giovan Pietro Bellori, *Nota delli musei, librerie, galerie, et ornamenti di statue e pitture ne' palazzi, nelle case e giardini di Roma* (Rome, 1664). For a discussion of one of the most noteworthy Roman collectors, see *Cassiano dal Pozzo. Atti del Seminario Internazionale di Studi*, ed. F. Solinas (Rome, 1989).

6. See Mercati's posthumous *Metallotheca* (Rome, 1717). See also Bruno Accordi, "Michele Mercati (1541–1593) e la Metallotheca," *Geologica Romana* 19 (1980): 1–50; Alix Cooper, "The Museum and the Book: The Metallotheca and the History

of an Encyclopaedic Natural History in Early Modern Italy," *Journal of the History of Collections* 7 (1995): 1–23.

7. Mercati, *Gli obelischi di Roma*, ed. Gianfranco Cantelli (Bologna, 1981), p. 292. See also Erik Iverson, *Obelisks in Exile*, volume1: *The Obelisks of Rome* (Copenhagen, 1968); Cesare d'Onofrio, *Gli obelischi di Roma*, second edition (Rome, 1967).

8. For a broader overview of these issues, see Rivka Feldhay, "Knowledge and Salvation in Jesuit Culture," *Science in Context* 1 (1987): 195–213; Rivka Feldhay and Michael Heyd, "The Discourse of Pious Science," *Science in Context* 3 (1989): 109–142; William J. Ashworth Jr., "Catholicism and Early Modern Science," in *God and Nature*, ed. D. Lindberg and R. Numbers (Berkeley and Los Angeles, 1986).

9. Steven J. Harris, "Transposing the Merton Thesis: Apostolic Spirituality and the Establishment of the Jesuit Scientific Tradition," *Science in Context* 3 (1989), p. 53.

10. Ibid., p. 55. For a general overview of the institutional structure of Jesuit scientific teaching, see François de Dainville, "Enseignement des sciences," in his *L'education des jesuites (XVIe–XVIIIe siècles)* (Paris, 1978). Schott supervised the Jesuit collection at the college in Würzberg; Lana Terzi supervised the one in Brescia.

11. Gian Paolo Brizzi, *La formazione della classe dirigente nel Sei-Settecento: I seminaria nobilium nell'Italia centro-settentrionale* (Bologna, 1976); Gian Paolo Brizzi, ed., La "Ratio studiorum." *Modelli culturali e pratiche educative dei Gesuiti in Italia tra Cinque e Seicento* (Rome, 1981).

12. For a brief discussion of Schall's career, see Jonathan Spence, *To Change China: Western Advisers in China 1620–1960* (New York, 1980; 1969), pp. 3–33.

13. On Jesuit travel, a good starting point is Steven J. Harris, "Mapping Jesuit Science: The Role of Travel in the Geography of Knowledge," in *The Jesuits*, ed. J. O'Malley et al. (Toronto, 1999).

14. Kircher, *China illustrata* (Muskogee, 1987), p. 99. In his instructions to missionaries, Loyola counseled: "Finally if there are other things that may seem extraordinary, let them be noted, for instance, details about animals and plants that either are not known at all, or not of such a size, etc. And this news . . . may come in the same letters or in other letters separately." Cited in Donald Lach, *Asia in the Making of Europe. I. The Century of Discovery* (Chicago, 1965), p. 319 (Loyola to Gaspar Barzaeus, February 24, 1554).

15. Ashworth, "Catholicism and Early Modern Science," pp. 154–160. This situation is now being remedied by volumes such as *The Jesuits*, ed. O'Malley et al. (Toronto, 1999).

16. For the details of the donation, see PUG, Kircher, ms. 558 (IV), f. 142 (May 7, 1651); Archivum Romanum Societatis Iesu (hereafter ARSI), *Fondo Gesuitico* 1069/5, III, n. 1 (November 13, 1651).

17. Laurie Nussdorfer, *Civic Ritual in the Rome of Urban VIII* (Princeton, 1992); Richard Krautheimer, *The Rome of Alexander VII 1655–1667* (Princeton, 1985); Rudolf Wittkower and Irma B. Jaffe, eds., *Baroque Art: The Jesuit Contribution* (New York, 1972); Margaret Murata, *Operas for the Papal Court, 1631–1668* (Ann Arbor, 1981).

18. L. de Guillelmus, "Amphitheatrum Christina Amazonis Olim Christinae nunc Marie Alexandrae (1656)," in *Queen Christina of Sweden and Her Circle*, ed. S. Åkerman (Leiden, 1991), p. 226.

19. Riccardo Villoslada, *Storia del Collegio Romano dal suo inizio (1551) alla sorpressione della Compagnia di Gesù (1773)* (Rome, 1954), pp. 276–277. For further details of Christina's visit, see Michael John Gorman, "'From the Eyes of All' to 'Usefull Quarries in philosophy and good literature': Consuming Jesuit Science, 1600–1665," in *The Jesuits*, ed. O'Malley et al., pp. 175–178; Findlen, "Un incontro con Kircher a Roma," in *Athanasius Kircher*, ed. Lo Sardo, pp. 44–46.

20. Biblioteca Apostolica Vaticana (hereafter BAV), Barb. Lat. 6499, f. 120 (Rome, October 15, 1655). As a prominent convert himself, Holstenius was assigned a special role in Christina's progress toward Rome.

21. Giorgio De Sepi, *Romani Collegii Societatis Iesu Musaeum Celeberrimum* (Amsterdam, 1678), p. 45. For more on Christina's interest in alchemy, see Wilma di Palma et al., eds., *Cristina di Svezia. Scienza ed alchemia nella Roma barocca* (Bari, 1990).

22. Findlen, *Possessing Nature*, pp. 380–392.

23. De Sepi, *Musaeum*, pp. 12, 38; Åkerman, *Queen Christina*, pp. 226–227; John Fletcher, "Astronomy in the Life and Correspondence of Athanasius Kircher," *Isis* 61 (1970), p. 57.

24. Mino Gabriele, *Il giardino di Hermes. Massimiliano Palombara alchimista e rosacruce* (Rome, 1986); L. Fiorani, "Astrologi, superstiziosi e devoti nella società romana del Seicento," *Ricerche per la storia religiosa di Roma* 2 (1978): 97–162; Fabio Troncarelli, ed., *La città dei segreti. Magia, astrologia e cultura esoterica a Roma (XV–XVIII)* (Milan, 1985), passim. Åkerman (*Queen Christina*, esp. pp. 171, 262) also discusses this subject.

25. Kircher, *Oedipus Aegyptiacus* (Rome, 1652–54), volume III, p. 6.

26. Lo Sardo, *Athanasius Kircher*, pp. 102–103.

27. See Iverson, *Obelisks in Exile*; D'Onofrio, *Gli obelischi di Roma*; Rivosecchi, *Esotismo in Roma barocca*, p. 137ff.

28. PUG, Kircher, ms. 563 (IX), f. 311r; ms. 568 (XIV), f. 139r (Trapani, April 17, 1653); De Sepi, *Musaeum*, p. 11.

29. Nicolas-Claude Fabri de Peiresc, *Lettres à Cassiano dal Pozzo (1626–1637)*, ed. Jean-François Lhote and Danielle Joyal (Clermont-Ferrand, 1989), p. 134 (May 4, 1634).

30. Kircher did not translate the hieroglyphs; that was not done until after the discovery of the Rosetta Stone in 1799. But he was successful in persuading himself and many of his contemporaries that he knew what he was doing. See Erik Iverson, *The Myth of Egypt and its Hieroglyphs in European Tradition* (Copenhagen, 1961).

31. Iverson, *Myth of Egypt*, p. 73.

32. PUG, Kircher, ms. 563 (IX), f. 311r.

33. Reilly, *Athanasius Kircher*, p. 58. For Kircher's consultation with Alexander VII on various obelisks, see the letter published in Angelo Maria Bandini, *De obelisco Caesaris Augusti . . . Commentarius* (Rome, 1750), p. 102, n. 1.

34. Kircher, *Oedipus Aegyptiacus*, volume 1, n.p. (Schott to the reader). See also Kircher, *Obeliscus Pamphilius* (Rome, 1650); Kircher, *Ad Alexandrum VII Obelisci Aegyptiaci nuper inter Isae Romani Rudera offossi Interpretatio Hieroglyphica Athanasii Kircher* (Rome, 1666).

35. Kircher, *Ad Alexandrum VII Obelisci Aegyptiaci*, preface, in William S. Heckscher, "Bernini's Elephant and Obelisk," *Art Bulletin* 29 (1947), p. 174; Kircher, *Vita* (Augsburg, 1684), p. 73.

36. Daniello Bartoli, *La Cina*, ed. Bice Garavelli Montara (Milan, 1975), p. 27.

37. Kircher, *Oedipus Aegyptiacus*, volume 1, sig. C.3r; De Sepi, *Musaeum*, n.p.

38. De Sepi, *Musaeum*, pp. 12–13.

39. Fletcher, "Astronomy," pp. 65–66 (Rome, November 8, 1648).

40. Jacob Burckhard, *Historiae Bibliothecae Augustae quae Wolfenbutteli est, duobus libris comprehensa* (Wolfenbüttel, 1744), volume II, pp. 130, 132, 148. For reproductions and partial translations of these passages, see Fletcher, "Kircher and Duke August of Wolfenbüttel: Museal Thoughts," in Casciato, *Enciclopedismo*; Fletcher, "Athanasius Kircher and Duke August of Brunswick-Lüneburg."

41. Marc Fumaroli, "Cicero Pontifex Romanus: la tradition rhétorique du Collège Romain et les principes du mécénat des Barberini," *Mélanges de l'École française de Rome* 90 (1978), p. 811.

42. Gioseffo Petrucci, *Prodomo apologetico alli studi chircheriani* (Amsterdam, 1677), preface.

43. Kircher, *Ars magna lucis et umbrae* (Amsterdam, 1646), preface. For more on Kircher's theatricality, see Saverio Corradino, "Kircher e Ramus," in Casciato, *Enciclopedismo*, p. 57; Jean-Claude Brunon, "Protée et physis," *Baroque* 12 (1987), p. 21; Catherine Chevalley, "L'*Ars magna lucis et umbrae* d'Athanase Kircher: 1646 et 1671," *Baroque* 12 (1987), p. 101.

44. Casciato, *Enciclopedismo*, p. 10.

45. Patricia Reif, "The Textbook Tradition in Natural Philosophy, 1600–1650," *Journal of the History of Ideas* 30 (1969): 17–32; Charles Schmitt, "The Rise of the Philosophical Textbook," in *The Cambridge History of Renaissance Philosophy*, ed. Q. Skinner and E. Kessler (Cambridge, 1988).

46. The place of Aristotle in the seventeenth century is a desideratum; the standard study remains Guido Morpurgo Tagliabue, "Aristotelismo e Barocco," in *Retorica e barocca*, ed. E. Castelli (Rome, 1955).

47. Charles Schmitt, *Aristotle in the Renaissance* (Cambridge, Mass., 1983), p. 97; Gabriele Baroncini, "L'insegnamento della filosofia naturale nei Collegi Italiani dei Gesuiti (1610–1670), Un esempio di nuovo aristotelismo," in *Ratio studiorum*, ed. Brizzi, pp. 185–192, 213–215.

48. Ratio studiorum, in *Saint Ignatius and the Ratio Studiorum*, ed. E. Fitzpatrick (New York, 1933), p. 168. See Feldhay, "Knowledge and Salvation," pp. 195–213.

49. Peiresc, *Lettres à Cassiano dal Pozzo*, p. 161 (December 29, 1634).

50. This is briefly discussed in Joscelyn Godwin, "Athanasius Kircher and the Occult," in Fletcher, *Athanasius Kircher*, p. 17.

51. Vasoli, *Enciclopedismo nel Seicento* (Naples, 1978), p. 45. For an equally informative survey of the nature of Catholic learning during this period, see Evans, *The Making of the Habsburg Monarchy*, pp. 311–345, 419–450.

52. The classic study of hermeticism remains Frances Yates, *Giordano Bruno and the Hermetic Tradition* (Chicago, 1964).

53. For more on this subject, see Paula Findlen, "Jokes of Nature and Jokes of Knowledge: The Playfulness of Scientific Discourse in Early Modern Europe," *Renaissance Quarterly* 43 (1990): 292–331.

54. Describing a flying fish sent by missionaries in Asia, Kircher wrote: "To this day visitors to our museum can see this and other prodigies of nature, and they have been able to do so for fifteen years." (*China illustrata*, p. 172) For more on this subject, see Katharine Park and Lorraine Daston, *Wonders and the Order of Nature* (New York, 1998). On the role of spectacle in the museum, see Rivosecchi, *Esotismo in Roma barocca*, p. 57ff.

55. Kircher, *Oedipus Aegyptiacus*, volume II, p. I. classis I. 6, cited in Evans, *Making of the Habsburg Monarchy*, p. 437.

56. Bartoli, *De' simboli trasportati al morale*, cited in Mario Praz, *Studies in Seventeenth-Century Imagery* (Rome, 1964), p. 19.

57. For a broader discussion of the ars signata, see Massimo Luigi Bianchi, *Signatura rerum. Segni, magia e conoscenza da Paracelso a Leibniz* (Rome, 1987). On Kircher's condemnation of the alchemy of Paracelsus and his followers, see Martha Baldwin, "Alchemy in the Society of Jesus," in *Alchemy Revisited* (Leiden, 1990), pp. 182–187.

58. Niels Stensen, *A Danish Student in His Chaos-Manuscript 1659*, ed. H. Scheplern (Copenhagen, 1987), p. 15.

59. Ashworth, "Catholicism and Early Modern Science," pp. 156–157. See Nicolaus Steno, "Ornamenta: Monumenta, Signa, Argumenta," in *Steno: Geological Papers*, ed. G. Scherz (Odense, 1969).

60. Kircher used this image constantly throughout his treatises. See, e.g., *Ars magna sciendi* (Amsterdam, 1669), sig. ***2v; *Arithmologia* (Rome, 1665), p. 73.

61. For a more detailed discussion of Kircher's views on magnetism, see Martha Baldwin, "Magnetism and the anti-Copernican polemic," *Journal for the History of Astronomy* 16 (1985): 155–174.

62. Kircher, *Magneticum naturae regnum* (Rome, 1667), p. 3. For a broader discussion of Kircher's metaphysical and physical system, see Godwin, "Athanasius Kircher and the Occult," in Fletcher, *Athanasius Kircher*. On the piedra de cobras, see Kircher, *China illustrata*, p. 74; Petrucci, *Prodomo apologetico*, p. 8ff.

63. De Sepi, *Musaeum*, p. 18.

64. Kircher, *Magnes sive de arte magnetica* (Cologne, 1643), in Ulf Scharlau, *Athanasius Kircher (1601–1680) als Musikschriftsteller: Ein Beitrag zur Musikanschauung des Barock* (Marburg, 1969), p. 6.

65. Giambattista Della Porta, *Natural Magick* (1658), ed. D. Price (New York, 1957), p. 3.

66. For the background to Kircher's natural magic, see William Eamon, "Technology as Magic in the Late Middle Ages and the Renaissance," *Janus* 70 (1983): 171–212; Lynn Thorndike, *A History of Magic and Experimental Science* (New York, 1958), volume VII, pp. 568–575, 590–621, and passim.

67. On burning mirrors, see Chevalley, "*Ars magna lucis et umbrae*," p. 103; Della Porta, *Natural Magick*, pp. 289–304, 371–378; Petrucci, *Prodomo apologetico*, pp. 99, 128–129. On the dove of Architas and automata, see De Sepi, *Musaeum*, pp. 19–20, 60–61; Kircher, *Ars magna lucis et umbrae*, pp. 772–773; Schott, *Magia universalis naturae et artis* (Bamberg, 1672), p. 253. On Kircher's indebtedness to Cardano and Della Porta, see Adalgisa Lugli, "Inquiry as Collection," *Res* 12 (1986), p. 122.

68. Chevalley, "*Ars magna lucis et umbrae*," p. 104.

69. Della Porta, *Natural Magick*, p. 219; Petrucci, *Prodomo apologetico*, pp. 94–97.

70. Kircher's frequently described protean nature in many of his experiments (e.g., in his *Proteus Catoptricus* and *Proteus Metallorum*) highlighted this capacity (De Sepi, *Musaeum*, pp. 38, 46). See also Hanafi, *Monster in the Machine*, pp. 71–73.

71. Kircher, *Mundus subterraneus*, volume II, p. 358. For a broader discussion of the image of nature as transformative, see Findlen, "Jokes of Nature," esp. pp. 310–314.

72. Gabriele Baroncini, "L'insegnamento della filosofia naturale," esp. pp. 185–192.

73. Ibid., p. 190; Pietro Redondi, *Galileo Heretic* (Princeton, 1985), p. 89.

74. Gaspar Schott, *Magia universalis naturae et artis (1657–69)*, volume 1, Prolegomena, 23, in Baldwin, "Magnetism and the Anti-Copernican Polemic," p. 170.

75. James Axtell, *The Invasion Within: The Contest of Cultures in Colonial North America* (Oxford, 1985), pp. 100–101, 114; Michael Adas, *Machines as the Measure of Man: Science, Technology and Ideologies of Western Dominance* (Ithaca, 1989), pp. 31–32, 57–61. Equally important was the use of music as a tool of conversion (Axtell, *Invasion Within*, p. 120). This may explain the popularity of works such as Kircher's *Musurgia universalis* (1650), which missionaries reported using in the instruction of natives (PUG, Kircher, ms. 567 (XIII), f. 155, Manila, July 15, 1654).

76. Kircher, *Ars magna lucis et umbrae* (1671), p. 775. Many contemporaries viewed Kircher as a disciple of Della Porta. For example, after reading Della Porta's *Natural Magic*, Marcantonio Riviera wrote Kircher asking for his help in constructing a parabolic mirror (PUG, Kircher, ms. 568, IV, f. 173, Aquila, April 10, 1643). Georg Philipp Harsdörffer wrote to Kircher to discuss the entire corpus of natural magic (PUG, Kircher, ms. 557b, IIIb, ff. 257–259, Nuremberg, February 27, 1654).

77. Schott, *Ioco-seriorum naturae et artis, sive magiae naturalis centuriae tres* (Würzburg, 1666), Century I, p. 35: "Inter secreta manuscripta, quae Romae inter P. Athanasii Kircheri Adversaria reperi, unum est, quo liber ita artificiosè concinnetur, ut dum folia evolvuntur, omnis generis figuras ostendant, ita tamen ut in una

eademque evolutione non nisi unius generis appareant." Also discussed in Lugli, "Inquiry as Collection," pp. 119–120.

78. *Constitutions*, in *Saint Ignatius and the Ratio Studiorum*, ed. Fitzpatrick, p. 101.

79. Kircher, *Ars magna lucis et umbrae*, p. 777; De Sepi, *Musaeum*, p. 39.

80. Kircher, *Ars magna lucis et umbrae*, p. 772.

81. De Sepi, *Musaeum*, pp. 40, 47, 57; Kircher, *Mundus subterraneus*, volume II, p. 66; De Sepi, *Ars magna lucis et umbrae* (1646), pp. 834–835.

82. Johann Koestler, *Physiologia Kircheriana Experimentalis* (Rome, 1675), in Thorndike, *A History of Magic and Experimental Science*, volume VII, p. 569.

83. Petrucci, *Prodomo apologetico*, p. 79. For a similar discussion of "experience" in Jesuit mathematics, see Peter Dear, "Jesuit Mathematical Science and the Reconstitution of Experience in the Early Seventeenth Century," *Studies in the History and Philosophy of Science* 18 (1987): 133–175; Dear, "Narrative, Anecdotes and Experience: Turning Experience into Science in the Seventeenth Century," in *The Literary Structure of a Scientific Argument*, ed. P. Dear (Philadelphia, 1991).

84. Kircher, *Magnes sive de arte magnetica*, in Evans, *Making of the Habsburg Empire*, p. 338.

85. Baldwin, "Magnetism and the Anti-Copernican Polemic," pp. 159–160.

86. De Sepi, *Musaeum*, pp. 47, 57.

87. Schott, *Ioco-seriorum naturae et artis, sive magiae naturalis centuriae tres*, Century III, p. 109.

88. Kircher, *Mundus subterraneus*, volume II, pp. 2, 27, 42, 52–53, 335–336; Schott, *Ioco-seriorum naturae et artis, sive magiae naturalis centuriae tres*, Century II, p. 139. On the fossil controversies, see Nicoletta Morello, *La nascita della paleontologia nel Seicento: Colonna, Stenone e Scilla* (Milan, 1979); Paolo Rossi, *The Dark Abyss of Time: The History of the Earth and the History of Nations from Hooke to Vico* (Chicago, 1984); Martin J. S. Rudwick, *The Meaning of Fossils: Episodes in the History of Paleontology*, second edition (Chicago, 1985); Rhoda Rappaport, *When Geologists Were Historians, 1665–1750* (Ithaca, 1997).

89. Kircher, *Mundus subterraneus*, volume II, p. 87. For the opposing view of this debate, see Findlen, "Controlling the Experiment: Rhetoric, Court Patronage and the Experimental Method of Francesco Redi," *History of Science* 31 (1993): 1–30.

90. Schott, *Ioco-seriorum naturae et artis, sive magiae naturalist centuriae tres*, Century II, p. 147.

91. Baldwin ("Magnetism and the Anti-Copernican Polemic," p. 172) argues that ultimately this was why Jesuit natural philosophers discussed magnetism less after 1660. Yet lodestones continued to be displayed in the museum, long after Kircher ceased to publish on this subject.

92. A. Rupert Hall and Marie Boas Hall, eds., *The Correspondence of Henry Oldenburg* (Madison and London, 1965–86), volume II, p. 567 (London, October 12, 1665) and p. 615 (London, November 21, 1665).

93. Petrucci, *Prodomo apologetico*, pp. 8, 21. On the controversies around these experiments, see Martha Baldwin, "The Snakestone Experiments: An Early Modern Medical Debate," *Isis* 86 (1995): 394–418.

94. Daniel Georg Morhof, *Polyhistor literarius, philosophicus et practicus* (Lübeck, 1747 edition; 1688), volume II, p. 156. Chevalley ("*Ars magna lucis et umbrae*," p. 97) underscores Kircher's fondness for creating neologisms. New words established the "fact" of the new disciplines Kircher created. Foremost among these fields of inquiry, of course, were his investigations into artificial and universal languages, a subject I have not discussed in this essay. For more on this topic, see George McCracken, "Athanasius Kircher's Universal Polygraphy," *Isis* 39 (1948): 215–228; Nick Wilding, "'If You Have a Secret, Either Keep It or Reveal It': Cryptography and Universal Language," in Stolzenberg, *Great Art of Knowing*.

95. PUG, Kircher, ms. 566 (XII), f. 40 (Florence, June 24, 1675); ms. 558 (IV), f. 149 (Melitae, January 1667).

96. PUG, Kircher, ms. 564 (X), f. 150 (Rome, July 19, 1667).

97. Jacop Spon, *Voyage d'Italie, de Dalmatie, de Grece, et du Lévant, fait aux années 1675 & 1676* (The Hague, 1724), volume I, p. 26.

98. Hieronymus Langenmantel, ed., *Fasciculus epistolarum* (Augsburg, 1684), in Reilly, *Athanasius Kircher*, p. 161.

99. PUG, Kircher, ms. 555 (I), f. 271 (Florence, January 14, 1655); ms. 566 (XII), f. 29r (Perugia, December 10, 1677).

100. PUG, Kircher, ms. 562 (VIII), f. 108r (Pavia, March 16, 1664).

101. ARSI, Rom. Historia (1704–29). 138. XVI, f. 174v (Filippo Bonanni, *Notizie circa la Galleria del Collegio Romano*, 1716). Thanks to Nick Wilding, whose careful reading of the iconography of the museum has suggested more precisely which part of the museum we are supposed to see in the De Sepi illustration.

102. Kircher, *Magneticum regnum naturae*, sig. *5r.

103. De Sepi, *Musaeum*, pp. 65, 38. The correspondence is now collected in fourteen volumes (ms. 555–568) at the Gregorian University. See Fletcher, "A Brief Survey of the Unpublished Correspondence of Athanasius Kircher, S. J. (1602–1680)," *Manuscripta* 13 (1969): 150–160. The Athanasius Kircher Correspondence Project, edited by Michael John Gorman and Nick Wilding, has now made these materials available on line.

104. Kircher, *Magneticum naturae regnum*, p. 346; Kircher, *Phonurgia nova* (Campidonae, 1673), sig. Cv.

105. BAV, *Autografi Ferrajoli. Raccolta prima*. VI, f. 182 (Rome, April 12, 1662).

106. Schott, *Ioco-seriorum naturae et artis, sive magiae naturalis centuriae tres* (Bamberg, 1677), p. 18, in Lugli, "Inquiry as Collection," p. 118. On the role of Tesauro as a spokesman for the Jesuit system of etiquette, see Denise Aricò, "Retorica barocca come comportamento: buona creanza e civil conversazione," *Intersezioni* 1 (1981): 317–349.

107. Fletcher, "Kircher and Duke August of Wolfenbüttel: Museal Thoughts," in Casciato, *Enciclopedismo*, p. 287; Fletcher, "Athanasius Kircher and Duke August of Brunswick-Lüneberg," in Fletcher, *Athanasius Kircher*, pp. 120–121.

108. Villoslada, *Storia del Collegio Romano*, p. 278; Gorman, "Consuming Jesuit Science."

109. Villoslada, *Storia del Collegio Romano*, p. 275. Kircher's letters to Francesco Barberini are in BAV, Barb. Lat. 6467, ff. 37–39. Alexander VII and Kircher shared many intellectual interests. Kircher sent him manuscripts filled with descriptions of alchemical secrets, astrolabes, cryptograms, and the mystical properties of numbers; see BAV, Mss. Chigi. F.IV.44 and 64; J.VI.225; PUG, Kircher, ms. 563 (IX), ff. 300–301. Alessandro Chigi's successor, the librettist Giulio Rospigliosi, appears only once in relationship to Kircher. In 1668, one year after he became Clement IX, his family visited the Roman College museum (Villoslada, *Storia del Collegio Romano*, p. 277).

110. Kircher dedicated *Lodestone* (1641), *Egyptian Language Restored* (1644), and the second half of *Subterranean World* (1664) to Ferdinand I.

111. Fletcher, "Johann Marcus Marci Writes to Athanasius Kircher," *Janus* 59 (1972): 95–118. Marci exhibited a similar philosophical eclecticism in his own work; see Giuliano Mocchi, *Idea, mente, specie. Platonismo e scienza in Johannes Marcus Marci (1595–1667)* (Soveria Manelli, 1990).

112. On Leopoldo's visits in 1650 and 1668, see Edward Goldberg, *After Vasari: History, Art and Patronage in Late Medici Florence* (Princeton, 1988), pp. 19, 23; PUG, Kircher, ms. 564 (X), f. 165 (Rome, May 12, 1668). On Kircher's visit to Tuscany, see PUG, Kircher, ms. 558 (IV), f. 84 (Rome, September 12, 1661). On the exchange of books, see Biblioteca Nazionale Centrale, Florence, Autografi Palatini. II, 70 (Rome, May 31, 1655); PUG, Kircher, ms. 555 (I), ff. 53, 93 (Florence, August 29, 1665 and July 10, 1666); ms. 566 (XII), f. 9 (Florence, April 1, 1676); Jean-Michel Gardair, Le "Giornale de' Letterati" de Rome (1668–1681) (Florence, 1984), p. 201.

113. Petrucci, *Prodomo apologetico*, p. 18. Leopold I owned most of Kircher's books and many of Schott's (Evans, *The Making of the Habsburg Monarchy*, p. 317). For a specific discussion of the omnipresence of one Habsburg image in natural philosophy, see Ashworth, "The Habsburg Circle," in *Patronage and Institutions*, ed. Bruce Moran (Woodbridge, 1991).

114. PUG, Kircher, ms. 565 (XI), f. 7 (Rome, April 25, 1673). Kircher dedicated his *New Polygraphy* (1663), *Great Art of Knowledge* (1669), and *Tower of Babel* (1679) to Leopold, as well as his *New Way of Making Sound* (1673).

115. Fletcher, "Athanasius Kircher and the Distribution of His Books," *The Library*, fifth series, 23 (1968): 108–117.

116. Fitzpatrick, *Saint Ignatius and the Ratio studiorum*, pp. 214, 251.

117. I owe the term "noble knowledge" to Pamela Smith (*The Business of Alchemy: Science and Culture in the Holy Roman Empire*, Princeton, 1993).

118. To situate the gift-giving practices employed by Kircher in a broader context, see Findlen, "The Economy of Scientific Exchange in Early Modern Italy," in *Patronage and Institutions*, ed. Moran.

119. Kircher, *Phonurgia nova*, p. 91.

120. PUG, Kircher, ms. 555 (I), f. 126 (Herzberg, April 14, 1664); ms. 564 (X), f. 181r (Naples, August 4, 1663). Caramuel's correspondence is reproduced in Ramon

Ceñal, "Juan Caramuel. Su epistolario con Atanasio Kircher, S. J.," *Revista de filosofia* 12 (1953): 101–147. For more on artificial languages as noble knowledge, see Fletcher, "Kircher and Duke August of Wolfenbüttel: Museal Thoughts," in Casciato, *Enciclopedismo*, p. 286; Fletcher, "Athanasius Kircher and Duke August of Brunswick-Lüneberg," in Fletcher, *Athanasius Kircher*, p. 108.

121. PUG, Kircher, ms. 563 (IX), f. 99 (Rome, n.d.).

122. Peiresc, Lettres à Cassiano dal Pozzo, p. 254 (October 31, 1636). See Peter N. Miller, *Peiresc's Europe: Learning and Virtue in the Seventeenth Century* (New Haven, 2000).

123. Ceñal, "Juan Caramuel," 122 (Spira, July 26, 1644).

124. Baldwin ("The Snakestone Experiments") discusses the tensions between Kircher and Redi in some detail.

125. Paul Friedlander, "Athanasius Kircher und Leibniz. Ein Beitrag zur Geschichte der Polyhistorie im XVII. Jahrhundert," *Rendiconti della Pontificia Accademia Romana di Archeologia* 13 (1937): 229–247, esp. pp. 241–242.

126. Boyle, *Works*, volume VI, p. 277, cited in Reilly, "A Catalogue of Jesuitica in the Philosophical Transactions of the Royal Society of London (1665–1715)," *Archivum Historicum Societatis Jesu* 27 (1958): 340–341. Oldenburg's response went as follows: "I deny not but some of them are also ingenious and curious in matters of a philosophical nature; but these that are so, are I doubt not obliged, or at least think themselves obliged, to discover such observations to their own tribe, and would I believe be unwilling to communicate them to their heretics, except they were sure they would be well requited for it." For further discussion of the attitude of the Royal Society toward the Jesuits, see Clelia Pighetti, *L'influsso scientifico di Robert Boyle nel tardo '600 italiano* (Milan: Franco Angeli, 1988), pp. 93–99.

127. *The Correspondence of Henry Oldenburg*, volume VIII, p. 324 (Breslau, October 29, 1671).

128. Petrucci, *Prodomo apologetico*, p. 1.

129. Edward Chaney, *The Grand Tour and the Great Rebellion: Richard Lassels and "The Voyage of Italy" in the Seventeenth Century* (Geneva, 1985), p. 104; Reilly, *Athanasius Kircher*, pp. 18, 148. On Southwell's visit, see Boyle, *Works*, volume VI, p. 299. On Boccone's visit, see Biblioteca Nazionale Centrale, Florence, Magl. viii. 496, f. 4v (Rome, August 11, 1678).

130. For a summary of Kircher's missionary correspondence, see Josef Wicki, "Die Miscellanea Epistolarum des P. Athanasius Kircher, S. J. in Missionarischer Sicht," *Euntes Docete* 21 (1968): 221–254.

131. PUG, Kircher, ms. 563 (IX), f. 292 (Rome, April 16, 1664). In 1631 Kircher requested to be sent to China, but the astronomer Adam Schall was sent instead (Reilly, *Athanasius Kircher*, p. 123).

132. Kircher, *Mundus subterraneus*, volume 1, sig. ***v, sig. ***2.

133. Fletcher, "Astronomy," pp. 59–60; PUG, Kircher, ms. 564 (X), f. 89 (Chile, March 14, 1656); ms. 567 (XIII), ff. 135–136 (Peru, July 20, 1653).

134. Kircher, *China illustrata*, p. 6 and iv. D'Orville sent a sample of piedra de cobras in 1659; PUG, Kircher, ms. 562 (VIII), f. 36 (Macao, February 1, 1659).

135. The Grand Duke of Tuscany, Ferdinando II, mentioned Grueber's visit and inquired about the forthcoming book (PUG, Kircher, ms. 555, I, f. 45, Livorno, March 19, 1666).

136. Kircher, *China illustrata*, p. iv; PUG, Kircher, ms. 566 (XII), f. 217r (Chile, n.d.).

137. PUG, Kircher, ms. 567 (XIII), f. 155 (Manila, July 15, 1655).

138. BAV, Autografi Ferrajoli. Raccolta prima. VI, f. 185 (Rome, February 24, 1662).

139. PUG, Kircher, ms. 564 (X), f. 87v (Milan, August 22, 1668).

140. BAV, Ms. Chigiano R. V. g (37/6), in G. Inchisa della Rocchetta, "Il museo di curiosità del card. Flavio I Chigi," *Archivio della società romana di storia patria*, third series, 20 (1966), pp. 151–152, n. 18. The "father" in question was Alejandro Fabián, not a Jesuit but a close correspondent of Kircher's. Thanks to Clara Bargellini for clarifying this detail.

141. Maximilian Misson, *A New Voyage to Italy* (London, 1695), volume II, p. 139; André Robinet, *G. W. Leibniz Iter Italicum (Mars 1689–Mars 1690). La dynamique de la Republique de Lettres* (Florence, 1989).

142. ARSI, Rom. Historia (1704–29). 138. XVI, ff. 175v–177r.

143. Ibid., f. 180v.

144. In some respects, Ciampini replaced Kircher as the center of scientific activity in Rome by hosting the Accademia Fisico-Matematica in his home. See W. E. K. Middleton, "Science in Rome, 1675–1700, and the Accademia Fisicomatematica of Giovanni Giustino Ciampini," *British Journal for the History of Science* 8 (1975): 138–154; J.-M. Gardair, *Le "Giornale de' Letterati"" de Rome (1668–1681)* (Firenze, 1984). Bonanni's *Bibliotheca scriptorum Societatis Jesu* is found in the Biblioteca Nazionale Vittorio Emanuele, Rome, Fondo Gesuitico. 1334. The best biography of Bonanni remains "Elogio di P. Philippo Buonanni," *Giornale de' letterati d'Italia d'Italia* 37 (1725): 360–388.

145. Casciato, *Enciclopedismo*, pp. 23, 39. See also R. Garrucci, "Origine e vicende del Museo Kircheriano dal 1651 al 1773," *Civiltà cattolica* 30, XI, ser. 10 (1879): 727–739. The exhibit catalogue for the 2001 Rome exhibit at Palazzo Venezia is Lo Sardo, *Athanasius Kircher*.

146. Ashworth, "Catholicism and Early Modern Science," p. 160. W. E. K. Middleton ("Science in Rome, 1675–1700," p. 139) wrote, more harshly: "At no time in the seventeenth century was Rome a center of scientific progress."

147. On the comparative framework in which to view Kircher's contributions, see Findlen, "The Janus Faces of Science in the Seventeenth Century: Athanasius Kircher and Isaac Newton," in *Rethinking the Scientific Revolution*, ed. M. Osler (Cambridge, 2000).

148. Christiaan Huygens, *Oeuvres complètes*, xxi. 811, cited in Fletcher, "Astronomy," p. 59.

Pious Ambition: Natural Philosophy and the Jesuit Quest for the Patronage of Printed Books in the Seventeenth Century

Martha Baldwin

In 1661, at the age of 53, the professor of mathematics at the Jesuit college at Würzburg published a book he envisioned as "an encyclopedia of all mathematical disciplines" and dedicated it to the Holy Roman Emperor, Leopold. In his letter of dedication Schott professed to offer his book to the emperor with some trepidation. What could have unnerved the stalwart author, who had endured religious persecution and exile from his native Germany during the Thirty Years' War, two decades of tedium in Sicily (where he taught theology and philosophy), and painfully cold winters in Mainz and Würzburg? Why should this intrepid priest, respected experimenter, and accomplished teacher hesitate to offer his erudite volume to a Habsburg emperor who frequently received such tributes? As Schott explained in his dedication, he feared that his work might not measure up to his patron's lofty standards of excellence: "You are so wise that you grasp difficult mathematical doctrine; you will quickly assess whether my work is worthy or not of a Caesar."[1] The modern reader might be tempted to dismiss this as an exercise in obsequiousness, yet such an example of baroque rhetoric is quite illuminating on early modern patronage strategies in general and on publication agendas within the Society of Jesus in particular.

The astonishing production of scientific and mathematical books in the seventeenth century proceeded with the approbation and encouragement of Jesuit administrators, rectors, provincials, and superiors who anxiously supervised their charges' expenditures of time and energy. Conversely, despite the Society's insistence on self-abnegation for the greater glory of God, individual members willfully and astutely engaged in patronage strategies and such activity ultimately enhanced their personal reputation as well as that of the Order. The gratification of ambition, which might seem incongruous with the promotion of piety, may help explain some of the tensions—both creative and inhibiting—that affected the lives of Jesuit practitioners and the production of their books during the early modern period. Moreover, Jesuit authors occasionally availed themselves of the patronage system in order to evade or disregard the wishes of their superiors. For example, in 1665 Schott defied General Oliva's orders to become rector of the small Jesuit college at Heiligenstadt. Though he was not able to cash in on his prodigious publication record, Schott's reputation and standing among influential patrons—in addition to his poor health—did allow him to evade, albeit delicately, the orders of the General. Indeed, Oliva appears to have been persuaded by Schott's plea that his talents were better spent at Würzburg, whose quiet library appealed to Schott much more than the time-consuming administrative duties in the hinterlands.[2]

Recent scholarly work has examined the range and content of the burgeoning production of Jesuit mathematics and natural sciences.[3] This essay, in contrast, focuses on the cultural context within which Jesuit books on natural philosophy, mathematics, and natural history were produced and, in particular, on the self-presentation of the authors. In order to publish their books and make a name for themselves, early modern Jesuit mathematicians and natural philosophers relied heavily on a patronage system, often endorsed by their superiors who counted on their members' publications to enhance the reputation of their schools and teachers. In attempting to portray the culture within which Jesuits penned their books on natural philosophy, saw them through press, and oversaw their distribution in the republic of letters, I have examined the letters of dedication of natural philosophy books written by members of the Society and some of their correspondence relating to the production and publication of their books. I focus on the career and publication patterns of two of the Society's most prolific authors of mathematics and natural philosophy in the early modern period, Christoph Clavius and Athanasius Kircher. Indeed, so successful and productive were the two that they were freed from the need to teach the standard courses and appointed *scriptors*. As conspicuous success stories, their publication and patronage strategies deserve special scrutiny. I suggest that their astonishing rates of publication offered the Order much-appreciated opportunities to advertise the expertise of Jesuit teachers. I also argue that the hierarchy not merely tolerated but openly directed other, more obscure early modern Jesuit practitioners to seek out patrons for their books. Since neither Clavius nor Kircher can be considered representative of the Jesuit intellectual, I also examine the less glamorous figures, including those who were working at great distance from Jesuit headquarters at Rome and who might have, as Schott did, bemoaned being burdened with teaching and administrative duties in the provinces instead of teaching mathematics at the Collegio Romano.

Clavius Sets the Stage

Christoph Clavius (1538–1612) set an example for later natural philosophers in the Society to follow. He also played an important role in providing the rationale for the century's later production of Jesuit books in mathematics and natural philosophy. Best remembered today as an astronomer whose teaching provided a foil for the later Galileo, Clavius was best known in his day as a teacher of mathematics and an author of textbooks. Almost singlehanded, Clavius oversaw the establishment of mathematics as a standard part of the Jesuit curriculum, first in the Collegio Romano and then in other Jesuit colleges. Much of his accomplishment was due to his longevity (he taught for more than 50 years at the Collegio Romano) and to his energy (he saw through publication countless editions of his mathematical commentaries, enough to fill five massive folio volumes at the end of his life).

However, Clavius's beginnings gave no indication of his brilliant future. Born in Bamberg, Germany, in 1538, Clavius left his native city at the age of 16. Though it is not clear what caused him to leave his hometown, which he would regard with enormous nostalgia in his later years, we know that he entered the newly founded Society of Jesus in Rome at the age of 18. Along with other young recruits, he was sent to study at the university at Coimbra, where the Society was rapidly gaining influence. By 1556 he was enrolled in courses at the newly instituted Jesuit college at Coimbra. In 1561, presumably at the orders of his superiors, he returned to the Jesuit college in Rome. There he would spend the remainder of his life involved with the teaching of mathematics and natural philosophy in the Collegio Romano, founded only a decade earlier and only eleven years after the Society of Jesus itself. In 1563, only two years after he returned to Rome from Coimbra, Clavius began teaching mathematics in the Roman College. He taught steadily until 1571, then appears to have been granted time off to publish his work on Euclid and to take final vows. He returned to teach from 1575 to 1578. Though it is not yet clear precisely when he was relieved from the burden of teaching (a privilege of being recognized as a *scriptor*), he conducted private advanced mathematics seminars from 1563 until 1610, two years before his death. In doing so, he bequeathed to his Society a group of competently trained mathematical astronomers who would make substantial contributions after his death.

It is easy for historians to forget that Jesuit mathematicians and scientists were not just teachers and scholars but also members of a religious order whose minds and characters were subject to intense training and formation. At the Collegio Romano, Clavius began the course of theological studies and pursued them at the same time as his teaching of mathematics. By 1564 Clavius was ordained a priest, yet he continued his theological studies at the Collegio far longer. Indeed, he did not take his final vows until 1575, when he was 37 years old.

Clavius's work as an astronomer and mathematician was perhaps best known to his contemporaries from his membership on the commission established under Pope Gregory XIII to reform the calendar. While his defense of the new calendar, vehemently denounced by such well-regarded men as Michael Maestlin and Joseph Scaliger, has long interested historians of science, Clavius has also been widely credited with having an important impact on the pursuit of natural philosophy and mathematics within the Society. Historians have pointed to his defense of the study of mathematics and natural philosophy, claiming that it was Clavius's contribution that resulted in their allotted place in the Jesuit curriculum as set forth in the *Ratio studiorum* of 1599. In this document, the pursuit of such studies was deemed useful for young nobles training for military and government careers as well as for young missionaries who would take their knowledge overseas. In addition, for 50 years Clavius trained an impressive number of Jesuit mathematicians and philosophers, including Odo Van Maelcote, Gregory of St. Vincent, Pietro Lembo, Peter Guldin, Orazio Grassi, Christoph Grienberger, and Guiseppe Biancani.[4]

Yet while these facets of Clavius's life are better known to historians of the period, much remains to be learned from a careful examination of the history of his published works. As a prodigious producer of mathematical textbooks and treatises over 40 years, Clavius witnessed in his own lifetime many reprintings of his works and sometimes supervised corrections and revisions of the later editions.[5] In good humanist tradition, his first published work was a traditional commentary on the ancient texts of Euclid (1570), and his second was a commentary on the thirteenth-century treatise on the sphere by Sacrobosco (1574). Such commentaries were a traditional part of university curricula in his day. Clavius continued to re-edit, revise and add to the original 1570 edition throughout his life. Careful comparison of the editions has allowed scholars to trace the evolution of Clavius's mathematical thought. Moreover, in the same years that he was editing and updating his commentaries, Clavius also issued a large number of mathematical textbooks, many designed for instruction in Jesuit schools. The first of these, which drew on *Elementa Euclidi*, was his *Epitome arithmeticae practicae* (1583); it was followed by *Geometria Practica* (1604), and *Algebra* (1608). The six Latin and four Italian editions of his *Epitome arithmeticae practicae* published during his lifetime revealed a steady demand for such products both inside and outside the Jesuit educational structure. No doubt Clavius's appointment as *scriptor* enabled him to spew forth such a prodigious amount of books, but his energy and steady devotion to mathematics set an almost inimitable example for other Jesuit natural philosophers.

Although his burgeoning publications undoubtedly impressed fellow mathematicians and wearied students, Clavius also used his books to woo and win the approval and support of important Catholic nobles in defraying the costs of their publication. It is striking that many of his early volumes directed primarily to students as well as the re-edited epitomes of later years lacked letters of dedication. While full examination of his correspondence may reveal what prompted Clavius to begin dedicating his books to patrons, we know that his early textbooks lacked such embellishments, which would soon become de rigeur in Jesuit publications.

By 1581, as his mathematical reputation was steadily growing, Clavius turned to the stratagem of dedicating his less textbook-like volumes to specific noblemen. In that year he dedicated a work on the construction of sundials to Stephan Bathory, king of Poland-Lithuania. Why would a mathematician of undistinguished German origin, a teacher in Rome, and an articulate champion of papal calendar reform dedicate a technical book to a Polish king? Clearly Stephan Bathory and Christoph Clavius had no personal acquaintance. Moreover, it is extremely unlikely that the king took any profound interest in sundials. But research into the history of the

Society of Jesus in Poland-Lithuania suggests that the 1580s were critical years for Jesuits in Poland, and that their extremely inauspicious—indeed hostile—beginnings in this hinterland had just begun to improve. Moreover, the unenviable reputation of the Jesuits in Poland for drunkenness, arrogance, and loose morals would vex successive Generals of the Society throughout the seventeenth century, as Stanislaw Obirek has demonstrated. But simultaneously, Poland also held great promise to the Society as the region of Eastern Europe where Jesuits promised to triumph over both Orthodoxy and Protestantism. The coexistence of the promise of Poland to become the showpiece of Jesuit missionary work, together with the fear of the hierarchy that it might not be able to control the behavior of its members in such a remote geographical and cultural region, may well explain why Jesuit superiors at Rome directed the prominent Clavius to write a laudatory preface to Stephan.[6]

Clavius's superiors must also have steered him toward patrons for other publications. In 1588 he dedicated his defense of the new Roman calendar to the Holy Roman Emperor Rudolf I.[7] Further research may reveal more precisely what rewards such dedications might have produced for Clavius, but we can assume that his dedications did produce some positive benefit for him or for the Society, for in subsequent decades he steadily increased his use of this stratagem. Kings and priests with royal connections were not the only ones who received dedications. In 1604 Clavius dedicated his work on practical geometry to Georg Fugger—a descendant of a famous mercantile, metallurgical, and banking family, a loyal Roman Catholic, and the baron of Kirchberg and Weissenhorn. Clavius had apparently been successful in using his German connections to win the financial backing of the Fugger baron, for he stated bluntly in his dedicatory letter: "You have exhorted me to finish this work. In accord with your liberal gentility, you have put down on the table no small amount of money for the expenses of printing this book."[8] Not relying exclusively on his German connections, Clavius dedicated other volumes to Italian princes. He had earlier offered his work on astrolabes (1593) to Francisco Maria, Duke of Urbino, and his 1608 algebra to Juan de Guevara, seneschal of Naples.

In dedicating his books to such magnates, Clavius sought to earn the validation of men in the secular world who exercised considerable cultural, political, and economic power in Catholic Europe. Although the dedicatory letter of his books was by no means an invention of Clavius (indeed it was a literary commonplace in the day), Clavius presided over its introduction to Jesuit publications in mathematics and natural philosophy.

The Dedicatory Letter in Its Jesuit Configuration

Although it appears that the Society's hierarchy encouraged authors to seek funds outside the Society for publishing books, it is important to note that more than money to finance publications was at stake in the delicate matter of choosing a patron. Indeed, whereas many secular natural philosophers were directly dependent on court patronage for their livelihood, Jesuit natural philosophers were not encumbered by such considerations. Furthermore, they had no families to support, and, having taken vows of poverty, they had carefully considered and formally pledged themselves to pursue a life of material simplicity.[9] But if the Jesuits were avowedly less interested in the financial benefits of the patronage system that permeated early modern culture, the Order was especially sensitive to the importance of earning and maintaining a favorable reputation among European monarchs and nobility. Moreover, Jesuit provincials and rectors were careful to seize every opportunity to engage the favorable attention of Catholic nobles by the solicitation of patronage, for they were acutely aware that Jesuit books of mathematics and natural philosophy enhanced the reputation of the Society in general. This attentiveness on the part of superiors and provincials to winning the favor of important men was by no means novel to the Society in the seventeenth century, nor was it encouraged exclusively—or even primarily—among those seeking to publish books. Indeed, Ignatius of Loyola, in the founding document of the Society, had advised his followers to strive to earn and retain the goodwill of "the temporal rulers and noble and powerful persons whose favor or disfavor does much toward opening or closing the gate to the service of God and the good of souls."[10]

It had become customary from the very beginning of the seventeenth century for superiors, provincials, and rectors to expect that individual natural philosophers seek outside subsidies to defray the costs of publication. Again they did not apply this policy exclusively to natural philosophers and mathematicians, for other Jesuits were eager to see their writings on various subjects in print. The same letters of dedication appear in Jesuit manuals of prayer and spirituality, theological treatises, religious and secular histories, grammars, manuals for preaching and administering confessions, commentaries on ancient philosophers, treatises on ethics and moral philosophy, and textbooks for use in every part of the Jesuit school curriculum. Books on natural philosophy and mathematics were only part of the far broader Jesuit book production, and Jesuit natural philosophers and mathematicians fell under the same procedures and protocols demanded of other authors. Some of these procedures had been spelled out early in the history of the Society. The *Constitutions* had made it clear that publication of books by Jesuits was not to be undertaken without the express approval of the hierarchy.[11]

Superiors and provincials were not only authorized to ensure that books penned by Jesuits avoid heretical statements; they were also well positioned to advise authors on how to get their works published. Alert to the opportunity to use a book's publication as an outward sign of the erudition and orthodoxy of members, superiors occasionally suggested potential patrons and publishers to authors. Moreover, by virtue of the Society's efficient bureaucracy and highly centralized network of international correspondence, Jesuits wishing to appear in print enjoyed a considerable advantage over non-Jesuits, who were left on their own to negotiate the social and economic complexities of the system of noble patronage. Furthermore, a Jesuit natural philosopher writing in an obscure college in one part of Europe could count on the services of a Jesuit court confessor or a Jesuit with well-established court connections to present his request for a subsidy or see his book through press. In this sense, membership in the Society provided the Jesuit natural philosopher with important information about who might be a receptive patron and how he might best be approached. This policy must have been helpful to young and unknown authors; while some natural philosophers had close friendship and acquaintance with their patrons, most did not. Under such circumstances, officials within the Jesuit hierarchy assigned patrons to Jesuit authors. Thus Niccolo Cabeo, who lived and taught in Ferrara, dedicated his work to Louis XIII, although he had never met this French king, and Niccolo Zucchi addressed his patron, the archduke of Austria, "at the order of my moderator."[12] This monetary policy of the hierarchy to encourage outside subsidies for book publication cemented the pattern of patronage evident in seventeenth-century Jesuit books on natural philosophy, mathematics, and natural history.

While letters of dedication placed the natural philosopher's work under the protection and defense of noblemen, entrusted formal ownership of the work to the patron, and declared the author the humble and grateful servant of the chosen patron, they left no doubt that the authors were also interested in concrete fiscal subsidies. Just as Clavius had spoken of Fugger's "putting money on the table" to see his book on geometry through the press, so too did the French Jesuit Honoré Fabri make the financial aspect of patronage equally clear when he published his book on optics. Writing 60 years after Clavius, Fabri dedicated his book to Prince Leopold of Tuscany and said that the book was his way of discharging a debt of gratitude owed to a prince who had showered him with private rewards.[13]

On occasion the expenses of publishing books, especially lavishly illustrated ones, forced a natural philosopher to acknowledge multiple patrons. Thus, although Athanasius Kircher dedicated his 1646 treatise on optics to the Archduke Ferdinand, the eldest son of the Holy Roman emperor Ferdinand III, he noted in his letter to the reader that he had also received financial subsidy and encouragement from three other individuals. These were the German baron of Monte S. Georgio, the Italian bureaucrat and noble Cassiano dal Pozzo, and Marcus Marci, a court physician at Prague.[14]

It may be a frustration to modern historians that these letters of dedication never indicate exactly how much money flowed from a noble patron to the particular Jesuit author. However, it is important to realize that in the cultural context of the seventeenth century such crass information would have detracted from the symbolic importance of a monetary gift. Authors commonly proclaimed that their works would have never gone to press without these outside subsidies. Jean François stated the matter most succinctly in the 1652 dedication of his book on geography to Henri de la Motte Odencourt: "Your liberality allowed this book to be published . . . and my resolve to complete it has been dependent on your approbation."[15]

Just as Jesuits obtained funds for seeing their books through the presses, their patrons derived benefits, albeit less tangible ones, in return for assuming the expenses of publication. Commonly a Catholic noble could expect to find the antiquity and nobility of his ancestors extolled. When Swabian-born Christopher Scheiner dedicated his *Pantographice seu Ars Nova Delineandi* in 1631 to Prince Paolo Sabello, orator of the Holy Roman Emperor in Rome, he patiently listed the names of his benefactor's famous ancestors, including all 33 cardinals and innumerable bishops and abbots, which he had gleaned from the famous annalist Baronius. Similarly, when the Bolognese Riccioli dedicated his *Almagestum Novum* of 1651 to Cardinal Hieronimo Grimaldi and to Prince Onoratus II of Monaco, he gave no mere nod to their noble ancestry; he included a nine-folio-page long genealogy of the house of Grimaldi and traced its long-standing connection to the principality of Monaco. Despite the temptation to dismiss these genealogical accounts as unimportant, one should remember that they imparted to the ruling families of the early modern period a vivid sense of the legitimacy of their power. Moreover, any defense of this legitimacy was particularly treasured in an era when the fortunes of powerful families waxed and waned with alarming frequency, according to victory or defeat in the widespread, continuous territorial wars of the seventeenth century.

The attention Jesuit natural philosophers paid to their patrons' genealogies also provided subject matter for the illustrators and poets to display their skills at emblems and encomia. Engraved frontispieces laden with iconographic references to a patron's genealogy commonly preceded the letter of dedication—Habsburg eagles, Farnesian lilies, Orsini roses, and French fleurs de lis were common visual adornments to the austere texts of natural philosophy.[16] Frequently, Latin verses contributed by Jesuit humanists followed the letters of dedication. These too made frequent references to dynastic emblems and genealogies. Thus, variations in the treatment of the prefatory material allowed the Jesuit natural philosopher to embellish upon his patron's genealogy and to enhance the contemporary assumption that genealogy legitimated political power and wealth.

In establishing himself as a client of a particular patron, a Jesuit natural philosopher would frequently extol his patron's military virtuosity and courage. Since the exercise of arms was a primary responsibility and profession of European nobility in the seventeenth century, the Jesuit defense of the military profession as a noble employment was not surprising in its cultural context. Georges Fournier stated that the end of the profession of arms was to secure justice, protect the feeble, and maintain the states in peace.[17] Jesuit writers proved themselves deft in avoiding offending any potential Catholic patron by targeting their praise of a patron's military conquests to his exploits against the Turks and Protestants—both considered, if not literal agents of Satan, then certainly enemies of all Catholic nobles. Cabeo, in his work on magnetism dedicated in 1629 to King Louis XIII of France, remarked on his patron's successes against Calvinists both within his own kingdom and in the Swiss canton of Berne, while the Italian Francesco Lana

Terzi in 1683 praised the military success of Leopold I and his allied troops in their wars against the Turks on the Austrian frontier.[18]

In addition to praising the military virtuosity of their noble patrons, Jesuit natural philosophers expressed esteem for their patrons' skill at governing in peacetime. In one of his books, Fabri paid tribute to his patron's administration of public affairs in Lyon as president of the local senate; in another work, the French Jesuit admired Cosimo de Medici's "admirable prudence, skill and outstanding knowledge of political affairs" in Tuscany.[19] Similarly, Fournier, in a work on hydrography, praised Louis XIII's unification and centralization of the French provincial admiralties and his strengthening of the French navy.[20]

It was also a standard feature of a Jesuit letter of dedication to pay tribute to a patron's erudition and love of arts and letters. With their humanist training, Jesuit natural philosophers were quick to remind their patrons that it was the custom of ancient natural philosophers such as Archimedes, Apollonius, and Aristotle to offer their works to men learned enough to judge them fairly. Clavius wrote to Francisco Maria, Duke of Urbino: "To whom could I more justly dedicate my discoveries [on the astrolabe] than to you who are excellent beyond the rest with respect to your cognition of mathematics?"[21] In concluding his dedicatory epistle, Clavius humbly remarked that he hoped his book would acquire grandeur by resting on a shelf of the duke's illustrious library. The modern reader might read such a sentence with mistrust for its false humility, but one need only remember that such protestations about the insignificance of the author's writings were standard expressions of a client to a patron. Indeed, how common is it in modern scholarly works to read after fulsome thanks to mentors and colleagues the phrase "of course, all errors are my own"?

Moreover, these Jesuit natural philosophers pointed out, what better evidence was there of a nobleman's true love of learning than his patronage and promotion of the mathematical sciences and natural philosophy? If erudition were not essential for a noblemen, certainly the promotion of the sciences was a necessary consequence of a nobleman's erudition. Had not wise monarchs in every age and every part of the world fostered the production of treatises on natural philosophy and mathematics? Had not Ptolemy, Caesar, Alfonso of Castile, Charlemagne, and Ferdinand II supported the sciences generously?[22] The Italian Jesuit Filippo Buonnani also reflected on monarchical patronage of learning when he wrote his 1681 taxonomic and descriptive work on mollusks. Learned monarchs were a constant inspiration to humble men of letters, he was certain. Had not the ancient example of Alexander the Great and the recent one of Louis XIV encouraged modern naturalists to collect animal specimens and provided contemporary nobles with worthy examples to emulate in the promotion of natural history?[23]

Patrons of Jesuit books on natural philosophy could almost always count on some paean to their religious piety and private morals. Jean François dedicated his work on hydrography to the nobles of Britanny, whom he admired because of their inviolable piety toward God and church; Fournier, in his edition of Euclid, praised the piety of Nicolas Foucquet, who used the gifts of his body and mind to make himself pleasing to God.[24] Though Jesuit clients commonly extolled their patrons' religious virtues in vague terms, Riccioli exclaimed Ranuccio of Monaco's piety toward God and Mary and mentioned specifically his pilgrimage with his wife to the Laurentian church at Rome.[25] Kircher spoke of Leopold Wilhelm's tenaciously innocent private morals while living in a military camp where licentiousness was rampant.[26] Again, though such tributes to a patron's piety may strike modern ears as insincere flattery, in the seventeenth century religious piety was an esteemed attribute of any virtuous noble and much revered by Jesuit religious. One might admire the tact and delicacy of Cabeo, who, while refraining from comment on the dubious private mores of his patron Louis XIII, urged him to emulate the sanctity and piety of his ancestor St. Louis.[27]

Paying tribute to the personal virtues of a figure whom he had never met may well have strained the imagination of the Jesuit natural philosopher penning a dedicatory epistle. It must have been far easier to record and honor the favors his patron had accorded directly to his own religious society, facts presumably fed to the author by his more enlightened and socially attuned provincial or rector. Clavius had inaugurated the Jesuit tradition of dedicating mathematical books to benefactors of the whole Society of Jesus in his dedications to the Polish royal family. In 1586 he reminded his patron, Cardinal Andreas Bathory, of the enormous debt of gratitude all Jesuits owed to the Cardinal's father, King Stephan Bathory. In establishing the Jesuit academy at Vilna, the king had erected the flagship Jesuit school in eastern Europe, and everywhere within his realms he had granted protection and bestowed munificence upon the Society.[28] Twenty-five years later, in a dedicatory letter to Fugger, Clavius declared it was his habit to choose as patrons of his numerous books only "someone whom the whole order of our Society has always experienced as its fiercest defender and most loving patron."[29] Similarly, Cabeo and Fournier praised Louis XIII for his support for Jesuit colleges throughout France, Schott honored the duke of Franconia for maintaining the Jesuit gymnasia in his realm, and Kircher commended the French nobles of Avignon for their support of the Jesuit college there.[30] Scheiner joined the chorus of his confreres when applauding the generosity of Maximilian Archduke of Austria to the Jesuit college at Innsbruck; Riccioli praised the support of the Farnese family for the Jesuit college at Parma.[31]

Buried not far beneath the surface of the flowery baroque prose of such dedicatory letters lay the author's concern for his patron's eternal salvation. The Council of Trent had never deemed good works irrelevant to salvation, and the tone of these letters leaves no doubt that the Jesuit author viewed support and protection of his Society as a visible sign of interior enlightenment, if not grace. Hence, Lana Terzi ended his letter to the head of the Habsburg dynasty with thanks to God for having wisely entrusted the empire's government to Leopold. He prayed that God might "give vigor to [the emperor's] sword to exterminate His enemies . . . for the benefit of Christianity, and [might] conserve his most august majesty for the example of posterity, for the maintenance of the Catholic religion and for the immortal glory of his own great name."[32]

Thus, the letters of dedication, with their tributes to the noble ancestry, military virtue, erudition, zeal for Catholicism, and religious piety of the patron, form a recognizable literary genre. If the Jesuit motive for such florid letters seems obvious (namely, procuring financial support for the individual's books and enlisting the religious and political support for the broader activities of the Society), it must also be recalled that patrons received equally cherished reciprocal benefits for the fame and glory of their royal houses and for the salvation of their private souls.

The Jesuit Author and His Audience

In addition to letters of dedication, the prefaces to the reader in Jesuit books on natural philosophy provide valuable information on the intended audiences of the books. Hence, they offer critical evidence about the cultural context of Jesuit natural philosophy in the early modern era. Without exception, each of these Jesuit natural philosophers spent part of his career as a teacher within the Society. Most spent their entire careers as teachers. Their printed works bear the mark of being refinements of their classroom teaching and of frequently held private colloquia with the learned local nobility. When Mario Bettini's publisher came out with the fourth edition of the *Apiaria* in 1645, his editor remarked that, before publication, Bettini had tested his work in front of his students at the Jesuit gymnasium at Parma and in front of various local doctors, nobles, and princes. The editor also noted that, as a teacher, Bettini had hoped his book would aid both students and fellow teachers. Bettini's work included a commentary on the first six books of Euclid, a traditional part of Jesuit mathematical curriculum and a form followed by Clavius a half century earlier. Bettini, like Clavius, was eager to introduce to teachers the enticing and alluring presentation of Euclid he had devised for his own students.[33]

In 1661 Schott advised his reader that he had written his *Cursus Mathematicus* for novices and for students of mathematics. He even went so far as to include special instructions for novices on how to proceed through the enormous text and exhorted them to study the chapters in an exactly prescribed order. He then appended a letter of his own teacher Kircher "ad tyrones mathematicos" where the master praised the author for successfully and appropriately adapting the more difficult parts of mathematics to the understanding of schoolboys.[34] This persistent sensitivity to student audiences is also reflected in the work of the Belgian Jesuit Charles Malapert, who went so far as to dedicate his commentary on Euclid to "the young studious mathematicians in the Academy at Douai" whom he deemed a sufficient theater for his humble renditions of the foundations of mathematics.[35] Giuseppe Biancani, an instructor of mathematics at Parma, said that he felt goaded to write his work on cosmology for the sake of his students "who were complaining loudly every year that no text existed which handed down in a clear and certain way an introductory treatise of sidereal knowledge."[36]

While students in Jesuit schools provided the targeted audience for an ample portion of these treatises, by no means did the authors write exclusively or even primarily for the classroom. In fact, the prohibitive cost of books in the early modern period would have placed them beyond the reach of most students. Even in those Jesuit colleges designed especially for the offspring of nobility, private ownership of textbooks cannot be assumed. Indeed, the authors spoke of their hopes that the Catholic youths they taught would one day find their scientific training useful long after they had emerged outside the walls of the Jesuit gymnasia and colleges. Riccioli expressed his expectation that some of his students would "either be drawn to sacred purples or priestly garments; or will render famous the Catholic Church by the splendor and doctrine of their own life; or be drawn to civil prefectures or military lordships on land or sea."[37] Since many of these Catholic nobles would one day be called to defend Catholic lands, Jesuit natural philosophers and mathematicians promoted especially the military applications of their theoretical works. Bettini's posthumous editor clearly stated that one of the author's primary purposes in assembling his mathematical work—which included sections on projectiles, fortifications, and navigation—was "to prepare mathematical aids for religious soldiers in war against the public enemies of the true religion."[38] Fournier wrote an enormous treatise on navigation, with chapters on naval architecture, fortification of harbors, and naval siegecraft on behalf of the officers of the French navy.[39] Casati, in addition to works following closely the Jesuit school curriculum, published a work on the use of a compass, which he deemed useful to surveyors, civil and military architects, bombardiers, and military sergeants.[40] Schott included a long chapter on military fortification in his *Organum mathematicum*, where he stated the proprietary rights of kings, princes, and nobles over the mathematical sciences.[41]

Jesuit authors of books on more theoretical and abstract scientific matters frequently claimed that these types of science should be of particular interest to the learned nobility. At times these authors reported that various nobles had entreated or commanded them to write their volumes in order that they might have a clear exposition of the latest scientific discoveries and theories. Biancani said he had written his book to comply with "the just desire and prayers of several learned men who were confused by the obscurity of astronomical books yet tantalized by the new discoveries in astronomy."[42] Kircher claimed that he had composed his astronomical work at the urging of Ferdinand III, who wished to have enlightened his personal interest in "the perplexing novelties of the skies whose complexities were far greater than the ancients had imagined."[43] Kircher instinctively grasped the need for astronomical books to address an audience other than professional mathematicians and astronomers. Angling for a wider audience, he stated that the discoveries of sunspots, lunar topography, the moons of Jupiter, and the infinite stars of the galaxy had "stimulated anxiously not just mathematicians and philosophers, but also the curiosity of princes."[44] Moreover, other Jesuits, such as the Belgian Malapert, argued that the very princes and nobles whose patronage had promoted modern scientific discoveries stood to be the most interested in the results. Clearly, he envisioned his books as not just for professors and students. In writing his dedicatory epistle to his book on astronomy to the Habsburg prince Philip IV, Malapert invoked the long tradition of royal support of astronomical studies. Had not the Habsburgs supported the priests of Urania, the muse of astronomy? Had not Regiomontanus, Puerbach, Copernicus, and Kepler benefited from royal munificence? Had not Alfonso of Castile preserved the Arabic knowledge of astronomy while European astronomy was collapsing? Were not the Spanish Habsburgs fostering its study at the royal college of Madrid?[45]

As a consequence of making modern scientific doctrines comprehensible and palatable for a noble audience, many Jesuit writers consciously labored to make their scientific discourses entertaining. This courtly audience explains in large part the proclivity toward experiments and fantastical machines seen in much Jesuit scientific writing. Kircher crammed his works with speaking statues, magical lanterns, mirrors, magnetic devices, hydraulic machines, fountains for court gardens, and stagecraft for court theaters. Jacques Grandami claimed to write his work on magnetism for "wise men, who fatigued by the serious thought of more important matters, or by the exertion of labors are recreated by the most pleasing spectacle of admirable nature." It was his hope that after engaging in scientific experiments they "might return themselves as stronger and refreshed men to other concerns more related to public utility."[46] The entertainment and recreational goal of writers playing to courtly audiences can also partially explain the Jesuit fascination with collecting the arcana and mirabilia of natural history, a trait so prominent in Nieremberger, Lana Terzi, and Schott. In his compilations of natural arcana, such as fossils, bizarre meteorological events, giants, and dragons, Schott believed he served the cause of natural philosophy by making it enticing to nobles: "I conclude that kings and princes for whom the weight of the scepter is refreshed by the levity of the written word and whose anxieties over administering public affairs are tempered by the reading of books, are seized with no greater zeal nor with more ardor than by the inquisition of natural things."[47]

This concern to reach out to a noble audience and to offer court entertainment reached its high point in Schott's book *Ioco Seriorum Naturae et Artis, sive Magiae Naturalis Centuriae Tres*. Here Schott gave instructions on such dinner party tricks as how to perforate the head of a chicken and keep it alive. His directions on the construction of exploding glass spheres were intended not as boring lessons on chemistry but as jokes to be played in a court setting. He gave no chemical explanation why filling a sphere of glass with a mixture of vinegar and salt niter and then subjecting it to heat produced a violent explosion. He merely gave instructions for the prank. And if he failed to include a dedicatory letter for such an unorthodox presentation of his knowledge of natural philosophy, one must not conclude that his book (which included a recipe for driving a dinner guest from the banquet table by doctoring his wine with powdered rabbit dung) was unpalatable to his audience. Though few books of Jesuit natural philosophy displayed the mirth found in Schott, it should not be forgotten that levity and wit were prominent features in the court culture of early modern Europe.

The Choice of a Patron

In choosing a patron for his book, the Jesuit natural philosopher could hope for a good match between the subject matter of his text and the personal predilections of his patron. Obviously he could tailor his writing to please his patron, but this was far easier for him to do if he had some first-hand acquaintance (or second-hand reports) of the tastes of his patron. Throughout the century it was common practice for Jesuits to dedicate their published volumes to a local magnates. Thus, French Jesuits commonly dedicated their books to French noblemen—for example, Vincent Léotaud dedicated his book to Hugo de Lionne, Marquis de Berni, and Georges Fournier dedicated his works of 1643 to Nicolas Foucquet, François de l'Aubespine, and the king of France. Similarly, Antoine Lalouvère dedicated a work on geometry in 1660 to the Prince de Condé, brother of Louis XIV.[48] Milliet de Chales, a Savoyard by birth, dedicated his work on military fortifications to Victor Amée II, duke of Savoy and Prince of Piedmont.[49] Clavius, at the end of his life, clearly dedicated his massive five-volume

Opera mathematica to the bishop of Bamberg, Ioannes Godefrid, out of nostalgia and affection for his native city. That he had left his town as a 16-year-old and had never returned did not weaken his sentiment.

But ties of geography, language, and political loyalty were not always paramount in the choice of a patron. At times the subject matter of a text seemed to dictate the choice of an appropriate patron. Milliet de Chales dedicated his work on navigation to the Marquis de Seignelay, Secretary of the State of France, since he wisely recognized that the prince of his native land-locked duchy of Savoy harbored no interest in such matters.[50]

In keeping with this strategy to seek out princes known to be receptive to Jesuit books, many Jesuit natural philosophers were prodded to dedicate their volumes to members of the house of Habsburg. Undoubtedly this practice owed much to the widely perceived warmth of the Habsburgs for foreign talent and to their reputations as staunch supporters of the Society.[51] Niccolo Zucchi, a Jesuit at Parma, addressed a work on optics to Leopold Wilhelm, Archduke of Austria and Governor of Belgium and Burgundy.[52] Riccioli dedicated the second edition of his *Geographia and Hydrographia* to Bartholomew Berthold, advisor to Ferdinand, Archduke of Austria, and his *Astronomia reformata* to the archduke himself. Lana Terzi, who spent his entire career in his native northwestern Italy, dedicated all his published works to Leopold I, the Holy Roman Emperor.[53] Clearly not all these provincial Jesuits had personal acquaintance with the great men to whom they sent their books, and presumably the books were not sent by post but were presented by a Jesuit court confessor or adviser.

Nor were Jesuits alone in correctly assessing the Habsburgs to be particularly interested in the patronage of the fine arts, music, mathematics, and natural philosophy. Indeed, talented Protestant astronomers, notably Brahe and Kepler, had found employment at the court of Rudolf II.[54] Indeed, Galileo had received a gift of a jeweled necklace from Charles, the brother of the Archduke Leopold of Austria, in recognition of his contributions to natural philosophy.

But the Habsburgs had strong motives for patronizing Jesuit writers, even if they did not do so exclusively. After the decree of 1633, the Habsburgs may well have been concerned about what kind of science they could endorse and patronize without risking the taint of heresy. Jesuit mathematics and natural philosophy may well have appeared a safe candidate for their patronage. Moreover, the physical destruction and economic chaos in

Germany resulting from the Thirty Years' War, made the Habsburgs particularly sensitive to the political need to inculcate religious orthodoxy in their subjects and to establish their personal reputation for religious piety among their fellow Catholics. Historians need not seek ulterior motives for the well-documented religious devotion of Habsburg princes,[55] but without cynicism historians may also note the potential economic and political stability which members of the house of Habsburg could derive from the diligently constructed mythology of the *pietas Austriaca*. The conscious promulgation of the myth of the Holy Roman Empire as the guardian of Christendom was apparent in every letter of dedication to a Habsburg prince written by a Jesuit natural philosopher. Additionally, the Habsburgs leaned heavily on the Jesuits to operate the schools in its domains, and they commonly used Jesuits as court confessors, diplomats, and political advisors.[56]

Jesuits on the Defensive

While letters of dedication and recent quantitative studies on membership and book publications of seventeenth-century Jesuit natural philosophers might suggest a flourishing and strong period for the Society, the reality of the situation was far different. Indeed, the reputation of the Society of Jesus faced severe strains among learned Europeans during this period. John O'Malley has documented the defamatory anti-Jesuit campaign begun in 1614 by an ex-Jesuit, Hieronymus Zaborowski,[57] whose book *Monita secreta* found sympathetic readers in Protestant and Catholic Europe for generations. Moreover, the influence of Jesuit royal confessors in court politics was resented by competing factions of nobility. For various reasons, the Society endured expulsions from France (1594–1604) and Venice (1606–1656), preludes to the more famous expulsions of the eighteenth century. Further hostility arose from controversies with the Dominicans and Franciscans on the Chinese Rites question and the doctrine of grace. Pascal's vitriolic denunciation of Jesuit lax moral teaching percolated throughout France, and, even if it did not gain friends for the severe Augustinian position of the Jansenists, it cemented the image of the Jesuits as moral equivocators and verbal tricksters. Ill will toward Jesuits also ran high among natural philosophers, since Jesuit fidelity to the papal position condemning the teaching of Copernican theory as physical reality was well known—and sharply resented—among the learned. Moreover, the treatment of Galileo during his trial earned the Society of Jesus the enmity of many Catholic scientists. Not infrequently this enmity spilled over to Jesuit natural philosophers as a group.[58] Animosity from Protestant quarters was even more pronounced. Thomas Sprat, a champion of the great scientific advances occurring in England, did not mince words when, in 1667, he assessed the sincerity of the Jesuits' commitment to experimental science: "It is likely they have cherish'd some Experiments, not out of zeal to the continuance of such studies, but that the Protestants might not carry away all the glory, and thence withal get new strength to oppose them."[59] Understandably, then, many viewed Jesuit natural philosophers as defenders of an outdated Aristotelian philosophy.

Such attacks on the reputation of the Society were keenly felt within. In response to the alarming growth of anti-Jesuit sentiment at the middle of the seventeenth century, General Vincenzo Caraffa requested Sforza Pallavicino to write a general defense of the Society, and the obedient Italian Jesuit immediately agreed to do so. What resulted was *Vindicationes Societatis Iesu*, which was presented by Pallavicino to an assembly of the Society's hierarchy at Rome in 1649, immediately after the death of Caraffa. The subtitle of the volume, *Quibus multorum accusationes in eius institutum, leges, gymnasia, mores refelluntur*, left no doubt about its apologetic intent.

Pallavicino, a descendant of a noble Parman family, had entered the Society in 1637. When charged with writing the official apology, he was a professor of philosophy and theology at the Collegio Romano. Despite his earlier literary proclivities, he had gained the respect of Caraffa for his sober theological writings. Later, he became one of Pope Alexander VII's chief advisers on theological questions. In recognition of his service to the papacy, Alexander made Pallavicino a cardinal and entrusted him with the task of writing a history of the Council of Trent that would refute Paolo Sarpi's markedly anti-papal version of the same event.[60]

Pallavicino cited the wealth of the Society of Jesus as one of the greatest sources of the hatred it so often encountered. Boldly addressing the issue, he noted that a society of 18,000 required enormous resources to feed, cultivate, house, and educate its members, no matter how moderately they lived. As a further defense of the lifestyles of his confreres, he noted the aristocratic background of many of its members. He argued that such men had forfeited a far more sumptuous life in the secular world and had forsaken large patrimonies.[61] But clearly, he intimated, there was no diet of bread and water for these recruits.

Pallavicino went on to identify the two chief sources of Jesuit wealth in his own century: the gifts and bequests of princes or ruling heads of states and the bequests and generosity of lesser (and presumably Catholic) nobles. Pallavicino defended his confreres from the oft-repeated charge of avarice, noting that this accusation more truly reflected the jealousy and avarice of men who had lost out in the competition for patronage and bequests. He fully recognized the commonly accepted Jesuit practice of seeking monies and honors for its religious houses and colleges from royal and aristocratic patrons, but he remonstrated that the success of the Society in earning the respect and trust of European nobles and princes had found its just reflection in such financial rewards.

Pallavicino also noted that the Society's success in founding and operating colleges and gymnasia throughout Catholic Europe had brought upon it the jealousy and envy of others involved in the business of education. While it lies outside the purpose of this essay to chronicle the considerable, even prodigious, expansion of Jesuit schools in the seventeenth century, it suffices to note that no one in the seventeenth century challenged this assumption. In trying to explain the reasons for the Jesuits' success in the realm of education, Pallavicino paid tribute to his brothers' outstanding learning and to their diligence and integrity in teaching.

Pallavicino sought to defuse the jealousy of the Catholic European educational establishment by reminding readers that the constitutions governing the Society firmly forbade the pursuit of law and medicine by its members. But he did recognize that the Society posed a threat to those who wished to educate Catholic royalty and aristocracy. While boastful of the Society's success in earning the privilege and responsibility of teaching the sons of kings, Pallavicino candidly recognized this as a source of great envy among others engaged in teaching the liberal arts, natural philosophy, and mathematics. If the Society had succeeded in being entrusted with the education of the privileged classes, it was because the excellence of its educational establishments had been recognized by the careful consumers of its services, the European nobility. Conscious of the acuity of the nobility in judging the schools entrusted with raising their sons, he wrote that "princes are not about to entrust to any other men the province in which the health and felicity of the republic devolves, except to those whom they judge best."[62] He cogently argued that gifts to Jesuit colleges should be viewed as indicative of the justly earned and highly favorable assessment of the nobility on the quality of its educational establishments.

Not avoiding the harsh reality of recent Jesuit expulsions from France, England, and the Republic of Venice, Pallavicino sought to redress this record by giving a full history of the favors bestowed on the Society by the ruling houses of Europe. In his mind, this historical record formed an important part of his apology for the Society, and thus he devoted the concluding pages of his text to it While not denigrating favors of the papacy (to which, after all, the Society was indebted for its very charter and operating privileges), Pallavicino was astute enough to calculate that the source of the Society's tarnished reputation lay far from the ecclesiastical centers of power in the city of Rome. He did not deem insignificant the papacy's bestowing upon particular Jesuits the status of sainthood, beatification, or the office of cardinal or preacher in one of the Holy City's famous pilgrimage churches. But Pallavicino did suggest that the papacy's entrusting the national colleges of the Germans, the Hungarians, the Anglicans, the Scots, the Greeks, the Irish, and the Maronites in the Holy City to the Society and the founding of the Collegio Romano might have been more important.[63] He recognized that the Jesuits, as the teachers of priests in training who would return to their home districts after their years of residence in Rome, had crucial access to the minds of those who would one day be important persons in the ecclesiastical hierarchy of Catholic kingdoms.

Though he followed a literary, cultural, and religious tradition in placing the papacy at the head of his list of potentates showering favors upon his Society, Pallavicino singled out the House of Habsburg as its most important benefactor. The Holy Roman Emperor had evinced his esteem for the Society by consigning to it the safeguarding of the Catholic religion, the education of youth, and the regimen of his own conscience. Moreover, Pallavicino noted that lesser German Catholic princes, priests, and military officers shared the Emperor's favorable sentiments toward the Society.

In addition to the Habsburgs, other royal houses had bestowed special favors upon the Society. The Bathory kings of Poland had found the Jesuits useful after their wars against the Protestant heretics and had handed over to the Society the administration of the ancient academy at Vilna as well as the supervision of many other excellent schools and churches.

While admitting the checkered record of the Jesuits in France, Pallavicino depicted his brothers there as innocent victims of internal wrangling. Henri IV had mistakenly identified the Jesuits as responsible for an assassination attempt on his life. But, Pallavicino boasted, this monarch was the same man who later had begged the Jesuits to return and who in due time had entrusted to the Society the colleges at La Flèche, Clermont, and Béarne. Clearly confident that the favors of Louis XIII on the Society would continue on their present pattern, the Jesuit asserted that the present monarch's bequests of churches, colleges, and money rivaled that of all other benefactors. And, Pallavicino claimed, it was Louis XIII who in 1622 had obtained from Pope Gregory XV the status of sainthood for Ignatius, the beloved founder of his Society.

The Society was indebted to the Spanish kings for the abundance of colleges and gymnasia in the New World. While Pallavicino boasted of the aristocratic background of Spanish Jesuits, "the offspring born from her best families," he also extolled the sagacity and piety of the Spanish kings and the Spanish aristocracy who had entrusted the Society with a "very great multitude of colleges," including the administration of the royal Athenaeum at Madrid. The king of Portugal also had entrusted the Society with running new colleges and academies.

While the Jesuits' record in Italy was one of pride and accomplishment on the whole (it had won the favor and financial grace of the Estes in Ferrara, the Gonzagas in Mantua, the Grimaldis in Monaco, and the Farnese in Parma), Pallavicino met the issue of the expulsion of the Jesuits from the Venetian Republic head on. That issue was a particularly sensitive one for Pallavicino, a Venetian who was proud that his family had shed blood for the Venetian Republic in many generations of warfare. Though the Venetian quarrel with the papacy had been patched over by the time he wrote (1649), the Society had not yet been allowed to return (and would not be for another two decades), and this was a painful matter to the author.

Though Pallavicino's work was defensive, it was also self-congratulatory. Pallavicino never saw the Society's quest for the favors of ruling houses as a necessary evil for keeping its educational or preaching missions in operation. Rather, like his contemporaries, he saw favors and patronage as truly deserved rewards for excellence. If the Society were to recoup its early prestige, it would have to continue to garner the respect and support of the ruling princes and nobles. Thus, the attitude of the Jesuit hierarchy, as shown in this officially commissioned apology for the Society written by one of its most eminent members, reveals an encouraging and positive attitude toward the attainment of every sort of privilege and favor for the Society.

Pallavicino's attitude toward the activities of Jesuit natural philosophers was unequivocal: he attributed to them a hefty share of the Society's success in earning the respect of educated men and in its broader educational mission. As he defended the pursuit of natural philosophy in the Society, Pallavicino also noted that the publication record of Jesuit natural philosophers had contributed significantly to the fame, esteem, and respect which the Society commanded among learned men. Indeed, he overstated his case when he wrote that, excepting Galileo (whose fame and reputation he recognized as dazzling enough to blind others to the presence of lesser luminaries), learned men outside the Society had attracted less fame and their books would prove less enduring than those of Jesuit natural philosophers. With great pride Pallavicino could state that the Society had produced "very many books whose repeated editions have quickly exhausted the typesetter and bookseller," and that "many men have followed these books, few men have found fault with them, and all men have read them."[64]

Kircher's Exemplary Career as a Client

The curious and tight nexus among the Jesuit hierarchy, Catholic princes and emperors, and Jesuit natural philosophers is best illustrated by the career of Athanasius Kircher (1618–1680). Although Kircher's later years were quite atypical of a Jesuit natural philosopher (largely as a result of his astounding success in attracting noble patronage), his early career was by no means unusual for a Jesuit novice. From a pious but socially undistinguished German family, Kircher sought admission to the Society at the age of 15. In a posthumously published autobiographical account, Kircher claimed that he had chosen the Jesuits in preference to other religious orders which his natural brothers had entered because he had believed that the Jesuits would offer him opportunities commensurate with his intellectual talents. Admitted into the novitiate at age 16, Kircher began the lengthy course of studies which all novices followed. But in 1622 he was forced to flee the Jesuit seminary at Paderborn when it was attacked by Protestant forces in the Thirty Years' War. His autobiography recounts his flight—on foot, insufficiently clothed against the hardships of the winter, and under-nourished—in advance of the Protestant armies, whose hatred for Catholic clerics in general and for Jesuits in particular made him fear for his life.[65]

Arriving in the small German town of Heiligenstadt, Kircher resumed his studies at the Jesuit seminary there. He came to the attention of the local nobility when he designed the stage machinery for a drama prepared by the local elector, Joannes Suicardus, for the entertainment of a visiting legation of German nobility. Kircher's interest in optical illusions and theatrical machinery continued to absorb him for the rest of his life, and in his later works, including *Ars magna lucis et umbrae*,(1643), he devoted much attention to such matters. Moreover, Kircher's involvement in theatrical machinery was not at all surprising in the context of the Society of Jesus. The Jesuits had a long theatrical tradition, and theatrical performances were often mounted at Jesuit colleges and gymnasia.[66] In his autobiography, Kircher revealed that the Jesuit hierarchy had quickly recognized his natural talent for contriving theatrical machinery, and that after the departure of the legation his fame had spread to the prince. It was not insignificant that the local prince had as his confessor Joannes Reinbardus Ziegler, a Jesuit who happened to be highly interested in mathematics and natural philosophy. Together with the Jesuit provincial at Afschaffenburg, Ziegler pressed for Kircher to be introduced to the prince.

Impressed by Kircher's mathematical knowledge and technical skills, the prince soon asked him to map the recently changed boundaries of his domain. He was allowed time off by his superiors from his routine studies to perform such services, but eventually he was required to return to Mainz to complete the course in theology. Ordained to the priesthood in 1628, Kircher then spent a full year in spiritual training, the mandated custom for all men belonging to the Society. In this year he and his brothers were expected to lay aside all intellectual pursuits and devote themselves exclusively to their spiritual welfare. At the end of this year, his superior assigned him to take up a teaching post at Würzburg. He taught mathematics and Syriac, and he might well have spent his whole career there had not the invading armies of the Lutheran King Gustavus of Sweden forced his entire college to dissolve overnight.

The position of the Jesuits in Germany looked especially bleak at this point in the war, and the Jesuit superiors ordered many of the younger men to flee into France. Kircher was among the German Jesuit exiles. He was expected to take up his teaching duties at once upon reaching France, and he did so at the Jesuit school at Lyon. In his next post, at Avignon, he came to the attention of Nicolas Claude Fabri de Peiresc, an internationally respected scholar of antiquities and patron of learning. Kircher had apparently managed to smuggle out of the library in Germany a valued Arabic commentary and he used this possession to whet the appetite of Peiresc, a collector of manuscripts and a language scholar. The bait worked well. Peiresc was quite taken with the manuscript and with Kircher's broad knowledge of languages, especially Hebrew, Chaldaic, Arabic, and Aramaic. In recognition of the young German's talents, Peiresc opened his library to him and consulted him often on matters of the ancient languages.[67]

Although Peiresc would prove important to him, Kircher carefully avoided being identified with a sole patron. When he published his first book, which concerned a horological device for observing stars, he chose to dedicate it not to Peiresc but to a group of nobles at Avignon with whom he presumably had shared his invention. In addition to naming all six men, he extolled Avignon as a location for making astronomical observations and stated that the weather conditions of southeastern France were as fine as those Ptolemy had enjoyed in Egypt.[68]

In 1632 Kircher received a letter from General Mutio Vitelleschi ordering him to take up a position as mathematician to the Habsburg emperor in Vienna. Peiresc intervened with the pope and with his well-postitioned friend at Rome, Cardinal Francesco Barberini, to have the orders countermanded. He believed that Kircher's talents were those of a linguist, not a mathematician. Moreover, for selfish reasons, Peiresc was particularly eager for Kircher to work in Rome translating certain Coptic and Arabic manuscripts. Peiresc's intervention with Catholic hierarchy outside of the Society was ultimately successful, and the Society's General agreed, at the urging of Cardinal Barberini, to reassign Kircher to work at Rome on a project of interpreting the hieroglyphic inscriptions of the obelisks.

In addition to his success in having Kircher posted to Rome, Peiresc supplied Kircher with letters of introduction to learned men at Rome. Peiresc wrote from Aix to Barberini's secretary, Cassiano dal Pozzo, of his conviction that Cassiano and the cardinal would come to admire Kircher's "great mind, his curious inventions and rare experiments which he practices and multiplies every day, as well as his most exquisite erudition." Peiresc assured Cassiano that he would consider himself honored by every favor he and Barberini could extend to Kircher.[69]

In 1634, when Kircher reached Rome, the Society and the Church were still recovering from the aftermath of the trial of Galileo. As a young German exile, Kircher had not stained his hands in any way in the furor. Furthermore, he had arrived in the Holy City with important letters of introduction to a potential patron and to humanist scholars employed in the various ecclesiastical bureaucracies. From this point on, Kircher's career increasingly unfolded according to the dictates of the system of patronage, a system whose rewards both he and his Jesuit superiors were eager to attract and retain.

Kircher's first book to be published during his long residence in Rome was *Prodromus coptus sive aegyptiacus* (1636). It did not contain the Coptic-Arabic lexicon that Peiresc had longed for; rather, it was an introduction to the larger project, which he promised to complete at a later date.[70] Judiciously, he chose to dedicate it to Cardinal Barberini, and he mentioned in the dedicatory epistle that Barberini had defrayed the cost of publication and had always favored the Society of Jesus with expressions of goodwill.

In addition to his duties as a professor in mathematics and natural philosophy at the Collegio Romano, Kircher received special assignments through Barberini's intervention. In 1637 he was assigned to accompany the Landgrave of Hesse (a recently converted German noble who had become the darling of the pope) on a trip to Sicily and Malta. Also accompanying the Landgrave was Lucas Holstein, an accomplished humanist scholar. Though the sojourn doubtlessly had its irritating aspects (General Vitelleschi expected Kircher to teach mathematics to Jesuit novices at the College in Malta and to take confessions from the Landgrave), it gave Kircher an introduction to a papal bureaucrat, the Sienese Fabio Chigi. Chigi, presiding over the arid fortress at Malta as the pope's delegate, welcomed the company of a bright outsider. This acquaintance would later prove extremely useful: Chigi would be elected pope in 1655. While Kircher was on Malta, the inherent conflict between serving his Society as professor of mathematics and serving the demands of the patronage system became apparent. When the Landgrave's tour consumed far more time than the Jesuit hierarchy had anticipated, Kircher received orders from the Society's General to return to his teaching duties at the Collegio Romano.[71]

Earlier in 1637, Kircher had petitioned his Jesuit superiors to send him to China to participate in the Jesuits' missionary efforts there. They denied his request, but they never spelled out the reasons for the denial. One can only surmise that they believed that his talents could better be put to use in Rome. Thus, Kircher continued to teach at the Collegio Romano and to write many books on natural philosophy.

Freed from the demands of Peiresc (who had died in 1638) to produce works on ancient languages, Kircher was at liberty to turn his talents to natural philosophy and mathematics. In the next two decades he published important works in these fields. He dedicated *Magnes sive de arte magnetica* to the Habsburg emperor Ferdinand III. Printed in a small edition of 500, it soon went through a second printing.[72] Eager to earn approval from his new patron, Kircher in his dedicatory letter proclaimed Ferdinand philosopher, mathematician, orator, Caesar, Hercules, and Maecenas. He also proclaimed himself the possession of Ferdinand, since Germany had been his motherland. Indeed, Kircher wrote, both Germany and the Society properly belonged to Ferdinand. Kircher was further freed from earlier expectations when Pope Urban VIII (Maffeo Barberini) died in 1644. The new pope, Innocent X, was notoriously hostile to the Barberini family. Despite the hazards of having one's patron die or fall from power, Kircher did not suffer with the accession of Innocent. This may have been due in part to his luck in having chosen the Habsburgs as patrons of his early works, for Innocent was himself a strong ally of the Habsburgs.

Kircher's quest for Habsburg patronage was apparently successful beyond his dreams, for he continued to publish books dedicated to various members of the royal household. He did not waste a dedication of his long-awaited Coptic grammar and dictionary on its original patrons—Peiresc had died, and Barberini was no longer in the limelight. He chose instead to use its publication as an opportunity to cement his relationship with Ferdinand III and dedicated it to him.[73] When he published his work on optics a few years later, he dedicated it to Ferdinand's son and spoke glowingly of the father in his dedicatory letter.[74] Later he dedicated a work on acoustics to the emperor's brother, Leopold Wilhelm, the archduke of Austria, and a work on numerology to Francisco de Nadasd, a magistrate in Hungary and an influential advisor to the Habsburgs.[75]

Even though Kircher's ties to the Habsburgs were strong, he avoided putting all his eggs in one basket. He continued to pay heed to the papacy. In 1650, Innocent X called upon him to interpret the Egyptian hieroglyphs on an obelisk in one of the ancient Roman ruins. Kircher recounted in his autobiography that General Caraffa, delighted that the pope had entrusted the task to a Jesuit, made every effort to free Kircher from his routine teaching duties.[76] In fact, Kircher, like Clavius earlier, was soon given a permanent dispensation from all teaching duties. This extraordinary privilege allowed the Jesuit hierarchy to use Kircher's talents more exclusively to serve the Society by earning the esteem of noble patrons. This gamble on the part of the Jesuit hierarchy paid off. When Kircher sent the Habsburg emperor Ferdinand III a copy of his book telling of the "Pamphilian" obelisk that had been re-erected in Innocent's honor, the monarch responded swiftly with an offer to subsidize the printing of Kircher's next work, the enormous and costly *Oedipus Aegyptiacus*, whose volumes would be dedicated to Innocent *and* Ferdinand. The work appeared in four volumes between 1652 and 1656, was lavishly illustrated, and used many expensive typefaces. Kircher noted on the title page that Ferdinand had borne the publication expenses entirely, and Kircher's correspondence reveals that the Jesuit received from the emperor the enormous sum of 3000 scudi for the project.[77] In addition, Kircher cleverly dedicated short chapters in the enormous work to a wide array of lesser patrons.

Even when Kircher dedicated his 1656 work on cosmology to Queen Christina of Sweden, he mentioned in his preface that his esteemed patron Ferdinand III had asked him to write the book. In all probability Kircher was testing the waters for patronage possibilities with the recent convert (who had installed herself in Rome), and by paying tribute to his old patron, whose generosity was well established, he was covering himself in case of rejection.[78] Moreover, Kircher sent a copy of the published book to the Tuscan Leopoldo de Medici in the hope of generating a new source of patronage for his subsequent books. A year earlier, Leopoldo had thanked Kircher for dedicating a chapter of his *Oedipus aegyptiacus* to him and his brother, and Kircher was eager to pursue Leopoldo's expression of Medici gratitude. Kircher's hunger for Medici support was so great that he tried to gloss over the fact that his Tychonian cosmology and his narrative technique of truth revealed in a dream were antithetical to those of Galileo. Aware that the Medici held Galileo's work in high esteem, Kircher went so far as to try to persuade Leopoldo that he had always followed in Galileo's footsteps.[79]

In 1661 Kircher freed himself from all worries over publication expenses by entering into a highly unusual business arrangement with his publisher, Joannes Jansson van Waesberghe of Amsterdam.[80] By agreeing to have his books published exclusively by the widely respected Dutch firm, and in return for an advance lump sum of 2200 scudi, Kircher was in essence liberated from the financial constraints that had set the wheels of his patronage system in motion.[81]

With the election of Cardinal Fabio Chigi (Alexander VII) to the papacy in 1655 and with the accession of Leopold I as Holy Roman Emperor in 1658, Kircher managed not only to survive but to thrive. Cleverly, he never revealed his marketing agreement to his old patrons, and he continued in his relentless pursuit of the monetary and social rewards of the very system from which he had been enabled to escape. Nor did his output flag—he produced seventeen volumes for Jansson after signing the contract, even though he received no form of payment from the publisher after the initial sum. In fact, his marketing coup seems to have stimulated, rather than quelled, his taste for patronage. His correspondence reveals that he made repeated promises of book dedications to the Protestant Duke Augustus of Brunswick-Luneberg. Kircher's books, however, reveal that such promises were empty—he never wasted a dedication on a sickly patron, and Augustus constantly remarked on his tenuous health.[82]

While Kircher and his confreres may well have interpreted his relief from teaching duties as a reward for his encyclopedic learning, no one interpreted it as a form of early retirement. Indeed, in 1651, almost immediately after being freed from teaching duties, Kircher was put in charge of a large bequest of treasured antiquities, the collection of the recently deceased Roman aristocrat Alfonso Donini. While his superiors decided to allocate space for the collection within the walls of the Collegio Romano, Kircher also gained permission to add his own amassed treasures—books, scientific and theatrical apparatus, and specimens of natural history. What resulted was a seventeenth-century museum of natural marvels housed in the Collegio Romano. Kircher was also accorded the services of an assistant curator, Giorgio de Sepi, who published a catalog of the museum in 1678.[83]

Paula Findlen has described the museum as a showpiece for the Jesuit order and as a spectacle that competed with numerous other attractions in the Holy City.[84] Indeed the museum was the very representation of the patronage system, for in it visiting patrons and potential new patrons could see what kind of gifts counted in the Jesuits' eyes. Clearly, published books were only one medium of exchange for Jesuits and patrons in a highly articulated system of exchange and reciprocity. Portraits, artifacts of natural history, and scientific instruments all had currency too. In appointing Kircher director of the museum, the Society acknowledged him the most successful Jesuit of his day in attracting the patronage of the European nobility.

One might ponder whether Kircher became the pawn of the Jesuit hierarchy or its honest and honored servant. In either case, it is clear that he, with the full support and approval of his superiors, was remarkably successful in attracting considerable patronage for his own scholarly work and good will and esteem for the Society. His ability to survive the exile of the Society from Germany, the death of Peiresc, the fall of the Barberini, the uncertain dynastic succession of the Habsburgs, and the changing personalities and policies in both the papacy and the Society of Jesus was due entirely to his willingness to cast his net widely for the harvest of any potential patron, a policy that paid off well for his own career and ultimately for the religious society he served.

The Perils of Patronage

Despite its heavy investment in patronage, the Jesuit hierarchy and the individual natural philosophers over whom it had oversight were prone to suffer from the built-in weaknesses of the patronage system. Patrons were subject to the vagaries of dynastic succession and to political and financial instability. Their losses could easily injure, if not devastate, their clients. In recent articles examining Galileo's astute patronage strategies, Mario Biagioli and Richard Westfall portrayed Galileo as a highly visible client willing to take great risks in return for high stakes in the intricate game of patronage.[85] In contrast, most Jesuit natural philosophers and mathematicians were clients of very low visibility. They rarely participated in court life, and they depended on intermediaries to present the books they dedicated to their chosen patrons. Accordingly, Jesuit natural philosophers did not suffer great falls from grace such as could befall those directly attached to court life. But at times reversals of a patron's political fortune did put Jesuit practitioners in difficult positions. For example, George Fournier found himself in an awkward position after dedicating a book to Nicolas Foucquet. When Louis XIII stripped Foucquet of power (partly because the monarch was highly jealous of the nobleman's luxurious lifestyle), many of his dependents were seriously jeopardized.[86] Fournier survived the scandal with more ease than others and continued to publish books in his later years. He also proved more judicious in his later choice of patrons.

Book dedications did not necessarily result in a direct expression of a patron's esteem for a client, but were often offered, in keeping with advice received from Jesuit superiors, as blind gambles in the hope of receiving some sort of recognition. In such a system, not every gamble paid off. When Kircher offered his book on cosmology to Christina of Sweden, he, like many other ambitious learned men of his day, must have hoped to extract great rewards. A recent convert who had abdicated her throne, Christina had received theological and spiritual guidance from the Jesuits during her conversion and was widely known to have given generous support to natural philosophers. Hence, there was every reason to hope that she would patronize Jesuit publications. Though Kircher did not mention the matter in his autobiography, we may assume that his hopes, like those of many others, were dashed when it became evident that Christina's diminishing resources did not allow her to make good on her promises to scholars.[87]

In addition to inconveniencing their clients by untimely deaths or falls from power, patrons could also vex their clients by being meddlesome and importunate. Peiresc is a clear example. Annoyed that his client Kircher had put aside work on the Arabic manuscript and on the Coptic lexicon that he desperately desired to see published, Peiresc pestered the secretary to Cardinal Francesco Barberini to intervene with Kircher and to see that he put aside his studies on magnetism. "I think it would be good if you would resolve to take on the duty of midwife [of the lexicon] and to intervene in the name and authority of Cardinal Barberini to make him resolve to publish the work."[88] When Peiresc realized that his pleas had been ignored, he grew more importunate. Two months later he wrote to the cardinal's secretary again, this time offering to underwrite all the expenses of having the volume published in France. Peiresc's letter also reveals to what extent a learned patron might attempt to interfere with an author's production:

> [The book] could much more easily be published over here [France] by Monti than over there [Italy], especially since Kircher lacks the patronage for something which requires so much capital. And if he would resolve to send me the copies, I would be sufficiently encouraged to undertake the printing, lightening the work as much as possible of the figures which are too expensive and deleting the less necessary figures. I will voluntarily pay the expenses of the copyists, designers, and engravers but I would have to be assured that he is following Barachia [the manuscript in question], otherwise I would not wish to have pledged my word.[89]

In analyzing correspondence related to the patronage system, historians should not be misled by its delicate and polite language. Whereas Peiresc couched his letters to Kircher in the most polite of terms, according to the dictates of the patronage system, his letters to others about Kircher were far less veiled. In fact Peiresc was openly skeptical and derisive when writing to others about Kircher's intellectual talents.[90] Nevertheless, he was relentless in prodding his recalcitrant client. He wrote letters to get influential figures in Rome to inform Kircher of his anonymous complaints and to threaten him with the fictitious report that another scholar was about to publish a work on the same subject.[91]

Although Kircher's relationship with Peiresc demonstrates that a Jesuit client could acquire remarkable protection from such meddling by having multiple patrons, the system worked both ways. Patrons, too, had multiple clients and the latter were dispensable; there was always steady competition from other natural philosophers and mathematicians seeking recognition and reward for their books. In cases of controversial interpretation of observational data, the patronage system did not prevent opposing clients from each appealing to the same patron for recognition and legitimation. For example, the French Jesuit Honoré Fabri chose to dedicate his work interpreting telescopic observations of Saturn to Leopold de Medici, brother of the grand duke (and grandson of Cosimo II, in whose honor Galileo had named the Medicean stars). Fabri chose his patron with the full knowledge that Christiaan Huygens, a Dutch Protestant and a professed Copernican, had recently submitted a different interpretation of same phenomena to Leopold. While the heated debate between Fabri and Huygens continued for several years, each author continued to earn the approval of Leopold and to submit printed sallies to him. In this instance, the competition for a single patron severely injured Fabri's reputation in the eyes of those attached to Leopold's court.[92]

Important cultural pressures must have also operated on individual Jesuit natural philosophers. Historians have suggested that demands of intellectual conformity imposed as a result of the banning of a realist interpretation of Copernicanism in 1616, and the placing of Galileo's *Dialogues* on the Index of Prohibited Books in 1633, were keenly felt. Yet other internalized pressures are especially relevant here. As part of the spiritual program of the Society, individual Jesuits were instructed in self-abnegation and self-denial when confronted with worldly ambition, either material or intellectual. The standards for membership in the Society were clearly stipulated. The *Constitutions* and the spiritual training of members forbade any selfish quest for social recognition: "It will also be of the highest importance toward perpetuating the Society's well-being to use great diligence in precluding from it ambition, the mother of all evils in any community or congregation whatsoever. This will be accomplished by closing the door against seeking, directly or indirectly, any dignity or prelacy within the Society. . . . The professed should similarly promise to God our Lord not to seek any prelacy or dignity outside the Society."[93] The *Constitutions* clearly required the motivation and behavior of the Jesuit be exactly the opposite of those of "men of the world who . . . love and seek with such great diligence honors, fame, and esteem for a great name on earth."[94] However, by denying that they sought the approval of the learned ruling elite for their own reputation, and by claiming that they wished all glory to be deflected on the Society (or on God and the Church), Jesuit practitioners seeking noble patronage could avoid the perception that they were violating the mandated humility and abnegation. Such self-effacing statements abound in Jesuit letters of dedication. For example, at the peak of his intellectual reputation, Clavius referred to the ponderous 759-folio-page tome on the astrolabe that he presented to the powerful and virtuous Duke of Urbino as a mere trifle (*hoc meum munusculum*).[95] Rather than dismiss such protestations of humility as hollow rhetoric, one may read them as evidence of the friction generated by the religious demand for humility and the human quest for esteem and validation. When one is further mindful that individuals tended to join the Society at the age of 16 or 18 and that membership may have been subconsciously motivated by a desire to seek a vocation outside the menial, disagreeable, or boring occupations that might have befallen them had they remained in secular society, such conflicts over the matter of reputation and social esteem take on greater meaning. Moreover, a lifetime spent living in a fraternal and celibate community under the constant scrutiny of superiors and peers for moral and spiritual orthodoxy might well have aggravated, rather than controlled, the desire to be noticed and esteemed by persons outside the Society's structure.

Authors of books on natural philosophy and mathematics were also subject to rigorous scrutiny, and potential disapproval, by censors, who could be considerably more meddlesome than an annoyed patron.[96] Even Kircher was harassed by the censors on at least one occasion.[97] Approbation, in fact, was a precious commodity for Jesuit practitioners, and formal approbation from a noble patron must have been particularly valued.

Conclusion: The Diminishing Returns of Patronage

Although the production of books by Jesuit mathematicians and natural philosophers proceeded with full approbation of the Jesuit hierarchy, it should not be forgotten that within the Society the pursuit of mathematics and natural philosophy was never envisioned as a goal. Getting into print and obtaining the necessary patronage to secure publication (and reputation) always fell under the larger umbrella of the Society's educational mission. This broader goal, in turn, was subservient to the ultimate end of the Society: the salvation of souls for the greater glory of God.[98]

Nor were natural philosophers the only Jesuits seeking to get their books published and recognized. Other Jesuits produced books on theology, literature, rhetoric, and grammar, and manuals of prayer. In all likelihood, these authors competed with their confreres for the praise and rewards accorded by a finite set of Catholic nobles.

Furthermore, although some Jesuits gained entrance to court, natural philosophers were rarely among them, as these posts were reserved for confessors.[99] Jesuit practitioners continued to reside in the Society's colleges and to perform their routine administrative and teaching duties. While their secular counterparts were free to accept positions at court and at court-owned laboratories and observatories, Jesuits were more constrained. Their scientific observations and experiments took place within spaces controlled and owned by the Society.[100] As scientific instruments and apparatus became increasingly more expensive, and as only academies or formal societies devoted exclusively to scientific observation or experiment could afford the best equipment, Jesuit facilities became dated.

By the third quarter of the seventeenth century, Jesuit natural philosophers faced a further constriction of resources available to those seeking patronage. With the foundation of scientific academies, members of the ruling elite of Europe who valued mathematics and natural philosophy came to focus their financial support on the academies. Barred either by specific regulation or by practice from membership in these societies, Jesuit practitioners became somewhat marginalized from these new institutional sources of validation and financing. The only Jesuit admitted to the

Accademia dei Lincei was the astronomer John Schreck (Johannes Terrentius). But Schreck joined the Society *after* being admitted to the academy, and since he almost immediately accepted to serve as a missionary in China, his participation in the academy was sharply curtailed. The Accademia del Cimento had no Jesuit members. Although Jesuits were never officially barred from membership, the ill will of Galileo's disciples toward the Society may well have prevented invitations.

In England, the secretary of the Royal Society, Henry Oldenburg, was openly hostile toward Jesuits. He was decidedly opposed to a suggestion to use the well-organized Jesuit network of foreign missionaries as a means of eliciting reports on the natural history of exotic countries for the Royal Society. He believed that Jesuits would be unreliable correspondents, "considering the principall end of such mens voyages, which is, to propagate their faith, and to greaten and enrich themselves by their craft." Those few who were intelligent and curious in matters of interest to the Society, he believed, were "obliged, or, at least, think themselves so, to discover such observations to their owne Tribe, and would, I believe, be unwilling to communicate them to heretiques, except they were sure, they should be very well requited for it."[101] There were no Jesuit members during his tenure as secretary. In France the laws regulating the Académie Royale des Sciences specifically forbade Jesuit membership, although Jesuits made spectacular contributions on several Academy-financed scientific expeditions overseas.[102]

The older system of patronage did not collapse overnight, but it faced severe strains and reduced resources. In France the rise of the monarch's financial control lessened the abilities of lesser nobles to patronize intellectual and artistic projects.[103] Despite the foundation of the Académie des Sciences, Jesuit natural philosophers did not stop trying to use the patronage networks and practices of an earlier era for the publication of their books. Paolo Casati, for example, dedicated his 1684 book on mechanics to Louis XIV and stated in his dedicatory epistle: "I can perceive your very full merits on our Society. We wish not to show ourselves ungrateful toward you."[104] In Italy toward the end of the seventeenth century the old system was also showing signs of strain. When Francesco Eschinardi, a professor of mathematics at the Roman College, wished to publish his *Cursus mathematicus* (1689), he did not appeal directly to the Florentine grand duke; he dedicated the book to another natural philosopher, Francesco Redi, who, as court physician and adviser, might intercede with the Medici on his behalf. He also hoped that Redi himself might help defray the cost of publication, for he stated in his dedicatory letter that Redi's erudition, eloquence, and love of learning had naturally prompted his promotion of the scientific efforts of others. ("You have fostered the literary efforts of foreigners in a most friendly way and you have patronized men zealous of philosophy."[105])

Furthermore, while Jesuit natural philosophers were in practice confined to Roman Catholic patrons, their competitors were not so constrained—as the case of Huygens demonstrates.[106] Jesuits could approach Protestant printers, but they had no such liberties with respect to Protestant patrons.

Within the patronage system, Jesuit practitioners were rarely judged solely as natural philosophers. They carried considerable baggage by virtue of being Jesuits. A patron's response to a Jesuit book might well be colored—negatively or positively—by his reaction to other affairs of the Order that had little bearing on the contents of the book. Non-Jesuit natural philosophers labored under fewer preconceptions and had a far wider net of potential patrons. That the rate of Jesuit publications continued as strongly as it did throughout the last quarter of the century suggests that the Jesuit hierarchy was particularly adept in extracting the diminishing rewards from a significantly strained system of aristocratic and royal patronage of the sciences.

Notes

1. Gaspar Schott, *Cursus mathematicus* (Würzburg, 1661), dedicatory epistle.

2. On Schott's difficulties with his Jesuit superiors and his efforts to negotiate his assignments with them see Marcus Hellyer, The Last of the Aristotelians: The Transformation of Jesuit Physics in Germany, 1630–1773 (Ph.D. dissertation, University of California, San Diego, 1998), chapter 6. Hellyer cites the illuminating correspondence between Schott and his Roman and provincial superiors.

3. See Peter Dear, "Jesuit Mathematical Science and the Reconstitution of Experience in the Early 17th Century," *Studies in the History and Philosophy of Science* 18 (1987): 133–175; Dear, *Discipline and Experience: The Mathematical Way in the Scientific Revolution* (Chicago, 1995); Ugo Baldini, *Legem Impone subactis: Studi su filosofia e scienza dei gesuiti in Italia, 1540–1632* (Rome, 1992); Steven J. Harris, "Transposing the Merton Thesis: Apostolic Spirituality and the Establishment of the Jesuit Scientific Tradition," *Science in Context* 3 (1989): 29–65; Rivka Feldhay, "Knowledge and Salvation in Jesuit Culture," *Science in Context* 1 (1987): 195–213; Rivka Feldhay and Michael Heyd, "The Discourse of Pious Science," *Science in Context* 3 (1989): 109–142; William Wallace, *Galileo*

and His Sources: The Heritage of the Collegio Romano in Galileo's Science (Princeton, 1984); Wallace, "The Problem of Apodictic Proof in Early Seventeenth Century Mechanics. Galileo, Guevara, and the Jesuits," *Science in Context* 3 (1989), pp. 67–88. Steven J. Harris ("Transposing the Merton Thesis," pp. 40–45) has documented the number of Jesuit publications in natural philosophy, mathematics, astronomy, and physics.

4. On Clavius (1537–1612) see James M. Lattis, *Between Copernicus and Galileo: Christoph Clavius and the Collapse of Ptolemaic Cosmology* (Chicago, 1994); Ugo Baldini, ed., *Christoph Clavius e l'attività scientifica dei Gesuiti nell'età di Galileo* (Rome, 1995); H. L. L. Busard, "Clavius," in *Dictionary of Scientific Biography* (New York, 1970), volume III, pp. 311–312; Ugo Baldini, "Christoph Clavius and the Scientific Scene in Rome," in *Gregorian Reform of the Calendar*, ed. G. Coyne et al. (Vatican City, 1983). See also Baldini's valuable "L'attività scientifica nel primo Settecento," in *Storia d'Italia, Annali 3. Scienza e technica nella cultura e nella società dal Rinascimento a oggi*, ed. G. Micheli (Turin, 1980), esp. pp. 513–526. On Clavius's publications, see Carlos Sommervogel, *Bibliothèque de la Compagnie de Jésus* (Brussels and Paris, 1890–1910). On Clavius's formation of Jesuit mathematicians, see Baldini's essay in this volume.

5. The enduring worthiness of Clavius's textbooks in the eyes of subsequent generations is attested to in a 1653 letter of Cosimo Galilei (nephew of the deceased philosopher) to his tutor Vincenzo Viviani. Cosimo, a young and impecunious student at the University of Pisa, wrote, as students have for centuries, to ask that certain precious items be forwarded to him from home. His list of forgotten but cherished necessities included soap, a shaving mirror, and one book: Clavius's *Sfera*. It is not surprising that the young Cosimo had spent his earlier years in the hands of the Jesuit schoolmasters. See Paolo Galluzzi and Maurizio Torrini, eds., *Le Opere dei Discepoli di Galileo Galilei* (Florence, 1984), volume II, pp. 102, 107.

6. Clavius, *Gnomonices libri octo* (Rome, 1581), dedicatory epistle. On the difficulties of the Jesuit mission in Poland, see Stanislaw Obirek, "The Jesuits and Polish Sarmatianism," in *The Jesuits*, ed. J. O'Malley et al. (Toronto, 1999).

7. Clavius, *Novi Calendarii Romani Apologiae* (Rome, 1588).

8. See dedicatory epistles to Clavius's *Geometria Practica* (Rome, 1604), *Astrolabium* (Rome, 1593), and *Algebra* (Rome, 1608). Such epistles, rarely paginated, appear immediately after the title page in most seventeenth-century books.

9. Ignatius Loyola's Spiritual Exercises, the basis of the Jesuit program of spiritual instruction, required each person seeking instruction to consider soberly the use of his discretionary income: "In all these works he should desire and seek nothing but the greatest praise and glory of God our Lord. For each one must realize that he will make progress in all spiritual matters in proportion to his flight from self-love, self-will, and self-interest." (*The Spiritual Exercises of St. Ignatius*, New York, 1964, p. 87)

10. Ignatius Loyola, *The Constitutions of the Society of Jesus* (St. Louis, 1970), p. 337 [823, 824]. The *Constitutions* were written about 1556, translated into Latin, and revised slightly in 1599. Written by Ignatius, they are considered the formative organizational document of the Society. Ignatius was known for living modestly,

but he was also particularly skillful at winning the financial support of aristocrats and wealthy merchants for his Society. See Candido de Dalmases, *Ignatius of Loyola, Founder of the Jesuits: His Life and Work* (St. Louis, 1985); Ignatius, *Autobiography* (New York, 1974).

11. Article 653 of the *Constitutions* expressly mandated that he "who has talent to write books useful for the common good and who has written them ought not to publish any writing unless the superior general sees it first, and has it read and examined." With the expansion of the Society, a bureaucracy of censorship was required. On the internal censorship of Jesuit books submitted to the hierarchy for publication, see Ugo Baldini, "Una fonte poco utilizzata per la storia intellettuale: le "censurae librorum" e "opinionum" nell'antica Compagnia di Gésu," *Annali dell'Istituto storico italo-germanico in Trento* 11 (1985): 19–67, reprinted in *Legem Impone Subactis*.

12. Nicolo Cabeo, *Philosophia magnetica* (Ferrara, 1629), dedicatory epistle; Niccolo Zucchi, *Optica Philosophia Experimentis et Ratione a fundamentis constituta* (Lyon, 1652–1656), dedicatory epistle to volume I.

13. Honoré Fabri, *Synopsis Optica* (Lyon, 1667), dedicatory epistle.

14. Athanasius Kircher, *Ars Magna Lucis et Umbrae* (Rome, 1646), dedicatory epistle and letter to the reader. On Cassiano dal Pozzo, see Nicholas Claude Fabri de Peiresc, *Lettres à Cassiano dal Pozzo (1626–1637)* (Clermont-Ferrand, 1989), pp. 9–28. On Johannes Marcus Marci von Kronland, see R. J. W. Evans, *The Making of the Habsburg Monarchy 1550–1700* (Oxford, 1979), pp. 323–337. Marci befriended many Jesuits and joined the Society in the last year of his life, 1662.

15. Jean François, *La science de la géographie* (Rennes, 1652), dedicatory epistle. Henri de la Motte Odencourt was Bishop of Rennes.

16. Excellent analyses of these frontispieces are found in the work of William B. Ashworth Jr. See his "Light of Reason, Light of Nature: Catholic and Protestant Metaphors of Scientific Knowledge," *Science in Context* 3 (1989): 89–107; "Catholicism and Early Modern Science," in *God and Nature*, ed. D. Lindberg and R. Numbers (Berkeley, 1986); "The Habsburg Circle," in *Patronage and Institutions*, ed. B. Moran (Bury St. Edmunds, 1991).

17. George Fournier, *Traité des Fortifications ou Architecture Militaire tiré des places les plus estimées de ce temps pour leurs fortifications* (second edition, Paris, 1654), preface.

18. Francesco Lana Terzi, *Magisterium Naturae et Artis* (Brescia, 1684–1692), dedicatory epistle to volume 2.

19. Honoré Fabri, *Synopsis Optica* (Lyon, 1667), dedicatory epistle. Fabri's earlier *Tractatus Physicus de motu Locali* (Lyon, 1646) was dedicated to Petrus de Sève, Lord of DeFlechères, president of the parliament of Lyon, and a successful merchant.

20. Fournier, *Hydrographie*, second edition (Paris, 1667), dedicatory epistle.

21. Clavius, *Astrolabium* (Rome, 1593), dedicatory epistle.

22. Gaspar Schott, *Cursus Mathematicus* (Mainz, 1661), dedicatory epistle.

23. Filippo Buonanni, *Ricreatione dell'occhio e della Mente nell'osservationi delle chiocciole* (Rome, 1681), dedicatory epistle.

24. François, *La Science des Eaux* (Rennes, 1653), dedicatory epistle; Fournier, *Euclides Sex Primi Elementorum Geometricorum Libri in commodiorem formam contracti et demonstrati* (Paris, 1643), dedicatory epistle.

25. Giovanni Battista Riccioli, *Chronologia reformata* (Bologna, 1669), dedicatory epistle.

26. Kircher, *Diatribe De Prodigiosis Crucibus* (Würzburg, 1666), dedicatory epistle.

27. Cabeo, *Philosophia magnetica*, dedicatory epistle.

28. Clavius, *Fabrica et Usus Instrumenti ad Horologiorum Descriptionem Peropportuni* (Rome, 1586), dedicatory epistle.

29. Clavius, *Geometria Practica* (Rome, 1604), dedicatory epistle.

30. Schott edited and wrote the dedicatory epistle for Kircher's *Iter Exstaticum Coeleste Kircherianum* (Mainz, 1660); he dedicated it to Rev. D. Ioachimo, Baron of Gravenegg and Abbot of Fulda. Kircher dedicated his *Horologium Aven-Astronomico Catopricum* (Avignon, 1635) to various nobles of that city.

31. Christoph Scheiner, *Sol Elliptic* (Augsberg, 1615), dedicatory epistle; Riccioli, *Chronologia*, dedicatory epistle.

32. Lana Terzi, *Prodromo overo saggio di alcune inventioni nuove premesso all'Arte Maestra* (Brescia, 1670), dedicatory epistle.

33. Mario Bettini, *Apiaria Philosophiae Mathematica* (fourth edition, Bologna, 1645). See Antonio Maria Nelli's and Bettini's letters to the reader.

34. Schott's *Cursus mathematicus* contains a great deal of prefatory material. See Schott's prologue and the recommendations of other learned men, including Kircher, Balthasar Conrad (another Jesuit professor of mathematics), and Adam Kochansky (a Polish Jesuit and colleague of Schott's at the Jesuit college in Würzburg, whose letter is in verse).

35. Charles Malapert, *Euclidis elementorum Libri Sex priores . . . ad faciliorem captum accomodant* (Douai, 1620), dedicatory epistle.

36. Giuseppe Biancani (Blancanus), *Sphaera Mundi seu Cosmographia demonstrativa a facili methodo tradita* (Parma, 1654), preface.

37. Riccioli, *Chronologia*, dedicatory epistle.

38. Bettini, *Apiaria*, Nelli's preface to the reader.

39. Fournier, *Hydrographie*, dedicatory epistle.

40. Casati, *Fabrica et Uso del Compasso di proportione* (Bologna, 1664).

41. Schott, *Organum mathematicum* (Mainz, 1673), "Occasio Scribendi." The work was published posthumously by the Jesuit college at Würzburg.

42. Biancani, *Sphaera Mundi*, preface.

43. Kircher, *Itinerarium exstaticum* (Rome, 1656), "Preface to the studious reader of celestial philosophy."

44. Ibid.

45. Malapert, *Austriaca Sidera Heliocyclia astronomicis hypothesibus illigata* (Douai, 1633), dedicatory epistle.

46. Jacques Grandami, *Nova Demonstratio Immobilitatis Terrae Petita ex virtute magnetica* (La Flèche, 1645), preface.

47. Schott, *Physica Curiosa sive Mirabilia naturae et artis* (Mainz, 1662), dedicatory epistle.

48. Antoine Lalouvère, *Veterum Geometria promota in septem de Cycloide Libris* (Toulouse, 1660).

49. Claude François Milliet de Chales, *L'art de Fortifier ou de Défendre et D'Attaquer les Places suivant les methodes françoises, hollandoises, Italiennes et espagnoles* (Paris, 1677) and *Cursus seu Mundus Mathematicus* (Lyon, 1674). Both works were dedicated to Carl Emmanuel II, duke of Savoy.

50. Milliet de Chales, *L'art de Naviger demontré par Principes et confirmé par plusieurs observations tirées de l'expérience* (Paris, 1676).

51. Evans, *The Making of the Habsburg Monarchy*, pp. 151–154, 331–345.

52. Zucchi, *Optica Philosophia experimentis et Ratione a fundamentis constituta* (Lyon, 1652–1656).

53. Riccioli, *Geographiae et Hydrographiae reformatae libri duodecim* (Venice, 1672) and *Astronomiae reformata* (Bologna, 1665); Terzi, *Prodromo and Magisterium*.

54. On Habsburg patronage, see Evans, *The Making of the Habsburg Monarchy* and *Rudolf II and His World: A Study in Intellectual History, 1576–1612* (Oxford, 1973). See also Hugh Trevor-Roper, *Princes and Artists: Patronage and Ideology at Four Habsburg Courts, 1517–1633* (London, 1976), which deals with Habsburg patronage of the fine arts.

55. We know that Ferdinand II, in addition to saying mass twice a day, meditated daily on the death of Christ and kissed the floor five times each morning in memory of Christ's five wounds. See Evans, *Making of the Habsburg Monarchy*, p. 72.

56. See also Robert Bireley, S.J., *Religion and Politics in the Age of the Counterreformation, Emperor Ferdinand II, William Lamormaini, S.J., and the Formation of Imperial Policy* (Chapel Hill, 1981).

57. O'Malley, "The Historiography of the Society of Jesus: Where Does it Stand Today?" in *Jesuits*, ed. O'Malley et al., pp. 7–9.

58. For example, Descartes, in a 1634 letter to Mersenne, still harbored hope that the 1633 decree would not be binding as an article of faith on French Catholics, but concluded that Jesuits should now be considered enemies of Galileo: "If I may say so, the Jesuits have helped to get Galileo convicted: Father Scheiner's entire book clearly shows that they are no friends of Galileo." (John Cottingham et al., eds., *The Philosophical Writings of Descartes*, Cambridge, 1984–1991, volume III, p. 42)

59. Thomas Sprat, *History of the Royal Society* (St. Louis, 1956), p. 373.

60. For a full listing of Pallavicino's writings, see Sommervogel, *Bibliothèque de la Compagnie de Jésus*. On Pallavicino's work for Alexander VII, see Torgil Magnuson, *Rome in the Age of Bernini* (Stockholm, 1986), volume II, pp. 121–123.

61. Sforza Pallavicino, *Vindicationes Societatis Iesu, quibus multorum accusationes in eius institutum, leges, gymnasia, mores refelluntur* (Rome, 1649), pp. 380–388. Information on the social backgrounds of individual members of the Society would be interesting. We do know that Pallavicino's statement is partially erroneous, for many members came from modest family backgrounds. Yet Pallavicino's statement is certainly correct with respect to himself. The oldest son of a noble family, he certainly would have had every realistic expectation for a large patrimony and sumptuous lifestyle. He also claimed that members of the Society generally assigned their inheritances to the Society rather than to their relatives.

62. Ibid., p. 400.

63. Ibid., p. 399. These national colleges in Rome also served as important centers for foreign visitors.

64. Ibid., p. 200.

65. Kircher's autobiography, *Vita admodum Reverendi P Athanasii Kircheri, Societ. Jesu*, was originally published with *Fasciculus epistolarum adm. RP Athanasii Kircheri* (Augsberg, 1684). His early years in Germany are recounted on pp. 13–37 of the former. For vivid accounts of Kircher's life and patronage, see Ingrid Rowland, *The Ecstatic Journey: Athansius Kircher in Baroque Rome* (Chicago, 2000) and Daniel Stolzenberg, ed., *The Great Art of Knowing: The Baroque Encyclopedia of Athanasius Kircher* (Fiesole, 2001).

66. For the most thorough account of Jesuit theater, see Jean-Marie Valentin, *Le Théatre des Jésuites dans les pays de langue allemande (1554–1680)* (Berne, 1978).

67. For an excellent account of Peiresc as a promoter of Coptic studies, see Peter Miller, *Peiresc's Europe: Learning and Virtue in the Seventeenth Century* (New Haven, 2000). See also Peiresc, *Lettres à Cassiano dal Pozzo*, p. 133.

68. Kircher, *Horologium Aven-Astronomico Catoptricum* (Avignon, 1635), dedicatory epistle. The nobles were Jean de Cambis, M. D'Orsan, M. de Lagnes, Bartolomé Siffrey, Pierre Carré, and Claude Sylvestre. In the dedicatory epistle, Kircher stated that he had just received from his Jesuit superiors a letter reassigning him to Vienna. Publication of the work appears to have been delayed by about 18 months.

69. Peiresc, *Lettres à Cassiano dal Pozzo*, pp. 111–112 (September 10, 1633).

70. The Coptic-Arabic lexicon based on a work by Pietro della Valla did not appear until 1643, when it was included in Kircher's *Lingua Aegyptiaca restituta* (Rome, 1643).

71. On Kircher's trip to Malta, see Joe Zammit Ciantar, "Athanasius Kircher in Malta," *Studi Magrebini* 23 (1991): 23–65.

72. Kircher, *Magnes sive de arte magnetica* (Rome, 1641; second edition 1643). Gabriel Naudé, reporting on August 14, 1640 from Rome to Jacques Dupuy about books recently printed in Italy, noted: "Ce sera un livre bien curieux pour la matière et pour les figures qui y seront en grande quantité, mais aussi bien cher puisque

Hermanno n'en tire que cinq cents exemplaires" (Philip Wolff, ed., *Lettres de Gabriel Naudé à Jacques Dupuy (1632–1652)*, Alberta, 1982, p. 103).

73. Kircher, *Lingua Aegyptiaca restituta*, dedicatory epistle.

74. Kircher, *Ars Magna Lucis et Umbrae* (Rome, 1646), dedicatory epistle.

75. Kircher, *Musurgia Universalis sive Ars Magna Consoni et Dissoni* (Rome, 1650) and *Arithmologia sive de Abditis numerorum mysteriis* (Rome, 1665). Kircher also dedicated his *Diatribe de Prodigiosis Crucibus* (Rome, 1662) to Leopold Wilhelm.

76. Kircher, *Vita*, p. 57.

77. Kircher wrote of the subsidy in his *Vita* (p. 61). John Fletcher ("Athanasius Kircher and his Correspondence," in *Athanasius Kircher und seine Beziehungen zum geleherten europa seiner Zeit*, Weisbaden, 1988) confirms the subsidy by the Habsburg emperor. See also Fletcher, "Athanasius Kircher and Duke August of Brunswick-Luneburg, A Chronicle of Friendship," in ibid.

78. Kircher, *Itinerarium exstaticum coeleste* (Rome, 1656), preface. On the complexities of publishing the Itinerarium exstaticum, see Carlos Ziller Camenietzki, "L'ecstase Interplanetaire d'Athanasius Kircher," *Nuncius* 10 (1995): 3–32.

79. Leopoldo dei Medici to Kircher, June 12, 1655, and Kircher to Ferdinando II dei Medici, June 15, 1656, in *Le opere dei Discepoli di Galileo Galilei*, volume II, pp. 229, 347.

80. On Jansson see I. H. van Eeghen, *De Amsterdamse boekhandel 1680–1725* (Amsterdam, 1960), volume IV, pp. 160–161.

81. The contract which Kircher signed with Jansson is preserved in the archives at Rome. See Fletcher, "Kircher and Duke August."

82. Ibid., p. 288.

83. On the museum, see Giorgio de Sepi, *Romani Collegii Societatis Jesu Musaeum Celeberrimum* (Amsterdam, 1678); Filippo Buonanni, *Musaeum Kircherianum sive Musaeum a P. Athanasio Kirchero incoeptum* (Rome, 1709). Recent studies include Paula Findlen, *Possessing Nature: Museums, Collecting and Scientific Culture in Early Modern Italy* (Berkeley, 1994); William Schupbach, "Some Cabinets of Curiosities in European Academic Institutions," in *The Origins of Museums*, ed. O. Impey and A. MacGregor (Oxford, 1985), pp. 173–175.

84. Findlen, "Scientific Spectacle in Baroque Rome," *Roma Moderna e Contemporanea* 3 (1995): 625–665.

85. See Mario Biagioli, "Galileo, the Emblem Maker," *Isis* 81 (1990): 230–258; Richard S. Westfall, "Science and Patronage, Galileo and the Telescope," *Isis* 76 (1985): 11–30.

86. Other important clients of Foucquet included Pellison, La Fontaine, Molière, and the anatomist Pecquet. See Jacques Roger, "La politique intellectuelle de Colbert et L'installation de Huygens à Paris," in *Huygens et la France* (Paris, 1982). On the intricacies of the patronage system in early modern France, see Sharon Kettering, *Patrons, Brokers and Clients in Seventeenth-Century France* (New York, 1982).

87. On Christina's abuse of the patronage system after her abdication, see Susanna Akerman, *Queen Christina and Her Circle: The Transformation of a Seventeenth-*

Century Philosophical Libertine (Leiden, 1991). On the Kircher-Christina connection, see Michael John Gorman, "From 'The Eyes of All' to 'Usefull Quarries in Philosophy and Good Literature': Consuming Jesuit Science, 1660–1665," in *Jesuits*, ed. O'Malley et al.

88. Peiresc, *Lettres à Cassiano dal Pozzo*, p. 146 (September 7, 1634).

89. Ibid., p. 157 (November 3, 1634). Despite constant whining, Peiresc was unable to make his client perform exactly as he wished, for Kircher acquired other patrons in the meantime. The grammar was not published until 1643, six years after Peiresc's death.

90. Ibid., p. 237. Peiresc derided Kircher's inability to interpret certain Coptic and hieroglyphic inscriptions in letters to both Cassiano and Gabriel Naudé. At the same time, he was badgering Kircher to get on with the project.

91. Ibid., p. 161. In a letter dated December 29, 1634, Peiresc wrote to Cassiano del Pozzo, Barberini's secretary: "Tell him these things in such a way that he (Kircher) will not think that they come from me." In a postscript to the same letter (ibid., p. 165), Peiresc told Cassiano that he had informed Kircher that he would be scooped unless he hurried up with producing his work, and that "this should serve to advise him to hasten the edition he is preparing . . . and perhaps it would be good if the Cardinal would use his authority to pay the expenses for its printing."

92. The best account of the debate between Huygens and Fabri remains Albert Van Helden, "The Accademia del Cimento and Saturn's Ring," *Physis* 15 (1973): 237–259. Though Fabri held out for some years, he ultimately acknowledged the verity of Huygens's ring hypothesis in his *Synopsis Optica* (1667).

93. *Constitutions*, ed. Ganss [817], p. 334.

94. Ibid., [101], p. 108.

95. Clavius, *Astrolabium*.

96. Baldini's "Una fonte poco utilizzata per la storia intellettuale" remains the best examination of censorship within the Society. On the German scene, see Ziller Camenietski, "L'ectase interplanétaire d'Athanasius Kircher" and Marcus Hellyer, "'Because the Authority of the My Superiors Commands': Censorship, Physics and the German Jesuits," *Early Science and Medicine* 1 (1996): 319–354.

97. On the censorship of Kircher, see Baldini, "Una fonte" and Ziller Camenietzski, "L'ecstase Interplanetaire d'Athanasius Kircher."

98. Ignatius had set forth his idea of the ultimate end of all activity of the Society, including that of its schools and colleges (*Constitutions* [446], p 213): "The end of the Society and of its studies is to aid our fellowmen to the knowledge and love of God and to the salvation of their souls."

99. There were a few notable exceptions to this rule. Paolo Casati was assigned to travel to Sweden to serve as religious advisor to Queen Christina while she contemplated conversion to Catholicism. He subsequently served as rector of various Jesuit colleges and taught royalty, including Charles, brother of Ferdinand II. Juan Eusebio Nieremberg taught natural history at Madrid while also serving as confessor to the Infanta. Niccolo Zucchi's teaching duties were interspersed with assignments to preach at the Apostolic Court and to accompany the papal legate

Alessandro Orsini to the court of Ferdinand II. Kircher's assignment to Malta with the young Landgrave of Hesse is discussed above.

100. How performing experiments within Jesuit-controlled spaces affected Jesuit natural philosophy remains to be studied. Undoubtedly such a study will draw on Steven Shapin and Simon Schaffer's *Leviathan and the Air Pump* (Princeton, 1985). See also Gorman, "From 'The Eyes of All' to 'Usefull Quarries in Philosophy and Good Literature.'"

101. Henry Oldenburg to Robert Boyle, March 24, 1667 or 1668, in *The Correspondence of Henry Oldenburg*, ed. A. Hall and M. Hall (Madison and London, 1965–86), volume IV, p. 274.

102. On why the Jesuits were excluded, see Roger Hahn, *The Anatomy of a Scientific Institution: The Paris Academy of Sciences, 1665–1803* (Berkeley, 1971), pp. 15–16. For a more accurate and detailed examination of Jesuit participation in the French Academy, see Florence Hsia, "Jesuits, Jupiter's Satellites and the Académie Royale des Sciences," in *Jesuits*, ed. O'Malley et al.

103. See Kettering, Patrons; Kettering, *French Society* (Harlow, 2001); David Lux, "The Reorganization of Science 1450–1700," in *Patronage*, ed. Moran.

104. Casati, *Mechanicorum libri octo* (Lyon, 1684), dedicatory epistle.

105. Francisco Eschinardi, *Cursus physicomathematicus* (Rome, 1689), dedicatory epistle.

106. I am not aware of exceptions to this general rule, though there may be some. Kircher was patronized by the Protestant Duke Augustus of Luneburg, and he received several Protestant visitors at his museum, but he never dedicated a book to the Protestant German prince.

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Tradition and Scientific Change in Early Modern Spain: The Role of the Jesuits

Víctor Navarro

Spain, as is only too well known, participated hardly at all in the achievements and advances of European science in the seventeenth century. Owing to a confluence of political, social, economic, and ideological factors, Spain was increasingly distanced from the scientific activity that marked the century elsewhere in Europe. Ideological isolation, initially imposed to preserve religious orthodoxy, acted increasingly as a barrier to new philosophical and scientific ideas. Institutions that offered opportunities for the cultivation of science tended to be nothing more than pale remnants of those of the previous century. The universities, which in the sixteenth century had been receptive to innovation, became stagnant and continued to perpetuate an obsolete structure of disciplines. Indeed, the overall decline of university education was reflected in the fact surgery, mathematics, and astronomy were among the seven chairs called "rare"—that is, uncommon or exceptional—and often remained vacant because of a dearth of even minimally qualified professors, on the one hand, and of student interest, on the other. While the chairs of natural philosophy and medicine continued to be occupied, their incumbents imparted instruction in accord with the worst kind of scholasticism, and they completely ignored new ideas and methods. In the Casa de Contratación in Seville, for example, one of the great institutions of applied science in sixteenth-century Europe, instruction in navigation, astronomy, and mathematics declined until it virtually disappeared around the middle of the seventeenth century.[1]

Notwithstanding this marked decline, however, scientific isolation was never complete. The knowledge emanating from the scientific revolution continued to trickle into a small number of Spanish institutions, encouraged by persons or groups that made singular efforts to assimilate it. Insofar as physics and mathematics were concerned, the Jesuits played a major role in this process for a number of reasons. First, the only institutions that displayed any vitality in scientific studies, especially in mathematics and in the framework of Jesuit ideology,[2] were colleges established by the Society in Spain, especially the Imperial College of Madrid.[3] Second, membership in the Order permitted Spanish professors, or foreign professors stationed in Spain, to maintain contact with Jesuit practitioners elsewhere in Europe and, through them, to keep abreast of new scientific ideas. Finally, Jesuit eclecticism and the cautious but progressive manner whereby members of the Order approached modern science were well suited to the Spanish environment, which was resistant (if not indifferent) to innovations. Thus, Spaniards who favored innovation in these areas, even those who were not members of the Society, embraced the Jesuits for their effort to introduce the new science in Spain.

The Imperial College of Madrid

The "Reales Estudios" of the Imperial College of Madrid was established around 1560; schools of grammar, rhetoric, and theology were added in 1572. (Among the students were Lope de Vega and Quevedo.) The Imperial College was established in 1609. In 1623, Philip II informed General Vitelleschi, that he intended to establish a generously endowed "Estudios Generales" in the capital, and offered the Jesuits its directorship and chairs. The Count-Duke of Olivares, Hernando Chirino de Salazar, and the rector of the Jesuit College, Pedro de la Paz, also wrote Vitelleschi of these plans. In addition, Vitelleschi was sent a report detailing the scope of the project, the anticipated endowment, the specifics of the chairs to be founded, and the personnel required. After some negotiations, Vitelleschi accepted the plan, and in 1625 the curriculum of the new program—the principal aim of which was to educate the children of the nobility—was drawn up.[4]

The Imperial College established "lower-level courses of Latin grammar" and advanced courses distributed among seventeen chairs: Erudition, Greek, Hebrew, Chaldean and Syriac, Chronology, Logic, Natural Philosophy, Metaphysics, two of Mathematics, Ethics, Politics and Economics, "The Art of War" ("wherein Polybius and Vegecius are interpreted and the ancient erudition on this topic is read"), Natural History, "Opinions of the Ancient Philosophers," Moral Theology and Cases of Conscience, and Holy Scripture. The chairs of mathematics were described as follows: "In the morning an instructor will read on the sphere, astrology, astronomy, astrolabe, perspective, and prognostications. In the afternoon another instructor will read geometry, geography, hydrography and on clocks."[5]

The establishment of the Imperial College encountered opposition from the other religious orders as well as from the Castilian universities, which saw their interests and privileges threatened. An analogous opposition to the creation of a new Jesuit College also arose at the University of Louvain, and the professors there dispatched Cornelius Jansen to Madrid in June of 1626 to defend the cause of the university.[6] The quarrel was finally resolved with the suppression of the projected chairs of Sumula and Logic, the prohibition of granting degrees, and the reduction of the endowment.[7]

It has been argued that the Imperial College replaced, or absorbed, the so-called Academy of Mathematics of Madrid, thereby precipitating the decay of Spanish science.[8] It must be pointed out, however, that this "Academy," founded by Philip II in 1582, consisted of a single chair (mathematics and cosmography), occupied by the Chief Cosmographer of the Indies, and was a dependency of the Council of the Indies.[9] In 1625, the year the Imperial College was founded, the incumbent of the chair, Juan Cedillo Diaz, died. The king decreed that until a suitable successor could be found the lectures would be read by those Jesuits who, in the opinion of the director of the Imperial College, were qualified. It was further decreed that the lectures would continue to be delivered at the site of the "Academy," on the Calle del Tesoro. The Jesuits offered mathematics and cosmography courses in the "Academy" until 1628, when the superintendent of the Estudios convinced Philip IV to remove the lectures to the Imperial College. At the same time, it was ordered that the Jesuit responsible for the teaching should be named Professor and also Chief Cosmographer of the Indies. From that time until the expulsion of the Jesuits in 1767, the chair and the post associated with it were filled, without exception, by members of the Imperial College. The chair itself survived until 1783.[10] Moreover, the chair of fortification and artillery that Julio Cesar Firrufino held from its foundation in 1605 until 1650—and which had frequently been associated with the "Academy of Mathematics"—was in fact a creation of the Council of War. Dependent on offices distinct from those of the "Academy." It continued to function autonomously even after the creation of the Royal Studies.

The official inauguration of the Reales Estudios took place in 1629. Using the first lectures as his inspiration, Lope de Vega wrote a long poem for the opening ceremony.[11] Insofar as the scientific chairs were concerned, initially the only lectures delivered were those on natural history, imparted by the titular of this chair, Juan Eusebio Nieremberg. Juan Bautista Poza spoke on behalf of those professors who had been appointed but had not yet arrived to take up their duties.[12] In order to ensure the prestige of the Royal Studies, the Jesuits brought to Madrid foreign members who had distinguished themselves both as teachers and as researchers. These included the Swiss-German Juan Bautista Cysat, who read mathematics during the academic year of 1627–28 but, for reasons unknown to us, left Madrid by 1629.[13] Though unsuccessful in his attempt to attract Gregory of St. Vincent,[14] Vitelleschi was able to recruit in 1629 one of his best students, Jean-Charles della Faille.[15] In the same year, Claude Richard was also named professor of mathematics.[16] Other foreigners who taught in the Royal Studies of the Imperial College during its first decades, included the Pole Alexius Silvius Polonus (1593–c.1653),[17] the Scot Hugo Sempilius,[18] and the Italian Francisco Antonio Camassa (1588–1646).[19] Mathematics was also taught by the Castilian José Martínez,[20] and military art by the Basque Jesuit Francisco Isasi.[21]

The printed and manuscript works written by the Jesuits of the Imperial College offer information on the scientific atmosphere of the institution, the knowledge of its professors, and the quality of instruction. Particularly relevant in this respect are the works of Juan Eusebio Nieremberg (1595–1658), a native of Madrid of German origin. Principally known for his numerous theological works, Nieremberg served between 1629 and 1644 as professor of natural History and Holy Scriptures. In 1630 he published *Curiosa filosofía y tesoro de las maravillas de la naturaleza* [*Curious Philosophy and Treasure of the Wonders of Nature*], expanded three years later with a section titled "Oculta filosofía."[22] This is an outstanding example of the literature on curiosities—treating minerals, plants, animals, and humans—belonging to the tradition of natural magic and books of secrets, with special emphasis on the extraordinary and the marvelous. Owing to the renown of its author, the work proved very popular, as its numerous reprintings attest.[23] One part of the book was devoted to the study of magnetism, another to what Nieremberg called "the revised philosophy of the heavens." In book 4 he discussed the "magnetic stone which does not attract iron, nor points to the poles of the world, nor any other star," following closely the information and ideas expounded in *De magnete* of

William Gilbert, a number of whose experiments he describes. Nieremberg agrees with the English author that the Earth is a magnet, even adopting his nomenclature for the poles; he also followed Gilbert in discussing various movements associated with magnetism, such as variation and inclination. Indeed, Gilbert is cited repeatedly as the author who was "ahead of all others in this philosophy, whose experiments [he] found most true," and whose conclusions Nieremberg followed even while dissenting from him on the matter of the rotation of the earth. In this context Nieremberg mentions the 1616 condemnation of heliocentrism, citing Copernicus, Zúñiga, and other supporters of that theory, though claiming that the condemnation was basically aimed at the movement of the earth's motion, not its rotation around its axis. But even the latter motion seemed to Nieremberg a needless and scarcely supported hypothesis. In another passage Nieremberg controverts Galileo's efforts to explain the flux and reflux of the sea by the earth's rotation. Finally, he echoes, in passing, Gilbert's distinction between electric and magnetic phenomena.[24] As far as I am aware, this text is the first exposition published in Spain of the new theories of magnetism and, in particular, of the work of William Gilbert.

Nieremberg's "Revised Philosophy of the Heavens" appears well informed about the new astronomical ideas and discoveries prevalent c. 1629. Nor does he shy away from discussing their cosmological implications. While opposing Copernicus's theory, he regards Ptolemy's as obsolete, accepting—as was common among Jesuits—Tycho Brahe's theory. He cites approvingly Galileo's discoveries on lunar topography, as well as the satellites of Jupiter and Saturn. (Saturn's rings were believed to be satellites until the 1660s.) He also alludes to the phases of Venus—which "can be seen with optical instruments to be half illuminated, like a half-moon"—and to sun spots, adopting on this issue the position of some of his confreres that they were satellites of the sun. He denies the solidity of "celestial spheres," citing observations of the paths of comets, "novae," and planetary motions; he defends the corruptibility of the heavens, the movement of stars under their own impetus, and the common nature of the earth and stars.[25] Thus, the cosmological ideas expounded by Nieremberg were strongly influenced by the hew astronomy and were in accord with the viewpoints of the best astronomers of the Jesuit order.

In 1635 Nieremberg published in Antwerp a treatise on natural history, titled *Historia naturae maxime peregrinae libris XVI distincta*, that attempted to synthesize classical natural history (Aristotle, Theophrastus, Dioscorides, Pliny, Aelianus) with the mediaeval and Reanissance tradition (Albert the Great, Clusius, Gesner, Garcia d'Orta, Aldrovandi.) Particular attention was devoted to Spanish naturalists, including González de Oviedo, Nicolás Monardes, Jose de Acosta, and, above all, Francisco Hernández. Nieremberg incorporated 160 chapters of Hernández's *Historia de las Plantas de Nueva España* (the results of the latter's famous scientific expedition to the New World) and reproduced several other contributions of Hernández relating to animals. In addition, Nieremberg's book included magnificent engravings by Christiffel Jegher, which preserved the Amerindian style of the originals, in contrast to those which illustrated the Roman edition of Recchi's summary. Thus, Nieremberg's work played a key role in making known in Europe the results of the Hernández's expedition.[26] In the same book, Nieremberg also treated astronomical and cosmological questions similar to his discussion in the *Curiosa filosofia*. The motivation for his book, as well as for the establishment of a chair of natural history in the Reales Estudios, may be sought, at least in part, in the Jesuits' efforts to seek legitimacy and acquire patronage through advertising the great contribution of the Spanish naturalists of the sixteenth century.

As various scholars have pointed out, the Jesuits, more than any other religious order, developed the teaching of pure and "mixed" mathematics in numerous colleges throughout Catholic Europe.[27] However, the Jesuits of the Imperial College emphasized the importance of the mathematical sciences and their many applications in an environment that was not particularly receptive to such studies. In 1635, in an effort to ameliorate such indifference, the Jesuit Hugo Sempilius published his *De mathematicis disciplinis*, dedicated to Philip IV. Sempilius addressed the object, the purpose, the dignity, and the utility of such mathematical disciplines as geometry, arithmetic, optics, statics, music, cosmography, geography, hydrography, meteors, astronomy, astrology, and the calendar. He also tackled the question as to whether mathematics was a true science,[28] and in this he closely followed the position of his co-religionist Giuseppe Biancani in *De mathematicarum natura dissertatione* (Bologna, 1615).[29]

Biancani, and Sempilius after him, maintained that mathematics was a true science in the Aristotelian sense. Alessandro Piccolomini, Pietro Catena and Benito Pereira denied the mathematical disciplines such a status, because they did not envisage any kind of cause and did not obey the formal canons of syllogistic logic. Without analyzing Sempilius's reasoning and the various interpretations put forward in this controversy, it is clear that his position can be interpreted—analogous to Giacobbe's interpretation of Biancani—as indicative of his adherence to traditional Aristotelian scholasticism.[30] Nevertheless, his (partly rhetorical) defense of mathematics as a true science was clearly designed to promote its instruction in the Imperial College on equal footing with the other disciplines and, in general, to direct the attention of the directors to its importance and usefulness. Moreover, as Peter Dear argued, maintaining the boundaries between the disciplines by asserting that mathematics differed from other sciences enabled Jesuit practitioners to avoid identification, or compromise, with controversial and dangerous physical doctrines, or to avoid the need to confess their ignorance of the subject matter.[31] This enabled Jesuit mathematicians to avoid open confrontation with philosophers and theologians of the Order, who were, on the whole, faithful guardians of traditional Aristotelian scholastic learning.

This conception of mathematics did not imply, however, that mathematics was considered inadequate for the analysis of physical questions. As Clavius had already pointed out, natural philosophers had much to learn from the mathematical disciplines, which were becoming increasingly indispensable to them. Sempilius explicitly asked how natural philosophers could discuss points, lines, surfaces, or indivisibles without geometry, and whether these were positive or negative and real or imaginary. The same applied to rarefaction, condensation, and movement. Without geometry, said Sempilius, a philosopher studying motion must take refuge in material and formal distinctions. But with the help of geometry he can deduce from some movements (e.g., circular and rectilinear ones) many other movements.[32] Furthermore, though occasionally Sempilius declined to comment on the "essence" of the heavens (because it was not a mathematical issue),[33] in many other cases he did not hesitate to discuss topics that traditionally fell within the domain of natural philosophy (the solidity of the spheres, lunar topography, sunspots, sublunar fire, the true system of the world, planetary motion), bringing to bear the new discoveries and observations of Tycho Brahe, Muñoz, Galileo, Kepler, and Scheiner, among others.[34] He also mentioned the satellites of Jupiter and Saturn and the phases of Venus. In discussing the object and the utility of each of the mathematical disciplines, Sempilius displayed considerable erudition, evidence for which can be found in the extensive subject index of authors from classical antiquity until his time that he appended to the book, and which was prepared, as he himself indicates, with the composition of a future Mathematical Dictionary in mind. The list is particularly noteworthy with respect to Spanish authors of the sixteenth and early seventeenth centuries, an eloquent proof of the efforts of the Jesuits of the Imperial College to place themselves within the scientific tradition of their adopted country.[35]

As noted earlier, in 1629 Claude Richard (1589–1664) was named to the chair of mathematics, and perhaps also to the affiliated post of Chief Cosmographer.[36] Richard had previously taught Hebrew at the Jesuit college in Toulon and mathematics the Jesuit college in Lyon. He published two voluminous treatises on mathematics. The first, *Euclides elementorum geometricorum* (1645), contains, in addition to the *Elements*, many commentaries on other works, some by Richard himself. The commentaries on Euclid are followed by others on Isidore of Miletus, Hypsicles of Alexandria, and François de Foix (Franciscus Flussatem Candallam) on the five regular solids and their inscription upon a sphere; questions of proportionality of segments according to Werner and Juan Bautista Villalpando[37] are followed by Richard's own observations and notes.[38] The second work is a magnificent edition of the first four books of Apollonius's *Conics* (1655), based on Federico Commandino's edition, and with a great number of propositions and corollaries added to the text.[39] Richard also studied optics and magnetism,[40] and left many manuscripts on mathematics, astronomy, and the military arts, some of which had been prepared for his lectures.[41] One such work is a treatise on the sphere "read in Madrid to the pages of his Majesty Philip IV in 1639."[42] Some of his cosmological ideas are expounded in a short work on the comet of 1652, where he describes the observations he carried out between September 20 and September 30 with "the King's excellent long-range telescope." He discusses the "substance of the heavens," and he mentions observations of comets, "novae," the satellites of Jupiter and Saturn, and the Milky Way carried out by Brahe, Galileo, and others in order to defend the thesis that the heavens could not be "hard and impenetrable." Richard asserts that the "substance of all the stars, planets and comets is of elementary fire" and that the movers of all the stars are angels.[43] In other manuscripts on astronomy and cosmology Richard provides a detailed discussion of the nature of the heavens, holding that they are fluid, that there are no celestial spheres, and that processes of generation and corruption occur there—again basing himself on, among others, Brahe and Galileo. Richard also describes Galileo's writings on sunspots and explains the Tychonic system, which provides a superior account of all heavenly phenomena without assuming the (prohibited) motion of the earth.[44]

Another professor at the Imperial College with important scientific activities was the Belgian Jean-Charles della Faille, who studied in Antwerp with Gregory of Saint Vincent and taught mathematics in Dôle and in Louvain, where he succeeded his teacher. In 1629 della Faille began teaching in the Imperial College, where he enjoyed a distinguished teaching career. Apart from the courses in the Royal Studies, he gave private lessons in mathematics to various members of the nobility and taught military arts and fortification to the royal pages. In 1638 Philip IV named della Faille Chief Cosmographer of the Council of the Indies, and in 1644 he appointed him preceptor to his illegitimate son Juan José de Austria. Della Faille soon became the prince's trusted adviser, and accompanied him on his military campaigns. The education that Juan José de Austria received from della Faille must have exerted a decisive influence on his interest in modern science, for he subsequently became a Maecenas to Spanish scientists, employing as his personal physician such significant figures in Spanish scientific renewal as Juan Bautista Juanini.[45]

Della Faille had a close personal and scientific relationship with Michael Florent van Langren, cosmographer and mathematician to the king of Spain in Brussels, who competed for the prize offered by the Spanish crown to find the solution to the problem of longitude. Van Langren's idea was to utilize the phases of the moon instead of its eclipses.[46] Della Faille defended his friend's proposal, but no decision was reached. In della Faille's letters to van Langren one can appreciate the breadth of his scientific interests and the attention and critical spirit with which he followed progress in mathematics, astronomy, geography, cartography, and natural philosophy.[47]

Della Faille's sole publication is *Theoremata de centro gravitatis partium circulis et ellipsis* (Antwerp, 1632), written at the suggestion of Gregory of St. Vincent.[48] Della Faille's exposition is rigorously geometrical and Archimedean, and the text was highly praised by the young Huygens. Della Faille mentions that he had published *Theses mecanicae*, of which no including *Tratado de cónicas*, *Problemas para escrivir reloxes* [Problems Relating to Solar Clocks], one consisting of (mainly classical) mathematical works,[49] one on architecture,[50] a *theoricas* of the planets "according to the two hypotheses, the one that supposes the earth's motion and the other that supposes it to be immobile," and one on geometrical method.[51] In the last, della Faille defended not only traditional Aristotelian logic but also an inventive logic by means of combinatory calculus, a subject that had attracted the attention of Jesuit practitioners ever since Clavius.[52] In the same work he refers to algebraic applications to geometry and mentions a treatise on the topic. It is noteworthy that he translated Giovanni Battista Baliani's *De motu naturali gravium solidorum* into Spanish.[53] Della Faille was acquainted with this work through Baliani's friend Antonio Balbi, a former student at the Collegio Romano. Balbi, who visited Madrid in 1638, had been charged by Baliani to acquaint mathematicians there with his work and elicit their judgement of it.[54] The following year, della Faille wrote to Baliani praising his book.[55]

Della Faille was also interested in questions of marine cartography and apparently drew a nautical map using his own method to resolve the "problem of rhumbs." Although the exact nature of the method is unknown, he was obviously acquainted with Mercator's projection and cognizant of its advantages for navigation.[56] It is reasonable to assume that the Jesuits of the Imperial College contributed to the introduction of such projection to Spanish nautical maps, as the published works and manuscripts of Spanish cosmographers before this time—such as Céspedes, Cedillo, and others—contain no reference to Mercator.

Sebastián Izquierdo and Encyclopedism

Very little is known about the attitude of Jesuit professors of philosophy—either Spaniards or those residing in Spain—toward new ideas. The general impression is that they remained staunch supporters of the scholastic tradition and the teachings of Suárez, Toledo, Pereira, and the school of Coimbra.[57] Rodrigo de Arriaga, who incorporated certain new ideas into his *Cursus philosophicus* (first published in 1632), is not representative of the Spanish environment, as he worked in Prague and his influence on Spain has yet to be determined.[58]

A very interesting exception to this general conclusion is Sebastián Izquierdo, a native of Alcaraz (Albacete province), who taught philosophy and theology in the Jesuit colleges of Alcalá de Henares and Murcia until

1681, when he was transferred to Rome. In 1659 Izquierdo published his *Pharus Scientiarum*, which was intended to expound a method of scientific knowledge and which consequently must be considered within the domain of the history of seventeenth-century logic. Moreover, the search for an "Ars generalis sciendi" places it within the Lullian tradition, whose influence was felt throughout the seventeenth century, culminating in the work of Leibniz.[59] As Vasoli pointed out, Izquierdo conjoins the notion of a "universal art" with that of "encyclopedia," conceived as *scientia orbicularia, seu circularis*, which is not an *aggregatu omnium scientarum* but rather a *specialis scientia* comprehending all the others.[60] Izquierdo's work presents a syncretism in which both traditional Aristotelian logic and Baconian empiricism are encompassed. In view of the conservatism of peninsular philosophical literature of the seventeenth century, this work is of evident interest for the partially novel elements it contains. Noteworthy, for example, is Izquierdo's advocacy of observation and experiment as the basis of scientific knowledge, and his inclination toward the *mos geometricus* in the development and exposition of philosophy.

The *Pharus* contains some original ideas that can be considered immediate precursors of Leibniz's *De Arte Combinatoria* (1666).[61] Both works are inspired by the same emphasis on inventive logic and, with it, the methodology of science. Izquierdo's work influenced some later Spanish authors, including Caramuel, Zaragoza, and the Valencian scientists of the late seventeenth century.[62]

The Mallorcan Astronomer Vicente Mut and the Reception of Modern Astronomy in Spain

In the middle decades of the seventeenth century, Mallorca was a scene of notable activity in science. This activity centered on Vicente Mut, who maintained close ties with several foreign Jesuit practitioners living in Spain. Born in Palma de Mallorca in 1614, Mut studied humanities with the Jesuits, whose cassock he wore for several months. Later he studied mathematics and jurisprudence, pursuing a military career until he became Sergeant Major of Palma, contador (administrator), and engineer. He also practiced law and served as a jurate of the city and official chronicler of his homeland. He died in Palma in 1687. Mut published books on history, hagiography, military tactics, fortification, and astronomy. His *Historia del*

Reyno of Mallorca (1650), written as a continuation of Juan Dameto's history, stands out from his other works.[63]

In Mut's treatise on fortification, *Arquitectura militar* (1664), I have found the first attempt in Spanish literature to apply Galilean dynamics to the launching of projectiles. Mut argued that a ball shot vertically from the top of a galley, regardless of the ship's speed, will fall at the foot of the mast. For additional details he refers the reader to Galileo, Mersenne, and Gassendi. Further on, but still in the context of the discussion on ballistics, he mentions the Galilean law of falling bodies. When treating horizontal firing, he correctly analyzes the trajectory of the projectile in a parabola.[64]

Mut published three astronomical works: *De Sole Alfonsino restituto* (Palma, 1649), *Cometarum anni MDCLXV* (Mallorca, 1666), and *Observationes motuum coelestium* (Mallorca, 1666). The first is a study of the diameter of the sun, its parallax, and the breadth of the terrestrial shadow. The estimate of the apparent diameter of the sun is accomplished through a measure similar to the one adopted by Scheiner (whom Mut mentions) for observing sunspots, consisting of obtaining the image of the star when it passes through the meridian on a screen perpendicular to the optical axis of the telescope. Riccioli mentions Mut's technique in his *Almagestum Novum*, as does Milliet Dechales in his *Cursus seu mundus mathematicus*.[65]

The *Observationes motuum coelestium* presents the results of more than 20 years of patient observation of the heavens. Some of Mut's observations, however, had already been published by Riccioli—with whom Mut corresponded—in the latter's *Almagestum Novum* (1651) and *Astronomia reformata* (1665).[66] In the dedication to the *Observationes*, Mut "offer[s] these observations to whomever wants to submit the tables of celestial motions for examination." He proceeds to enumerate the authors who, in his judgment, have most contributed to the progress of astronomy:

> With the means of the old astronomy, the great Atlas of Tycho Brahe sustained this volume [*molem*] on his robust shoulders, he who, although wearied by carrying so great a burden, aided Longomontanus [Christian Severin]. In the same conditions labored Kepler, who tabulated the movements of Mars with more precise figures. . . . Father Juan Bautista Riccioli, in his *New Almagest,* structured the whole of astronomical learning with his wise pen and most exact observations, making greater things possible.

Finally, Mut laments that "some famous astronomers, who set down their own observations with great precision, have greatly mutilated those of others which might serve to refute their preconceived hypotheses."[67]

Observationes motuum coelestium consists of three parts. In the first he describes various observations of lunar eclipses carried out with a telescope composed of two convex lenses—the instrument described by Kepler—of almost "eight palms," each about 160 cm in length. He provides data on the parallax and diameter of the moon, the horizontal parallax of the sun, and so forth, utilizing the astronomical tables of Kepler and Lansberg. The chapter ends with a tabular summary. Mut concludes by concurring with Kepler that these observations require that the eccentricity of the sun be nearly a bisect, which supposes an important modification of the opinions expressed in his previous work, where he still favored a pre-Keplerian solar theory. The second part, titled "Observationes planetarum, cum adnotationibus astronomicis, praesertim circa motus per Ellipses," begins with a description of the method employed to adapt his telescope to the measure of angular celestial distances and continues with the results of his observations, several of which are reproduced in Riccioli's works.[68] Kepler's first law is introduced by Mut in reference to Mars: he recognizes that for Mars the most appropriate tables are those of Kepler, although he adds that they are composed by virtue of a "most abstruse" calculation for ellipses. Then, after reiterating Boulliau's point that Kepler's method is not "geometrical," Mut reaffirms his conviction that the planets orbit in circles, "inasmuch as circular motion is the most appropriate for all revolutions . . . that the celestial bodies of the universe repeat without interruption." Nevertheless, he continues, "since for ease of calculation the whole set of circles may be resolved in ellipses, I think that systems made up of ellipses must be admitted."[69]

Like most contemporary astronomers, Mut did not understand the underlying significance of Kepler's work. Therefore, when faced with the undeniable difficulty of Kepler's method, instead of the second law he used the so-called simple elliptical hypothesis of Boulliau-Ward, consistent in supposing that the planet moved uniformly with respect to the second focus of the ellipse. Likewise, he incorporated the correction introduced by Boulliau in order to achieve a higher degree of precision in the longitude of Mars.[70] Moreover, Mut does not mention that even though Boulliau rejected Kepler's celestial physics, he was a convinced Copernican who attempted to develop Copernicus's program in a coherent way. For Mut, planetary theories are falsae propositiones [imaginary suppositions].[71] Still, Mut's work is of particular interest in the Spanish context, because it is the first discussion of Keplerian ellipses by a native author.

Mut's third part is a pamphlet of 20 pages on the comet of 1664, with some additional observations relating to another comet which was sighted the following year. In it, he includes observations made in Valencia which he had communicated to his friend, the Jesuit José de Zaragoza, as well as those of other Mallorcan observers such as Miguel Fuster. He recorded in a table the progress of the comet in December and January, including the hour of observation, longitude, latitude, angle of the orbit with the ecliptic, and the distance from the node.[72] With reference to the trajectory, Mut observes that, having rejected the Aristotelian belief in the impenetrability of the heavens, modern authors like Kepler, Galileo, Cysat, and Gassendi (following Seneca) locate comets in the highest region of the atmosphere or else in the ether, according to a movement of rectilinear trajectory in the plane of a maximum circle. This opinion seems plausible to him, because it accounts correctly for all the phenomena of comets, but he still thinks that "something must be added":

> Since the comet of this year [1664] traced nearly a semicircle against the sequence of the signs [of the Zodiac], it seems impossible that it should pass from Libra to Aries with a rectilinear movement, as through a chord, inasmuch as in this right trajectory it would have been near the earth, even extraordinarily close, with an excessive parallax, which in fact was not so large. In effect, the chord which subtends the maximum circle through a quadrant is nearer the center. This difficulty also occurs under the system that accepts the movement of the earth, so that the comet which, owing to its rectilinear trajectory, we fear will fall to earth, Kepler feared would also fall into the sun.[73]

To explain why the comet's trajectory seems to appear as a semicircle, Mut likens the movement of a comet to the parabolic trajectory of a projectile, just as he studied it in his *Arquitectura militar*. Thus, when "the rectilineal movement weakens," the comet "inclines in a parabolic trajectory." This explanation by analogy with the trajectory of projectiles was also used by Hevelius.[74]

Vicente Mut was also a correspondent of Athanasius Kircher, whom he calls "Magnus Scrutator Naturae, Coeli et Soli."[75] In the seven surviving letters, Mut sends Kircher news about his work and astronomical observations, mentions the interest awakened in him by Kircher's works, and, taking advantage of his brother's trip to Rome, asks for advice on which scientific books to buy.[76] He must also have been in contact with the mathematicians of the Imperial College, some of whose astronomical observations he occasionally cites. As I have noted, he had a notable influence on

José de Zaragoza, one of the most important Spanish scientists of the second half of the seventeenth century, who became professor of mathematics at the Imperial College of Madrid.

José de Zaragoza and the Origins of Spanish Scientific Renewal

José de Zaragoza (1627–1679) studied in the University of Valencia, where he won the doctorate of theology. In 1651 he entered the Society of Jesus, fulfilling the novitiate in Huesca. He taught rhetoric in Calatayud, and then arts and theology in Palma de Mallorca. There he met Vicente Mut and Miguel Fuster, both of whom were instrumental for his scientific training.[77] After leaving Mallorca, Zaragoza taught theology in Barcelona. Around 1660 he was transferred to the College of St. Paul in Valencia, where he remained for more than a decade, officially teaching theology but privately devoting himself to research and teaching in mathematics. In Valencia, he himself recounted, he collaboratedwith several persons well versed in astronomy.[78] For example, he cites astronomical data received from the mathematician and musician Félix Falcó de Belaochaga, mentor of the scientific reformers of Valencia at the end of the century, and the aristocrat Enrique de Miranda.[79]

Zaragoza published various works on mathematics, mainly of a didactic nature. Such were his *Arithmética universal* (Valencia, 1669), an elementary compendium of arithmetic and algebra, his *Geometría especulativa y práctica* (Valencia, 1671), and his *Trigonometría* (Mallorca, 1672). Though these works contained no substantial contribution to mathematics, they nevertheless represented a notable pedagogical effort for this period and were important within the impoverished Spanish context. Zaragoza's most important mathematical work is the *Geometria magna in minimis* (three volumes, Toledo, 1674). This work, although tightly linked to classical methods (a very common characteristic among Jesuit mathematicians), contains a number of original ideas. Zaragoza uses the concept of the "minimum center" of a system of points (or barycenter, in physics), analogous to the one employed by Giovanni Ceva four years later, and with it he fashions a geometrical theory which turns out to be isomorphic to that of the statics of a system of isolated bodies. Some of the results he achieved, as Recasens Gallart noted, are the construction of a geometrical theory of barycentric calculation; restitution and generalization, in terms of classical geometry, of the fifth of the "plane loci" of Apollonius; calculation of the concurrence of transverse lines passing through the vertices of a triangle (a theorem named after Ceva); the quadratic relationship between the sides of a quadrilateral and its diagonals (Euler's theorem); and a resolution of the problem of the minimum tetrahedron.[80] Unfortunately, Zaragoza's work never received the diffusion it merited, and his contributions were unknown to European mathematicians.

In astronomy, Zaragoza, like Mut, was an excellent observer. Among his many observations, those of the comets of 1664 and 1667 stand out. The report on the first, submitted to the Academy of Sciences of Paris, is preserved in manuscript form and constitutes a detailed study of the phenomenon in 50 pages.[81] It begins with a description of his observations, as well as those of other astronomers, including Mut, Enrique de Miranda, Miguel Fuster, the Jesuit Milliet Dechales, the professor of mathematics at the Collegio Romano F. Gottignies and the Italian astronomer Giuseppe Montanari. He then studies the apparent motion of the comet and attempts to analyze its trajectory, concluding that it falls somewhere between a curve and a straight line. He adds: "I leave it an ellipse, because it could be obtained from either [a circular trajectory or a rectilinear one]." On the "true place" of the comet, Zaragoza demonstrates that it was always "above the moon," from which he deduces that, contrary to "the common peripatetic philosophy and its prince Aristotle," the heavens are fluid and corruptible. Finally he alludes to astrological predictions and briefly observes that "the judgment of their effects is reserved for judicial astrologers, who will be able to make new judgments, if they accept the truth of these observations."[82] The same comet also prompted Zaragoza to write *Discurso contra los astrólogos*, whose principal thesis was that the effects of these phenomena "cannot be known with any certainty, nor even conjectured with medium probability." This attitude of reserve and skepticism regarding astrological prediction was shared by Mut, who in one of his first works points out that "prognostications are very harmful to the Republic, because too much credit is given them; if an astrologer is correct once (surely a rarity), no one recalls the infinity of times he was wrong."[83] Cassini thought Zaragoza's observations of the comet of 1667 were the first in Europe, and they were mentioned in the *Journal des Savants* and the *Memoirs* of the Academy of Sciences of Paris.[84]

Zaragoza wrote many other works on astronomy and composed astronomical tables. He prepared some of these unpublished works for his classes at the Imperial College.[85] The only example of this material that reached print is *Esphera en común celeste y terráquea* (1675). This work, intended to be a revision of the traditional texts on the Sphere, adapted to the new discoveries, and it is an eloquent example of the author's concern to diffuse advances in scientific knowledge in Spain. The book follows the traditional outline: I. De la Esphera en común. II. De la Esphera celeste. III. De la Esphera terráquea. In general, Zaragoza limits himself to synthesizing the information and ideas contained in texts on this subject published in Europe in the seventeenth century by his co-religionists, especially Giovanni Battista Riccioli, although occasionally he includes his own observations. In the description of the various astronomical systems he includes the heliocentric theory, of which he says "it is condemned by the Congregation of the Cardinals of the Inquisition as contrary to Holy Scripture, even though as a hypothesis or supposition everyone might take advantage of it for the calculation of planets, for only the reality of this construction is condemned, not its possibility."[86] Also, like Mut, he addresses Kepler's first law and expounds the so-called elliptic hypothesis of Boulliau-Ward.[87] Moreover, in his discussion of magnetism in the third part of the book, he indicates that "even though Kepler attributes the course of the planets to the sun's magnetism," nevertheless "all the appearances of planetary motion are saved through a spiral motion."[88] This theory of remote origins is to be found in the works Biancani[89] and other Jesuit authors, as well as in those of Bacon and those of various Spanish authors of the sixteenth century.[90]

Zaragoza also comments on new astronomical discoveries—the phases of Venus and Mercury, satellites of Jupiter and Saturn, sunspots, lunar topography, and observations of comets and "novae"—and discusses their cosmological consequences, although cautiously and not without ambiguity and vacillation. Thus, he rejects the notion of celestial spheres, asserting that the heavens are fluid and the stars corruptible. He locates the "novae" in the planetary sky in order to maintain the solidity of the firmament. Yet he notes that the firmament may be fluid and that the "stars move through it like birds through the air."[91] He does not mention the rotation of the sun, possibly because it was associated with the possibility of an analogous motion of the earth.

The third part of the *Esphera* is a compendium of mathematical and physical geography as it was understood at the time. Notions of the descriptive geography of countries are absent.[92] Navigation is addressed in a discussion of the problems of the determination of latitude and longitude and of the loxodromic curve. Zaragoza also discusses the earth's interior, expounding some of the ideas contained in the *Mundus Subterraneus* of his confrere Kircher (with whom he corresponded).[93] Zaragoza accepts the existence of subterranean fire postulated by Kircher, a fire whose breathing tubes are volcanos, and he alludes to Kircher's "fire-dwellers, water-dwellers and air-dwellers," with respect to which he writes, with some skepticism: "I do not reject them because they are possible, nor do I accept them because it is not possible to confirm them as fact." This skepticism appears on other occasions, as when, in discussing subterranean life, he comments that "Father Kircher gives a history of subterranean men that is stranger than the stories of Batuecas [a valley in the province of Salamanca associated with fables and legends]."[94]

In the Academy of History is preserved the index of a complete "course" of physical and mathematical sciences planned by Zaragoza, though it is not known whether he actually wrote it. In eight volumes, it was to deal with geometry, arithmetic, algebra, harmony, astronomy, geography, navigation, trigonometry, optics, statics, architecture, pyrotechnics, mathematical instruments, and questions on physics and mathematics—that is, "all the questions that are related to both physics and mathematics, which are numerous, curious, and very difficult."[95]

Finally, Zaragoza was interested in the construction of scientific instruments. His last published work, *Fábrica y uso de varios instrumentos matemáticos* [*Construction and Use of Various Mathematical Instruments*] (Madrid, 1675), concerns the description and use of a series of instruments, built by himself in collaboration with the Jesuits Baltasar de Alcázar and Juan Carlos Andosilla, for geometric, topographical, and astronomical purposes. His Valencian associates also possessed instruments designed by Zaragoza during his stay in Valencia.

Scientific Activity of the Jesuits at the End of the Seventeenth Century

After Zaragoza's death, the chair of mathematics was again occupied by a foreigner, the Austrian Jacob Kresa. Kresa held the chair for 15 years,[96] and many of the works published in Madrid during his stay there bore his censure or approval. Kresa also held the post of the Chief Cosmographer[97] and resided for a time in Cádiz, probably assigned to the Royal Navy.[98] In Cádiz, Kresa directed a number of theses; he also presided over mathematical examinations held at the Jesuit college, where there was a chair of mathematics.[99] Kresa's presence undoubtedly influenced the development of mathematics among the Jesuits of Cádiz. Out of this environment came the most important work in this subject published in Spain in the second half of the century after Zaragoza's *Geometria magna in minimis*: Hugh de Omerique's *Analysis Geometrica* (Cádiz, 1698).

Omerique was born in Sanlúcar de Barrameda in 1634. Though not a Jesuit, he was closely associated with them. He probably studied with Jesuits, and by 1689 he was living in Cádiz, were he worked as "Contador de cuentas y particiones." In that year Kresa published in Brussels a Castilian version of Euclid's *Elements* with additions of his own, in which he included problems devised and solved by Omerique, adding that from this author geometry would receive its "best polishing" and that his works would soon appear in print.[100]

Only two of Omerique's works survive: the first part of *Analysis Geometrica* and some "Artificial Tables" of logarithms. The former deals with the resolution of geometrical problems by the analytical method: relations are established between the data and the unknowns, on the basis of which the value of the quantities sought is deduced. The work bears Kresa's "censure" and two "judgments" by José de Cañas and Carlos Powell, professors of mathematics in the Jesuit College of Cádiz. It includes, in addition, a short treatise by Powell, *Algorithmus Rationum*, in which Clavius, Commandino, Tartaglia, Campano, Kircher, Ozanam, Gregory of St. Vincent, Tacquet, and Wallis are cited, attesting to the mathematical erudition of the Cádiz professors.

Omerique's work was praised by Newton: "I have lookt into De Omerique's Analysis Geometrica and find it a judicious and valuable piece answering to the Title. For therin is laid a foundation for restoring the Analysis of the Ancients which is more simple and more ingenious and more fit for a Geometer then the Algebra of the Moderns. For it leads him more easily and readily to the composition of Problems and the Composition which it leads him to is usually more simple and elegant than that which is forct from Algebra."[101] Whiteside considers Newton's elegy of Omerique's book as a "profound venture" in geometrical analysis to be exaggerated, since its scope is restricted to plane problems (straight lines and circles).

Still, Whiteside asserts that Omerique's definition of the nature and objective of analysis ("to adopt a question as a conclusion, advancing through necessary consequences to the certain and determinate") is clear and precise enough, and his selection of problems illustrative, praiseworthy, and eclectic, giving evidence of his wide reading, not only in Euclid and Pappus but also in their modern successors Viète, Ghetaldi, Gregory of St. Vincent, and Frans van Schooten.[102]

Another man who taught mathematics in the Reales Estudios of the Imperial College in the last decades of the century was Jean François Petrei. Born in Besançon in 1656, Petrei entered the Society of Jesus in 1656 and taught humanities and rhetoric in the province of Lyon. In Madrid, according to Simón Díaz, he taught grammar and rhetoric for eight years, "erudition" for three, and mathematics for three.[103] The Academy of History preserves numerous manuscripts and letters that attest to the range of his scientific interests.[104] Several of the manuscripts consist of his notes on the writings of Descartes, Schooten, Regis, Willis, Arnauld, Hobbes, Huygens, and Rolle and of the Jesuits Scheiner, Riccioli, Fabri, Schott, and Pardies; others are unfinished works on fortification, geometry, algebra, optics, astronomy, geodesy, and astronomical observations of eclipses, comets, and planets. Petrei kept in touch with members of the Academy of Sciences of Paris, and there still survives a long letter from La Hire in which the French astronomer informs the Jesuit of the shipment of the micrometer designed by Picard and Auzout, explaining its use and includes the results of observations of solar and lunar eclipses carried out with such an instrument.[105] Petrei also corresponded with José Pérez, professor of mathematics at the University of Salamanca since 1673, on diverse astronomical, mathematical, and philosophical topics (especially the works of Thomas Hobbes) and with Juan Bautista Corachan, whose sole surviving letter informed Petrei on scientific activities in Valencia.[106]

Another text attesting to the activities and achievements of the Jesuits of Madrid at the end of the century is Pedro Hurtado de Mendoza's *Espejo Geográfico* [*Geographical Mirror*] (Madrid, 1690–91). The author describes himself as corresponding secretary of Gregorio de Silva y Mendoza, duke of Infantado, and an important political figure in the court of Charles II. The duke, moreover, had been a disciple of José de Zaragoza at the Imperial College, and the latter dedicated to him his *Euclides nuevo antiguo* (1678). The duke was a patron of intellectuals and historians, and Hurtado de

Mendoza dedicated his book to him. Hurtado informs us that he had studied with Jesuits and acknowledged that he was a disciple of an unnamed member of the Order, thereby giving the impression that the book is the fruit of such instruction. For these reasons it has been speculated that the name which appears on the book's title page might be a pseudonym for Jean François Petrei. Be that as it may, the Jesuit associations of the *Espejo geográfico* are clear.[107]

In his introduction, Hurtado de Mendoza takes pains to delimit the scope of geography with respect to the other sciences. He says that geography can be divided up in three ways: artificially (in what relates to the celestial circles), into zones, climes, longitude, and latitude; naturally, into lands, isthmuses, islands, and other such divisions; and politically, into empires, kingdoms, republics, and other states. His text is organized according to this division. He is up to date on the question of the size of the earth, showing his familiarity with research carried out in France by members of the Parisian Academy of Sciences. The discussion on the magnitude of the earth leads him to the issue of metric unity. Here he refers to Huygens's idea of using the length of a simple pendulum with a period of one second to define a universal measure of length. He also mentions the center of oscillation and the isochrony of the cycloid pendulum.[108] In cosmography, Hurtado de Mendoza's position on Copernicus is similar to that of Zaragoza and other Spanish authors receptive to new ideas: he accepted the Copernican theory as a hypothesis, valid for "saving the appearances." Though recognizing that "however much Father Riccioli and others, both mathematicians and philosophers, have tried to counter this hypothesis with reasons and experiments, there is not reason enough to oblige us to negate its possibility," he ultimately submits to the dictates of the Roman Inquisition insofar as the physical truth of Copernicanism is concerned.[109]

In the second part, Hurtado displays his good understanding of the geography of the New World. He mentions Bernhard Varenius with reference to the northern limits of North America, and he has reasonably good information about Greenland and the Arctic islands. He has first-hand information on China, even unpublished materials from Jesuit missionaries. With regard to the peninsular or insular character of Korea, he writes "I hoped to embellish this point with notices from the new and exact map of the Kingdom of Korea that the aforementioned Father Antonio Thomás says has been sent to this Court," lamenting that "until now it has not arrived here nor in any other part of Europe with which that notable missionary corresponds." He also reflects the influence of Kircher, whose organicist theories he defends, comparing the hydrographic network with the human circulatory system and displaying in passing a good understanding of the discoveries of Harvey and Malpighi.[110]

With its three equally balanced parts, the *Espejo Geográfico* is a good example of European geography at the end of the seventeenth century. It is also a good example of the Jesuits' geographical knowledge, insofar as Jesuits are cited frequently (Clavius, Riccioli, Milliet Dechales, Fabri, Ciermans, Grimaldi, Tacquet, Acuña, and Rodríguez, to name a few). There are also references to Mersenne (on sound), to Henry Oldenburg (on an expedition to Guinea), and to Vicente Mut and Ismael Boulliau (on the correction of specific geographical points, such as the length of the Mediterranean).

The Pre-Enlightenment Movement of Renewal and the Influence of the Jesuits

In the last decades of the seventeenth century, those who wished to break with traditional knowledge and its suppositions adopted a clearly delineated program of systematic assimilation of modern science. At the heart of this program was an awareness, which Spanish scientists made explicit, of the scientific backwardness of the country. Spain had remained marginal to modern science. Valencia, Zaragoza, Madrid, Barcelona, Seville, and a few other cities were the stages on which the so-called *novatores* of the turn of the century performed. Ever since his arrival in 1687 to Madrid, we are told by Diego Mateo Zapata, one of the protagonists of medical reform, he had been aware of "the public and celebrated salons enlightened and adorned by the men of most dignity, status and learning then known, such as the Marqués de Mondejar, don Juan Lucas Cortés of the Royal Council of Castile, don Nicolás Antonio . . . who spoke of modern philosophy, as they did of all the sciences."[111] In 1687, in Madrid, the Valencian Juan de Cabriada published his *Carta filosófica, médico-chymica* [*Medico-Chemical Philosophical Letter*], which López Piñero considers an authentic manifesto of the renewal of medicine, as well as of the adjoining disciplines of biology and chemistry.[112] Cabriada mounted a courageous attack on the scientific backwardness into which the country descended.

"How pitiful and shameful it is that we must be the last to receive the public notices already diffused throughout Europe, as if we were Indians,"[113] he thundered, suggesting, among other remedies, the creation of an Academy of Sciences analogous to that of Paris. In Seville, the modernist efforts culminated with the establishment in 1700 of the Royal Society of Medicine and Sciences, the first Spanish scientific institution devoted to the cultivation of the new knowledge. Among the founding members were Zapata and Juan de Cabriada. Also in Seville, there existed since 1681 the College of Saint Telmo, which played a role in the renewal of navigation studies. In Zaragoza the Italian physician Juan Bautista Juanini, who had settled in Spain in 1667 when he entered the service of Juan José de Austria, contributed decisively to the diffusion of modern ideas among some physicians there. Naturally, such groups were small and frequently confronted the opposition of the dominant conservatives. Thus, for example, the founders of the Royal Society of Seville had to engage in numerous polemics and overcome the opposition of the traditionalists of the University of Seville, while in Zaragoza one of the principal *novatores* at the University, José Lucas Casalete, was condemned for his teachings by colleagues in the universities of Salamanca, Alcalá, Valladolid, Valencia, Barcelona, Lérida, and Huesca. Still, the *novator* movement (so termed by its detractors) managed to consolidate itself and expand its area of influence, setting the basis for the significant scientific developments of the enlightenment.[114]

The movement of renewal achieved its greatest clarity and energy in the field of medicine and in the chemical and biological sciences closely linked to it. In mathematics, astronomy, physics, and related sciences, the movement lacked the coherence it had in the former disciplines. That was due to the different kind of resistance that Spanish society offered to each field. The new astronomy, for example, was weighed down by the condemnation of Copernicanism, which was strictly upheld by all offices of coercion. For its part, the new physics had to contend with Aristotelian doctrines, as a central component of the traditional world view still remained closely linked to metaphysics and, through it, to theological doctrines. In the final analysis, as López Piñero noted, the diversity of situations confronting each science correlated to the degree of autonomy that it had attained with respect to philosophy. The relative autonomy enjoyed by medicine meant that the debate between "ancients and moderns" in related fields was allowed to take place, without the participants' running the risk of being accused of heterodoxy. Astronomy and physics, by contrast, remained more subordinate, at least insofar as theory was concerned, to the reigning doctrines of cosmology and natural philosophy. It is hardly necessary to insist that astronomy and physics experienced the most dramatic changes in the course of the scientific revolution, giving rise to a new conception of the physical world radically distinct from the Aristotelian one.

For all these reasons, inasmuch as radical and systematic critiques of scholasticism were not possible, eclecticism assumed much greater importance in mathematics and physics than it did in medicine, biology, or chemistry. Indeed, eclecticism was the dominant mode in the progressive appropriation and assimilation of modern science by the Jesuits, and hence their special importance in the diffusion of modern science in Spain. In this sense, the work of late-seventeenth-century modernizers should be considered a continuation of the efforts of their predecessors—such professors of the Imperial College as Vicente Mut, Sebastián Izquierdo, and José de Zaragoza, and other Spaniards (including Juan Caramuel) who, though working outside the country, maintained contacts with Spaniards and influenced them greatly.[115] Others, including Kresa, Omerique, Petrei, and Hurtado de Mendoza, must also be reckoned as participants in this movement. The Spanish modernizers regarded their predecessors as their teachers, whether directly or indirectly, and regarded themselves as part of this tradition and under its protection.

One of the principle sites of this pre-Enlightenment movement of scientific and philosophical modernization was the city of Valencia, where the bio-medical disciplines, physics, and mathematics flourished.[116] The revival of the exact sciences began during the 1660s, coinciding with José de Zaragoza's stay in the city. Among his numerous disciples were Falcó de Belaochaga, Diego Felipe de Guzmán (marquis of Leganés and captain-general of Valencia in this period), Enrique de Miranda, José Vicente de Olmo (secretary of the Inquisition, and José Chafrión. In 1681 Olmo published in Valencia a geographical treatise, titled *Nueva descripción del orbe*, that was based in great part on Philippe Briet's *Parallela Geographiae* (1648) and Riccioli's *Geographiae et hydrographiae reformatae*.[117] In this work Olmo shows his familiarity with certain Galilean themes, such as the law of falling bodies and the laws of the pendulum, as well as the use of this instrument to measure time. He refers to Huygens's suggestion to use the pendulum as a clock to solve the problem of hourly transport in the determination of geographical longitudes. He also studies questions of magnetism, following Jesuit writers. In regard to the "subterranean world," he makes ample use of Kircher's works.[118] The most interesting section, on account of its breadth and novelty in the Spanish context, is the one devoted to cartography, where Olmo studies in great detail the different cartographic projections proposed from Ptolemy's time up to the present.[119]

Zaragoza's other disciple, José Chafrión, resided in Italy as an engineer and a soldier in the service of the marquis of Leganés.[120] There he was in contact with Caramuel, bishop of Vigevano, whom he greatly admired. Caramuel's *Arquitectura civil, recta y oblicua* (Vigevano, 1678) contains a "mathematical discourse" by Chafrión whose objective is to exalt Caramuel's scholarly attainments in "all the arts, sciences and faculties." Chafrión also published a *Curso Mathemático* (Milan, 1693) composed of eleven treatises relating to arithmetic, geometry, the sphere, geography, algebra, trigonometry, logarithms, and military arts (focusing on fortifications). In the section on artillery he notes that the work of Galileo and Torricelli had invalidated all previous works on the firing of projectiles,[121] but the section on astronomy basically reproduces extracts from Zaragoza's published treatise on the subject. Upon returning to Spain, Chafrión worked occasionally as a civil engineer in Catalonia and Valencia.

In the 1680s, a number of tertulias (salons) and academies arose in Valencia. Initially literary in character, they progressively incorporated scientific and philosophical themes into their discussions. Olmo and Falcó de Belaochaga were members of tertulias, which proved instrumental in trianing young Valencians in the techniques of astronomical observation. One of the tertulias was functioning in 1687 as an academy of mathematics, and its members stated explicitly that their aim was to lay the foundations for a future Valencian science on a par with that of Europe. It held "conferences" to discuss mathematics, the laws of motion of Galileo and Descartes, statics, hydrostatics, and hydraulics. Courses on these subjects were offered, and experiments in physics were carried out, as were telescopic and microscopical observations.[122] The chief architects of the group were three Valencia priests: Baltasar de Iñigo, Juan Bautista Corachán, and Tomás Vicente Tosca. Fully cognizant of Spain's scientific backwardness, the three set themselves the task of assimilating and popularizing the new science and its methods not only in Valencia but more broadly in Spain, availing themselves of Jesuit scientific literature. Jesuit eclecticism also served them as a guide and a model for their program. Corachán's surviving papers include extensive extracts from the works of Schott, Riccioli, Fabri, Scheiner, Zaragoza, Milliet Dechales, and other Jesuit authors.[123] In his *Avisos del Parnaso* [*News from Parnassus*]—a popularizing work in the form of a scientific-utopian fable—Corachán presents as principle protagonists of his "Parnassus" Clavius, Grimaldi, Fabri, Kircher, Boyle, and Descartes.[124] The work even includes a fragment of Descartes's *Discourse on the Method* in Castilian translation. The Parnassus imagined by Corachán is essentially a literary representation of the ideal scientific society envisioned by Valencian intellectuals—a society in which "ancients" and "moderns" could meet and discuss scientific and philosophical topics, with reason and experience (in matters not contrary to faith) serving as the ultimate arbiters.[125]

The contribution of the Valencian *novatores* to the introduction of modern science and philosophy in Spain culminated with the publication of Tomás Vicente Tosca's *Compendio Mathemático* (nine volumes, Valencia, 1707–1715) and his five-volume *Compendium philosophicum* (Valencia, 1721). The *Compendio Mathmemático* is modeled after the didactic encyclopedic "courses" published in Europe in the second half of the seventeenth century, principally by Jesuit scientists. As various authors have pointed out, the Jesuits in the course of the seventeenth century were steadily enlarging and developing the scope and content of "pure" and "mixed" mathematics in order to incorporate, with all due caution, the new scientific knowledge. One of the most famous and widely diffused works in this genre was Claude François Milliet Dechales's *Cursus seu mundus mathematicus* (three volumes, Lyons, 1674), which served as Tosca's principal guide.[126] Tosca, moreover, took special care to incorporate the findings of Spanish authors, including Izquierdo, Caramuel, Mut, Zaragoza, and Omerique. Besides elements of "pure" mathematics (Euclid's *Elements*, arithmetic, algebra, geometric analysis following Omerique, combinatorial analysis, trigonometry, logarithms, and conics), the work addresses mechanics (simple machines and applications to the study of muscular contraction, following Borelli), Archimedean statics, hydrostatics (Torricelli, Pascal, et al.), falling bodies (free fall, inclined planes, pendulums), hydraulic machines, hydrodynamics, acoustics, movement of projectiles, optics (theories on the nature and propagation of light, geometric optics, photometry, optical systems and instruments, Cartesian theory of colors), magnetism, and the earth's motion (for which, Tosca concludes, there are no decisive arguments, pro or con, except religious ones). The modernity of the *Compendio* varies from one treatise to another, although the upper limit can be fixed globally at the "great Newtonian synthesis." Tosca's norms are those of the new science: mathematics as its language, observation and experiment as its methodological criteria.

Within the Spanish context, the *Compendium philosophicum* was the most serious attempt to date to revise traditional philosophical discourse in the light of the new science.[127] Despite his professed eclecticism, Tosca subscribes to the fundamental theses of the mechanical philosophy. In analyzing the concept of matter, for example, he avails himself of the corpuscular philosophy, elaborating a theory that draws not only on Descartes but also on Gassendi and Emmanuel Maignan. To explain notions of space and time, he refers to late scholastic authors such as Francisco de Toledo, making subtle distinctions between "intrinsic" and "extrinsic" place, in an attempt to adapt them to the new physics. Insofar as local movement is concerned, he accepts, and clearly expounds, the concept of movement as a state and the law of inertia. In sum, Tosca's work forms was a part of the process of progressive renewal in the teaching of natural philosophy that took place in Europe under the influence of Cartesianism, before the diffusion of Newtonian physics.

Scientific Activity in Eighteenth-Century Spain and the Role of the Jesuits until the Expulsion (1767)

Scientific activity experienced considerable development in Spain throughout the eighteenth century, right up to the reign of Ferdinand VII. One could even say that in the final phases of the Enlightenment there existed in Spain the foundation for a genuine and "modern" scientific activity that ensured the assimilation of advances produced in other European countries without delay and made original contributions possible. This scientific development was in part a continuation of the renewal process of the previous century and in part a consequence of the requirements and objectives of the new Bourbon regime and the reformist policies of its leaders. Moreover, the uneven pace of scientific growth during this period corresponds to a general process of diffusion, European in nature, of which Spain constitutes a particular case.[128]

At the root of the promotion of scientific activity was the struggle against isolation from the rest of Europe. Studying science abroad, which had been prohibited during the Counterreformation, was now encouraged, and grants for it were awarded. The process began with a 1718 decree by Philip V, and it became common during the second half of the century. Among those benefiting from such grants were many of the important scientific figures of the period.

Recruitment of foreign scientists and technologists was another measure intended to erase Spanish backwardness. The Italian José Cervi arrived in 1714 as physician to Isabel of Farnese and came to play an important role in Spanish medicine.[129] However, most arrived around the middle of the century. Their presence was felt in virtually every discipline. In physics and mathematics we find the Frenchmen Louis Godin and Charles Le Maur, the Italian Cipriano Vimercati, the Czech Christian Rieger, and the Austrian Johannes Wendlingen; the last two were Jesuits. In chemistry and metallurgy we find the Frenchmen Franois Chavaneau and Joseph-Louis Proust, the Swede Thaddeus von Nordenflicht, and the German Friedrich Sonneschmidt.[130] In natural history we find the Irishman William Bowles, the German Christian Herrgen, and the Swede Pehr Loeffling.

Moreover, the enlightened regime attempted to put in place an ambitious plan of educational reform and technological renewal, hoping to create an infrastructure for the cultivation of the new science. This was one of the motives behind a long series of attempts, commencing during the reign of Charles III, to reform the universities and develop scientific education within them.[131] At the same time, new scientific and technological institutions, oriented toward modern science, came into being as a result of the modernization of the army and the navy.[132]

Scientific studies also achieved high levels of performance in a variety of other institutions, some quite local, with greater or lesser support of the central regime. The Barcelona Academy of Sciences, founded in 1764, is a good example. Many other institutions were military in nature, including the Academia de Guardias Marinas of Cádiz (1728), which had an important Observatory established in 1753; the Marine Guard Academy of El Ferrol (1776); the Academy of Mathematics of Barcelona (1772); the Academy of Artillery of Segovia (1763); and the Colleges of Surgery of Cádiz (1748), Barcelona (1760), and Madrid (1780). Some other institutions, like the Seminary of Nobles in Madrid (1725), depended directly on the Crown;

others owed their existence to individual initiatives, such as the Asturian Institute of Gijón (1794), which Jovellanos organized to train engineers and pilots. In a similar manner, the schools of chemistry, mechanics, navigation, and botany were endowed by the Junta de Comercio of Barcelona (1758). The Sociedades Económicas de Amigos del País also functioned as active nuclei of scientific work and teaching, especially in relation to the "useful" arts. The Basque Society, founded by private initiative in 1765, established the Patriotic Seminary of Vergara, which for some years was one of the most brilliant scientific center in Spain. The Botanical Garden in Madrid (1755) achieved world renown. Its basic contribution was in coordinating the great Spanish botanical expeditions of the period, led, for the most part, by naturalists who had studied in the Garden's school.[133] Finally, new institutions were created in the Spanish colonies, especially the College of Mines in Mexico City (1792), whose origin and success were indicative of the reception of modern science in New Spain, especially in those sectors most related to the development of the territory's mineral wealth.

Jesuit scientists participated actively in this new phase of Spanish science until the Society's expulsion in 1767, although they lost the leadership role they had enjoyed in the previous century.[134] Besides the chairs of the Reales Estudios of the Imperial College and the associated post of Cosmographer of the Indies, the fathers of Society also offered scientific instruction in the Seminary of Nobles, founded in Madrid in 1725.[135] In Barcelona, at the College of Nobles of Cordelles, also operated by the Society, chairs of physics and mathematics were endowed around 1754—one of which was held by the Jesuit Tomás Cerdá, one of the best mathematicians in eighteenth-century Spain.[136] The Jesuit presence was also pronounced at the University of Cervera, created by Philip V after the suppression of the traditional Catalan universities.[137] At this university, several Jesuit professors, including Cerdá, attempted to revive philosophy on the foundation of the new scientific and philosophical currents. At the University of Gandía, governed by Jesuits from its foundation in 1547, three chairs of medicine were established in 1700, a chair in anatomy was added in 1747, and a chair in surgery was added before 1767.[138] Unfortunately, we lack information on the possible introduction of scientific instruction in other Spanish Jesuit centers. However, based on the contents of public examinations held in many of the these institutions, one may at least infer the availability of instruction in mathematics and descriptive geography.[139]

In the first decades of the eighteenth century, the teaching staff of the Reales Estudios of the Imperial College and the Seminary of Nobles included Pedro de Ulloa, José Cassani, Carlos de la Reguera, Pedro Fresneda, and Gaspar Alvarez. Although none of them produced any outstanding contributions, they published diverse works in mathematics, astronomy, geography, and military arts, generally oriented toward teaching and modeled on the *Cursus* of Dechales or the *Compendio Mathemático* of Tosca. Cassani was one of the founders of the Royal Spanish Academy and collaborated in editing of the *Diccionario de Autoridades*. He was also an official of the Inquisition. In 1737, Cassani published a *Tratado de los cometas* which displays his ignorance of not only the recent theories by Newton and Halley but of the earlier ones of Hevelius and Dörffel too. Cassani made several observations of eclipses, some with Pedro de Ulloa; the results were submitted to the Parisian Academy of Sciences, which published abstracts of them in its *Memoires*.[140] Pedro de Ulloa also published *Elementos de Matemáticas* (1707), which incorporated Cartesian analytic geometry.[141] The first professor of the Seminary of Nobles about whom we have information was the Jesuit Gaspar Alvarez, author of *Elementos geométricos de Euclides* (1739). In 1734 Alvarez presided over certain "mathematical conclusions" advanced by his students, pertaining to practical geometry, artillery, hydrostatics and hydraulic machines, optics, geography, and astronomy, whose contents confirm the elementary character of teaching at the seminary. The conclusions assert that "the earth does not move, but remains immobile in its place," although accepting the Copernican theory "as a hypothesis."[142]

Renewal in the content of instruction in the Imperial College and the Seminary of Nobles began during the 1750s with the incorporation of Newton's theories, experimental physics, and infinitesimal calculus. This was the result of the confluence of several factors. Foremost was the impact of the expedition sent by the Paris Academy of Sciences to the Viceroyalty of Peru to measure an arc of the meridian and test the various theories on the shape of the earth. As it is well known, two Spaniards, Jorge Juan and Antonio de Ulloa, participated in this expedition.[143] Upon their return, the Spaniards published the results of the expedition in five volumes, with the financial support of the Marquis de la Ensenada. The first volume, edited by Jorge Juan and devoted to astronomical and physical observations, was the first comprehensive exposition of the results of measurement of the arc of meridian to appear in print. In it Juan displays his mastery of the theories of Newton and Huygens and of more recent mathematical techniques, such as infinitesimal calculus. When discussing the earth's motion Juan still felt obliged to add that "this hypothesis is false," but any attentive reader would have recognized that this was out of character.[144] It should also be pointed out that the Jesuit Andrés Marcos Burriel intervened on behalf of Juan and Ulloa in their negotiations with the Inquisitor General on the subject of Copernicanism.[145]

Jorge Juan subsequently became the principal science and technology advisor to the the Marquis de la Ensenada, Secretary of the Navy, who entrusted him with overhauling the Navy and sent him to London to collect information on ship construction, to hire technicians, and to acquire instruments. Upon his return, Juan directed the reorganization of naval construction. From 1752 on, he served as director of the Academia de Guardias Marinas of Cádiz. There he established an astronomical observatory and surrounded himself with professors, including Louis Godin, Vicente Tofiño, and Pedro Virgili. With Virgili, he organized a scientific "assembly" which he envisioned converting into a national academy of science in Madrid, with Ensenada as its patron.[146]

Besides the reorganization of the Navy, there was a general effort by the middle of the century to improve the quality of military instruction. A "Hall of Mathematics" was founded in Madrid in 1750 in the barracks of the royal guard, where mathematics, including the algebraic study of conics and differential calculus, was taught.[147] Likewise, mathematical schools for artillery were created in Barcelona and Cádiz (1751), and instruction was upgraded in the military engineering schools in Barcelona and other cities. These reforms received a fresh impetus with the appointment in 1756 of the Count of Aranda as director general of artillery and engineers. To bring the education of military engineers up to date, and to procure adequate instruments and textbooks, the Military Mathematical Society was founded in Madrid in 1757, under the direction of Pedro Lucuce, who had been director of the Military Academy of Barcelona. The members of this society (among them the Frenchman Le Maur) prepared a textbook that included arithmetic, algebra, geometry, differential and integral calculus, rational mechanics, fortification, artillery, and astronomy. Although the text was never published, and the society dissolved three years later owing to internal conflicts, its activities and the texts published by individual members are a good indication of their excellent scientific education and the degree of the institutionalization of post-Newtonian mechanics and astronomy in Spain.[148] Le Maur's 1761 "Discourse on Astronomy" and his observations of the Transit of Venus of the same year offer an excellent summary of the state of the discipline, including an exposition of the basic principles of Newtonian dynamics and the law of universal gravitation; commentaries and references to perturbations, and the three-body problem (together with the solutions of Clairaut, D'Alembert and Euler); D'Alembert's research on the precession of the equinoxes; Maupertuis's hypothesis on the ring of Saturn; and the most recent studies on the shape of the earth. It is interesting to note that Le Maur displays no reserve at all regarding Copernicus's theory, which he considers an established axiom of the new astronomy and of the new celestial mechanics.[149]

The Jesuits did not remain on the sidelines of these new developments in Spain. Already in 1746–47, when he was named director of the Seminary of Nobles, Burriel tried to modernize instruction there, relying on the technical advice of the Valencian polymath Gregorio Mayans. Moreover, Burriel enthusiastically took on the task of revising the works of Ulloa and Juan on the Peruvian expedition and, as we have seen, in their conflict with the Inquisition over the work's Copernicanism (or rather Newtonianism), he served as mediator, again with help from Mayans.[150] The new scientific spirit in the seminary, and Juan's influence on Burriel, can be detected in the "conclusions," held in 1748 and presided over by the professor of mathematics Esteban Terreros y Pando.[151] There, the seminarians took up the question of the shape of the earth, explicitly referring to the expeditions to Lapland and Peru and, in the section of astronomy, debated not only the Copernican system, as a "hypothesis," but Newtonian celestial mechanics as well. The seminary's new *Constitutions*, published in 1755, provided for instruction in philosophy "in such a way that it be useful to the public"; logic, metaphysics, general physics (where the "opinions of Gassendi, Descartes, Maignan, Newton, and Leibniz" were to be taught, "without omitting those of the chemists, adopting the most true, with the appropriate critiques"); "particular" physics, the sphere, astronomy, moral philosophy and experimental physics are all included in the course of study. With regard to experimental physics, Ferdinand VI had bestowed on the seminary a collection of instruments. The chair of mathematics was responsible for the entire discipline, including "Cartesian" and infinitesimal calculus, in addition to the "mixed" subjects such as optics, fortification, astronomy and navigation.[152]

To carry out this program, the Jesuits called upon some foreign Jesuit professors. Around 1750, the Czech Johannes Wendlingen was invited to Spain (apparently at the suggestion of the king's confessor, Francisco Rávago) and appointed professor of mathematics at the Imperial College.[153] A few years later, the Austrian Christian Rieger was given similar appointment. After being named Cosmographer of the Indies, Wendlingen addressed a memorandum to the king in which he indicated how it would be be "more useful and necessary for the greater service of Your Majesty to teach mathematics as it is done in Europe today," at the same time suggesting that a "useful and instructive philosophy" be imparted in all the universities. In addition, Wendlingen made a series of recommendations related to his office of cosmographer "to arrange and display the maps."[154] With the patronage of Ensenada, Wendlingen directed the construction of a new astronomical observatory in the Imperial College for which he had access to the instruments acquired by Jorge Juan in London. He also had a special classroom, acquired books to support his teaching, and planned the development and publication of a course of mathematics in 42 volumes, of which only four appeared (1753–1756).[155] Wendlingen also made several astronomical observations that were summarized in the *Philosophical Transactions*.[156]

The other foreign Jesuit mentioned—the Austrian Rieger, who had been a professor of mathematics, physics, and architecture at Görz and Vienna—probably arrived in Madrid in the late 1750s.[157] There he published *Observaciones del tránsito de Venus por el disco del Sol* (1761), a treatise on civil architecture (1763), and a treatise of electricity (1763) that contained the first published account in Spain of Benjamin Franklin's experiments. Several manuscripts by Rieger on mechanics, mathematics, and astronomy still survive; these were probably drawn up for his lectures at the Imperial College at the early 1760s and designed for an encyclopedic course on the physical sciences and mathematics. The manuscripts deal with arithmetic, algebra, geometry, the astronomy of La Caille, geography, spherical trigonometry, stereographic projections, mechanics, optics, chronology, hydrostatics, hydraulics, acoustics, and undulatory motion in general; they also include an "easy introduction to the algorithm of fluxions." Reiger expounds planetary motion from a Copernican perspective, albeit with some caution. Having explained that the planets move around the sun, he adds: "As the earth lies in between these movable bodies (between Venus and Mars), and appears to be of the same nature, it is inferred in the Copernican system that it moves around the sun . . . and so all apparent movements are clearly explained." Besides La Caille, Rieger cites, among others, Wolff, Belidor (on machines), Newton, and Boscovich.[158]

As I have noted, modern science was not generally taught in Spanish universities until the reign of Charles III. Nevertheless, in certain centers, including Valencia and Cervera, some professors of philosophy or of mathematics strove to modernize their instruction by eclectically incorporating aspects of the doctrines of Gassendi, Maignan, and Descartes, or of other recent work in physics and mathematics.[159] Notable examples at Cervera, where most of the professors were Jesuits, were Mateo Aymerich and Tomás Cerdá. The former, both in his *Systema antiquo-novum. Jesuiticae Philosophiae contentiosam et experimentalem philosophandi methodum complectens* (1747) and in his *Prolusiones philosophicae* (1756), insisted on the need to introduce students to advances in experimental physics, to which he devoted a substantial part of his writings. "Let no one be surprised," he wrote in the prologue to *Systema antiquo-novum*, " to find herein many excellent and worthy topics about which there has until now reigned a profound silence in the Academies of Cataluña and Spain."[160] Even more pronounced was Cerdá's desire to promote recent scientific knowledge (evident in his 1753 *Jesuiticae Philosophiae Theses*, where he bases his discussions of physics, astronomy, and mathematics on Kepler, Descartes, Gassendi, Huygens, Cassini, Clairaut, Jorge Juan, Nollet, and Newton).[161]

In 1755 Cerdá travelled to Marseilles to complete his scientific education under the French Jesuit Esprit Pezenas, author of the French version (1749) of MacLaurin's *Treatise of Fluxions*. After returning to Barcelona in 1757, he held (until 1764) the chair of mathematics at the College of Nobles of Santiago de Cordelles, a position expressly created for him.[162] Cerdá composed various works on mathematics, physics, and astronomy, attempting to place the study of these sciences on the level "where they now are in England and France."[163] Some of these works were published between 1758 and 1760; others remained in manuscript form. Among the latter are drafts on differential calculus that explain problems of maxima and minima and the radii of curvature and of evolutes, a manuscript on Newtonian mechanics that makes ample use of differential calculus, and a treatise on astronomy in which Cerdá expounds Newtonian celestial mechanics.[164] The last is essentially a Spanish translation of Benjamin Martin's *Philosophia Britannica, or a New System of the Newtonian Philosophy, Astronomy and Geography* (1747) with some minor changes and additions by Cerdá. At the beginning of this manuscript, Cerdá describes the "three systems" of the world—the Ptolemaic, the Tychonian, and the Copernican—and notes that, although he offers no opinion on the truth value of any one of them, he "will only explain those phenomena which result from the latter (the Copernican), reserving for the present any discussion of which should be followed." Nevertheless, Cerdá speaks constantly of the "solar system" and accepts the possibility of a plurality of such systems around the stars. In another chapter he discusses at length the "mathematical principles on which the Copernican System is based." He changes some of Martin's paragraphs to eschew Martin's affirmations of the indubitable truth of the system.[165]

In 1762 the Inspector General of Artillery, the count of Gazola, merged the two artillery schools of Cádiz and Barcelona into a new institution located in Segovia. It opened its doors in 1764 with a lecture by the Valencian Jesuit Antonio Eximeno, "first professor" of the center, on "the need for theory in order to sustain practice." The lecture is replete with references to Newton, to the shape of the earth as confirmed by the expeditions to Lapland and Peru, and to Newton's work on the resistance of air to the motion of projectiles.[166] In 1764, to assist instruction in the New Segovian Academy, Cerda published *Artillery Lessons* (probably commissioned by Gazola, to whom the text is dedicated). In the prologue, Cerdá suggested (as Jorge Juan, Johannes Wendlingen, and others had done earlier), the creation of a National Academy of Sciences, a project that was not realized in this period.

In 1764 Cerdá was summoned to Madrid, where he remained until the expulsion of the Society. The king entrusted him with teaching mathematics to the royal princes and appointed him Chief Cosmographer of the Indies. Cerdá probably also held a chair of mathematics at the Imperial College.

After the expulsion of the Society in 1767, most of its members emigrated to Italy, where they continued to be active in different areas of learning.[167] Some, including Francisco Llampillas and Juan Francisco Masdeu, participated in a polemic with Tiraboschi and other Italian authors over Spanish contributions to culture, philosophy, and science. The Valencian Juan Andrés, author of a number of works on Galileo, published an ambitious seven-volume history of culture that contained the first general history of science written by a Spanish author. From his exile in Italy, Andrés followed the turn that culture and the sciences had taken in Spain with interest and optimism: "Spain, once a tenacious supporter of scholastic subtleties, has expelled them from her schools and has wisely applied useful knowledge in their place. Feijóo, Juan, Ulloa, Ortega (Casimiro Gómez Ortega, director of the Botanical Garden), and other physicists, mathematicians and naturalists; Luzán, Montiano and Mayans, embroiderers of the language, rhetoric, poetry and theatre; Martí, Flores, Finestres, the two Mayans, Pérez Bayer, the two Mohedanos and other antiquarians and scholars of every kind provide clear proof of the ardor that animates Spain to good scholarship."[168]

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Notes

1. José María López Piñero, *Ciencia y técnica en la sociedad española de los siglos XVI y XVII* (Barcelona, 1979).

2. In the sense expressed by Steven J. Harris in "Transposing the Merton Thesis: Apostolic Spirituality and the Establishment of the Jesuit Scientific Tradition," *Science in Context* 3 (1989): 29–67. Harris (p. 48) expands upon Rivka Feldhay's proposal to "cover more than just the Jesuit educational program, developing the value-structure of the Society, and exploring further the institutional ramifications of the Jesuit image of knowledge." See also Harris, Jesuit Ideology and Jesuit Science: Scientific Activity in the Society of Jesus, 1540–1773, Ph.D. dissertation, University of Wisconsin, 1988; Rivka Feldhay, "Knowledge and Salvation in Jesuit Culture," *Science in Context* 1 (1987): 195–213; Ugo Baldini, *Legem impone sub-*

actis. Studi su filosofia e scienza dei gesuiti in Italia, 1540–1632 (Rome, 1992); *Antonella Romano, La contre-réforme mathématique. Constitution et diffusion d'une culture mathématique jesuite à la Renaissance* (Rome, 1999).

3. And, at the end of the century, the Jesuit College of Cádiz. We do not know whether scientific instruction was introduced in other colleges of the Society. According to Alberto Dou, mathematics was also taught at the Real Colegio de Santa María y San Jaime (Cordelles) in Barcelona, at the College of Nobles of Calatayud, and at Bilbao, all directed by jesuits. But that probably occurred only in the eighteenth century. (Alberto Dou, "Las matemáticas en la españa de los austrias," in *Estudios sobre Julio Rey Pastor (1888–1962)*, ed. L. Español González (Logroño, 1990); Dou, "Matemáticos españoles jesuitas de los siglos XVI y XVII," *Archivum Historicum Societatis Iesu* 66 (1997): 300–321) At the University of Gandia, the only teaching center of the Order permitted to grant degrees, there was no chair of mathematics. In 1700 three chairs of medicine were established there.

4. José Simón Díaz, *Historia del Colegio Imperial de Madrid* (Madrid, 1952–1959).

5. Ibid., volume I, pp. 67–68.

6. R. Pérez Goyena, "Jansenio en las Universidades de España," *Razón y Fe* 56 (1920): 451–465, cited on pp. 80–81 of Díaz, *Historia del Colegio Imperial*, volume I.

7. Díaz, *Historia del Colegio Imperial*, pp. 71–97.

8. Such was the opinion of F. Picatoste y Rodríguez (*Apuntes para una Biblioteca Científica Española del siglo XVI*, Madrid, 1981, p. 149) and of other liberal Spaniards of the nineteenth century.

9. For several years, Francisico de Bobadilla, count of Puñoenrostro, availed himself to the rooms of the "Academy" in the house on the Calle del Tesoro to lecture on various subjects of mathematics and military science, as well as on topics related to his chair. The most complete study of the Madrid "Academy of Mathematics" is M. I. Vicente Maroto and M. Esteban Piñeiro, *Aspectos de la ciencia aplicada en la España del Siglo de Oro* (Valladolid, 1991).

10. According to Vicente and Esteban, all appointments of Jesuits as professor-cosmographer included, as a legal prop, a complete copy of Philip IV's decree of 1628 ordering that the subjects taught by the professor be the same as had been taught by García de Céspedes, who had held the chair from 1607 to 1611. Furthermore, in each instance the phrase "until such a time as a capable person can be found to teach them." appears, indicating that the king applied to the fathers of the Imperial College for the position of Chief Cosmographer, in view of the lack of any other qualified persons. See e.g. Vicente and Esteban, *Aspectos*, pp. 199–200.

11. According to Díaz (*Historia del Colegio Imperial*, volume I, pp. 97–98), the Jesuits produced theatrical works with great success. Hugh Sempilius also describes the inauguration, reporting that "exquisite machines" were displayed (*De mathematicis disciplinis*, Antwerp, 1625, p. 95): "Archite columba, musca norimbergensis, dracones volantes, et id genus alia." This accords nicely with the Baroque taste for novelty and artifice described in José Antonio Maravall, *La cultura del Barroco* (Barcelona, 1975).

12. Díaz, *Historia del Colegio Imperial*, volume I, p. 97ff. For Lope de Vega's poem on the first lectures in the Royal Studies, see ibid., pp. 99–115.

13. Cysat, then, lectured in the Imperial College before the inauguration of the Reales Estudios. See Joaquín Sarralle, "Los matemáticos del Colegio Imperial," *Razón y Fe* 156 (1957): 421–438, citing Bernahard Duhr, *Geschichte der jesuiten in der landen deutscher zunge (in der ersten halfte des XVII Jahrhunderts)* (Berlin, 1913). In the Catálogos trienales de la Provincia de Toledo (Díaz, *Historia del Colegio Imperial*, volume I, p. 573) he is called Bautista Suati (Cat. 1628).

14. Henri Bosmans, "Gregoire de Saint-Vincent," *Mathesis* 38 (1924): 250–256; Bosmans, "Gregoire de Saint-Vincent," *Biographie National Belge*, volume xxi, pp. 141–171. In his letter to Gregory of St. Vincent, Vitelleschi wrote: "Votre Reverence est demandée nommément par le Roi Catholique pour enseigner les mathematiques à l'Académie de Madrid. Le P. della Faille envoyé pour y professer cette science est chargé d'un autre cours" (ibid., p. 147). Gregory declined the offer for reasons of health.

15. Compare H. P. Vanderspeeten, "Le R. P. Jean-Charles della Faille, de la Compagnie de Jésus, precepteur de Don Juan d'Autriche," *Collection de "Precis Historiques (Brussels)*, second series, 3 (1874), pp. 77–83, 111–117, 132–142, 191–201, 213–219, 241–246.

16. Vicente and Esteban (*Aspectos*, pp. 198–199) reproduce the report of Juan de Billela, Intendant General of the Royal Studies, dated August 7, 1629, which recommended that Claude Richard be named to "a chair in which mathematics is taught" in the Royal Studies. The authors presume that this refers to the chair of the "Academy of Mathematics," with its associated post of chief cosmographer. The document cited, however, only refers to the "Studies" of the Imperial College, without any mention of the "Academy" chair, vacant since the death of Cedillo, as was habitual in both previous and later documents. Nevertheless, considering that a little later della Faille was named professor of mathematics in the Studies and that there had been an attempt to appoint Gregory of St. Vincent to a second chair, it is possible that their interpretation may be correct. Be that as it may, I believe that the "Academy's" chair was in fact absorbed by the mathematical chairs of the Reales Estudios. This must to have raised some protests, for in 1636 Felipe IV dictated new ordinances which enjoined the cosmographer-professor of mathematics to read, "in our House and Palace, and near the Council of Indias," an hour in the morning on days that lectures were given. See Vicente and Esteban, *Aspectos*, p. 169.

17. Alexander Birkenmajer, "Alexius Sylvius Polonus (1593–ca. 1653), a little-known maker of Astronomical Instruments," *Vistas in Astronomy* 9 (1967): 11–13. According to Birkenmajer, Polonus studied in the College of Kalisz, where the Belgian poet and mathematician Charles Malapert held a chair. Afterward, he and Malapert moved to Belgium; both then went to the Imperial College at Madrid, where Malapert was due to occupy a chair of mathematics. However, Malapert fell sick and died upon arriving in Spain. Polonus remained in Madrid until around 1638, building in 1634 an Archimedean Sphere at the Imperial College which showed, according to Birkenmajer, the celestial movements "according to the helio-

centric theory." This conclusion is probably mistaken. The Archimedean Sphere followed the geocentric system, and the Madrid Jesuits had strong reasons for not displaying enthusiasm for heliocentrism.

18. Hugh Sempill, born in Craifever, Scotland, was a nephew of Colonel William Sempill, who, in 1627, founded the Seminario de Colegiales Seculares in Madrid for the ordination of priests of the "Scottish Mission." Hugh Sempill joined the Jesuits in Toledo in 1615; in 1627 he was named rector of the Scottish Seminary. While in the Netherlands in the party of the Princess, he was appointed professor in the Reales Estudios of the Imperial College, as appears in a protocol preserved in the Archives of Simancas, Estado, leg. 2641: "Of the letters to be sent regarding the Estudios Reales and the professors to be appointed." In his *De mathematicis disciplinis* (1635), Sempill is enthusiastic about the foundation of Estudios and the inclusion of mathematical instruction. For more on Hugh Sempill, see *Dictionary of National Biography*, volume XVII, p. 1173.

19. Camassa was born in Lecce and entered the Society in 1607 in Naples. There he studied and taught humanities, theology, philosophy, and matehamtics, and was expressly required by Philip IV to teach the military science in the Reales Estudios. In 1637, Camassa accompanied Spanish troops under the command of the Marquis of Leganés to Italy. He died in Zaragoza. See Romano Gatto, *Tra Scienza e Immaginazione. Le matematiche presso il collegio gesuitico napoletano (1552–1670)* (Firenze, 1994), pp. 185, 269–270; Carlos Sommervogel, *Bibliothèque de la Compagnie de Jésus (Brussels, 1890–1900)*, volume II, p. 175; Díaz, *Colegio Imperial*, volume I, p. 545.

20. Martínez was Born in Pareja (Guadalajara) around 1603 and entered the Order around 1620. He taught mathematics between 1635 and 1640, probably as an assistant or aid to della Faille. (I owe this information to Ugo Baldini.) There is some information on Martínez in Díaz, *Colegio Imperial*, volume I, p. 559. Some of his manuscripts are preserved in the Academy of History. One of these is a Treatise on Cosmography and Its Properties dated October 20, 1635 (Col. Cortes, 9/2745).

21. Isasi was born around 1605 in Eibar and entered the Society in 1620. He also practiced military engineering. He died in 1650. In his correspondence with van Langren, della Faille mentions Isasi several times, including a reference to the latter's participation, as a military engineer, in the defense of Fuenterrabíaa against the French in 1638, comparing him to Archimedes. See Díaz, *Colegio Imperial*, volume I, p. 556; Omer van der Vyver, "Lettres de J. Ch. della Faille, S. J., Cosmographe du roi à Madrid, à M. F. van Langren, cosmographe du roi à Bruxelles, 1634–1645," *Archivium Historicum Societatis Iesu* 46 (1977): 72–183. To these professors we can add the teachers of Chronology, Francisco Macedo (1632–1635) and Claudio Clemente. On Macedo, see Sommervogel, *Bibliothèque*, volume V, pp. 244–246. On the professors of the Imperial College between 1627–1640, see Ugo Baldini, "As Assietências ibéricas da Companhia de Jesus e a actividade cientifica nas missôes asiáticas (1578–1640). Alguns aspectos culturais e institucionais," *Revista Portuguesa de Filosofia* 44 (1998): 195–245.

22. See Eduardo Zepeda-Henríquez, *Obras escogidas del R. P. Juan Eusebio Nieremberg* (Madrid, 1957), Hughes Didier, *Vida y pensamiento de Juan Eusebio*

Nieremberg (Madrid, 1976). No comprehensive study of Nieremberg's philosophical and scientific ideas exists. Didier (ibid., p. 463) characterizes the *Curiosa filosofía*, the *Oculta filosofía*, and the *Historia naturae* as unsubstantial. Lynn Thorndike (*A History of Magic and Experimental Science*, New York, 1923–1958, volume VII, pp. 330–333) characterizes the *Oculta filosofía* as an example of the survival in seventeenth-century Spain of the natural magic tradition. Elsewhere I have noted the significance of Nieremberg's works; see "El cultivo de la física en España en los siglos de la revolución científica," in *Historia de la física hasta en siglo XIX* (Madrid, 1983); "Nieremberg y Otín, Juan Eusebio," in *Diccionario Histórico de la Ciencia Moderna en España*, ed. J. López Piñero et al. (Barcelona, 1983), volume II, pp. 110–111. I am currently preparing a detailed study of Nieremberg in collaboration with J. M. López Piñero.

23. The *Curiosa filosofía* was republished in Madrid in 1632, in 1634, and in 1644, the *Oculta filosofía* in Madrid in 1638 and in Barcelona in 1645. The two works were published together in Madrid in 1643 and in Alcalá in 1649. Moreover, the two works were included in the 1651, 1664, and 1686 editions of the *Obras filosóficas* of Nieremberg. See A. Palau Dulcet, *Manual del librero hispano-americano* (Barcelona-Madrid, 1948–1977), volume XI, pp. 39–42.

24. Nieremberg, *Curiosa filosofía* (I cite the 1632 edition), folios 99v–143r. At the end of this section on magnetism (folio 147r), Nieremberg mentions the work of his confrere Niccolò Cabeo on the subject (Cologne, 1629), claiming to have read it after writing his own book.

25. Nieremberg, *Curiosa filosofía*, folios 166r–172r. Nieremberg proceeds to inquire whether "the stars have any life." He asserts that their matter is "corruptible and composed of the same material as the elements, and even with a mixture of their primary and secondary qualities." He does not consider whether angels are necessary to move the world or the stars and concludes that "if any life was tolerable in the stars it might fall somewhere between the vegetative and the sensible" (ibid., folios 173r–174r). Animism or pan-psychism of Platonic and Stoic roots,was a legacy of the Renaissance that Nieremberg shared with the Cistercian Juan Caramuel y Lobkowitz, a fellow student of Nieremberg at Alcalá. See Julián Velarde, *Juan Caramuel* (Oviedo, 1989), especially pp. 91–99.

26. Among the sources he used were the manuscripts of the expedition to New Spain, which had remained in Hernández's possession and which afterward were preserved in the library of the Imperial College. See José María López Piñero, "Los primeros estudios científicos: Nicolás Monardes y Francisco Hernández," in *Medicinas, drogas y alimentos vegetales del Nuevo Mundo*, ed. J. López Piñero et al. (Madrid, 1992), pp. 204–205. See also J. M. López Piñero and J. Pardo Tomás, *Nuevos materiales y noticias sobre la "Historia de las plantas de Nueva España" de Francisco Hernández* (Valencia, 1994), pp. 129–133.

27. F. Dainville, "L'enseignement des mathèmatiques dans les Collèges Jésuites de France du XVIIe au XVIIIe siècle," *Revue d'Histoire des Sciences* 7 (1954): 6–21, 109–123; Dainville, "L'enseignement des mathématiques au XVIIe siècle," *XVIIe Siècle* 30 (1956): 62–68; G. Cosentino, "L'insegnamento delle matematiche nei collegi gesuitici nell'Italia settentrionale," *Physis* 13 (1971): 205–217; J. L. Heilbron,

Electricity in the 17th and 18th Centuries. A Study of Early Modern Physics (Berkeley, 1979); Harris, *Jesuit Ideology*.

28. See pp. 7–21 of his *De mathematicis disciplinis*: "An Mathematicae sint verae scientiae."

29. On the ideas of Biancani, see H. Schüling, *Die Geschichte der axiomatischen Methode im 16 und beginnenden 17 Jahrhundert* (Hildesheim, 1969); Giulio Cesare Giacobbe, "Epigono nel seicento della Quaestio de certitudine mathematicarum: Giuseppe Biancani," *Physis* 18 (1976): 5–40; Paolo Galluzzi, "Il Platonismo del tardo Cinquecento e la filosofia di Galileo," in *Ricerche sulla cultura dell'Italia moderna*, ed. P. Zambelli (Bari, 1973); William A. Wallace, *Galileo and his Sources. The Heritage of the Collegio Romano in Galileo's Science* (Princeton, 1984); Peter Dear, "Jesuit Mathematical Science and the Reconstitution of Experience in the Early Seventeenth Century," *Studies in the History and Philosophy of Science* 18 (1987): 133–175; Dear, *Mersenne and the Learning of the Schools* (Ithaca and London, 1968), pp. 67–69. On the polemic about the epistemological status of mathematics, see, in addition, G. C. Giacobbe, "Il Commentarium de certitudine mathematicarum disciplinarum di Alessandro Piccolomini," *Physis* 14 (1972): 162–193; Giacobbe, "Francesco Barozzi e la 'Quaestio de certitudine mathematicarum,'" *Physis* 14 (1972): 357–374; Giacobbe, "La riflessione metamatematica di Pietro Catena," *Physis* 15 (1973): 178–196; Giacobbe, "Un gesuita progressita nella 'Quaestio de certitudine mathematicarum' renascimentale: Benito Pereyra," *Physis* 19 (1977): 51–86; A. C. Crombie, "Mathematics and Platonism in the Sixteenth Century Italian Universities and in Jesuit Educational Policy," in *Prismata*, ed. V. Maeyana and W. G. Saltzer (Wiesbaden, 1977); Adriano Carugo, "Giuseppe Moleto: Mathematics and the Aristotelian Theory of Science at Padua in the Second Half of the 16th Century," in *Aristotelismo veneto e scienza moderna*, ed. L. Oliver (Padua, 1983), volume I; Paolo Mancosu, "Aristotelian Logic and Euclidian Mathematics: Seventeenth-Century Developments of the Quaestio de Certitudine Mathematicarum," *Studies in History and Philosophy of Science* 23 (1992): 241–265.

30. See Giacobbe, "Epigono nel seicento."

31. Dear, "Jesuit Mathematical Science," pp. 164–165. See also Dear, *Discipline and Experience: The Mathematical Way in the Scientific Revolution* (Chicago and London, 1995).

32. Sempilius, *De mathematicis disciplinis*, pp. 54–55.

33. Ibid., p. 198: "Ad mathematicum propie pertinet caelorum quantitas, figura, motus, positionum, differentiae, numerus."

34. See book VII ("De Cosmographia") and book X, "De Astronomia." Sempilius describes the world system of Copernicus as in contradiction with the principles of physics and Holy Scriptures; that of Tycho Brahe strikes him as better, though he finds it to concede too little space for the three superior planets. He adds that other ingenious ways to explain these phenomena have also been proposed, but ultimately he refuses to pronounce on the matter and refers the reader to his *Diccionario Mathematico*.

35. See also Sempilius's manuscript Arithmética (Academia de la Historia, Madrid, col. Cortes, 9/2789), which includes logarithms and combinatorial analysis among other subjects. See also his Tratado de la guerra (Academia de la Historia, col. Cortes, manuscript 9/2168).

36. On Richard see *Diccionario*, ed. López Piñero et al., volume I, pp. 228–229; Sommervogel, *Bibliothèque*, volume VI, p. 1808.

37. On the Spanish Jesuit Juan Bautista Villalpando (1522–1608), see *Dictionary of Scientific Biography* (New York, 1976), volume XIV, pp. 29–30; *Diccionario*, ed. López Piñero et al., volume III, pp. 418–420.

38. Della Faille wrote to van Langren of the problems Richard had encountered when he had traveled to Flanders in secular dress in order to publish his edition of Euclid: "Father Ricardo, who is printing his Euclid in Antwerp, has gone a full year and a half without obtaining the two thousand reales he needs, having spent more than eight hundred ducats of his own money already, with more in sight." (Omer Van der Vyver, *Lettres de della Faille*, p. 179)

39. Though this was not published until 1655, Richard must have finished it by 1646. In a letter to Mersenne dated July 6, 1646, Gregory of St. Vincent writes, with reference to Richard's works, that, besides Euclid, "Plures tomos alios pollicetur, et inter caeteros Apollonium integrum cum suis notis aut commentariis. . . . Eundem authorem, Apollonium scilicet, imprimi intelligo in Hollandia cum quatuor librorum." (*Correspondence du P. Marin Mersenne*, ed. P. Tannery et al., Paris, 1980, volume XIV, p. 269) Mersenne was also interested in Richard's works on classical geometry, and offered to oversee their publication in the event they were published in Paris. Richard had contacted the bookdealer Berthier with an eye toward publishing his works in Paris, since he was unhappy with the edition of Euclid. See Richard's letters to Mersenne of May 30 and November 6, 1646, in ibid., pp. 296–299 and 598–601. In these letters Richard displays a lively interest in the Mersenne's works. Mersenne's reply has not survived. Some authors cite an edition of Rivault's Archimedes revised by Richard and published in Paris in 1646. See ibid., p. 298, n. 2. However, no copy of this (apparently ghost) edition has been located. In the Academy of History of Madrid I have recently come across a large number of manuscripts by Richard, which I am currently indexing and studying in collaboration with Santiago Garma, Enrique Recasens, and Vicente Salavert. These include materials related to the editions of Euclid and Apollonius; a treatise designed to replace (supplere) the last four books of Apollonius's Conics; commentaries on Archimedes's On the Sphere and Cylinder; treatises on the projection of circles, on the sphere and its astronomical applications (discussion of various planispheres); on plane and spherical trigonometry following various classical and Renaissance authors; on arithmetic and algebra (including combinatorial analysis); a treatise titled *Sphaera Catholica*, drawn up in 1637–38, "in quo fundamenta geometrica totius astronomiae cosmographiae geographiae et gnomonices faciuntur," according to the manuscript.

40. In his *Curiosa filosofía* (folio 134v), Nieremberg mentions Richard's experiments with diamonds. Sempilius (*De mathematicis disciplinis*, p. 81) mention's Richard's optical experiments.

41. Manuscripts in Academy of History.

42. Academia de la Historia, col. Cortes, manuscript 9/2680.

43. Academia de la Historia, Papeles de Jesuitas, Tomo 64, Doc. 16.

44. Academy of History, col. Cortes, manuscript 9/2780. One of the manuscripts of this volume is headed "Demonstratio ex phaenomenis caelestibus antiquorum ac recentiorum, unicum esse caelum fluidum, meabile, et non necessaario rotundum."

45. On della Faille, see the works by Vanderspeeten and van der Vyver; see also *Dictionary of Scientific Biography*, volume VII, pp. 557–558. On Juan de Austria's patronage of Juanini, see López Piñero, *Ciencia y técnica*, pp. 404–405. In his *Nueva idea physica* (Zaragoza, 1985), Juanini writes: "I have not found another prince who had talents as universal and eminent as D. Juan. . . . He was most learned in all areas of mathematics. . . . He understood everyone's ideas with great clarity . . . Aristotle . . . Tycho Brahe, Copernicus, Galileo and others. . . . Father della Faille, from the Company of Jesus, told the king that he no longer knew what to teach him." (cited in H. Kamen, *La España de Carlos II*, Barcelona, 1981, p. 546)

46. He based his procedure on the fact that the sun, from the new to the full moon, progressively illuminates the different lunar formations from east to west, the same formations disappearing in the course of the last lunar phases.

47. Van der Vyver, "Lettres."

48. Henri Bosmans, "Le traité De centro gravitatis de Jean Charles della Faille," *Annales de la Société Scientifique de Bruxelles* 38 (1914): 355–317.

49. These works are preserved as manuscripts by the family of della Faille, who provided me with copies through the courtesy of P. P. Bockstaele. Sommervogel (*Bibliothèque*, volume III, pp. 529–530) cites some of them.

50. Library of Royal Palace, Madrid, manuscript 3729. See F. J. Sánchez Cantón, *Fuentes literarias para la historia del arte español* (Madrid, 1914), volume V, pp. 276–279. On the mathematical portion of this treatise, see Isabel Vázquez Paredes, "La geometríaa en el Tratado de Arquitectura de Jean-Charles della Faille," *Revista Matemática Hispanoamericana* 32 (1980): 43–49; Vázquez Paredes, "Análisis geométricos de los cortes de piedras y arcos en el Tratado de Arquitectura de Jean-Charles della Faille," in *Actas VII Jornadas Hispano-Lusas de Matemáticas* (Barcelona, 1980).

51. Also preserved in the library of the della Faille family. In the Academy of History there is a more extensive copy, dated 1640 (Col. Cortes 9/2732).

52. See Ramón Ceñal, *La combinatoria de Sebastián Izquierdo* (Madrid, 1974), especially pp. 54–87.

53. The translation of Baliani's work is included in a volume of manuscripts preserved in the Academy of History (Col. Cortes 9/2751), attributed in the Cortes catalogue to Juan de Rojas and J. C. della Faille. The manuscript is titled *De el movimiento natural de los cuerpos graves*. In della Faille's correspondence with van Langren there is proof of the former's interest in the work of Baliani: "These days I have seen a little book of five or six fascicles of paper, in Genoa, by a gentleman

named Juan Bautista Baliano, of the movement of perpendiculars of weights hung from a string, by means of which we measure time. . . . Besides this it deals with the natural motion of falling bodies and those which descend on planes inclined towards the horizon." (Van der Vyver, "Lettres," p. 141) On della Faille's interest on mechanics, see also "Una lettera inedita del Torricelli ed altre dei geusiti R. Prodamelli, J. C. della Faille, A. Tacquet, P. Bourdin e F.M. Grimaldi," *Annali dell'Istituto e Museo di Storia della Scienza di Firenze* 5 (1980): 15–37.

54. See Claudio Constantini, *Baliani e i Gesuiti* (Firenze, 1969), p. 13.

55. Della Faille to Baliani, January 15, 1639, in Giovanni Battista Baliano, *Opere diverse* (Genoa, 1656). Della Faille had also connections with other friends of Baliani, including the Geonese Giovanni Anfossi, who was in Madrid around 1629–30 in the entourage of Cardinal Monti. Della faille entrusted him with the revision of his Theoremata de centro gravitatis. See Constantini, *Baliani e i Gesuiti*, pp. 16–17.

56. In his *Advertencias . . . a todos los profesores y amadores de la matemática tocantes a la proposición de la longitud por mar y tierra* (Madrid, 1634), van Langren mentions a Problema de los rumbos, a work by della Faille, and a "new and most ingenious speculation which denotes in particular the course that navigators want to follow on the sea" (folio 4r). On p. 5 of *La verdadera longitud* (1644) he invites the reader to study della Faille's works on the subject. In his correspondence with van Langren, della Faille refers several times to the subject of nautical charts. On February 24, 1635, he mentions various charts of increasing degrees of longitude made by Luis Carduchi (a mathematician and military engineer who succeeded Firrufino in the chair of fortification and artillery of the Council of War), by Camassa, and by Sempilius. He also mentions authors who had written on the problem of loxodromy: Pedro Núñez, Edward Wright, Simon Stevin, Willebrord Snell, and others. In other letters he refers to his own nautical chart which has the shape of a rhombus, whose advantages are difficult to assess with the information provided (see letter dated March 14, 1627). In a letter dated July 8, 1637, he comments approvingly on maps in Mercator's projection, recommending them for navigation. In a letter dated September 8, 1638, he says that making charts with increasing degrees is one of the functions of a cosmographer. (Van der Vyver, "Lettres," pp. 101–103, 111–113, 119–121, 137–142)

57. This is the opinion of Ramón Ceñal ("La filosofía española del siglo XVII," *Revista de la Universidad de Madrid* 11, 1962: 373–410) and Guillermo Frayle (*Historia de la filosofía española*, Madrid, 1971, volume I, p. 328). Nevertheless, there are numerous manuscripts on philosophical subjects preserved in the Academy of History which have not yet been studied, and these could provide new perspectives on the subject. For a preliminary description of some of this manuscripts, see Ramon Ceñal, "Manuscritos de filósofos jesuitas conservados en la Real Academia de la Historia," *Pensamiento* 15 (1959): 61–82.

58. On Arriaga and his relation to modern science, see *Diccionario*, ed. J. M. López Piñero et al., volume I, p. 78; Charles B. Schmitt, "Galilei and the Seventeenth-Century Text-Book Tradition," in *Novità celesti e crisis del sapere*, ed. P. Galluzzi (Florence, 1984). In addition to Arriaga and other non-Spanish authors, Schmitt mentions another Jesuit, Francisco de Oviedo, as representative of philosophy pro-

fessors who modified traditional doctrines to accommodate new scientific ideas. See also Thorndike, *History of Magic*, volume VII, pp. 399–402.

59. On the ideas of Izquierdo, see (in addition to Ceñal, *La combinatoria de Sebastián Izquierdo*) J. Carreras Artau, *Historia de la filosofía española . . . siglos XIII al XV* (Madrid, 1943), volume II, pp. 305–309; Paolo Rossi, *Clavis Universalis. Arte Mnemoniche e Logica combinatoria de Lullo a Leibniz* (Milan and Naples, 1960); José luis Fuertes, *La lógica como fundamentación del arte general del saber en Sebastián Izquierdo. Estudio del Pharus Scientiarum (1659)* (Salamanca, 1981); Cesare Vasoli, "I gesuiti e l'enciclopedismo seicentesco," in *Les jésuites parmi les hommes aux XVIe et XVIIIe siècles*, ed. G Demerson et al. (Clermont-Ferrand, 1988).

60. Vasoli, "I gesuiti," p. 495.

61. For an extended study of Izquierdo's combinatory analysis and its influence, see Ceñal, *La combinatoria de Sebastián Izquierdo*. See also Eberhard Knobloch, "Musurgia Universialis: Unknown Combinatorial Studies in the Age of Baroque Absolutism," *History of Science* 17 (1979): 257–275.

62. Above all in combinatory analysis. Insofar as general philosophical ideas are concerned, it is more difficult to establish lines of influence.

63. For biographical information on Mut, see J. M. Bover, *Biblioteca de escritores baleares* (Palma de Mallorca, 1868), volume I, p. 536. On his scientific works, see Víctor Navarro Brotóns, "Física y astronomía modernas en la obra de Vicente Mut," *Llull* 2 (1979): 43–62; Navarro Brotóns, "Riccioli y la renovación científica en la España del siglo XVII," in *Riccioli e il merito cientifico dei gesuiti nell' età barocca*, ed. M. Borgato (Florence, 2000).

64. *Arquitectura militar*, pp. 40, 81–84.

65. On Scheiner's procedure for observing sunspots, see J. Schreiber, "P. Christoph Scheiner, S.J. und seine Sonnenbeobachtungen," *Natur und Offenbarung* 48 (1898): 1–20. On the use of this technique by seventeenth-century astronomers for other ends, see Robert McKeon, "Les debuts de l'astronomie de precision. 1. Histoire de la realisation du micrometre astronomique," *Physis* 13 (1971): 225–288. Mut's application of the technique is mentioned in G. B. Riccioli, *Almagestum novum* (Bologna, 1651), volume I, p. 735, and in Claude-François Milliet-Dechales, *Cursus seu mundus mathematicus* (Lyons, 1674), volume III, p. 432.

66. Mut initiated his epistolary exchange with Riccioli in 1640, and became one of his principal correspondents. On May 25, 1647, Riccioli writes to Kircher: "Non dubito quin observationes D. Vincentij Muti fuerint valde exactae; habent enim nescioquos veritatis et diligentiae characteres." (I. Gambaro, *Astronomia e techniche di ricerca nelle lettere di G. B. Riccioli ad A. Kircher*, Geneva, 1989, p. 89) Riccioli cites many observations sent to him by Mut in his *Almagestum novum*. In the Chronicon of the *Almagestum novum*, Riccioli says of Mut: "Maioricensis, Astronomiae peritissimus observat sedulò Mairocae, scripsit egregium opusculum de Sole Alphonsino: Huic ego plurimum debeo." In the *Almagestum novum*, Riccioli mentions various observations and data of Mut's taken from the latter's *De Sole Alfonsino*, or obtained from letters Mut had written him, as Riccioli himself indicates. See e.g. references to the apparent true magnitudes of the fixed stars, to

the diameter of the inferior planets, and to the diameter and retrograde movement of Jupiter (volume I, pp. 423, 708, 711). Riccioli also writes that Mut was the first astronomer to measure the angular distances in the Pleyades (volume II, p. 412). In the *Astronomia reformata* references to Mut's observations abound, particularly relating to lunar eclipses and to the planets. Riccioli publishes a comparative chart of data obtained by Mut on the perigee of Saturn, and figures deduced from various tables—observations, Riccioli says, "nobis per literas liberalissime communicatae" (volume I, p. 285). The *Geographia et hidrographia reformata* (p. 364ff) contains information on lunar eclipses that Mut communicated to Riccioli in the years 1642–1650.

67. For a Spanish translation of the dedication and other texts by Mut, see J. M. López Piñero, V. Navarro, and E. Portela, *Materiales para la historia de las ciencias en España. S. XVI–XVII* (Valencia, 1976), pp. 238–243.

68. On the procedures for the measure of angular distances, Mut says: "Hanc speculationem intendat Astronomus; bracteam foraminulo perforatam superponat lenti remotiori Telescopii, ut Stella omnibus radiis adscitiis spolietur; seorsim etiam utatur Telescopio utriusque vitri convexi, subtensis filis in interiore foco; et ex comparatione tam ad diversos eiusdem planetae situs, quam ad Fixas, vel Lunae maculas minores, experietur differentiam diametrorum apparentium Martis, et Veneris ab Apogaeo ad Paerigeum multo esse minorem, quam requirant distantiae a Tabularum calculo deductae." (*Observationes motuum coelestium*, p. 54) Mut describes a telescope with two convex lenses and a aperture diaphragm, "subtensis filis in interiore foco," which he used since 1653. However, according to McKeon, the idea of introducing threads or a grid in the focus did not gain currency until after Huygens published his *Systema Saturnium* in 1659. Eustachio Divini, in his dedicatory letter to the lunar map he published in 1649, introduced a grid in the ocular, not in the focus. In 1662 Malvasia published his *Ephemerides Novissimae*, at the end of which he describes a grid placed in the focus of his telescope. Gascoigne's invention was not known until the 1660s. See McKeon, "Les debuts."

69. Mut, *Observationes motuum caelestium*, p. 63.

70. Curtis Wilson, "Kepler's Derivation of the Elliptical Path," *Isis* 59 (1968): 5–26; Wilson, "From Kepler's Laws, So-Called, to Universal Gravitation: Empirical Factors," *Archive for the History of Exact Sciences* 6 (1970): 89–170; Wilson, *Astronomy from Kepler to Newton: Historical Studies* (London, 1989). On the diffusion of Kepler's laws in the seventeenth century, see also J. L. Russell, "Kepler's Laws of Planetary Motion, 1609–1666," *British Journal for the History of Science* 2 (1964): 1–24; Victor E. Thoren, "Kepler's Second Law in England," *British Journal for the History of Science* 7 (1974): 243–256; I. B. Cohen, "Kepler's Century: Prelude to Newton," in *Kepler*, ed. A. Beer and P. Beer (Oxford 1975); Brian S. Baigrie, "Kepler's Laws of Planetary Motion, Before and After Newton's Principia: An Essay on the Transformation of Scientific Problems," *Studies in History and Philosophy of Science* 18 (1987): 177–208.

71. See Mut, *Observationes*, p. 68. In this respect Mut's ideas were similar to Riccioli's. For the latter (who rejected the celestial spheres), the planets in their motion obeyed Divine Providence, were driven by "motive intelligences," and appeared to human intelligence as an inextricable labyrinth. He openly opposed the

heliocentric theory and Kepler's attempt to unify astronomy and physics, maintaining that astronomy should be limited to "saving the appearances" by the use of geometrical models. Nevertheless, in the *Almagestum novum* Riccioli explained Kepler's theories and laws in great detail. In the *Astronomia reformata* he adopted the ellipse as a provisional basis for planetary theory, asserting that the determinations of the apparent diameters of the sun confirmed the bisection of the eccentricity. See Wilson, "From Kepler's Laws," pp. 103–106; Russell, "Kepler's Laws." See also Edward Grant, *Planets, Stars and Orbs: The Medieval Cosmos, 1200–1687* (Cambridge, 1984), p. 36 and passim; J. L. Heilbron, *The Sun in the Church: Cathedrals as Solar Observatories* (Cambridge, Mass., 1999).

72. Mut, *Cometarum*, p. 12.

73. Ibid., p. 13.

74. Althoug Hevelius studied the movement of the comet from the Copernican pespective. See J. A. Ruffner, "The curved and the straight: Cometary theory from Kepler to Hevelius," *Journal for the History of Astronomy* 2 (1971): 178–194. Mut's proposal was mentioned by A. G. Pingré in his *Cometographie* (Paris, 1783–1784), volume I, p. 143.

75. Mut, *De Sole*, p. 11.

76. Letters in Archivio della Pontificia Università Gregoriana, Rome. There are seven letters from Mut to Kircher, the first dated March 1646 and the last July 1651. In the first letter (xiii, folio 140r) Mut wrote: "Some admirers of mathematics in this kingdom have had news of the Magnetic Art which you have so wisely written, and with the occasion of my brother's trip to Rome, I wanted to kiss the hand of your excellency by means of this letter, asking you to guide him in the purchase of said book, along with a list which he has with him." John Fletcher ("Astronomy in the Life and Works of Athanasius Kircher," *Isis* 61, 1970: 42–67) mentions Mut (incorrectly cited as Vincentius Mutz) with respect to a letter he wrote to Kircher in 1669. See also Thomas F. Glick, "On the Influence of Kircher in Spain," *Isis* 62 (1971): 379–381; John Fletcher, "Athanasius Kircher and His Correspondence," in *Athanasius Kircher und seine Beziehungen zum gelehrten Europa seiner Zeit*, ed. Fletcher (Wiesbaden, 1988).

77. For Zaragoza's biography see Armando Cotarelo Valledor, "El P. Zaragoza y la astronomía de su tiempo," in *Estudios sobre la ciencia española del siglo XVI* (Madrid, 1935).

78. Cotarelo Valledor, "El P. Zaragoza," p. 109; Víctor Navarro Brotóns, *Tradició i canvi científic al País Valencià modern* (Valencia, 1985), p. 31 and passim.

79. The Academia de la Historia (Papeles de Jesuitas, tomo 187, 9/3760, doc. 15) preserves a manuscript with the title "Eclipse de luna observado en Valencia por D. Félix Falcó de Belaochaga a 29 de octubre de el año 1678." The correspondence between Falcó and Zaragoza on scientifics subjects is preserved in col. Cortes (9/2782). There is also a long letter dated 1658 from Falcó to Francisco Serrano on matters of civil and military architecture and music (in which discipline Falcó declares himself a disciple of Serrano). On Falcó as a teacher of Valencian men of science, see Navarro, *Tradició y canvi*. Francisco Serrano is another name to add to the list of Valencian mathematicians at mid century. Zaragoza mentions him pn p. 4

of his *Fabrica y uso de varios instrumentos matemáticos*, along with Falcó, as one "skilled in mathematics" as well as an expert in music. See V. Navarro and V. Rosselló, "Antecedents i orígens de la renovació científica valenciana de la darrería del segle XVII," in *IV Trobades d'Història de la Ciència i de la Tècnica*, ed. G. Blanes et al. (Alcoy and Barcelona, 1997). Among the Corachán manuscripts in the Biblioteca Mayansiana (Colegio del Corpus Christi, Valencia, BAHM-371) is a treatise on the astrolabe which Corachán atributes to Francisco Serrano.

80. E. Recasens Gallart, La Geometria magna in minimis de J. Zaragoza. El centre mínim i el Lloc 5e d'Appol.loni, doctoral dissertation, University of Barcelona, 1991; Gallart, "J. Zaragoza's Centrum Minimum, an Early Version of Barycentric Geometry," *Archive for History of Exact Sciences* 46 (1994): 285–320. See also, P. Peñalver and Bachiller, *Bosquejo de la Matemática española en los siglos de la decadencia* (Seville, 1930).

81. Discurso del cometa del año 1664 y 1665 (manuscript 1045, library of St. Geneviève, Paris, folios 42–92). Another copy of the work is preserved in the Academia de la Historia (Col. Cortes, 9/2705). Pingré (*Cometographie*, volume II, pp. 13–21) comments on this work and includes an extract from it (in French). For a study of the manuscript, and other astronomical works by Zaragoza, see Victòria Rosselló Botey, *Tradició i canvi científic en l'astronomia espanyola del segle XVII* (Valencia, 2000).

82. Zaragoza, *Discurso*, folios 73v–74r, 76r, 91r.

83. Biblioteca Nacional, Madrid, manuscript 8932, folios 58r–65v; Vicente Mut, *El príncipe en la guerra y en la paz* (Madrid, 1640), p. 198.

84. *Journal pour l'année MDCLXXVII* (Paris, 1718), volume IV, p. 120; *Memoires de l'Academie Royale des Sciences* (Paris, 1730), volume X, p. 592. In the *Memoires* we find Cassini's report, according to which Zaragoza's observations "ont precede celles des autres astronomes." The Library of the Observatoire of Paris has a letter from Zaragozà to Cassini about the comet and other queries (B-4, 12, suite) and a memorandum by Cassini that credits Zaragozà as being the first to have observed the comet (B4-1, p. 575). Cassini also states he discussed the subject with Zaragozà. I thank Antonio Ten for supplying me with a copy of Zaragoza's letter and Cassini's memorandum. The Academia de la Historia has a copy of this manuscript with the title "Observationes comeate habitae in oppido Argandae ab Astrophilo anno 1677" (Col. Cortes, 9/2707) According to Sommervogel (*Bibliothèque*, volume VIII, p. 1468), there is another copy in the Archivío Vaticano (Spagna, no. 149).

85. For example, in a manuscript titled *Astronomía teórica y práctica* (Biblioteca Nacional, Madrid, manuscript 8932) one reads "Tradita discipulis suis in Matritense academia Imperialis Collegii, 1673." See Cotarelo Valledor, "El P. Zaragoza," pp. 211–223.

86. Zaragoza, *Esphera en común*, pp. 45–46.

87. Ibid., p. 80. He does not mention the other two laws, nor does he comment, as Mut had done, on the alternatives proposed by Boulliau and other astronomers. However, in the unpublished Astronomia teórica y práctica (folios 19r–20r) he explains the elliptical motion as expounded by Boulliau without mentioning the modifications that the latter introduced into his initial theory.

88. Zaragoza, *Esphera*, pp. 199, 80.

89. William H. Donahue, *Dissolution of the Celestial Spheres: 1595–1650* (New York, 1981), p. 195.

90. Bacon proposes this spiral motion in his *Thema coeli*, no doubt basing himself on al-Bitruji (Alpetragius), although without recourse to spheres. (See *The Works of Francis Bacon*, London, 1857–74, volume III, pp. 779–780.) This solution was adopted in Spain in the sixteenth century by Jerónimo Muñoz and Diego Pérez de Mesa. On Muñoz, see Víctor Navarro Brotons and Enrique Rodríguez Galdeano, *Matemáticas, cosmología y humanismo en la España del siglo XVI. Los Comentarios al Segundo Libro de la Historia Natural de Plinio de Jerónimo Muñoz* (Valencia, 1988), pp. 17–247. On Pérez de Mesa, see *Diccionario*, ed. López Piñero et al., volume II, pp. 160–162. On the Jesuits and the spiral movement, see James Lattis, Christopher Clavius and the Sphere of Sacrobosco: The Roots of Jesuit Astronomy on the Eve of Copernican Revolution, Ph.D. dissertation, University of Wisconsin, 1989, pp. 149–165; Baldini, "Legem impone," pp. 125–127. On the spiral movement, see also Riccioli, *Almagestum novum*, volume I, pp. 152, 454–455, 504–505. See also ibid., volume II, p. 254ff. In the Conclussion (volume II, p. 260) Riccioli writes: "Probabilius est non dari corpus ullum, quod sit Primum Mobile, nec duos motus in stellis simul factos ad oppositas Mundi plagas, sed unicum versus Occidentem per spiras helicoidales, Fixarum quidem in caelo solido, Planetarum autem in fluido. Primi autem Mobilis vicem praestare tempus intelligibile, seu ideam diurni motus menti cuiusvis Intelligentia motricis insumam." Later (volume II, pp. 288–289), introducing his own system, he writes: "supra Saturnum est solida fixarum spherae per unicum spiralem item motum ab Intelligentia una vel pluribus, triplicem motum apparenter exhibens, nempe in longitudinem versus Occasum, in longitud. versus Ortum, et in latitudinem ob declinationis variationem, qui tamen revera unicus est in Occidentem." In the *Astronomia reformata* Riccioli abandoned his system and returned to Tycho's, reaffirming the unidirectionality of all the trajectories of the heavenly bodies by spires. See Michel-Pierre Lerner, "L'entrée de Tycho Brahe chez les jesuites ou le chant du cygne de Clavius," in *Les Jésuites à la Renaissance*, ed. L. Giard (Paris, 1995), p. 183, n. 93.

91. Zaragoza, *Esphera*, pp. 178, 167.

92. For a study of this portion of the work, see Horacio Capel, *La geografía como ciencia matemática mixta. La aportación del círculo jesuítico madrileño en el siglo XVII* (Barcelona, 1976), pp. 7–15.

93. See Fletcher, "Athanasius Kircher and his Correspondence," and Glick, "On the Influence of Kircher in Spain." In Athanasius Kircher's correspondence (Archivio della Pontificia Università Gregoriana, volume XIII, folio 130r) there is a letter from Zaragoza to Kircher, dated December 1655.

94. Zaragoza, *Esphera*, pp. 254, 256. On the influence of Kircher's ideas on the "subterranean world" in Spain, see Horacio Capel, *Organicismo, fuego interior y terremotos en la ciencia española del siglo XVIII* (Barcelona, 1976).

95. Academy of History, manuscript col. Cortes, 9/2782.

96. See Sommervogel, *Bibliothèque*, volume IV, pp. 1236–1237; *Diccionario*, ed. López Piñero et al., volume I, p. 493.

97. Vicente and Esteban, *Aspectos*, p. 171.

98. As is stated on the frontispiece of the Spanish edition of *Euclides* (Brussels, 1689).

99. Apparently the chair was created in 1689 under the sponsorship of the Count of Aguilar and Rodrigo Manuel Enrique de Lara, Commander in Chief of the Royal Navy (Capitán General de la Armada del Mar Oceano), who also had founded, in 1685, a School for the Royal Navy. The first professor was probably Kresa. In 1692 the professor was Francisco Blanco; in 1696; in 1699 it was Charles Powell. Another professor was José de Cañas, author of the unpublished Trigonometria esférica (1691). See Dou, "Matemáticos esdpañoles jesuitas," and M. Ravina Martin, "Notas sobre la enseñanza de las matemáticas en Cádiz a fines del siglo XVII," Gades 18 (1988), p. 48ff., cited by Dou. One of the theses cited is *Tesis matemáticas defendidas por el Excmo. Señor Don Iñigo de la Cruz en el Colegio de la Compañia de Jesús de la Ciudad de Cádiz* (Cádiz, 1688). Sommervogel (*Bibliothèque*, volume IV, p. 1237) attributes these works to Kresa. See also Juan Vernet, *Historia de la ciencia española* (Madrid, 1975), p. 114.

100. Pedro Berenguer y Ballester, "Un géometra español del siglo XVII," *Revista Contemporánea* 5 (1895): 449–457. On Omerique, see also *Diccionario*, ed. López Piñero et al., volume II, pp. 128–130.

101. *The Correspondence of Isaac Newton*, ed. H. Turnbull et al. (Cambridge, 1959–77), volume VII, pp. 412–413. For a review of Omerique's work, see *Philosophical Transactions* 21 (1699): 351–362.

102. *The Mathematical Papers of Isaac Newton*, ed. D. T. Whiteside (Cambridge, 1976), volume VII, pp. 198–199.

103. Díaz, *Colegio Imperial*, volume I, p. 567. See also Sommervogel, *Bibliothèque*, volume VI, pp. 630–631.

104. Academy of History, manuscript col. Cortes, 9/2709, 9/2710, 9/2728, 9/2729, 9/2733–2739, 9/2781.

105. Academy of History, manuscript col. Cortes, 9/2781.

106. Academy of History, manuscript col. Cortes, 9/2709 and 9/2727. In a letter dated 1683, Pérez conveyed to Petrei comments on geometrical issues discussed by Hobbes, adding that he had obtained permission from the Inquisitor General to read Hobbes's works. The following year, Pérez sent Petrei a copy of Hobbes's *De corpore*. Petrei read Hobbes's work carefully, as is attested by his notes and comments. In his letters, Pérez also discussed astronomy, mentioning his observations of sunspots and the satellites of Jupiter, and the instruments he uses, including a pendulum clock, a parallactic instrument, and a telescope. Besides Hobbes, he discusses Milliet Dechales, Descartes, Schott, and Riccioli. A 1687 letter from Corachán to Petrei is published in Ramón Ceñal, "El cartesianismo en España," *Revista de la universidad de Oviedo* (1945), p. 54. See also Navarro, *Tradició*. A treatise by Corachán titled *Exercitaciones Geométricas*, with marginal notes by Petrei, can be found among the latter's Petrei's manuscripts in volume 9/2727.

107. Capel, *La Geografía*, pp. 15–30. This work includes a study of the work of Hurtado de Mendoza. See also *Diccionario*, ed. López Piñero et al., volume I, pp. 465–466.

108. Hurtado de Mendoza, *Espejo geográfico*, volume I, p. 39ff.

109. Ibid., volume I, pp. 67–69.

110. Ibid., volume II, pp. 162, 178–180; Capel, *Organicismo*, pp. 19–20.

111. Diego Mateo de Zapata, "Censura," 18, in Alexandro de Avendaño, *Diálogos philosóphicos en defensa del atomismo* (Madrid, 1716).

112. López Piñero, *Ciencia y técnica*, pp. 421–429.

113. Cabriada, *Carta*, pp. 230–231, cited in J. M. López Piñero, *Medicina moderna y sociedad española. Siglos XVI–XVII* (Valencia, 1976), p. 180.

114. On the movement of renewal, see López Piñero, *Ciencia y técnica*.

115. On Caramuel, see Santiago Garma Pons, Las aportaciones de Juan Caramuel al nacimiento de la matemática moderna, Ph.D. dissertation, Valencia, 1978; Dino Pastine, *Juan Caramuel. Probabilismo ed Enciclopedia* (Florence, 1975); Velarde, *Juan Caramuel*.

116. Victor Navarro, La revolución científica en España. Tradición y renovación en las ciencias fisico-matemáticas, Ph.D. dissertation, Valencia, 1978); Navarro, *Tradició i canvi*.

117. Horacio Capel, *Geografía y matemáticas en la España del siglo XVIII* (Barcelona, 1982); Navarro, *Tradició i canvi*.

118. Olmo, *Nueva descripción del Orbe*, pp. 103–104, 197–207, 261.

119. Capel, *Geografía y matemáticas*, pp. 25–29.

120. On Chafrión, see *Diccionario*, ed. López Piñero et al., volume I, pp. 211–212.

121. Chafrión, *Escuela de palas, o Curso mathemático*, p. 204.

122. On the contents of these "conferences," see Navarro, *Tradició i canvi*, pp. 49–58.

123. On extant manuscripts by this author, see Víctor Navarro Brotóns, "Inventario de los manuscritos científicos que figuran en la Biblioteca Mayansiana," in *Primer Congreso de Historia del País Valenciano* (Valencia, 1973), volume I.

124. Biblioteca Mayansiana (Colegio del Corpus Christi, Valencia), manuscript BAHM-422. Mayans published this work in Valencia in 1747.

125. In a letter to Petrei (cited above), Corachán writes: "I attend an Academy, formed over the past few months from all kinds of sciences. Until now theologians, physicians, and mathematicians have attended . . . we plan to make it a substitute for the National Academies."

126. On the mathematical part of the *Cursus* of Milliet Dechales, see M. Cantor, *Vorlesungen über Geschichte der Mathematik*, second edition (Leipzig, 1880–1908), volume III, pp. 15–19. See also Navarro, *Tradició i canvi*, pp. 124–135.

127. For a study of this work, see Víctor Navarro Brotóns, "El Compendium Philosophicum (1721) de Tosca y la introducció en España de la ciencia y la filosofía modernas," in *La Ilustració española*, ed. A. Alberola and E. La Parra (Alicante, 1986); Navarro Brotóns, "Descartes y la introducción en España de la ciencia moderna," in *La Filosofía de Descartes y la fundación del pensamioento moderno* (Salamanca, 1997).

128. On science in eighteenth-century Spain, see Antonio Lafuente and José Luis Peset, "El conocimiento y el dominio de la naturaleza: la ciencia y la técnica," in *Historia de España*, ed. J. Zamora (Madrid, 1988). See also *Carlos III y la ciencia de la Ilustración*, ed. M. Sellés et al. (Madrid, 1988), the relevant chapters in Vernet, *Historia de la ciencia española*, and the section covering the eighteenth century in J. M. López Piñero, V. Navarro, and E. Portela, "La actividad científica y tecnológica," in *Enciclopedia de Historia de España*, ed. M. Artola (Madrid, 1988), volume III. On the diffusion of scientific and philosophical ideas, there is some interesting information in Francisco Sánchez-Blanco Parody, *Europa y el pensamiento español del siglo XVIII* (Madrid, 1991). For physics, see V. Navarro Brotóns, "La física en la España del siglo XVIII," in *Historia de la física hasta el siglo XIX* (Madrid, 1983). The classic work by Jean Sarrailh, *L'Espagne eclairée de la seconde moitée du XVIII siècle* (Paris, 1954), is still a source of valuable information.

129. See *Diccionario*, ed. López Piñero et al., volume I, pp. 210–211.

130. Nordenflicht and Sonneschmidt were engaged by Fausto de Elhuayar when he was head of the Royal Mining Tribunal to introduce von Born's method of silver refining to Peru and New Spain. See *Diccionario*, ed. López Piñero et al., volume II, pp. 113–114, 332–333.

131. See Mariano Peset and José Luis Peset, *La Universidad Española (siglos XVIII y XIX)* (Madrid, 1974).

132. See Horacio Capel, Joan Eugeni Sánchez, and Omar Moncada, *De Palas a Minerva. La formación científica y la estructura institucional de los ingenieros militares en el siglo XVIII* (Barcelona and Madrid, 1988); Antonio Lafuente and José Luis Peset, "Militarización de las actividades científicas en la España ilustrada," in *La ciencia moderna y el nuevo mundo*, ed. J. Peset et al. (Madrid, 1985); Manuel A. Sellés and Antonio Lafuente, "La formación de los pilotos en la España del siglo XVIII," in ibid.

133. See Francisco Javier Puerto Sarmiento, *La ilusión quebrada. Botánica, sanidad y política científica en la España ilustrada* (Barcelona and Madrid, 1988).

134. Between the end of the seventeenth century and the reign of Charles III, the civil and ecclesiastical powers struggled to delimit their respective jurisdictions, and the Spanish clergy began to enter, albeit at a very slow pace, a process of modernization that would bring them up to the level of the intellectual elite. In this period, the Jesuits moved from a position of power to that of opposition. Their loss of key positions in the power structure began with the fall of their protector, the Marquis of Ensenada, and the subsequent fall of the king's confessor, Francisco Rávago (1755). See T. Egido, *Oposición pública y oposición al poder en la España del siglo XVIII* (Valladolid, 1971); François López, "El pensamiento tradicionalista," in *Historia de España*. I am unable to cover here the political and scientific policies of the Jesuits, which were not monolithic. Rather I shall summarize the most notable aspects of the participation by members of the Order in the scientific development of the period.

135. On the foundation of the Seminary of Nobles, see Díaz, *Colegio Imperial*, volume I, p. 165ff;, Antonio Lafuente, "La enseñanza de las ciencias durante la primera mitad del siglo XVIII," in *Estudios dedicados a Juan Peset Aleixandre* (Valencia, 1982), volume II.

136. On the College of Cordelles (so called in honor of its founder, Juan de Cordelles, and directed by the Jesuits since 1658), see José Iglésies Fort, *La Real Aacdemia de Ciencias Naturales y Artes en el Siglo XVIII* (Barcelona, 1964).

137. On the University of Cervera, see M. Peset and J. L. Peset, *La Universidad española*, pp. 65–85; M. Rubio y Borrás, *Historia de la real y pontificia Universidad de Cervera* (Barcelona, 1915–16).

138. See Mario Martínez Gómez, "Gandía ante la reforma carolina: el proyecto de plan de estudios de 1767," in *Claustros y estudiantes* (Valencia, 1989), volume II.

139. Antonio Eximeno probably also taught mathematics at the College of St. Paul in Valencia for a few years. On public examinations, see H. Capel, "La geografia en los exámenes públicos y el proceso de diferenciación entre geografía y matemáticas en la enseñanza durante el siglo XVIII," *Areas. Revista de Ciencias Sociales (Murcia)* 1 (1981): 91–112.

140. Cassani also published an *Escuela Militar de fortificación* (ca. 1705), whose principal source was Chafrión's *Palas*. On Cassani, see A. Cotarelo Valledor, "El tratado de los 'cometas' del P. Cassani (1703)," *Anales de la Asociación Española para el Progreso de las Ciencias* 1 (1934): 485–520; *Diccionario*, ed. López Piñero et al., volume I, pp. 193–194. As Cotarelo observed, though Cassani published the *Tratado . . . de los cometas* in 1737, it was written in 1703.

141. P. Peñalver y Bachiller, *Bosquejo de la Matemática española*, pp. 49–50; *Diccionario*, ed. López Piñero et al., volume II, p. 382.

142. *Conclusiones mathemáticas, dedicadas al serenissimo infante Don Phelipe. Defendidas por Don Antonio Bustillo, Don Joseph Avellaneda, D. Vicente de Borja, Don Mart'n de Areyzaga, y D. Joachín Palacio. Seminaristas en el Real de Nobles de Madrid. Presididas por el R. P. Gaspar Alvarez, de la Compañía de Jesús, Maestro de Mathematicas en el mismo Real Seminario, El Día 3 de octubre de 1734* (Madrid, 1734), pp. 76–77.

143. On this expedition, and the participation of Spaniards in it, see Antonio Lafuente and Antonio J. Delgado, *La geometrización de la tierra (1735–1744)* (Madrid, 1984): Lafuente and Antonio Mazuecos, *Los caballeros del punto fijo. Ciencia, política y aventura en la expedición geodésica hispanofrancesa al virreinato del Perú en el siglo XVIII* (Barcelona and Madrid, 1987). The technical and scientific aspects of the expedition have also been studied by James R. Smith; see his book *From Plane to Spheroid* (Rancho Cordoba, 1986).

144. Juan Juan, *Observaciones astronómicas, y Phísicas hechas . . . en los reynos del Perú* (Madrid, 1748). In the introduction (p. xvi), after expounding the theories of Huygens and Newton on the form of the earth, based on the effects of the earth's rotation on its axis, Jorge Juan says: "Thus did these great geniuses discuss the hypothesis of the diurnal movement of the earth, but even though this hypothesis were false, the evidence testifies against the perfect sphericity of the earth, once one admits the observation that bodies exercise, according to the pendulum experiments, less weight when near the equator than in greater latitudes." In 1765, Jorge Juan wrote a defense of Copernicanism addressed to Campomanes, president of the Academy of History; it was accompanied by a letter in which Juan wrote: "The Copernican system, of necessity results from Newtonian principles, something that

terrifies the ignorant. Today it is proven and since we are obliged crudely to deny that it is proven, it is better not to write about it." (Museo Naval, Madrid, manuscript 812) The essay on Copernicanism was published in the second edition of Juan's *Observations* (1774) under the title "Estado de la astronomía en Europa, y juicio de los fundamentos sobre que regieron los Systemas del Mundo, para que se sirva de guía al método en que debe recibirlos la Nación, sin riesgo de su opinión, y de su religiosidad."

145. Burriel, anticipating the possible prohibition of the work, appears to have suggested a number of changes to the authors, then convinced the Inquisition that the book disscussed the motion of the earth only as a hypothesis. The scientific referees were Pedro Fresneda and Gaspar Alvarez, who recommended routine approval. See Lafuente and Mazuecos, *Los caballeros del punto fijo*, p. 26.

146. On Jorge Juan, see *Diccionario*, ed. López Piñero et al., volume I, pp. 483–486. On the Observatory of Cádiz, see Antonio Lafuente and Manuel A. Sellés, *El Observatorio de Cádiz (1753–1831)* (Madrid, 1988).

147. See *Conclusiones mathemáticas . . . defendidas en el Quartel de Guardias de Corps* (Madrid, 1752). Presiding over the *Conclusiones* was Captain Pedro Padilla, author of *Curso militar de mathemáticas* (Madrid, 1753–1756), the first Spanish text to discuss differential calculus. For a description of Padilla's work, see Norberto Cuesta Dutari, *Historia de la invención del cálculo infinitesimal y de su introducción en España* (Salamanca, 1983), pp. 120–137. On the Academia de Guardias de Corps, see also Antonio Lafuente and José Luis Peset, "Las Academias Militares y la inversiópn en ciencia en la España ilustrada," *Dynamis* 2 (1982): 193–208; Capel et al., *De Palas a Minerva*, pp. 147–148 and passim.

148. On the Sociedad Militar de Matemáticas, see Cuesta Dutari, *Historia de la invención del cálculo*, pp. 188–239; Capel et al., *De Palas a Minerva*, p. 178.

149. Navarro, "La física en la España del siglo XVIII."

150. On Burriel, see Alfonso Echánove Tuero, *La preparación intelectual del P. Andrés Marcos Burriel (1731–1750)* (Madrid, 1971). On Mayans's relations with Burriel, see also Antonio Mestre, *Despotismo e ilustración en España* (Barcelona, 1976); for their correspondence, see Gregorio Mayans, *Epistolario, II: Mayans y Burriel*, ed. Antonio Mestre (Valencia, 1982). On Mayans's participation in the matter of Jorge Juan and Copernicanism, see Vicente Peset Llorca, "Acerca de la difusión del sistema copernicano en España," in *Actas del Segundo Congreso Español de Historia de la Medicina* (Salamanca, 1963), volume I.

151. *Conclusiones Mathemáticas . . . por el Seminario de Nobles . . . Presididas por el R. P. Mro. de Mathemáticas en el mismo Real Seminario* (Madrid, 1748). According to the Jesuit Manuel de Larramendi (*Corografía o Descripción General de la . . . Provincia de Guipúzcoa*, Barcelona, 1882, p. 283), the animator of this presentation of mathematical "conclusions" was Burriel (see Capel, "La geografía en los exámenes públicos," p. 98).

152. The *Constituciones* were published in Madrid together with a "Memoria histórica de la Fundación del Real Seminario de Nobles" in which it is indicated (p. 18) that Philip V funded this center because he "did not find any seminary devoted to the education of those nobles who normally did not attend universities, but were

employed in the service of the Palace and Court, in the administration of the business of the State; and of those who remained in their cities administering their houses and estates and who ought to be, owing to the birth, leaders of their regions." The memorandum also states that this seminary was modeled after the one that Louis XIV had established in France.

153. Wendlingen was professor of humanities in the Jesuit College of Prague. After the expulsion of Jesuits from Spain, he returned to Prague where he was Inspector of Mathematics and director of a science museum. See J. C. Poggendorff, *Biographisch-Literarisches Handwörterbuch (zur Geschichte) der Naturwissenschaften* (Leipzig, 1863–1976), volume II, p. 1296.

154. A copy of this memorandum is preserved in the Archivo General de Simancas, Marina (Negociado Indiferente, leg. 712).

155. In the Archivo General de Simancas, Marina (Negociado Indiferente, legs. 712 and 713) are found various letters and documents of Wendlingen on all these questions, along with reports and letters by Juan and Ulloa. Some of thee letters refer to instruments requested by Wendlingen and acquired by Juan in London.

156. Díaz, *Colegio Imperial*, volume I, p. 576.

157. Poggendorf, *Handwörterbuch*, volume II, p. 640.

158. Rieger's manuscripts are preserved in the Academia de Historia in a thick folder in the Cortes collection (9/2792). They are written in different hands. One of them is titled *Additions to the Astronomical Institutions that Father Rieger, Read in 1673*. The folder, which the collection's catalogue attributes to Rieger, also includes manuscripts by Cerdá. Cuesta Dutari (*Historia de la invención*, pp. 249–252) attributes all the writings on fluxions and differential calculus to Cerdá. Recently, Santiago Garma has distinguished more precisely which manuscripts belonged to Rieger and which to Cerdá; see "Cultura matemática en la España de los siglos XVIII y XIX," in *Ciencia y sociedad en España: De la Ilustración a la Guerra Civil*, ed. J. M. Sánchez Ron (Madrid, 1988). Besides the handwriting, one criterion for this distinction is that Rieger, in his "Introduction to the Algorithm of Fluxions," always uses Newtonian notation, whereas Cerdá, in his manuscripts, uses the Leibnizian notation. Cerdá also comments on the similarities between differential calculus and fluxions.

159. On the University of Valencia, see Salvador Albiñana, *Universidad e Ilustración. Valencia en la época de Carlos III* (Valencia, 1988); Victor Navarro, "La ciència illustrada," in *Història del País Valencià*, ed. M. Ardit (Barcelona, 1990), volume IV, pp. 277–297; J. M. López Piñero and V. Navarro, *Historia de la ciència al País Valencià* (Valencia, 1995), pp. 295–326; J. M. López Piñero and V. Navarro, "Estudio Histórico," in *La actividad valenciana de la Ilustración*, ed. J. López Piñero (Valencia, 1998); V. Navarro, "Filosofía y ciencias," in *Historia de la Universidad de Valencia, ed. Mariano Peset* (Valencia, 2000), volume II.

160. Cited in Ignacio Casanovas, *La cultura catalana en el siglo XVIII. Finestres y la Universidad de Cervera* (Barcelona, 1953), p. 172.

161. See Cuesta Dutari, *Historia de la invención*, pp. 240–254. On Cerdá, see also Iglésies Fort, *La Real Academia de Ciencias Naturales*, pp. 41–47 and passim;

Diccionario, ed. López Piñero et al., volume I, pp. 206–207; Lluís Gassiot, "Tomàs Cerdà i els inicis de l'Acadèmia de Ciències de Barcelona," in *La Reial Acadèmia de Ciències i Arts de Barcelona als segles XVIII i XIX*, ed. A. Nieto-Galan and A. Roca (Barcelona, 2001).

162. The chair was solicited by the rector of the college with the support of the municipal government. See Iglésies, *La Real Academia de Ciencias Naturales*, p. 23. Among Cerdá's manuscripts is a description of the city of Barcelona in which he states that there were two chairs of mathematics. There is also a letter from Cerdá to Thomas Simpson, dated 1758, in which Cerdá provides information on his teaching activities at the Colegio de Cordelles.

163. T. Cerdá, *Liciones de mathemática o Elementos Generales de Arithmética y Algebra para el uso de la clase* (Barcelona, 1758), volume I, p. 2.

164. On Cerdá's manuscripts, see Lluís Gassiot, "Tomás Cerdá." The treatise on astronomy has been edited recently by Lluís Gassiot i Matas in Tomás Cerdá, *Tratado de Astronomía* (Barcelona, 1999). This work must have been written around 1760, as it alludes to the "present (year) 1760" (69r, 69v, 70v).

165. Cerdá, *Tratado de astronomía*, chapter 7, folio 17vff. On Cerdá's efforts to introduce the new physics in the Colegio de Cordelles, see the published accounts of different academic functions at the College in the early 1760s. In an Act (that is, a public disputation at the College) held in 1762, the section on physics began with an attack on "scholastics who regard experiments as an exercise degrading to the nobility of philosophy" and "who can deny that in the observation of natural things experimentation has made more progress in fewer years, than the prolix speculations of so many excellent minds had been able to achieve by mere ratiocination over a period of many centuries." Among the subjects covered in this and other academic acts were the nature of color (according to Newton), electricity and electrostatic machines, a pneumatic machine, barometers, telescopes, microscopes, and a "judicious critique" of the "world systems." See Iglésies, *La Real Academia de Ciencias Naturales*, pp. 22–28. Many of the founders of the Physical-Experimental Club of Barcelona, the forerunner of the Academy of Sciences, had been students of Cerdá at Cordelles. When the club was constituted in 1764, its members agreed to "grant Cerdá free admission to its meetings whenever he so desired" (ibid., p. 41). See also Gassiot, "Tomás Cerdá."

166. Antonio Eximeno taught rhetoric in the Seminary of Nobles of Valencia and mathematics at the College of St. Paul in the same city. After the expulsion, he went to Italy and became a musicologist. He published two works on philosophy and mathematics, *De studiis philosophicis et mathematicis instituendis* (Madrid, 1789) and *Institutiones philosophicae et mathematicae* (Madrid, 1796), which display his advanced mathematical formation. Like his co-religionist and compatriot Juan Andrés, to whom he dedicated the former work, he approved of the sensualism of Bonet and Condillac. See Miguel de Guzmán Ozamiz and Santiago Garma Pons, "El pensamiento matemático de Antonio Eximeno," *Llull* 3 (1980): 3–38. Eximeno's lecture, edited by Enrique Pardo Canalís, was published as *El Padre Eximeno, profesor primario del Real Colegio de Artillería de Segovia* (Segovia, 1987).

167. See Miguel Batllori, *La cultura hispano-italiana de los jesuitas expulsos* (Madrid, 1966).

168. J. Andrés, *Dell'origine, progressi e stato d'ogni letteratura* (Parma, 1782–1799). The work was reprinted in toto twelve times by 1844, and in part five times. Here I cite the Spanish edition (Madrid, 1795–1806), volume II, pp. 361–362. See Víctor Navarro Brotóns, "Juan Andrés y la historia de las ciencias," in *Estudios dedicados a Juan Peset Aleixandre* (Valencia, 1982), volume II.

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Jesuit Science in the Spanish Netherlands

G. H. W. Vanpaemel

The position of the Society of Jesus with regard to the scientific revolution has often been described as one of thorough conservatism. Already in the seventeenth century, commentators considered the Jesuits ardent and unremitting defenders of the scholastic-Aristotelian philosophy and stubborn adversaries of Galileo, Descartes, and Newton. In particular, whereas most historians of science have been willing to credit the Protestants with the rise of modern science, the Jesuits, imbued with the militant spirit of the Counter-Reformation, were assigned the unenviable role of dry and uncreative opponents to progress.

In recent years, a number of scholars have constructed a new and more comprehensive picture of Jesuit science during the sixteenth and seventeenth centuries. Most notably, Crombie and Wallace have argued for a positive influence of the Jesuit philosophy taught at the Collegio Romano on the early views of Galileo.[1] From a different perspective, Dear has shown that many Jesuit scientists of the early seventeenth century were not insensitive to the subtler methodological problems regarding the use of experiments in natural philosophy, for which they offered various interesting solutions.[2] Still other sympathetic appreciations of the Jesuit contributions to modern science were made by Heilbron, Ashworth, and many others.[3] Of course, such studies do not aim to deny that the Jesuits clung to their scholastic-Aristotelian heritage, or that by 1700 they had almost completely dropped out of the main currents of the scientific revolution. Yet, at least during the seventeenth century, their conservatism was not out of touch with many of the newer developments, representing an attitude of sharp intellectual criticism rather than mere institutional opposition. It is now recognized that within the Catholic Church the Jesuits formed an “intellectual and religious elite,” and that in this respect they can be considered the “new humanists” and the "protagonists of their century," a characterization referring not only to their theological and philosophical teaching but also to their scientific activities.[4]

The recent historical resurgence of interest in the Jesuits has, however, been built on a rather small empirical basis. Most scholars have indeed concentrated on the Italian Jesuits (mainly those associated with the Collegio Romano) and on a few others who stood in direct relation to them.[5] Undoubtedly those were the leading lights of their Order, directing, if not dictating, the intellectual efforts of their fellow Jesuits abroad. The Jesuits of Italy exerted an enormous influence on the philosophical and scientific activities of the Order as a whole. The Society indeed displayed, in the words of Redondi, an explicit "will to homogeneous and disciplined action," which set it apart from most of the other religious orders. The fifth General Congregation (1593), the highest legislative authority within the Order, had laid down in detail the philosophical views to be defended by the Jesuit professors, a regulation which was still enforced in 1730 by the sixteenth General Congregation.[6] The *Ratio Studiorum*, first drafted in 1586 but subsequently modified in 1599, remained the official guideline for the educational program of the Jesuit colleges and universities throughout the seventeenth century, unchanged by the newer intellectual developments. The Jesuit authorities in Rome actively guarded the conformity of all Jesuit actions to these basic regulations.[7]

But the structural discipline of the Society also allowed a certain measure of divergence from these general directions. To cite but one example, the typical architectural style of the Jesuit churches, designed by Carlo Borromeo, was not uniformly adopted throughout the Continent. Jesuit authorities did interfere with and sanction the projects for new buildings, but the final design was often determined as much by local taste and circumstances (such as the availability of building materials and the support of local civil authorities) as by the Roman directives.[8] Perhaps a similar argument may be made with regard to the observance of intellectual conformity among Jesuit scientists in the various provinces of the Order. Sweeping claims have been made, notably by Redondi, about the existence and effectiveness of an internal Jesuit "police force" constituted by the Society's censors and subject to the direct and exclusive control of the Father General. As part of an apologetic and scientific strategy, Jesuit scientists were instructed "to demonstrate rationally, with the arguments of mathematics and experience, the falsity of [Galileo's] Dialogue; that is, to confute the astronomical, mechanical, and cinematic concepts Galileo had used as illustrations." Similarly, "in conformity with the official dispositions" Jesuit scientists were bound to combat the geometry of indivisibles and the idea of a vacuum, both reputedly allies of atomism.[9]

Redondi's argument rests on his particular understanding of the controversy that developed in Italy between Jesuit philosophers and post-Galilean scientists. Whatever the merit of this interpretation, it is far from obvious that a similar argument can be extended outside the original Italian context. If Rome was the political and theological center of the Catholic world, with all its intrigues and its Counter-Reformation zeal, Jesuits in other countries may have been more sensitive to the challenge offered by such different circumstances as proximity to Protestant regions or preparation for and support of missionary activities. Must, indeed, all the diverse scientific activities of the Jesuits be interpreted as parts of one overriding polemical strategy initiated and pursued by the theologians, philosophers, and scientists at the Collegio Romano? Certainly there must have been some dissidents within the Society; otherwise there wouldn't have been any need for an internal "police force" in the first place. As in the case of Jesuit architecture, there may have been a far greater local divergence of views in the field of natural philosophy than has generally been acknowledged.

This essay will examine some characteristics of the scientific life of one of the most prosperous provinces of the Society, the Flandro-Belgian province in the Spanish Netherlands, during the seventeenth century. In particular, the Jesuit school of mathematics, founded in 1617 by Gregory of St. Vincent, harbored a tradition of outstanding mathematical research, which was highly regarded by contemporary observers, both within and outside the Society. These Jesuit mathematicians are not unknown by historians of science. Gregory, one of the Society's most talented mathematicians, has been thoroughly studied for his summation method of infinitesimals, which he put to good use in studying the centers of gravity.[10] Some of his students taught mathematics and physics at such important places as Madrid and Rome. Andreas Tacquet, who occupied the chair for more than 15 years, not only carried on the research initiated by Gregory but also authored a number of successful textbooks on geometry and astronomy. He is also cited by Redondi as one of the Jesuit authors who answered the Roman call to arms against Cavalieri's "atomist" mathematics.

There were many similarities between the Italian and the Flemish Jesuit mathematicians. The influence of Clavius, whose pupils included the Belgians Odo van Maelcote and Gregory of St. Vincent, is in both instances very apparent. Also, the mathematical research of the Flemish Jesuits retained many connections to Italy, through the cooperation with Grienberger at the Collegio Romano, or through the study of the works of Galileo, Toricelli, Cavalieri, and the Italian Jesuit Riccioli. The "Italian connection" may even be held responsible for the singular lack of interest the Flemish Jesuits were to show in Cartesian mathematics.

Notwithstanding these striking Italian influences, the Flemish Jesuits fit awkwardly into the Italian-based picture of the Society. Situated in a distant province, far from the hectic Roman atmosphere and under the political and cultural influence of Spain (and, moreover, in close contact with Calvinist culture in Holland), the Flemish Jesuits took a quite different attitude toward the scientific polemics of their time. The particular context of the Spanish Netherlands, a small outpost of a large and disintegrating empire, recently marked by vehement religious conflicts, put the Flemish province in a strikingly different position from Central Italy. The Spanish Netherlands were situated too far from the great courts of Europe to offer important opportunities for diplomatic initiative, while the Flemish Jesuits failed to invade academic life as it occurred in so many other Jesuit provinces.[11] This severely reduced the opportunities for Jesuit philosophers and scientists to find a proper assignment in the Spanish Netherlands. Without an adequate means to radiate its intellectual vigor upon the public sphere, the Flemish province appears as a studious but rather insular community of scholars, preaching devotion and preparing for missionary work but largely abstaining from intellectual polemics until the advent of Jansenism later in the century. Interestingly, the neighboring province of the Gallo-Belgian Jesuits, situated within the cultural influence of France, did engage in scientific discussions, most notably with Van Helmont.

From this particular perspective, the mathematicians of the Flemish province, shielded from the pressure of an agitated environment, can offer a valuable addition to our historical understanding of Jesuit science. The Flemish Jesuit scientist appears less as a polemical author, taking a firm stand in stormy debates, than as a sober, reclusive scholar, contributing from a marginal position his modest but substantial share to the great undertakings of the Society.

From Rome to Antwerp: A Cradle for Mathematicians

In 1640, when the Society of Jesus celebrated its first centenary, the Flandro-Belgian province was at its apogee.[12] The small, fugitive group of eight clerics who in 1542 fled Paris to settle in the university town of Louvain managed to survive the religious wars of the sixteenth century. By 1612 it had grown into a powerful army of about 1,000. Magnificent churches and colleges were built at an amazing rate. During the first two decades of the seventeenth century, 26 new houses, mainly colleges, were founded, bringing the total number of the Society's foundations in the Spanish Netherlands and the Bishopric of Liège to 43. The rapid growth of the province made it necessary in 1612 to divide the Belgian province, Germania Inferior, into two provinces, Flandro-Belgica and Gallo-Belgica, roughly along the linguistic border between Dutch-speaking and French-speaking regions. This did not hinder the extraordinary development of the two provinces. Membership continued to grow fast, reaching in 1631 a peak of 856 for the Gallo-Belgian province and in 1643 a peak of 867 for the Flandro-Belgian province. Claudio Acquaviva, the Father General of the Society, called these provinces the flower of the Society [illae provinciae sunt et semper habui pro flore Societatis].[13] Quite understandably, the pompous *Imago primi saeculi Societatis Iesu*, prestigiously published in 1640 by the Antwerp Plantin press to celebrate the first centenary of the Order, was written in an overtly triumphant and openly complacent style.

The success of the Society of Jesus in the Spanish Netherlands was not only a matter of membership and material prosperity. The Belgian Jesuits also made important contributions to the cultural and intellectual life of their order. One seventeenth-century biography of Jesuit authors enumerates nearly 1,600 individuals, 225 of whom were Belgian authors, including 124 from the Flandro-Belgian province.[14] Some of them, including the theologians Petrus Canisius and Martinus-Antonius Del Rio, acquired great international fame. Other important authors included the humanist and historian Andreas Schottius, the theologian Cornelius a Lapide, and the jurist and theologian Leonardus Lessius. Apart from these examples of individual scholarship, the Flandro-Belgian provinces also harbored two collective enterprises of intellectual research: the "Bollandists" (so called after Joannes Bollandius, author of *Acta Sanctorum*) and the Musaeum Bellarminianum (which, under the patronage of Cardinal Roberto Bellarmine in

Rome, concentrated on apologetic work against Protestant propaganda). The province also produced a number of outstanding architects, who were responsible for the introduction of the Roman baroque style to the Spanish Netherlands.

The Jesuits' influence on teaching and education in the Spanish Netherlands was enormous. In the Flandro-Belgian province there were sixteen colleges, attended by several thousand young students per year. A particular success for the Jesuit Order was its acceptance into the faculty of arts of the recently founded University of Douai. From 1569, Jesuit professors taught philosophy at the Collège d'Anchin. Although initially the faculty was rather averse to this development (the Jesuits abstained from charging fees), Jesuits soon came to dominate the faculty. They were less successful at the University of Louvain, the main intellectual center of the region. After a prolonged struggle, the Jesuits were prohibited from offering a public course in philosophy, for which a renewed monopoly was granted to the university. Also, the public course of theology, once taught by Bellarmine, was suppressed in 1625. This left the Flandro-Belgian province, after its separation from the Gallo-Belgian province and hence from the University of Douai, without any opportunity to teach public courses at the university level. Jesuits were allowed to provide such courses only for their own members or for members of other religious congregations. Apart from some "public" student disputes, to which outsiders were occasionally invited, the Jesuit courses played no role on the intellectual scene. It is difficult to envisage the consequences of this omen of failure. Only a comparison with the history of Jesuit science in other countries, such as Germany or France, where the Jesuits all but completely controlled academic philosophy, can suggest the grave handicap inflicted on the Society in the Flandro-Belgian province by its exclusion from the mainstream of intellectual ideas. The relations between the Society and the University of Louvain were at times quite strained, but at least before the advent of Jansenism later in the century there were numerous examples of personal friendship and mutual esteem.

Before the division of the Belgian province, the center of Jesuit scientific activities in the Spanish Netherlands was evidently Douai. Not much is known about the actual content of the philosophy courses at the Collège d'Anchin, but there appears to have been some predilection for mathematical studies before the end of the sixteenth century. Within a short period of time, the Jesuits at Douai produced at least three Jesuit scholars of outstanding mathematical ability. The first was François de Aguilon, from Brussels, who studied (with interruptions) philosophy and mathematics in Douai between 1586 and 1589[15] and who subsequently taught astronomy at the same institution for a few years. Another Douai student, possibly a pupil of Aguilon, was Odo van Maelcote (1572–1615), also from Brussels, who was soon invited by Christopher Clavius to study with him at the Collegio Romano. Van Maelcote became well known for his laudatory address to Galileo at the Collegio on May 18, 1611. Gregory of St. Vincent (1584–1667), born in Brugge, studied at Douai around 1600, then went to the Collegio Romano to study with Clavius. Each of these three mathematicians was much influenced by Clavius's views on the eminence of the mathematical sciences with regard to natural philosophy. To Clavius, the study of mathematics was indispensable for correctly understanding problems of a philosophical or physical nature.[16] Moreover, mathematics was a genuine science in its own right, capable of attaining true knowledge about the physical world. In particular, the astronomical hypotheses put forward by Ptolemy or by Copernicus were not to be regarded as merely convenient fictions to "save the appearances"; they were true depictions of the actual motions in the heavens.[17]

Although Clavius was by far the best and most famous mathematician of the Society, his views were not undisputed. Odo van Maelcote's lavish praise of Galileo's astronomical discoveries, backed up by the leading mathematicians Clavius and Grienberger, was frowned on by the theologians of the Collegio Romano.[18] Many years later, Gregory of St. Vincent, who had been present at the event and had taken Odo van Maelcote's side, was still regarded by Father Mutius Vitelleschi as someone who "by his free manner of speech and by his behavior might offend others."[19] Clavius's mathematicians at the Collegio Romano indeed formed something of an in-group within the Society, solidified both by their enthusiasm for the value of the mathematical sciences (including astronomy and optics) and by their common sense of a scientific vocation.[20] After Clavius's death in 1612, members of the group may have continued their research under the guidance of such mathematicians as Grienberger, Guldin, Grassi, and Scheiner. However, Odo van Maelcote died shortly thereafter, and Gregory was sent back to the Spanish Netherlands, no doubt carrying with him the memory of an unforgettable research experience and many of the inspiring views of his great teacher.

In Antwerp, Gregory of St. Vincent found a brother in arms in François de Aguilon. In his own way, Aguilon had promoted an esteem for mathematical studies among his fellow Jesuits. As an architect, he built a number of churches and, in particular, drew the plans for the magnificent baroque church of St. Ignatius in Antwerp, the pride of the Flandro-Belgian province. As a scientist, he wrote a textbook on optics, complementing the series of manuals written by Clavius for use in the Jesuit colleges. In the same vein as Clavius, Aguilon considered mathematics, and in particular the "mixed" discipline of optics, to be indispensable for the physical sciences. His optical textbook was advertised as useful to philosophers and mathematicians [philosophis iuxta ac Mathematicis utiles]. Aguilon's mathematical skills were further put to good use, when the Jesuit academy for church history, founded in Antwerp in 1612 and later transformed into the Musaeum Bellarminianum, sought his advice on matters of chronology. Finally, it was he who envisaged the idea for a school of mathematics.

As Ziggelaar demonstrated, it was under the impulse of Aguilon that Antwerp became the main center of Jesuit teaching in the Flandro-Belgian province. Already in 1606 there were some negotiations about providing a public course in mathematics, probably intended for merchants, gaugers, navigators and surveyors of the commercial town of Antwerp. In 1615 a second unsuccessful attempt was launched by Aguilon to provide mathematical training for the scholars working on church history. Aguilon may well have started to offer some mathematical instruction from that date. But it was the division of the Belgian province, necessitating a new educational institution for the Flemish Jesuit students, that made the provision of a course in mathematics necessary, along the lines prescribed by the Ratio Studiorum.[21]

Aguilon died on March 20, 1617, before he could see the results of his work, but a few months later Gregory inaugurated the projected course of mathematics. It was to be a great success.[22] Under Gregory's guidance the school produced an impressive number of mathematicians, which compares well with the teaching of mathematics at Douai during this period. Although mathematics was taught at Douai between c. 1620 and 1626 by Charles Malapert (1580–1639), a renowned scientist and mathematician in his own right, nothing is known about any of his students.[23]

We know little about the actual content of Gregory's mathematical courses. They probably were fairly elementary, being an obligatory part of the second year courses of the curriculum. But apart from the regular course, Gregory also selected a few outstanding students to receive further training. However, although the course of mathematics was open to the public and, indeed, was well attended by non-Jesuit students, such advanced training was probably reserved for Jesuits. Between 1617 and 1625, at least fourteen students, all Jesuits, are known to have received special instruction in mathematics from Gregory. Many of them—including Joannes della Faille, Philippus Nutius, Ignatius Derkennis, Jacob Durandus, Guilielmus Hesius, Guilielmus Boelmans, Theodorus Moretus, and Joannes Ciermans—later became teachers of mathematics or natural philosophy. After he had ceased to teach the public course, Gregory continued to train some outstanding students in private; one of them, Aegidius de Gottignies, became professor of mathematics at the Collegio Romano.

For Gregory these early years in Antwerp proved to be a period of extremely creative work. He developed his infinitesimal method *ductus plani in planum*, a powerful tool to develop an Archimedean-inspired mathematics, which convinced him that he would be able to square the circle. To obtain permission to publish his results, he forwarded some short treatises with specimens of his method to Christopher Grienberger at the Collegio Romano for examination. Characteristically, these treatises were in part written by some of his students, who were obviously well enough acquainted with his research projects to take on such a task. It was to become a habit with Gregory to involve his students in the elaboration of his scientific work. After the publication of his circle quadrature in 1641, Gregory became embroiled in controversies with several mathematicians. Again he mobilized his students to act on his behalf, providing them with arguments of his own construction.[24]

Thus, as was the case with Clavius in Rome, we find an instance of the formation of a small group of mathematicians, a scientific community, cemented together by a common research program. However, there was an important difference between Rome and the Spanish Netherlands: Gregory and his students concentrated exclusively on pure mathematics (with some excursions into statics), while the mathematicians of the Collegio Romano extended their interests to the whole of the mathematical and the physical sciences. This may have been due in part to the personality of Gregory, who was anything but a philosopher. Among the 15,000 manuscript pages he left behind, only eight relate to a topic of philosophical interest—a theory of the tides.[25] Yet even then the Flemish Jesuits were not completely left outside the debates on astronomy. The appearance of a comet in November of 1618 brought about a wide interest among scholars and poets in the Spanish Netherlands.[26] Gregory observed the comet with his students (probably using a telescope), then organized a public academic session in which his students defended a number of theses on the comet, probably supporting the Tychonic cosmology. These theses were published but unfortunately have not been preserved. The event signals their willingness to take a public stand on a controversial matter and to venture beyond the limits of pure mathematics.

Corpuscular Physics and Cartesianism

In 1625 Gregory of St. Vincent was called to the Collegio Romano to work with Grienberger on his circle quadrature. This ended the first and most glorious era of the school. During the next 10 years, the course of mathematics was continued with interruptions by several of Gregory's students. Their tenure as professors was often extremely short, not exceeding, with one exception, 2 years. During this same period, three promising students of Gregory left the province to take up teaching positions elsewhere. Della Faille went to Madrid and Moretus to Münster; Durandus settled in Graz.

In 1637, Joannes Ciermans was appointed professor, a position he held until 1641.[27] Ciermans had studied with Gregory, but unlike his teacher he showed only moderate interest in problems of pure mathematics. From about 1633, he drew attention to himself as an able mathematician and engineer, inventing and constructing machines. Later in his career, while he was waiting to leave for the Chinese mission, he was indeed hard at work as a military engineer and advisor to the Portuguese prince, fighting the Spanish king. He appears to have left the Order (or to have been expelled from it) around that time. Ironically, Ciermans died as a soldier in the service of Spain.

Ciermans's course of mathematics left some traces that enable us to get a general idea of its contents. In the jubilee year 1640, Ciermans published a volume of theses under the title *Disciplinae Mathematicae*, covering all the topics of his course: geometry, arithmetic, optics, statics, military arts, geography, astronomy, and chronology. A prominent place was given to the military arts, reflecting the fact that in these years of continuous warfare this was what Ciermans's students desired to learn. Apart from the military arts, Ciermans also showed a lively interest in statics, applied to mechanical, hydrostatic, and nautical constructions, and in optics. The latter, in particular, continued a line of research that had earlier been prominent in the work of Aguilon and of at least one of Ciermans's predecessors Boelmans.[28] Whereas Aguilon, however, had aspired to produce a comprehensive treatise on optics, of which only the first part on vision and light was published, Ciermans's theses mostly focused on topics of obvious practical interest. Ciermans did not dwell on such philosophical themes as the construction of the eye, the process of vision and perception, or the nature of light and colors. The optical theses in the *Disciplinae Mathematicae* mainly concerned the art of perspective and the laws of reflections and refractions.

Yet it is clear that Ciermans was interested not only in the mathematical laws that could be used as guiding principles in practical applications but also in their physical foundations. Following the realist school of Clavius, Ciermans saw no sharp distinction between mathematical reasoning and physical conceptions and freely mixed both kind of arguments. Through mathematics, the philosopher could learn new things about nature, which could not be known otherwise. Likewise, mathematics was to make use of physical reasoning to determine the actual state of nature. Ciermans believed, for example, that the visual perception of distance was not to be deduced from the geometrical angle of vision but rather from the structure of the eye and the vivacity of the colors. Through a combination of geometrical and physical reasoning, Ciermans thought himself able to deduce demonstratively the law and the cause of refraction. Transcending a purely geometrical treatment, he established with particular care that the angles of refraction were not related to the ratio of the densities of the two media but depended on some other physical property of the media [mole tota] that was responsible for the easy transmission of light.

Although Ciermans was never involved in the actual teaching of physics, his mathematics course evidently treated many physical questions, for which he might have offered alternative solutions to those professed in the regular course on natural philosophy. It is highly likely that Ciermans speculated on the nature of light, and that he did so on the basis of mathematical and experimental research, particularly in connection with prisms. One important document that provides information on such optical investigations is Ciermans's letter to Descartes, written in March of 1638—an invited reply to the latter's *Discours de la méthode* and the *Essais*.

In his letter, Ciermans declared himself a *scientiae amator* and proclaimed himself an ardent admirer of Descartes's unusual doctrines. "I love the genius," he wrote with more than customary politeness, "who, having left the familiar shores, dares to face the danger of the new world; and what else than discovering new lands it is, when one sets out to explain all the most hidden things in nature only by things that can be seen or touched, and without the help of any [scholastic] qualities."[29] Ciermans bestowed unrestrained praise on the *Géométrie*, which he considered not merely a fine treatise on geometry itself but also a work of pure mathematics touching on the whole field of the mathematical sciences. Yet he did not go into a detailed analysis of this work, nor did he bring up in his letter any geometrical arguments. Instead, Ciermans focused his attention exclusively on a passage in the *Météores* wherein Descartes discussed the physical causes of the prismatic colors.[30] Descartes explained these colors by a combination of two separate events. First, as the light particles hit obliquely the surface of a denser medium, they acquired a rotational movement, with a velocity roughly equal to their velocity of translation. Second, the motion of the outer particles of the ray was influenced by the slower ether particles in the dark bordering shadow regions. This caused a modification of their rotational velocity, which was subsequently transmitted in diminishing degrees to the inner particles of the ray, producing the different prismatic colors. From experimental evidence, Descartes then concluded that the greatest rotational velocity should be attributed to red and the smallest to blue.[31]

Ciermans rightly pointed out that in the set-up of the prism experiment discussed by Descartes the oblique surface necessary to induce the general rotational mode of the particles was located not at the entrance of the denser medium but at the exit. Descartes's geometrical analysis should, consequently, be inverted. Instead of being hindered by the denser medium, the light particles now should acquire an accelerated motion upon entering the less dense medium [liberiorem quasi campum nactus]. Particles, already in the less dense medium, would communicate their greater velocity to those neighboring particles at the point of leaving the prism. In this way, Ciermans argued, the rotational velocity would increase from the outermost to the innermost part of the ray, a conclusion exactly opposite to the one Descartes had arrived at. Ciermans's objection is quite valid. It appears that he had studied the subject carefully and that he was quite familiar with the experiment. In one instance, he pointed out that very often the blue color was seen to be slightly mixed with a faint red glow—probably, he speculated, because some of the fast spinning blue particles were slowed down by the ambient ether particles.

Ciermans's letter to Descartes does not reveal *stricto sensu* his own thoughts on the matter, since he explicitly stated that he only wanted to show some internal inconsistencies in Descartes's work. He thus necessarily accepted Descartes's principles as a ground for discussion. Ciermans did include some critical remarks on Descartes's corpuscular conception of light, but these were probably only meant to probe the depth of Descartes's understanding in these matters. For example, in passing Ciermans likened Descartes's views with Copernicus's system, evidently not in order to condemn it (for then he would have made a much less superficial remark about such a sensitive issue) but rather to elicit a more explicit confirmation or negation from his correspondent. Ciermans was putting Descartes to the test, inviting him to disclose just a bit more of his original thoughts, which evidently had caught the Jesuit's interest. In the same vein, Ciermans asked Descartes how the rotating particles of light, emitted by the sun and the distant stars, could reach us without alterations, and how it was possible that the sun was not yet depleted by the continuous streaming out of its particles.

Corpuscular explanations, such as those put forward by Descartes and eagerly studied by Ciermans, were not unfamiliar to Flemish Jesuits. Hesius, a student of Gregory and professor of mathematics a few years before Ciermans, is indeed reported to have introduced corpuscular explanations into his teachings. Interestingly, Hesius was the only mathematician of the group to also teach the physics course. In his *Elogium* it is said that "even before Descartes had done so, he had abandoned all external qualities and distinct modes, admitted by some foolish Peripatetics as a necessary evil in dealing with generation and corruption, and instead made use of streams of particles emanating from the brain and the sun, the movements of which he lucidly explained."[32] Was it a coincidence that Ciermans put precisely this problem of the "streams of particles" to Descartes, a problem which was apparently debated among the Jesuit mathematicians ? It is certainly not too daring to suggest that Ciermans's objections reflected his own preoccupations with corpuscular theories, and that he felt comfortable with the arguments presented by Descartes.

Ciermans's realist conception of the mathematical sciences also surfaced in his departure from standard doctrines in astronomy. First, he expounded the traditional view of astronomy as being merely an instrument for computation. Traditional astronomy was based on the principle that the movements of the heavenly bodies ought to be described only by a combination of circles and perfectly uniform velocities. In this way, however, astronomy could not attain to certain knowledge about the real fabric of the universe. A combination of circles could bring forth almost any line. This point was underscored by Ciermans when explaining how Copernicus had described the linear libration of the poles by making use of two circles, and how in the same way Kepler had constructed the elliptical orbit of Mars. The principle of astronomy, therefore, did not exclude any geometrical line, generated by a combination of circles, as a possible candidate for the real path of the planets. This may seem a convenient opening toward a familiar statement about "saving the appearances," but it was not. Like Clavius, who rejected Copernicanism because it was not in agreement with physical principles, Ciermans reasoned that the mathematical equivalence of the astronomical hypotheses created the possibility of introducing other criteria within astronomy for establishing the truth. "I do not know," he sneered, "what is the more to wonder at: that the human mind is able to make up such hypotheses, or that these, although being false, can still have such an accurate connection with the real world that they can with certainty predict the future motions of the heavenly bodies."[33] Obviously, the predictive power of the astronomical hypotheses could only be accounted for by accepting that they were somehow truly based in reality.

Indeed, discussing the orbit of the moon, Ciermans clearly stated a realist criterion for the astronomical hypotheses. Having reviewed each of the solutions given by Ptolemy, Copernicus, and Tycho, Ciermans suddenly changed tone and concluded with a short statement of a far more general kind : "The movements of the Planets will agree better with philosophical arguments and with the truth, if you let them run through a simple elliptical orbit."[34] This remark was evidently not restricted to the explanation of the moon's orbit, but was meant to be valid for all the Planets. Furthermore, Ciermans explicitly referred to truth and philosophical arguments. This is obviously not mathematical instrumentalism. By referring to an ellipse as "simple," Ciermans at once rejected the need to have recourse to an artificially constructed orbit, composed of a combination of eccentrics and epicycles. Although these combinations could well produce the same apparent movements as the simple ellipse and were, therefore, sufficient to save the appearances, Ciermans preferred the elliptical orbit not for mathematical convenience but because of the existence of philosophical arguments and most of all, because it agreed better with the truth. Whatever the merit of saving the appearances in astronomy, realist criteria clearly played a role in Ciermans's mathematics.

Ciermans was a friend of the astronomer Govaart Wendelin (1580–1667), the most pronounced advocate of Copernicanism in the Spanish Netherlands.[35] Like Kepler before him, Wendelin had abandoned the use of circular orbs to describe the movements of the planets, replacing them by elliptical orbits. In several passages of the *Disciplinae Mathematicae*, Ciermans referred to his Copernican friend. The philosophical arguments, to which he alluded to in the statement quoted above, may therefore be thought to reflect something of Wendelin's conception of a general magnetical attractive force, governing the solar system.

At least one other of Wendelin's preferred themes, the precession of the equinoxes, was embraced by Ciermans to direct the discussion toward heliocentrism. Contrary to Wendelin, however, Ciermans concluded that the precession of the equinoxes could not be taken as a definite proof either in favor or against Copernicanism, since the appearances could easily be saved in both ways. But here, too, Ciermans clearly was aiming for an understanding of the real world, and was not satisfied with a mere saving of the appearances.

Is the realism of Ciermans an exception among the Jesuit philosophers in the Flandro-Belgian province? Although no philosophy courses are known to survive, something of their views can be inferred from published theses—with due caution because of their often cryptic character. One set of philosophical theses, published in 1640 by Ludovicus De Scildere, shows for the most part a quite traditional rendering of scholastic-Aristotelian doctrine in the fields of logic, physics, and metaphysics, without any reference to the possibility of a contribution of mathematics to the field of natural philosophy.[36] Some of the physical theses, however, do take on new views in those topics that belonged closely to the domain of the mathematical sciences: the problem of the continuum, the heliocentric astronomy, and the *meteorologica*. The theses are stated without comment and may equally have been defended or disproved by the students. But the choice of topics reveals at least an awareness of contemporary philosophical views that found a place in the curriculum: the heavens are said to be incorruptible but fluid; if one would still like to consider them as solids, then at least Mercury and Venus should be placed within the celestial orb of (that is, orbiting) the sun. The triple motion of the earth in the Copernican world system apparently implies an immense increase in the dimensions of the universe, for which there is no need, but it is very difficult to refute the Copernican movements, in particular the daily rotation of the earth, by arguments based on experience. The darker regions on the moon are said to be regions of lesser density. The sunspots are minor planets.

One particularly interesting statement is made regarding an explanation of the tides. We know that some of Gregory's students worked on this problem. The theses of 1640 propose a quite original theory. The tides are said to be caused by the attraction of the moon, and, in order to account for them on both sides of the earth, the earth is held to be displaced from its "real" center. This would cause the water at the opposite side of the moon to flow into the evacuated space, which is nearer to the real center and hence in a lower position. This ingenious explanation, in fact wholly based on a mathematical (i.e. statical) argument, entails the possibility of at least a small movement or displacement of the earth, regulated by the motions of the moon. Such statements indicate a willingness among the philosophers to introduce new doctrines from the mathematical sciences into cosmology and physics. It is reasonable to assume that the Jesuit mathematicians supported the introduction of such novelties into the philosophy course. Yet these novelties did not change substantially the general purpose of the course, as their presence can only be discerned in a small number of rather marginal topics, most often situated near the end of the curriculum. Only two of the mathematicians were involved briefly in teaching philosophy, Hesius and Derkennis, and their views were surely not representative of other Jesuit philosophers. Their colleagues probably frowned at, or made merry of, the follies of the mathematicians. When Derkennis started working in 1642 on a series of alchemical experiments, for example, together with the college's physician, it was feared that he might abandon theology for chemistry [ex theologo chymicus factus est]. One of his confreres mockingly observed that "if these things work out, some of us believe that we will be in the possession of a universal remedy for all diseases." But he hastened to add that this would not take Derkennis away from the more serious theological studies: "You would laugh if you could see his apparatus made of glassware and other vessels. Time will show what in the end will come out of it. He is very secretive about it all. But certainly nothing bad should be feared to come from his furnaces, unless of course the philosopher's room would be set on fire."[37] Whatever inspired the researches of Derkennis, he would soon turn again to theology, becoming an important actor in the anti-Jansenist campaign of the Flemish Jesuits.

It is, significant, however, that the unorthodox novelties and researches of Gregory's mathematicians were known and tolerated—and in some cases even adopted by the philosophers—without raising much trouble. Perhaps discipline in this period was rather lax,[38] as Ciermans's *Disciplinae Mathematicae* was devoid of an imprimatur. But at the very time when Galileo in Italy and Descartes in Holland were laying siege on the fortresses of traditional learning, the Flemish Jesuits toyed freely with new ideas, without being reprimanded for doing so.

The Retreat from Realism

Gregory of St. Vincent had returned from Prague to the Flemish province in or shortly after 1632, but he did not resume his teaching post at the school of mathematics. He settled in the College of Ghent, where he worked as a confessor.[39] During the sack of Prague in 1631 he had been forced to leave his mathematical manuscripts behind, and not until 1641 were they restored to him. From that time on, he set himself to work intensively on his great book about the quadrature of the circle, begun almost two decades earlier. He again gathered around him a small number of private students, who assisted him in his work and who would take up his defense in the controversies to come.

In 1634 Gregory made a trip to Louvain in order to attend an academic session at the school of mathematics, presided over by his former student Boelmans. Among the students selected to perform he met a very talented young man who in time would become professor of mathematics: Andreas Tacquet. Tacquet occupied the chair from 1644, while still a student in theology, until his death in 1660.[40] Although Tacquet has never been a personal disciple of Gregory, there are many similarities between the two mathematicians. Like Gregory, and unlike Ciermans, Tacquet was very much drawn toward pure mathematics, working on fairly the same topics as his older colleague. His work was indeed an elaboration of Gregory's infinitesimal summation method, and it resulted in an important publication *Cylindricorum et Annularium libri IV*, first published in 1651 and augmented 8 years later by a fifth book (published in 1669, after Tacquet's death). In addition to this original work, however, Tacquet also spent much time composing several manuals for use in Jesuit colleges. More than Gregory, Tacquet was devoted to a career of teaching in the service of the Society. His life was utterly uneventful; he apparently never ventured outside the borders of his native province.

Tacquet's mathematical investigations were not part of his course, as had been the habit of Gregory. He apparently did not encourage students to participate in his work, although there were some mutual influences between his research and teaching activities. In 1650, for example, a student of Tacquet defended a *Dissertatio Physico-Mathematica* on the famous problem of Aristotle's wheel,[41] a subject to which Tacquet returned much later, in his fifth book of the *Cylindricorum et Annularium libri IV*. It is not clear whether Tacquet introduced here one of his pet problems into the course, or whether he was led to consider the problem as a result of teaching it.

With Tacquet, the glorious era of the school was over. It did not produce any great philosophers or mathematicians. Although Aegidius de Gottignies, later professor at the Collegio Romano, did attend Tacquet's course, he subsequently went to Gregory for advanced education. Another of Tacquet's noted students, Ferdinand Verbiest, worked in the Chinese mission and succeeded in being nominated to important offices at the emperor's court. But Verbiest was not a great mathematician. The key to his successful career was his skillful expertise in the fields of practical astronomy and military technology. Moreover, Verbiest probably did not learn these skills from Tacquet. Most authors refer to Adam Schall von Bell (1591–1666), his predecessor in Beijing, as the one who initiated him into scientific work and policies of the Jesuits in China. This was 20 years after Verbiest attended Tacquet's course. Still, Shall found Verbiest "well versed in mathematics," something that may be attributable to Tacquet's teaching.[42]

From the content of his textbooks, we can infer that Tacquet's course of mathematics was probably not very different from the one Ciermans had taught. A very important theme was still military technology. Other topics covered included geometry, arithmetic, statics, optics, and cosmography. Tacquet, however, followed a quite different approach. He was not an engineer like Ciermans, nor an architect like Hesius or Aguilon earlier. In general, his interest in natural philosophy appears to have been rather superficial. He may have performed a number of simple optical experiments, but his approach was invariably guided by mathematical speculations and calculations. Although the author of a highly technical textbook on astronomy, Tacquet never engaged in telescopic observations himself, or at least never mentioned them. His interest in astronomical instruments was limited to the construction and use of astrolabes.

Among Tacquet's most intimate friends was Ignatius Derkennis, the alchemist-theologian who in due time became rector of the Louvain college. With Derkennis, Tacquet shared a common interest in the composition of the continuum and the associated problems about infinite quantities. They may have also speculated together on problems of a physical nature. In one of his writings Tacquet made a passing reference to Derkennis, concerning a remark about how the moon reflected the light of the Sun but not its image.[43] In general, however, such philosophical inquiries were rare with Tacquet. He once even expressly distanced himself from a philosophical polemic on the continuum, which Derkennis had wanted to add as an appendix to one of Tacquet's books.[44]

Tacquet has written quite an impressive number of books, most of them teaching manuals for the different mathematical sciences to be used in Jesuit courses.[45] In particular, his posthumous *Opera Mathematica* gives us a revealing picture of his views on the relationship between mathematics and natural philosophy. Yet some caution must be observed. Tacquet composed his manuals to comply with an express demand made by General Goswin Nickel. Upon receiving Tacquet's *Cylindricorum et Annularium libri IV*, Nickel replied by urging the author to write a *cursus mathematicus*, properly adapted for use in the Jesuit colleges.[46] From the start then, Tacquet was well aware that his books would reach a large but inexperienced audience. Such an elementary exposition was representative of official Jesuit doctrine. Indeed, the *Opera mathematica* adheres to a certain extent to the strong post-Clavian attitude toward the mathematical sciences, in which mathematical hypotheses can only serve to save appearances, irrespective of the related philosophical questions. Yet we have no reason to doubt that Tacquet's writings truly reflect his own views.

Of the proposed *cursus mathematicus*, Tacquet published only two manuals during his lifetime, on geometry and arithmetic, but he was working on several others by the time of his death. His posthumous *Opera mathematica* contains five of these treatises (in addition, the *Cylindricorum et Annularium libri IV* was incorporated into the added fifth book, but it is not present in all extant copies). Two of the minor treatises, the *Geometrica practica* and the *Architectura militaris*, are of no particular interest here. The first and most important treatise, *Astronomia explicata ac demonstrata* (pp. 1–356), probably was in an advanced stage of composition, although Tacquet kept adding new material to it in 1659. The two remaining and rather short treatises, on optics and catoptrics, were probably edited from unfinished drafts. At various points Tacquet indeed referred to demonstrations and arguments to appear in the book on dioptrics, which was, however, not included. A manuscript of the dioptrics has not been found.

Most authors have drawn attention to Tacquet's explicit use of "saving of the appearances" in the *Astronomia* when discussing the Copernican system.[47] Tacquet rejected the Copernican system for religious reasons, but he still expounded the different astronomical hypotheses with equal care, pointing out the good and the problematic features of every proposed solution. Science alone could not decide which of the hypotheses was true. The truth of a hypothesis could not be ascertained by any evidence deduced from the phenomena. Hypotheses were meant to explain the phenomena, not vice versa. "You can explain the entire [field of astronomy] with the hypothesis that the earth moves, or the sun. For this reason, however, it is impossible to find out from the phenomena which hypothesis is absolutely true."[48] The astronomical hypotheses were not real, they were only meant to save the appearances. In particular, the function of an astronomical hypothesis was to make the motions of the celestial bodies accessible to mathematical treatment. He rejected the elliptical orbits of Kepler, as being too cumbersome and un-mathematical to work with. "For me this suffices to prefer the circle over the ellipse; as the goal of hypotheses is first of all to reduce the movements of the stars to numbers."[49]

The choice of an astronomical hypothesis was for Tacquet essentially a matter of practical concern, perhaps even determined by mere personal preference. "I have never liked the use of ellipses in astronomy—and I still don't," he confessed to the reader, thus bringing his discussion of Kepler's hypothesis to a conclusion. With a similar appeal to practical relevance, he excused himself from discussing the usual arguments in favor, or against, Copernicanism, because none of them really exceeded the level of mere probable statements. The veracity of astronomical hypotheses was further played down from a theological point of view. Elaborating on a well-known argument against heliocentrism, Tacquet proved that in the Copernican hypothesis the proportion of the dimensions of the fixed stars to the distance earth-sun, would be equal to the proportion of the dimensions of the same stars to the radius of the earth in the geocentric hypothesis. In the Copernican hypothesis therefore, the stars needed to be much larger and heavier than in the traditional view, a conclusion which conflicted with intellectual economy. But Tacquet observed that, as humans, we cannot know the whole purpose of the creation. The heavy stars may perfectly serve the Creator's intentions, which are, and always will be, unknown to us. True knowledge of the fabric of the heavens is, therefore, likely to remain forever unattainable.

This attitude toward the use and function of hypotheses was of course well developed within the context of astronomy. Tacquet merely adopted a widely diffused discourse in astronomical texts. The notoriety of the question which elicited these statements, may, however, obscure some of the finer conceptions regarding the relation between mathematics and natural philosophy. In his treatise on optics, Tacquet made, in fact, quite a different use of the word *hypothesis* but did not include any formal comments on his deviant use of the concept. Since the different (unfinished) treatises in the *Opera mathematica* were probably conceived to be unrelated technical manuals, there was perhaps no need, or opportunity, to do so. Equally, Tacquet may not have felt the necessity to explain his methodology, either because he had no clear understanding of the issue himself, or because he considered his methodological approach as sufficiently in agreement with standard practices.

Scholastic methodology, with which Tacquet was undoubtedly well familiar,[50] does attach several meanings to hypothesis. A hypothesis could contain avowedly unrealistic statements in order to "save the appearances," as was the case with the astronomical hypotheses. A second meaning of hypothesis, however, concerned statements of fact which were actually the case in well-defined circumstances, or alternatively, statements about idealized phenomena, e.g. without taking into consideration the influence of external impediments which were actually present.[51] Such suppositions were adopted to inquire into their causes: if a certain situation is granted to be the case (supposition), then which were the causes necessary to produce it ?

Nevertheless, this methodological distinction does not quite cover Tacquet use of hypotheses. His optical hypotheses served not as statements about phenomena to be explained, but as axioms or principles (Tacquet indeed referred to these both as *hypotheses* and as *principia*) on which a mathematical science could be built. His hypotheses were not idealized phenomena or particular occurrences in nature, but general and universal law-like statements about the physical world. One of his hypotheses stated, for example, that light proceeds along straight lines. Other hypotheses, however, implied metaphysical views. Tacquet's very first hypothesis stated that all visible things emitted images which were captured by the eye, where they determined the visual perception.[52] This hypothesis, Tacquet further maintained, could be demonstrated by an experiment of his own invention [constat illustri experimento, quod veteres ignorarunt; iam nescit nemo]. Although many of the experiments related by Tacquet were mere common observations, his use here of the word *constat*, opposed to the formula *patet experientia*, usually applied throughout the optical treatises, suggests a more elaborate kind of experiment, with a more subtle reasoning. *Patet* appealed only to the passive consent of the reader that something indeed was the case in normal experience. *Constat* denotes the unsuspected existence of an experiment, with which the reader is not expected to be familiar. This suggests a more inquisitive attitude, leading up to a demonstration of something which was not known or not believed before the experiment was actually performed. This did not prompt Tacquet, however, to give a full description of it. For a demonstration of the experiment and its interpretation, the reader was referred to the (unpublished) Dioptrics, a remarkable example of strict adherence to the disciplinary division of the subject matter, against the logic of the argument. Yet, although the proof of the hypothesis was obviously not self-evident, but the result of a careful experimental investigation, Tacquet was confident that the truth of the principle was sufficiently demonstrated to use it as the starting point of his optical treatise.

Tacquet repeated his claim that hypotheses could actually be demonstrated in another instance at the beginning of his second book on optics. Here Tacquet stated that objects seen under an equal angle, appear equal. But this hypothesis—supported in the text only by an appeal to the authority of Euclid, Alhazen, and Witelo—was exactly what Tacquet had profusely demonstrated in his first book! The fact that Tacquet did not refer to his previous discussion, only a few pages away, may have been a result of the unfinished state of the treatise or, as in the previous case, the result of a strict disciplinary division of the different chapters. Nevertheless, it is the case that for Tacquet hypotheses in one part of a mathematical science could well be demonstrated in another part.

Tacquet's use of the word *hypothesis*, meaning a statement of a universal and demonstrable property of the natural world, was very akin to the notion of physical law—such as the law of reflection at the beginning of his catoptrics. Tacquet called this law *prima ac perpetua lex*, again a reference to its fundamental and universal character. As with hypotheses, Tacquet maintained that this law could be conclusively demonstrated. Interestingly, he gave several independent ways to provide a demonstration. In the first place, the law could be deduced from what looked like an even more fundamental axiom, viz. that "nature always acts along the shortest path." Tacquet did not explain why he preferred not to take this axiom itself as the actual starting point of his treatise. He realized perhaps that the simple and well known axiom was not sufficient for all purposes. In fact the internally reflected ray between two points A and B on a closed and hollow sphere followed the longest path, not the shortest. Tacquet resolved this difficulty by showing that in this case there did not exist a shortest path. He felt justified to amend the axiom with the clause that nature only takes the shortest path when such a path exists. In this form, however, the axiom looses its self-evident character and requires further demonstration. For instance, Tacquet did not indicate which path nature takes when there is no shortest path. The "axiom" was thus found to be insufficient to provide a foundation for the experimentally verified law, but the truth of the law as a description of a matter-of-fact remained unharmed.

Tacquet attempted to prove the law of reflection by physical arguments. In particular, he mentioned the proof given by Descartes (the only reference to Descartes in the entire *Opera*), whom he criticized for not taking into account the loss of momentum which must occur in the reflected particles. This once again indicates that Tacquet considered the law not merely to be an approximation or an idealization of a phenomenon, for in that case the idealized Cartesian explanation would have been quite sufficient. For Tacquet, the law of reflection was a statement about the real world, where it was rigorously true. Although a physical proof was lacking, Tacquet did resort to a lower level of "mathematical" certainty. Unless Tacquet deliberately disregarded the methodological subtleties, his use of law-like hypotheses in the optical treatises reveal that for him the mathematical disciplines were a genuine science about the real world, not just an abstract model of it. They were based not on fictitious hypotheses to save the appearances, but on statements believed to be true in nature.

Something of this realist position also emerges in Tacquet's astronomy. Several passages of the *Opera* show Tacquet actively searching for, and scrutinizing, different arguments for their realist content. At one place, he scorns Riccioli for having introduced in his theory of the moon a fictitious point, even though he admits that the theory is most simple and perfectly "saves the phenomena."[53] In fact, although Tacquet rejected Copernicanism exclusively on biblical grounds—itself a perfectly realist argument, but with the corollary that scientific arguments can never be conclusive—he did consider the possibility of proving rationally the absolute truth or falsity of the Copernican astronomy by mathematical arguments. After having studied carefully all of Riccioli's 126 arguments for and against the Copernican world system, listed in the *Almagestum Novum* (Bologna, 1651), he conceded that a definite proof was not yet available.[54] None of the arguments proposed, Tacquet believed, exceeded the level of mere probability. Tacquet did not deem it worth while to include probable arguments in his textbook on mathematical science. Only when an argument appeared to attain the power of demonstration, did it deserve the attention of mathematicians. For this reason, he demonstrated that Riccioli's argument on the path of falling bodies, which according to Riccioli contradicted the hypothesis of a moving earth, was fallacious.[55] This exclusive attention for demonstrative arguments in mathematics possibly delineates the disciplinary boundary between mathematics and natural philosophy, as Tacquet may have perceived it. But the line between them was very thin. Perhaps the distinction was only in grade, not in kind. Probable arguments were indeed to be considered in astronomy, although Tacquet usually refrained from doing so.[56] Tacquet concluded that, since both the heliocentric and geocentric hypotheses agreed with the celestial phenomena, it would be impossible to construct an argument from astronomy which would settle the question, but he was more cautious as to the possibilities of ever finding a conclusive argument from natural philosophy.

The realism which Tacquet retained in his optical work, was thus overshadowed by his deliberate instrumentalism in astronomy. This evolution was enhanced by another feature of Tacquet's science, his reluctance to discriminate between competing explanations. This may have been a didactic strategy or a consequence of the fact that he was writing a textbook, rather than an original scientific work. A typical example of this distinct approach is offered by his discussion of explanations to account for the scintillation of the stars. Tacquet explained this phenomenon first according to Aristotle, who ascribed it to the distance between the stars and the viewer. Then he proceeded to the explanation of Scheiner and Biancani, who sought the cause in the influence of the atmosphere. A third explanation was given by Bruno, Kepler, and Riccioli, who presumed a rotation of the stars. Tacquet did not reject any of these explanations. Instead, he concluded his review by accepting the veracity of all explanations. No explanation was to be absolutely discarded, all explanations were useful and complemented each other. Other examples of the same approach include the multiple explanations of comets and sunspots. A similar inconclusiveness appeared in Tacquet's discussion of the newly discovered satellites around Jupiter and Saturn. Here, too, he was apt to accept rather too much than too little testimonies of observed satellites.[57]

This tendency to provide multiple explanations served a dual function. First, it introduced the student into an ongoing discussion, accurately analyzing the phenomena involved and presenting the various arguments. The Jesuit students were thus well prepared to take part in scientific debates. Second, by juxtaposing several explanations, Tacquet directed the attention of the student toward the understanding of the problematic phenomena, and away from the actual solutions that could be found. Indeed, the students were not instructed how one could proceed to solve the problem. Tacquet gave almost no examples of successful solutions, either by mathematical deductions or by experimental research. Most often, the student was directed toward the original works of the authors to learn and to judge their arguments for himself. It sufficed for Tacquet to indicate the variety of possible arguments. It should be noted, however, that in his optical treatises Tacquet did adopt a more conclusive style of argument, e.g. in his critical discussion and rejection of some of Aguilon's views.

The method of multiple explanations in natural philosophy was a logical continuation of "saving the appearances," as applied to mathematical hypotheses. Multiple explanations suggested the inconclusiveness of scientific arguments, contrary to the modern notion of causality. Whatever cause was to be assigned to a given phenomenon, other causes of a completely different nature could be adduced and defended with equal right. Almost any explanation could be accepted whenever it could be understood to produce the desired effect. In this sense, appearances were "saved" not by giving one possible (but not necessarily true) explanation to account for the phenomena, but by giving an indefinite number of explanations, all partially true but none conclusive.

The retreat from realism in astronomy and natural philosophy, apparent in Tacquet's manuals, can also be seen in contemporary Jesuit teaching of philosophy. Again, the evidentiary basis for assessing the content of the philosophy course is fragmentary. However, one interesting surviving document is a published thesis of philosophy, dating from 1673, four years after the publication of the *Opera Mathematica*. The thesis was defended under the supervision of Joannes Pollenter, professor of philosophy and soon to become a professor of theology, who was a vehement opponent of Jansenism. Pollenter's views reflect a thorough acquaintance with modern science, and the published theses demonstrate the importance attached to natural science in Jesuit philosophy. Of the 52 theses, some 32 deal exclusively with scientific or mathematical topics in a strict sense. Still others refer to natural philosophy, for example the theses on the doctrine of causes or the proper use of accidents and qualities. Thirteen other theses treat logic and metaphysics and seven are devoted to ethics.[58] Of the "scientific" theses, five refer to *De Anima* (including two theses on light and colors), four treat the philosophical foundations of physics (e.g. time, space, and the vacuum), and five consider astronomical (i.e. celestial) phenomena. The main part of the text, consisting of seventeen theses, considers the elements and their various uses in explaining *meteora*. Many of these topics would have been of interest in the course of mathematics as well, if taught by Tacquet and his predecessors. However, Pollenter treats them qualitatively without ever referring to a mathematical argument. On the other hand, the absence of theses treating the science of motion is remarkable. The study of motion was one of the basic parts of the Cartesian philosophy, which at that time was gaining momentum in learned circles in the Spanish Netherlands, and was well established at Louvain. Was it not taught at all, or was it considered to be part of mathematics, unsuitable for philosophical consideration?

Pollenter is indeed quite suspicious of the use of mathematics in natural philosophy. It may very well be that mathematics can help the student to have a better understanding of such things as the nature of infinity or the continuum but, Pollenter warned, many of the mathematical arguments themselves are extremely hard to understand. How could one envisage that infinitely divisible particles, which have no extension or even exist only in the mind, could add up to constitute an extended physical body? Certainly, the mathematicians, adopting such physically impossible hypotheses, could not aspire to demonstrate a physical truth. "Or could you be persuaded," Pollenter asked, "of the fact that concentric circles of which the radii have a proportion to each other of one to one hundred thousand, consist of an equal number of extended particles? This is exactly what the mathematicians would try to make you believe with their hypotheses."[59] If Pollenter directed his critical remarks at his fellow mathematicians, he couldn't have made a better point. Indeed, such problems about infinity and the continuum were exactly what the Flemish mathematicians, Tacquet and Gregory of St. Vincent in particular, had been working on. Pollenter surely did not deny the value of such research, yet he believed that it should have no place in natural philosophy.

Pollenter does appreciate the work of the mathematicians in combining their science with the subalternated sciences—i.e., with mixed (or applied) mathematics. Nevertheless, although Pollenter mentions with approval the attempts of several mathematicians and philosophers to follow a demonstrative method in physics and metaphysics, he warns that a completely rigorous science may not be accessible to humans. According to Pollenter, perfect science is to be acquired only through the knowledge of the causes or principles of all things. Such knowledge can never be complete or certain, since there may in fact be infinitely many possible ways to explain the properties of objects. Pollenter reproaches Descartes for his overconfident insistence on the evident nature of his principles and arguments. But he equally criticizes Aristotle and the Peripatetics, whose arguments are also based on deductions without certain foundations. Demonstrative science in the Aristotelian sense is indeed only rarely possible in natural philosophy. Pollenter favors a less strict methodology, adducing experiments, observations, and arguments from all sources to arrive at probable opinions. In particular, Pollenter scorns those philosophers—an obvious reference to the Cartesians—who congratulate themselves on having deduced all natural phenomena from real and true causes. Interestingly, in making this point, Pollenter found a useful analogy in astronomy: those philosophers "erroneously flatter themselves, as some of the hypotheses of the astronomers show abundantly." Furthermore, he added, even when numerous phenomena may appear to have been successfully deduced from their principles, much more remains unexplained and may turn out to be in contradiction with these principles. But this does not diminish the value of science, when studied with proper caution. "Nevertheless," he assured the reader, "I applaud such endeavors, and I think they open the road to true knowledge, if, that is, there should exist such a road."[60]

Pollenter's didactic strategy accords well with the structure of Tacquet's manuals. A discussion starts with an exposition of the different commonly accepted opinions. No attempt is made to positively exclude any opinions but in each case their degree of probability is indicated, for example by judging their intelligibility, their logical structure or their relation to other fields of knowledge. Sometimes a conclusion emerges, but it differs from other opinions only by a degree of probability. This approach is nicely illustrated by the discussion of rarefaction and condensation. Pollenter offers five explanations: The particles of matter penetrate each other, they are replicated, they are inflated, little *vacuola* are interspersed or, finally, minute particles [corpusculorum minimorum] enter or leave the pores of matter. Pollenter finds the first three explanations difficult to comprehend. The appeal to *vacuola*, little void spaces, is much easier to understand, but it introduces problems of a different kind—for example, about the existence of a vacuum—and in the end does not entirely solve the original problem. At last, the fifth explanation appears to be the only one to save natural philosophy from a recourse to mysteries, although even here certainly not everything has been sufficiently explained [tametsi neque in illa plana essent omnia]. Even then, a recourse to mysteries is not to be excluded a priori, since it may be said that it is exactly the aim of natural philosophy to lead the mind toward these mysteries of the faith. Thus Pollenter effectively leaves open every possibility.

Pollenter, like Tacquet, does not indicate how the truth or falsity of an opinion can be asserted. The evidence provided by experiments is accepted, but often with reservation—for example, Pollenter often adds the following clause: "if we can believe the outcome of the experiments related by such and such an author. . . ." This does not imply that he doubted the validity of experimental evidence. The pneumatic experiments of Torricelli, Berti, von Guericke, and Boyle are referred to without hesitation, attesting to the facts that experiments did not pose an epistemological problem. Human technology may, however, not always bring forth phenomena in the same way as nature does. Natural wells or fountainheads may not be due to quite the same causes as artificial fountains: "aliter ars, aliter fere natura agere solet." On the other hand, however, the products of nature are not different from the results of human industry, in particular from the artifacts of experimental science. Pollenter expressly points out the analogy between *ars* and *natura*:

> The philosophical mixture is the union of different mixable things: resolution is the reduction of a mixture into its components. Either this can happen by nature or by art. Art achieves this by pressure, percolation, distillation, sublimation, exhalation etc., not at all different from the way nature works. She also has her percolations, in the bodies of animals as well as in the earth, above and below the surface; she has also distillations, as in the rain, or dew etc. She also has sieves and all the usual furnaces, "gloves of Hippocrates" [a cotton bag through which a liquor is sunk to remove foul dirt], a "lazy Henry" [a type of oven for slow and even distillation], water-baths, dew-baths, etc. These are to her various sieves and furnaces: as diverse as the multitude of mixtures, so are also the various ways to mix the components etc.[61]

But experiments or observations do not lead to a more certain kind of knowledge. Even in those rare cases where Pollenter proposes and defends a solution of his own, he does not claim anything more than probability and conformity with experience. The most cogent argument made by Pollenter in his theses, concerns the nature of colors. He argues that the phenomena of colors can be adequately explained only if interpreted as caused by a mixture of light rays and darkness. But although Pollenter thus seems to take a firm stand on the matter, this does not resolve the dispute. Pollenter shows subsequently how this hypothesis can account for a wide range of phenomena. Rather than by providing an a priori argument, "proof" is more convincingly given a posteriori by experience. Similarly, Pollenter puts forward a hypothesis on the formation of ice, which can explain at least most of the phenomena. Again, the only real "proof" of the hypothesis is the conformity of the hypothesis to a large number of empirical phenomena.

Pollenter's use of empirical evidence strikingly resemble the common methodology among Cartesians, in particular that of Jacques Rohault. Most Cartesian physicists in the second half of the seventeenth century had discarded Descartes's metaphysical method, replacing it with a much less rigorous approach based on a rather free use of hypotheses.[62] As Rohault explained in the Preface of his *Traité de physique* (1671), evidence for such hypotheses can be gathered from experiments a posteriori to support a conclusion already fully stated at the beginning. No attempt is thereby made to falsify or discredit the hypothesis. Nevertheless, the truth of a hypothesis does not follow only from the experimental evidence. It is at least as much determined by the number, the elegance, the clarity, and the uniformity of the hypotheses used. Pollenter's physical theses sometimes correspond to such a Cartesian methodology in respect to the use of experiments, but his hypotheses have no a priori standards to obey. Pollenter objects to Descartes's methodological foundations of natural philosophy, in particular to his apodictic arguments on the absolute impossibility of a vacuum. Still, many of his explanations are in fact based on corpuscular hypotheses similar to that of Descartes—for example, where he defines light as caused by the pressure of small particles, or where he explains the tides as a result of pressure exerted by the moon on the earth's atmosphere. But these explanations do not bear the same scientific certitude as with the Cartesians. Pollenter does not consider modern science as presenting a break with the Aristotelian tradition. The Peripatetic philosophy is surely well suited for the Christian philosopher, Pollenter maintained, but only as long as it can agree with the phenomena. This means that there is no need to reject a priori the traditional qualities and accidents, and indeed they must be admitted in certain cases—as, for example, when speaking of the human soul. This stance notwithstanding, in other theses Pollenter still makes ample use of corpuscular explanations, without resolving the apparent contradiction. As long as science was merely considered to represent probable knowledge and not demonstrated truth, there was nothing the Jesuits couldn't accommodate in the frame of their instrumentalist methodology.

Decline

The high regard for the mathematical sciences, which Gregory of St. Vincent brought back with him from the Collegio Romano at the beginning of the century, was diluted by the mathematics of Tacquet's manuals and the theses of the Jesuit philosophy professors, turning into a rather technical, instrumentalist body of knowledge, intended simply to save appearances.

Whereas the first generation of Flemish mathematicians fostered a realist approach to the use of mathematical and mechanical hypotheses, the second generation reinforced the disciplinary boundary between philosophy and mathematics, relegating the latter to a lower level of truth. How did this happen? Most probably, it was a consequence of the evolving views of the mathematicians themselves. The instrumentalist methodology in mathematics, as well as in physics, was evidently imported from—and invariably illustrated by—its application in astronomy. The emphasis on astronomical instrumentalism was obviously a consequence of the official decrees against Copernicanism, while the reaction against the more modern, "Cartesian" realism, was heightened by the position taken by the Jesuits in the Jansenist controversy, which started in the 1640s.

Yet between the Clavian teaching of Gregory and the instrumentalism of Tacquet there was a period of transition in which a genuine realist approach was confronted with the new science. Such was the case with Hesius, Ciermans, and Derkennis, who indulged in experimental investigations and corpuscular speculations in order to build their own original conceptions of the natural world. This happened at the very moment when in Rome the doctrine of atomism was severely proscribed by the Jesuit censors. As Redondi put it, atomism for the Society of Jesus was the "preoccupation of the moment."[63] Yet in the Southern Netherlands, atomist theories were freely debated and investigated. Perhaps the obscure position of the mathematicians in the remote Flandro-Belgian province did not necessitate a disciplinary action, which would have drawn additional attention to the unorthodox views studied. But regardless of the actual effectiveness of the internal censorship emanating from Rome, of which we have no direct evidence, it does not seem to have had a dramatic impact on the scientific work of the Flemish mathematicians. It is well known that Gregory, at least at the beginning of his career, experienced difficulties in publishing his (purely mathematical) work, while in Douai Malapert experienced similar difficulties with his treatise on sunspots.[64] But as regards Ciermans, Derkennis, and Hesius—or even Tacquet—we have no evidence of their encountering censorship. When in 1657 the English Jesuit Franciscus Linus, professor of Hebrew and mathematics at the English college of Liège in the Gallo-Belgian province, complained to the General Nickel that Gregory's work on the quadrature of the circle would damage the reputation of the Society, Nickel dryly responded that he had no time for mathematics.[65] It seems as if the mathematicians were more concerned to find a publisher, willing to take a commercial risk, than to obtain permission to publish.[66]

This serves to underscore the conclusion that the work of the Flemish mathematicians was quite unrelated to Roman policies. It is striking that the only authors whom Tacquet criticizes in his *Opera*, are Jesuit: Aguilon, Scheiner, and Riccioli. Conversely, Kepler, Galileo, and Toricelli are invariably treated with great esteem. Galileo is not only praised for his telescopic discoveries, but also for his fundamental work on projectile motion—a major scientific breakthrough—which Tacquet complacently compares to his own work on the kinematics of circular motion (Aristotle's wheel). Tacquet refers to all of Galileo's major books, and encourages his students to consult them. The conflict between Galileo and Scheiner on the priority in observing sunspots is summarized by Tacquet, who points out that Scheiner acted in good conscience but that he was nonetheless wrong in his charges against Galileo. True, in his *Cylindricorum et Annularium libri IV* Tacquet was critical of Cavalieri's and Galileo's use of infinitesimals, but he did so for solid logical reasons, and did not go beyond the limits of mathematical discourse. Under the unequivocal heading *Aristoteles et Galileo nihil explicant*, Tacquet sharply criticized the lack of rigor allowed by Galileo in his explanation of the wheel of Aristotle.[67] But he did not put in doubt the originality, or merit, of his adversary's work.

Tacquet stated firmly that Cavalieri's use of indivisibles was not to be admitted, effectively showing with a few simple examples the pitfalls in using it.[68] The problem with the method lay in the fact that Cavalieri had considered a line to consist of an infinite number of points, a surface of an infinite number of lines, and a solid of an infinite number of surfaces. Mathematical objects were thus constituted by other objects which were different in kind [heterogenea] from the first object. Tacquet pointed out that equalities established between one kind of objects, could not always correctly be extended to equalities of another kind. "Yet," Tacquet added, "I do no want to detract any deserved praise from such a very beautiful invention."[69] The method could indeed be rescued if one would restrict the use of infinitesimal quantities to objects of the same kind [homogenea]—that is, if one considered a line as being constituted by an infinite number of infinitesimal lines, etc. Such infinitesimal lines were evidently no longer indivisible and, as such, Tacquet's remarks may be interpreted as an implicit rejection of some atomist strain in Cavalieri's method. But such a conclusion takes the matter much too far. Whatever philosophical satisfaction Tacquet may have derived from his mathematical rejection of Cavalieri's purported atomism, it was not carried into the printed text. Tacquet himself even applied the method of *heterogenea* to demonstrate some propositions, although in every case he also gave other demonstrations of his own to the same propositions. There is nothing un-mathematical about the whole discussion that could reveal a hidden target.

Nor was the new science portrayed unfavorably in philosophy texts. Pollenter referred without reservation to the experimental work of the Galilean scientists Torricelli and Berti, and to Galileo's sunspot observations, analogous to his discussion of the astronomical observations of the Jesuits Scheiner, Fabri, and Riccioli, or those of Campana, Huygens, or Hodierna. Nor did Pollenter mention the decree against heliocentrism or Galileo's condemnation.[70] And whereas Tacquet explicitly rejected the Copernican hypothesis on biblical grounds—without reference to the Roman decrees—he did not even include Galileo's name among the defenders of Copernicanism.[71] Thus, whatever the attitude of the Italian Jesuits toward the Galilean science, the Flemish Jesuits cannot be said to have shown any particular aversion toward Galileo and his disciples.

But such a tolerant attitude toward the new science was superficial. The Flemish Jesuit did not take part in contemporary scientific controversies and seem to have been content to pursue their investigations in private. Consider the case of Ciermans. After his initial letter to Descartes, he refused to engage himself in further criticism. Similarly, although the corpuscular philosophy of the Cartesians clearly appealed to Jesuit mathematicians, they did not pursue such interests and adhered to the official doctrine. At the same time, the University of Louvain was deeply influenced by Cartesianism and would soon reorganize its curriculum to incorporate the new philosophy. The Jesuits were attentive onlookers, but never participators.

When in the 1630s the Louvain theologian Libertus Froidmont (Fromondus) attacked the Copernican views of the Dutch minister Philippus van Lansbergen, the conflict was followed with keen interest. Theodorus Moretus, a student of Gregory, highly esteemed Froidmont's book: "The times have arrived or soon will arrive," he wrote from Prague, "when the errors of the atheists, which spread by the most curious ways, even among Catholics, will be refuted with the aid of mathematics."[72] But the Flemish mathematicians did not respond to such a call to arms.

Derkennis, who early in his career had taught a course of mathematics, published *De Deo uno trino Creatore* (Brussels, 1655), a voluminous work that alluded to the rise of Cartesianism and to the raging controversies surrounding it.[73] But, as a theologian, Derkennis's concerns lay elsewhere: he was a formidable opponent of Jansenism from the start. Indeed, during the second half of the century, Jansenism wholly determined the actions of Jesuits in the Spanish Netherlands. Tacquet's successor in the chair of mathematics, the theologian Ignatius De Jonghe, engaged in the anti-Jansenist movement and became, together with Pollenter, a member of a secret congregation to combat Jansenism.[74] In comparison with this all-encompassing crusade, mathematical investigations became peripheral, at best, to the members.

One point where theological polemics and scientific debates could have intersected was the alleged association between Jansenists and Cartesians. It was widely believed that the two were quite closely linked,[75] and the rise of both Jansenism and Cartesianism at the University of Louvain could have made an obvious target for Jesuit action. But the strategy adopted by the university resulted in a very different development. From the last decades of the seventeenth century, intellectual life at the university slipped into a puzzling state of public silence. The university went through extremely difficult times, charged with Jansenism and losing its grip on the student population as a result of political unrest and French military campaigns that diminished its area of recruitment. Student numbers fell sharply, and many disciplines all but disappeared. This structural crisis was enhanced by the growing success of the University of Douai, situated in France but attracting large numbers of students from the Spanish (from 1714 Austrian) Netherlands.[76] Furthermore, while Louvain had been publicly discredited as a cradle of Jansenism, Douai managed to steer clear from such accusations.[77]

Louvain "reacted" to this with silence. Between 1660 and 1774 only one philosophical book was published by a member of the faculty of arts. It was an anonymous, and vehement, attack on Cartesianism, *Cartesius seipsum destruens*. But it was not representative of the actual doctrine taught. Since the middle of the seventeenth century, the faculty of arts had been in the vanguard of the Cartesian movement. The curriculum was already adapted to the new teaching in 1658, and a prominent Cartesian—Gerard Van Gutschoven, who collaborated with Clerselier on the posthumous edition of the *Traité de l'Homme*—was appointed professor of mathematics and anatomy. With the growing opposition against Jansenism, however, the Louvain professors of philosophy opted to conceal their true opinions from public view.[78] An official visitation of the university in 1673 recorded that although all the professors of philosophy firmly denied teaching Cartesian doctrines, in reality they did. Student notebooks reveal the espousal of Cartesian natural philosophy among Louvain professors. By the end of the century, the philosophy professor Martinus van Velden raised an outcry when organizing, against the stipulations of the faculty, a public disputation in which he defended both Copernicanism and Cartesianism.[79] The case, however, was not so much about the truth of the new science as it was about the appropriateness of publicly debating such opinions.

The self-imposed silence of the university may have thus robbed the Flemish Jesuit mathematicians and philosophers of an opportunity to engage in battle—had they been willing to do so. But whatever the circumstances, during the final decades of the century the school of mathematics did not produce mathematicians of Gregory's or Tacquet's stature. It took five years to find a replacement to Tacquet, and subsequently the course was taught intermittently by a number of professors who failed to distinguish themselves. The only original publication by a Flemish mathematician after 1680 was De Jonghe's *Geometrica Inquisitio* (1688), a work in the old tradition of Gregory and completely out of touch with the newer developments of the calculus.[80] More important, the Flemish Jesuits appear not to have made the transition from pure mathematics to experimental physics. Such a transition occurred at most universities during the second half of the seventeenth century. In Leiden, the mathematician Burchardus de Volder inaugurated the first course of experimental physics on the Continent in 1674. Similarly, Johann I Bernoulli in Groningen and Martinus Van Velden in Louvain—both mathematicians—introduced experimental physics into the philosophical curriculum. But as far as we know, the Flemish Jesuit mathematicians never made such an attempt. This is the more surprising since such a transition would have been quite congenial to the Jesuit predilection for "mixed mathematics." Building mathematical instruments, scale models, pneumatic engines, and optical apparatus had been the hallmark of mathematicians such as Aguilon and Ciermans. Even Tacquet instructed his students on how to build astrolabes and sundials and how to create optical illusions. However, the further step toward experimental physics was not taken. This may have been due to the absence of any pressing needs caused by public teaching duties, which in the universities often provided the first stimulus for building a physical cabinet. But the declining Flemish mathematical tradition, which increasingly lost contact with the more recent developments, may have been equally responsible.

Scientific life in the Spanish Netherlands was generally not conducive to scientific research. There were no learned societies or academies where the natural sciences were studied, and there were no physical cabinets or informal meeting places where individual scientists could discuss their research. Already in 1667, the Liège mathematician René François de Sluse complained in a letter to Oldenburg: "[Scientific] studies languish among us, and learned men devote their efforts to law and other branches of knowledge more highly valued by the crowd. There are some who pursue chemistry either for money or for medicine's sake. I know no one who explores the secrets of nature merely in the interest of knowledge."[81]

My interpretation of the self-imposed silence of the University of Louvain cannot be applied to the fields of medicine, pharmacy, and surgery. The faculty of medicine showed no signs of restraint or censorship in its publications.[82] For example, the Louvain anatomist Philip Verheyen published *Corporis humani Anatomia* (1693), in which he freely used both chemical and corpuscular theories to investigate the finer structures of bodily tissues and humors. This was not a philosophical tract, however; Verheyen's approach was purely instrumental, leaving his readers the choice between competing explanations. His research did cause, on the other hand, the introduction of the first microscope, bought by Van Velden from Leeuwenhoek, to Louvain shortly before the end of the century, thus promoting the new experimental philosophy.[83]

Medical research never featured prominently among the Flemish Jesuits. After Lessius's *Hygiasticon* (1613), a work on hygiene and lifestyle, only two medically related works were published by Jesuits in the Spanish Netherlands. In 1653, the anonymous pharmaceutical handbook *Pharmacia Galenica & Chymica, Dat is de Apotheker ende Alchymiste ofte Distiller-konste* appeared, the authorship of which has been attributed to the Jesuit brother Jan Bisschop. It was fairly successful and at least five editions were published.[84] A pharmaceutical and surgical book titled *Enchiridion medicum oft Medicyn boexcken* was published by another Jesuit brother, Engelbert Capueel, in 1723.[85] A rather modest harvest.

The decline of the Flemish school of mathematics had many other causes, not all of them intellectual. First, the financial situation of the Flandro-Belgian province deteriorated rapidly after the glorious year 1640. The many new buildings erected in the period of spectacular growth had put a severe strain on Jesuit finances, while the number of novices began to fall earlier than in other provinces. Nor were the missions as attractive to young people as they have been earlier. The Jesuit policy of accommodation was under fire and was countered by non-Jesuit (in particular, French) initiatives. Although the Spanish authorities still encouraged Belgian Jesuits to work in their South American colonies, the emphasis had shifted toward Portuguese and French destinations such as China and Canada. The growing importance of French countries may have spurred French-speaking Gallo-Belgian Jesuits to enter missionary work. Tacquet's student Verbiest was succeeded as head of the Beijing Observatory by the Gallo-Belgian Antoine Thomas. Furthermore, in 1704 a royal chair of hydrography was created for the Jesuits by the French government at Douai, emphasizing once more the shift of mathematical teaching in the Belgian provinces toward the South.

The Flemish mathematicians did not succeed in establishing a modern scientific approach to natural philosophy. Their influence as a group was too small to effect a lasting transformation of the philosophy course. This did not close all the doors for sincere scientific interest among the Jesuits. As we have seen, Pollenter's philosophy was deeply influenced by modern scientific debates, although at the same time he was much less impressed by the contributions of mathematics to natural philosophy. Indeed, when the philosophical position of the Society was discussed at the seventeenth General Congregation of 1751, the Belgian Jesuits were counted among the most progressive.[86] Together with their French and English colleagues, the Belgian Jesuits opposed the conservative faction of the Portuguese and Spanish delegations, with the Italians holding the middle ground. Some of this progressive attitude toward science can be discerned from a published thesis of 1727 in which the influence of Newtonian science is explicitly stated.[87] The thesis was published by an English Jesuit at the college of Liège in the Gallo-Belgian province. The history of this college, however, is difficult to relate to the scientific life of the Flemish province.[88] The tone of the thesis is very similar to Ciermans's theses. Instrumentalism had faded again and had been replaced by a clearly realist position. This is particularly striking in the unproblematic acceptance of Newton's centripetal force of gravitation. Only with regard to heliocentrism does the author make use of an instrumentalist escape clause: "I do not doubt in the least that the earth *in aeternum stet; etenim firmavit orbem terrae qui non commovebitur*: Yet I will explain the position of the heavens and the world with the Copernican hypothesis according to Newton's principles: the uniformity in the system of the Planets appears indeed wonderful and agreeable."[89] These theses could have been the natural continuation of the work of the Flemish school of mathematics, but they were not. Involvement with modern science in the Flandro-Belgian province declined sharply around 1700 and did not, as far as we know, reemerge until much later in the nineteenth century.

Notes

1. A. C. Crombie, "Sources of Galileo's Early Natural Philosophy," in *Reason, Experiment, and Mysticism in the Scientific Revolution*, ed. M. Righini Bonelli and W. Shea (New York 1975), pp. 157–175, 303–305; A. Carugo and A. C. Crombie, "The Jesuits and Galileo's Idea of Science and Nature," *Annali dell"Istituto e Museo di Storia della Scienza di Firenze* 8 (1983): 1–69. Several studies by William A. Wallace have been brought together in *Prelude to Galileo: Essays on Medieval and Sixteenth-Century Sources of Galileo's Thought* (Dordrecht and Boston, 1981). See also Wallace, *Galileo and His Sources: The Heritage of the Collegio Romano in Galileo's Science* (Princeton, 1984).

2. Peter Dear, "Jesuit Mathematical Science and the Reconstitution of Experience in the Early Seventeenth Century," *Studies in the History and Philosophy of Science* 18 (1987): 133–175.

3. John L. Heilbron, *Elements of Early Modern Physics* (Berkeley and Los Angeles, 1982), especially pp. 93–106; William B. Ashworth Jr., "Catholicism and Early Modern Science," in *God and Nature*, ed. D. Lindberg and R. Numbers (Berkeley and Los Angeles, 1986). See also the special issue of *Science in Context* titled "After Merton: Protestant and Catholic Science in Seventeenth-Century Europe" (volume 3, 1989), to which these and other authors contributed.

4. Pietro Redondi, *Galileo Heretic* (Princeton 1987), pp. 119–120.

5. Luce Giard, ed., *Les Jésuites à la Renaissance. Système éducatif et production du savoir* (Paris, 1995). The ongoing research program on Jesuit archives still focuses mainly on Italy and France, with minor attention to Portugal and Spain.

6. B. Jansen, "Deutsche Jesuiten-Philosophen des 18. Jahrhunderts in ihrer Stellung zur neuzeitlichen Naturauffassung," *Zeitschrift für katholischen Theologie* 57 (1933): 384–410.

7. On Jesuit policies to safeguard uniformity in the teaching of philosophy even before the Galileo case, see Richard J. Blackwell, *Galileo, Bellarmine, and the Bible*

(Notre Dame, 1991), pp. 139–142. See also Adrien Demoustier S.J., "La distinction des fonctions et l'exercice du pouvoir selon les règles de la Compagnie de Jésus," in *Les Jésuites à la Renaissance*, ed. Giard; Ugo Baldini, *Legem impone subactis. Studi su filosofia e scienza in Italia 1540–1632* (Rome, 1992), pp. 75–119.

8. On the Belgian provinces, see J. Braun, *Die belgischen Jesuitenkirchen. Ein Beitrag zur Geschichte des Kampfes zwishen Gotik und Renaissance* (Freiburg-im-Breisgau, 1907).

9. Redondi, *Galileo Heretic*, p. 290. See also J. C. H. Aveling, *The Jesuits* (London, 1981), p. 221: "The Jesuits could have used their freedom from the shackles of the system to promote a real and creative intellectual life in their own small, rival group of universities and Academies. . . . But their promising efforts were largely thwarted by the Gesu, and, still more, by the stolid conformism of most of their colleagues who were content to settle down in a mental rut even narrower and more conservative than that of the old universities."

10. "His work is to be kept in mind in constituting the first attempt explicitly to formulate in a positive sense . . . the limit doctrine." (Carl B. Boyer, *The History of the Calculus and its Conceptual Development*, New York, 1959, p. 138) See also J. E. Hofmann, "Das Opus Geometricum des G. a Sancto Vincentio und seine Einwirkung auf Leibniz," Abhandlungen der Preussischen Akademie für Wissenschaften. Math. Nat. Klasse, 1941, no. 13.

11. For a general overview, see Heilbron, *Elements*. On Germany, see K. Hengst, *Jesuiten an Universitäten und Jesuitenuniversitäten. Zur Geschichte der Universitäten in der Oberdeutschen und Rheinischen Provinz der Gesellschaft Jesu im Zeitalter der konfessionellen Auseinandersetzung* (Paderborn, 1981). For France, see F. de Dainville, *L'éducation des Jésuites (XVIe–XVIIIe siècles)* (Paris, 1978).

12. Poncelet, *Histoire de la Compagnie de Jésus dans les anciens Pays-Bas. Etablissement de la Compagnie de Jésus en Belgique et ses développements jusqu'à la fin du règne d'Albert et d'Isabelle* (Brussels 1926). See also *De Jezuïeten in de Nederlanden en het Prinsbisdom Luik (1542–1773)* (Brussels 1991).

13. Quoted in Poncelet, *Nécrologie des jésuites de la province Flandro-Belge* (Wetteren, 1931), p. xliii.

14. P. Alegambe, *Bibliotheca scriptorum Societatis Iesu* (Antwerp, 1643), cited, with additional statistics, in J. Andriessen, "Apostolaat met de pen. Intellectuele en artistieke activiteiten," in *Jezuïeten in de Nederlanden*.

15. A. Ziggelaar, *François de Aguilon S.J. (1567–1617). Scientist and Architect* (Rome, 1983); C. De Maeyer, "Le Père François Aguilon architecte jésuite du XVIIe siècle," *Bulletin de la Société Royale d'Archéologie de Bruxelles* 9 (1933): 113–127.

16. This was in fact a widespread view held by many Jesuit scientists at the end of sixteenth century amd reflected in the *Ratio Studiorum*. See G. Cosentino, "Le Matematiche nella Ratio Studiorum della Compagnia di Gesù," *Miscellanea Storica Ligure* 2 (1970): 171–123 ; Cosentino, "L'insegnamento delle matematiche nei collegi gesuitici nell'Italia settentrionale. Nota introduttiva," *Physis* 13 (1971): 205–217.

17. See the works of Wallace and Dear mentioned above. See also William H. Donahue, *The Dissolution of the Celestial Spheres 1595–1650* (New York, 1981), pp. 59–62; James M. Lattis, *Between Copernicus and Galileo: Christoph Clavius and the Collapse of Ptolemaic Cosmology* (Chicago, 1994).

18. Gregory of St. Vincent to Christiaan Huygens, October 4, 1659, in *Oeuvres Complètes de C. Huygens*, volume II, pp. 489–490.

19. Quoted in H. Van Looy, Chronologie en analyse van de mathematische handschriften van G. A Sancto Vincentio, Ph.D. dissertation, Leuven, 1979, p. 2. See also Van Looy, "Chronologie et analyse des manuscrits mathématiques de Grégoire de Saint-Vincent (1584–1667)," *Archivum Historicum Societatis Iesu* 49 (1980): 279–303.

20. "Solidarity and vigilance—together with discipline, devotion to the order and the common life, and research—turned this large group of natural philosophers, mathematicians, and astronomers into a particularly united and competitive subgroup within the Collegio Romano's broad cultural community." (Redondi, *Galileo Heretic*, p. 127)

21. Ziggelaar, *Aguilon*, pp. 47–52.

22. O. Van de Vyver, "L'école de mathématiques des jésuites de la province flandro-belge au XVIIe siècle," *Archivum Historicum Societatis Iesu* 49 (1980): 265–278.

23. After Malapert's departure in 1626, there was apparently no mathematicus at Douai until 1704. F. de Dainville, "L'enseignement des mathématiques dans les collèges jésuites de France du seizième au dix-huitième siècle," *Revue d'histoire des sciences et de leurs applications* 7 (1954), pp. 6–21, 109–123.

24. Van Looy, Chronologie, pp. 9, 277–329.

25. "Assertio de vera causa aestus marini" and "Assertio de aestu maris"; Van Looy, Chronologie, p. 42. Gregory also "inherited" the papers of Aguilon, who at the time of his death had been working on a second book on optics, but these again contain only the mathematical theorems, possibly because Gregory did not keep the others.

26. G. Monchamp, *Galilée et la Belgique. Essai historique sur les vicissitudes du système de Copernic en Belgique* (St. Truiden, 1892), pp. 45–71; T. van Nouhuys, "Copernicus als randverschijnsel: de kometen van 1577 en 1618 en het wereldbeeld in de Nederlanden," *Scientiarum Historia* 24 (1998): 17–38.

27. O. Van de Vyver, "Jan Ciermans (Pascasio Cosmander) 1602–1648. Wiskundige en vestingbouwer," Communications from the Seminar in the History of Science at the University of Louvain, no. 7 (1975).

28. A. Ziggelaar, "The Sine Law of Refraction Derived from the Principle of Fermat—Prior to Fermat? The Theses of Wilhelm Boelmans S.J. in 1634," *Centaurus* 24 (1980): 246–262.

29. Ciermans to Descartes, March 1638, in *Oeuvres de Descartes*, ed. C. Adam and P. Tannery (Paris, 1897–1913), volume II, pp. 55–62.

30. "Fol. 258 Meteor," *Oeuvres de Descartes*, volume VI, pp. 332–333.

31. On Descartes's explanation of refraction, see A. I. Sabra, *Theories of Light from Descartes to Newton* (Cambridge, 1967; reprint: 1981), especially chapter 4.

32. "Docuit ac mathesim anno altero evoluit nostris, externisque ante Renatum Carthesium valedicens qualitatibus, et modis distinctis, malo quibusdam Peripateticis necessario, pereunti nascentique cum fungis, intentus suptilioribus corpusculis, et athomis copioso cerebri et solis profluvio, eorumque motui dilucide explanando." (Elogium R. P. Guilielmi Hesii, quoted in J. Gilissen, "Le Père Guillaume Hesius. Architecte du XVIIe siècle," *Annales de la Société Royale d'Archéologie de Bruxelles* 42 (1938): 216–255)

33. J. Ciermans, *Disciplinae Mathematicae* (Louvain, 1640), Augusti hebdomas tertia, "principia."

34. Ibid., "lunae via."

35. F. Silveryser, "Godefroid Wendelen, sa vie, son ambiance et ses travaux," *Bulletin de l'Institut Archéologique Liégeois* 58 (1934): 91–158; ibid. 60 (1936): 137–190.

36. Theses [Physica] xxiii and [Meteora] xlix (tides), in *Philosophia Iesu suo saeculari Societatis Iubilaeo consecrata. Praeside R.P. Ludovico De Scildere soc. Iesu Philosophiae Professore* (Louvain 1640).

37. Letters by Frans de Cleyn, August 22 and October 17, 1642, in L. Ceyssens, *Sources relatives aux débuts du jansénisme et de l'antijansénisme, 1640–1643* (Louvain, 1957), pp. 452, 470.

38. This would certainly apply to the "catastrophic years" 1645–1661, when the Society was in effect without a General. See Aveling, *The Jesuits*, p. 249.

39. During these years the Spanish Netherlands were at war with France. Gregory is said to have given spiritual assistance to the Spanish soldiers while exercising his missionary zeal on French soldiers in captivity. See F. V. Goethals, *Lectures relatives à l'histoire des sciences, des arts, des lettres, des moeurs et de la politique en Belgique* (Brussels, 1838), volume IV, p. 177.

40. H. Bosmans, "Le jésuite mathématicien anversois André Tacquet (1612–1660)," *De Gulden Passer–Le Compas d'Or* 3 (1925): 63–87.

41. For this famous problem, see I. E. Drabkin, "Aristotle's wheel: Notes on the history of a paradox," *Osiris* 9 (1950): 162–198.

42. N. Golvers and U. Libbrecht, A*stronoom van de Keizer. Ferdinand Verbiest en zijn Europese Sterrenkunde* [with a Dutch translation of Verbiest's *Astronomia Europea*] (Leuven, 1988), p. 37.

43. Tacquet, *Opera mathematica*, p. 343.

44. A. Tacquet, *Arithmeticae Theoria et Praxis* (Louvain, 1656). This work contains a short "Appendix in qua ostenditur hypothesim infinitae multitudinis actualis terminum infinitesium implicare" composed by Derkennis.

45. For a complete bibliography, see C. Sommervogel, *Bibliothèque de la Compagnie de Jésus* (Brussels, 1897), volume 7.

46. Quoted in Bosmans, "Tacquet," p. 83.

47. For a useful overview and interpretation, with regard to the Jesuit doctrine of perfecta obedientia, see S. Vanden Broecke, "Sacra Scriptura non docet falsum.

André Tacquet en de onmogelijkheid van de aardbeweging," in *Geloven in het verleden*, ed. E. Put and M. Marinus (Leuven, 1996).

48. Tacquet, *Opera Mathematica*. Astronomia, volume I, p. 13.

49. Ibid., p. 238: "ob difficultates et ageometriam in calculo: quae ratio vel mihi sufficit, ut circulum Ellipsi anteponam; quando Hypothesium finis potissimus est, ut syderum motus ad numeros revocentur."

50. On several occasions (e.g., in his letters to Huygens) Tacquet discussed the methodological problem of how true knowledge could emerge from false hypotheses.

51. Wallace, "Galileo and reasoning ex suppositione," in *Prelude to Galileo*, pp. 129–159.

52. Tacquet, *Opera Mathematica*. Optica, p. 135.

53. Tacquet, *Opera Mathematica*. Astronomia, p. 78ff.

54. Tacquet does not enumerate these arguments in his textbook. He refers the student directly to the works of Riccioli, Copernicus, Kepler, Van Lansbergen, and Boulliaud.

55. Tacquet, *Opera mathematica*. Astronomia, p. 326. For the history of this particular argument, see Alexander Koyré, "A documentary History of the Problem of Fall from Kepler to Newton," *Transactions of the American Philosophical Society*, n.s, 45 (4): 1955. Tacquet's contribution is mentioned on p. 393. See also S. Vanden Broecke, "Scriptura."

56. The eighth book of the *Astronomia* is completely devoted to controversial matters: heliocentrism, comets, sunspots. On page 339 Tacquet frankly informs the reader: "De his inquam aliisque similibus attingo pauca, quia pauca scio. Me taedet Mathematicis ratiociniis assuetum coniecturis referendis excutiendisque immorari. Ne tamen te Lector omnino ieiunum demittam, haec pauce accipe."

57. In this Tacquet's approach resembles the method used by Riccioli in his *Almagestum Novum* to discuss the Copernican and Tychonian cosmologies.

58. Some theses are counted twice, e.g. when a physical topic is combined with a metaphysical discussion. For example the final thesis : Odor, sapor, &c. intellectio, volitio. The first thesis Sapientia seu Philosophia is not included in any of the categories.

59. *Philosophia Universa . . . Praeside R.P. Joanne Pollenter Societatis Jesu Philosophiae Professore* (Ghent, 1673), thesis 21.

60. Ibid., thesis 26.

61. Ibid., thesis 31: "Mixtio Philosopho est miscibilium alteratorum unio: resolutio est mixti in sua miscibilia reductio. Utraque vel natura perficitur, vel arte. Ars utitur, expressione, percolatione, distillatione, sublimatione, exhalatione &c. non omnino dissimiliter operatur natura. Habet & haec suas percolationes, qua in corporibus animalium, qua in terrae superficie & visceribus; habet & distillationes quasi in pluvia, rore &c. Habet illa cola sua, & fornaces, vulgaria, manicam Hippocratis, pigrum Henricum, balneum maris, balneum roris &c. Sunt & huic tum cola varia, tum fornaces: ut scilicet est mixtorum varietas tanta, ita est & mixtionum modorumque miscendi &c."

62. On Cartesian science and experiments, see Desmond M. Clarke, *Occult Powers and Hypotheses: Cartesian Natural Philosophy under Louis XIV* (Oxford, 1989), especially pp. 202–204; T. McClaughlin, "Le concept de science chez Jacques Rohault," *Revue d'histoire des sciences* 30 (1977): 225–240; G. Vanpaemel, "Rohault's Traité de Physique and the teaching of Cartesian physics," *Janus* 71 (1984): 31–40.

63. Redondi, *Galileo Heretic*, pp. 240–244.

64. Roland, S.J., "Charles Malapert. I. Etudes astronomiques. Analyse comparée. II. Etudes mathématiques. Aperçu historique," *Mémoires et publications de la Société des Sciences, des Arts et des Lettres du Hainaut*, second series 6 (1859): 1–29.

65. Conor Reilly, "Francis Line, Peripatetic (1595–1675)," *Osiris* 14 (1962), p. 227.

66. The correspondence of Theodorus Moretus, nephew of the famous Plantin-Moretus printers in Antwerp, reveals how he tried, in vain, to persuade his own family to publish one of his books. In one of his letters he concedes that printers have good reasons not to like books written in Greek or on mathematical subjects. See H. Bosmans, "Théodore Moretus de la Compagnie de Jésus, mathématicien (1602–1667). D'après sa correspondance et ses manuscrits," *De Gulden Passer–Le Compas d'Or*, n.s., 6 (1928): 57–163. The Flemish Jesuits usually used Jacob Meursius, one of the cheaper Antwerp publishers.

67. Tacquet at one place maintains rather condescendingly that the arguments of Galileo can easily be contradicted by any philosopher in promptu. Yet I do not think that this expression points to the necessity of bringing in any philosophical objections against Galileo's use of infinitesimal quantities. Throughout his argument, Tacquet concentrated on the improper and unrigorous handling of the infinitesimals by Galileo, not on the use of the infinitesimals as a legitimate mathematical tool. See *Cylindricorum et Annularium libri V* (1669 edition), pp. 149–150.

68. Oldenburg singled out this and Tacquet's rejection of Copernicanism in his review of the *Opera Mathematica* in the *Philosophical Transactions* (1668).

69. Tacquet, *Cylindricorum et Annularium libri IV* (1651, second edition 1669 as part of the *Opera mathematica*), Scholium to prop. 12 of book I, pp. 13–15.

70. This attitude was also adopted at the University of Louvain, where until the middle of the eighteenth century the condemnation of Galileo was not mentioned in the student courses. See G. Vanpaemel, *Echo's van een wetenschappelijke revolutie. De mechanistische natuurwetenschap aan de Leuvense Artesfaculteit (1650–1797)* (Brussels, 1986), p. 70; Vanpaemel, "Terra autem in aeternum stat. Het kosmologie-debat te Leuven," *De Zeventiende Eeuw* 2 (1986): 101–117.

71. Tacquet, *Opera Mathematica*, p. 321.

72. Letter from T. Moretus to Balthasar I Moretus, September 27, 1637, quoted in H. Bosmans, "Théodore Moretus," pp. 93–94.

73. See Monchamp, *Histoire du cartésianisme*, pp. 279–294. Monchamp even speculates that Derkennis commented on the quarrels between Plempius and Van Gutschoven.

74. See L. Ceyssens, *Sources relatives à l'histoire du Jansénisme et de l'Anti-jansénisme des années 1677–1678* (Louvain, 1974), pp. xvii–xxi.

75. On the Spanish Netherlands, see Monchamp, *Histoire du cartésianisme*, pp. 96–98. On France, see Clarke, *Occult Powers and Hypotheses*, pp. 28–34.

76. G. Dehon, "L'université de Douai pendant la première moitié du XVIIIe siècle," *Revue du Nord* 50 (1968): 317–350.

77. G. Dehon, "Un épisode de la querelle janséniste à l'université de Douai. La commission d'enquête de 1702," *Mélanges de science religieuse* 27 (1970): 49–57.

78. G. Vanpaemel, "Cartesianism in the Southern Netherlands: the Role of the Louvain Faculty of Arts," *Bulletin de la Société royale des sciences de Liège* 55 (1986), no. 1: 221–230.

79. Vanpaemel, *Echo's van een wetenschappelijke revolutie*, pp. 75–79.

80. P. Bockstaele, "Een vergeten werk over de kwadratuur van parabolen en hyperbolen: Ignatius de Jonghe's Geometrica Inquisitio," *Scientiarum Historia* 9 (1967): 175–181. De Jonghe was not the only example of a professor who spent much of his time editing the posthumous works of their predecessors, notably Gregory and Tacquet.

81. A. Hall and M. Hall, eds., *The Correspondence of Henry Oldenburg* (Madison and London, 1965–1986), volume II, p. 537.

82. F.-A. Sondervorst, *Geschiedenis van de geneeskunde in België* (Brussels, 1981), pp. 93–114.

83. G. Vanpaemel, "Filip Verheyen (1648–1710) en de geneeskunde te Leuven op het einde van de zeventiende eeuw," *Periodiek* 44 (1989): 77–85.

84. P. Boeynaems, "Broeder Jan Bisschop en zijn Pharmacia Galena et Chymica," *Pharmaceutisch Tijdschrift voor België* 53 (1956): 197–201.

85. P. Boeynaems, "Engelbertus Capueel (1642–1733). Geneesheer, chrirug, apotheker en lid van de societas Jesu," *Vlaamsch geneeskundig tijdschrift* 24 (1941): 504–509.

86. See Bernard Duhr, *Geschichte der Jesuiten in den Ländern deutscher Zunge* (Freiburg, 1907–1928), volume IV, p. 4.

87. *Conclusiones ex universa philosophia propugnandae . . . praeside R.do Patre P. Guilielmo Kingsley* (Liège, 1728).

88. A.-C. Bernès and P. Lefèbvre, "Le collège des Jésuites anglais à Liège: un foyer de conservatisme?" in *Libert Froidmont et les résistances aux révolutions scientifiques* (Haccourt 1988).

89. *Conclusiones*, thesis 42.

The *Storia Letteraria D'Italia* and the Rehabilitation of Jesuit Science

Brendan Dooley

Almost as soon as an encyclopedic journal titled *Storia letteraria d'Italia* appeared on the Italian publishing scene in 1750, it became embroiled in controversy. "It ought to be called the 'Storia letteraria of the Company of Jesus,'" wrote Paolo Maria Paciaudi to the Reggio naturalist Janus Plancus, intending no compliment, "because there is not a single page in it that does not praise some Jesuit."[1] Even the sympathizer Scipione Maffei, a learned amateur who was considered the literary conscience of Northern Italy, did not expect it to amount to much.[2] But nine years and fourteen volumes later, when the *Storia* finally stopped circulating its 1,200-odd copies to a readership that customary practices of sharing may have multiplied to nearly ten times that number, bringing the printer "incredible earnings" that continued through several offshoots, the journal had made a considerable contribution to the genre of literary and scientific publication.[3] And by giving full coverage and encouragement in the circa-75-page science section of each 500-page volume to work by Giambattista Morgagni, Giovanni Targioni Tozzetti, Vincenzo Riccati, Ruggero Giuseppe Boscovich, and others, judging the best contributions, and reinforcing the standards that the most innovative scientists set for themselves, it considerably enriched the scientific culture of Italy between the age of Antonio Vallisneri and that of Galvani and Volta. Now, with the recent appearance of an impeccable bibliographic aid, it can at last be analyzed with some convenience.[4]

The Jesuit Journalist

Recent scholarship has had some difficulty situating the *Storia* within accepted historiographical categories. The standard work on Venetian literary journalism leaves it out altogether—not just because of its infrequent publication, which eventually sped up to semi-annual, but also for its supposed lack of interest, already impugned by its earliest enemies, in providing any real information on anything other than the quotidian affairs of the Jesuits.[5] Alternatively, it is credited with having successfully "imitated" literary journalism without ever actually having done any and with trying to deliver a dose of Catholic propaganda in the guise of a pre-digested and purified version of some modern ideas. On these grounds, the standard reference work on journalism in Italy devotes a three-page survey to the *Storia*'s coverage of Jansenism, of Church government, and of the theological and ecclesiological ideas of the Modenese historian Ludovico Antonio Muratori, without a single word about its coverage of science.[6]

All these judgments can be attributed, to some extent, to the nasty reputation of the journal's founder and editor, the Venetian Jesuit Francesco Antonio Zaccaria. Even before embarking on publication of the journal, Zaccaria began to distinguish himself by an unusually voluminous authorship of scholarly and polemical works, which in the end was to amount to more than 150 titles in theology, patristics, ecclesiology, ethics, politics, and antiquities, including multiple editions.[7] And after succeeding Muratori in the prestigious custodianship of the Este family library, he began directing a considerable entrepreneurial operation to distribute these works to centers all over the peninsula and beyond.[8] Rather than as one of the best-known and most controversial writers of the mid eighteenth century, however, most recent scholarship has preferred to see Zaccaria as the arch-enemy of the most important reforming trends of his time. "The Jesuits' champion," he apparently opposed the moral severity, the rigorous self-examination, and (in his best-known work, the *Anti-Febronius*) the decentralized ecclesiological model advanced by the Jansenists, widely regarded as having been agents of progress.[9] If Zaccaria cannot be shown to have contributed to this advanced trend of Catholicism, perhaps he can be accommodated within the group of "enlightened Catholics" interested in propounding a moderate, rational Catholic faith, somewhere between the Jansenists and the most zealous papal supremacists, in spite of his occasional disagreements with the group's leader, Muratori.[10] This attempt has nonetheless been traced to a superficial understanding of his work—an understanding not sufficiently in tune with the duplicity of "Jesuitical" prose, between the lines of which the stoutest opposition to modern political and religious thought reputedly could be found.[11]

Indeed, there can be little doubt about Zaccaria's apologetic intentions in undertaking the *Storia*. During the course of his ten-year preaching apprenticeship in the cities of North-Central Italy, while treading some of the same paths as the Jesuit missionary Paolo Segneri, Zaccaria matched wits with Muratori, Daniele Concina, and Giovanni Lami in some of the great theological debates of the times. In each case, he tried to join his preaching activities with his theological ones by transforming polemics that began in Latin among a tiny number of experts into polemics in Italian among what he fully recognized would be an audience including the same assorted crowds he encountered in church—as he said, "a book . . . in the vernacular . . . circulated among everyone."[12] And at some point during these activities he must have become aware of the significant advantages of a journal. "Apologies are read by few, if they are big volumes," he later remarked, "and if they are handbills, they are apt to get lost; this does not happen with articles of a journal, which are read by many and last for the whole duration of the work."[13] He credited the political gazettes and handbills with having brought a knowledge of geography to every "common person, second-hand dealer and barber," and no doubt he hoped to do the same for the main propositions of modern theology.[14]

When he began the *Storia*, Zaccaria continued the same polemics with renewed vigor. He supported the practice—regarded by Muratori as superstitious, irrational, and socially disruptive—of swearing blood oaths to protect the honor of the Virgin Mary. Like Alfonso Maria de' Liguori, whose main work he later furnished with an introduction, Zaccaria believed that an attack on Marian piety threatened the Church's pastoral mission just when the faithful were being most heavily assailed by anti-ecclesiastical propaganda and borne away by currents of unbelief.[15] For similar reasons, he stood up for the increasingly embattled probabilist moral theology against the Friulian theologian Daniele Concina, defending it as an approach more useful in pastoral practice than the rigorist approach of demanding a strict examination of conscience and close attention to moral rules because less likely, at least over the short term, to discourage ordinary people from seeking absolution.[16]

Zaccaria's next cause was to defend the wisdom and grandeur of Christ's apostles, and the present ecclesiastical hierarchy by extension, against Lami's suggestions, likewise reflecting on the present, about the original ignorance and simplicity of both. With little-concealed reforming implications, Lami sought to apply the advanced historiographical methods of the school of St. Maur against the legendary account of the origins of the Church Triumphant. Zaccaria attempted to pull the ground entirely out from under the controversy by pointing to the apostles' radical transformation through the miracle of Pentecost.[17]

Of all the polemics to which Zaccaria responded in the *Storia*, the noisiest ones attacked the Jesuits' supposedly reactionary philosophical and scientific approach and outmoded educational policies. True, the Jesuits were not thought to be the only opponents of progress among the eighteenth-century clergy. Resentment still festered against Neapolitan ecclesiastics—and not just the infamous Jesuit Giacinto De Cristoforo—who had persecuted the atomists in the "atheist trials," placing, according to Pietro Giannone, a "hard yoke . . . on the necks of our Neapolitans."[18] The Roman Holy Office's recent condemnation of Francesco Algarotti's 1737 *Neutonianesimo per le dame*, ostensibly for its propagandistic tone, was not much help.[19] The University of Padua naturalist Antonio Vallisneri directed his scorn indiscriminately against "monks and . . . priests" of every sort, especially those "of Rome."[20] The Franciscans maintained their reputation as inveterate Scotists.[21] But the Jesuits were held more particularly responsible than anyone else for the decline of science in Italy. Lami seemed to sum it up in this doggerel, published in Florence:

If ever you've heard a Jesuit talk
At fallacious speeches you'll certainly balk
Molina, it seems is all that he reads
And in physics on none but Ptolemy he feeds. . . .
There in the corner, where he's not worth a pr- - -
He shits on himself, and on the muses does stick
All his satirical stench. . . .[22]

And whatever they might do, the Jesuits were associated with Galileo's persecutors of a hundred years before—even Zaccaria himself, in reference to whom the Tuscan reformer Bernardo Tanucci quoted the seventeenth-century poet Benedetto Menzini: "How very powerful are the Guelphs and those who 'stuck Galileo with a papal stinger.'"[23]

The Jesuits and Science

Intending to undermine such criticisms by insisting on the Jesuits' positive contributions, Zaccaria enlisted the Jesuit mathematician Lionardo Ximenes to co-author the section on science for each of the first eight volumes of the *Storia*.[24] It was an inspired choice. Born in Trapani, Sicily, Ximenes had met Zaccaria in Rome while completing his theological instruction after a brief teaching tour of the Jesuit colleges at Florence and Siena. In Rome he apparently had come under the influence of Boscovich, a friend of Zaccaria, and perhaps also of Orazio Borgondio, Boscovich's empiricist instructor in scientific methods at the Collegio Romano and his predecessor in the chair of mathematics.[25] He quickly acquainted himself with the best of contemporary work. On completing his studies, he accepted an invitation to join the household of the patrician Vincenzo Riccardi in Florence, where he began making original contributions in astronomy and where, after overseeing the construction of the observatory of San Giovannino, he produced *Del vecchio e nuovo gnomone fiorentino* (1757), a treatise on the use of meridians for charting solar movements that became one of the most consulted works of its kind. As the grand duke's mathematician and geographer, he began to perfect the technical training that later qualified him for a chair at the university, helped him match wits with his counterpart Boscovich (then mathematician for the Republic of Lucca) in a dispute about hydraulic engineering on nearby rivers, and guaranteed his renown in the two most ambitious land reclamation projects of the century: the drainage of the Pontine marshes around Rome and of the Maremma near Siena. Ximenes—one of the busiest of the Jesuit mathematicians, and "the greatest hydraulic engineer of the time"—could be depended on to set an example of Jesuit science at its best.[26]

Together, Zaccaria and Ximenes sought to provide unique information about a host of Jesuit practitioners who they claimed had been slighted or entirely ignored by their lay contemporaries—Francesco Maria Plata, an electrical experimenter from Trapani, Niccolò Arrighetti, a physicist in Siena, Antonio Lecchi, a mathematician in Milan, Giovanni Caraccilo, a physicist in Naples, Paolo Mangini, an astronomer in Venice, and Carlo Benvenuti, a physicist in Rome, to name a few.[27] The work of Treviso mathematician Vincenzo Riccati, they said, was equal to that of Pierre Varignon, the Bernoulli family or Georg Bernhard Bilfinger, and had only been ignored because of the affiliation of its author.[28] The work of the Frenchman Guillaume-Hyacinthe Bougeant was derided because "unfortunately, he was a Jesuit."[29] And whenever possible, Zaccaria and Ximenes transcribed favorable opinions sent in by others about the accomplishments of the Order. One correspondent wrote: "[The] Company . . . is among the holiest, the wisest, the most respectable."[30] The errors of a few, he argued, did not affect the virtue of the many. The *Storia* authors agreed.

Zaccaria and Ximenes provided perhaps the earliest simple account available in any modern language of the matter theory of the "valorous Jesuit" Boscovich.[31] Extracting his ideas on the subject from the treatise *De lumine* (published in 1748), they explained how Boscovich conceived of the elements of matter not as particles but as true mathematical points somewhat like the monads of Leibniz. They accounted for his insistence on the necessity for a repellent force in nature, vaguely suggested by Isaac Newton, holding these points at a proper distance from one another, along with the attractive force that brought them together. Drawing on direct experience mainly in chemistry, Boscovich believed only such a force could explain hardness and density and the lack of compenetration and transmutation between bodies under normal conditions. And Zaccaria and Ximenes described his diagram of the law determining the interrelations between this force and the force of attraction, consisting of a curve showing the relative change in the two forces on one axis with changes in distance between particles on the other, so that repulsive forces increase infinitely as the distance between bodies becomes infinitely smaller. After indicating at least a few of the broad claims for the system that Boscovich was to make for himself ("it explains reflection, refraction, and diffraction of light"), Zaccaria and Ximenes presaged the enthusiasm whereby the full explanation of the ambitious theory was to be received in his masterwork, the *Philosophiae naturalis theoria*, 10 years later. "Everything is full of ingenuity," they commented "and an admirable force of reasoning."[32]

If the *Storia* authors were to some extent guilty of the pro-Jesuit partiality Janus Plancus's correspondent attributed to them, their coverage of science was by no means entirely one-sided. They named nearly as many Scolopians, Camaldolites, Franciscans, and Cistercians in their coverage of science in the *Storia* as they did Jesuits, and at least as many lay scientists (particularly in the field of medicine, where ecclesiastics rarely went). And they showed no reluctance to criticize work by Jesuits when it was incommensurate with the highest contemporary standards—as in the case of Arrigheti, who had asserted, among other things, that the moon did not gravitate toward the earth. "It cannot be said that there is nothing in this theory that cannot be approved," they observed, "for both the Cartesians and Newtonians and all the modern physicists agree that the moon gravitates rigorously toward the earth, like a stone or any other heavy body."[33]

Indeed, Zaccaria, in overseeing the production of the approximately 75 percent of the journal that was devoted to science and all other non-religious subjects, may well have intended to provide not so much an apology as an attractive, useful, complete, and for the most part dispassionate encyclopedic tool, like the analogous Jesuit *Mémoires de Trévoux*, to entice potential customers to buy into the rest.[34] He certainly set out with every appearance of wishing to follow the example of the defunct encyclopedic *Giornale de' letterati d'Italia*, rightly viewed as the Italian forerunner, because of its influence and its popularity, of what had become one of the most commonplace literary genres of the time.[35] In the course of his preaching tour of Italy, Zaccaria met Apostolo Zeno, the *Giornale*'s former director, who attended several of his Lenten sermons in Venice and may even have suggested the project. And he actually began to collect material while on his last preaching stop, in Florence, where he observed the next successful encyclopedic journal, Giovanni Lami's *Novelle letterarie*, in action, and where he took Ximenes on board.

The Making of a Journalist

Zaccaria's varied background was in some ways ideal for the publisher of an encyclopedic journal. Son of a prominent Florentine lawyer operating in Venice, he began his education in the Jesuit college there and showed considerable talent for theological debate at a very early age. The tale of his engaging in a famous disputation at age 13 may be apocryphal, but already at 23, after a novitiate in Vienna and a stint teaching rhetoric in Gorizia, the Austrian province sent him in 1737 as one of two candidates for theological instruction at the Collegio Romano. His horizons began to broaden as he befriended a future ecclesiastical historian and librarian (Pietro Lazzari), a physician (Giuseppe Benvenuti), and scientists (Ximenes, Boscovich, and perhaps Borgondio).[36]

Still lacking real expertise in any field except theology, Zaccaria acquired yet another field during his preaching tour of the cities of Italy: local history and antiquities. Wherever he went, he devoted most of his free time to visits to libraries and conversations with local scholars, with appreciable results. Besides the literary historian Apostolo Zeno, and Giovanni Lami, who was not only a journalist but also a founding member of the Colombaria Society dedicated to ancient and medieval antiquities and a publisher of collections of scholarly dissertations on those subjects, he also met Angelo Maria Querini, bishop of Brescia and a skilled orientalist. Zaccaria's grasp of paleography and his knowledge of contemporary scholarship were enough to permit him to identify, in the Servite convent library of Florence, a version of the *Expositionum fidei Catholicae* that had escaped the careful attention of Muratori. In his *Excursus literarii per Italiam ab anno 1742 ad annum 1752*, modeled on Jean Mabillon's *Iter italicum*, Zaccaria recorded his experiences, including lists of monuments and codices previously neglected or badly described by others, occasionally even giving variant readings. And in so doing, he earned not only the support of the Florentine antiquary Antonfrancesco Gori but the almost unqualified praise of the Royal Society of Göttingen's *Göttingische Anzeigen von Gelehrten Sachen*.[37]

What he lacked in scientific expertise, Zaccaria made up for with his faith in self-improvement. In a letter to young Brescian nobleman, Lorenzo Covi, Zaccaria offered encouraging words concerning the possibility of his being able to contribute something important in spite of the apparent abundance of brilliant minds in all fields. The mystique of authorship, wrote Zaccaria, inevitably dissipated when modern productions were divided into their three large categories: transcriptions or editions of authoritative writings, compilations or collections of works written by others, and original works. All these categories invited new contributions, even the last; no matter how many books were in existence, there still remained something new to say. "In such a multiplicity of books that we have on particular subjects or on entire scientific faculties, the original ones that have actually increased the arts are very very few, and the sciences are very far from having attained perfection."[38] Zaccaria gave the example of what he preferred to call "filosofia e matematica"—his blanket term for the exact sciences. No adequate complete course on philosophy yet existed—a complaint he and Ximenes were to repeat later in the *Storia*, with an incitement to his readers to try their hand at providing one—and almost all the major issues were still in dispute.[39] Never be too impressed by the so-called experts, Zaccaria warned.

His contribution to the coverage of scientific issues in the first eight volumes of the *Storia* was the masterpiece of Zaccaria's autodidacticism. He could not claim a perfect understanding of mathematics, biology, botany, physics, chemistry, engineering, surgery, pharmacology, and medicine. But the remarks he wrote up with Ximenes's help showed a satisfactory comprehension of the material, and the remarks he made entirely on his own in biology and medicine occasionally included original observations. He once said: "Permit me, who have proposed to narrate the discoveries of others, to offer a suspicion of mine to the judgment of the scholars," and went off on a theory of his own about the formation of the blood.[40] When attacked, he was willing to defend his credentials. "We cannot judge differently," he replied concerning a work on medicine, "not because we are, as [our opponent] gives us the honor of declaring us, simpletons and completely devoid of these matters and like parrots simply repeating what others say, but because the reasons he brings to bear to support his cause are prejudices and little stories rather than arguments worthy of his learning, his rank and his age."[41]

And since the *Storia* (unlike Angelo Calogerà's Venetian *Raccolta di opuscoli scientifici e filologici*) did not ordinarily propose substantive original contributions, Zaccaria and Ximenes sought to make it original at least in its approach to an already well-represented genre.[42] Only in their annual publication schedule did they emulate the *Novelle della repubblica letteraria*, a simple collection of disconnected book reviews organized by Calogerà and Medoro Rossi Ambrogio according to place of publication. Such a rhythm was calculated to weigh lighter on readers' purses than the more hurried publication schedules of most of the other would-be successors of the quarterly *Giornale de' letterati d'Italia*—from Lami's nervous weekly *Novelle letterarie* to the only slightly more leisurely monthly *Giornale de' letterati* of Ridolfino Venuti and his collaborators in Rome. What the *Storia* authors later attributed to another writer seemed to rebound directly back to their own enterprise: "He is not in such a hurry; and has the air of one who takes his own time. Therefore he does not refrain from deviating here or there where a fresh shade beckons or an admirable green space invites him to rest a little, or a pleasant hillock permits him a lovely view of the far-off horizon."[43]

In spite of their leisurely pace, Zaccaria and Ximenes emphasized their break with the past by adopting the model of some political journalism rather than that of most literary journalism. After all, they believed, the main battles of the age were being played out just as much—if not more—in the literary salons, drawing rooms and coffee houses as they were in the countryside outdoors. And just as it was occasionally necessary to look at a hundred small skirmishes to see the general trend of a battle, and at a hundred battles to see the general trend of a war (as Innocenzo Montini tried to do in the political annual *Storia dell'anno*), so the arts and sciences required an occasional attempt to take the measure of every achievement and every conflict. Therefore, unlike Scipione Maffei's short-lived *Osservazioni letterarie*, they offered to speak synthetically about everything that had come out on each topic rather than to select one or two pet topics and write about them in great detail. Unlike Luigi Pavino's Venetian *Giornale de' letterati oltramontani*, predominantly a translation of the *Journal des sçavans* with a little of the *Mémoires de Trévoux* thrown in for good measure, they offered virtually no reprints or translations from other journals. Nor, unlike the *Saggi* of the Etruscan Academy of Cortona, did they devote themselves exclusively to archaeology. And, unlike the *Memorie sopra la fisica e la scienza naturale* of Lucca, the *Commentarii* of the Bolognese scientific Istituto, the Bolognese edition of the *Commentarii* of the scientific academy of St. Petersburg and the Neapolitan translated edition of the *Philosophical Transactions* of the Royal Society, they did not devote themselves exclusively to science. Instead, they did everything possible to gain some perspective on all intellectual events, to ruminate about them, and, most of all, to get in the last word.[44]

Having adopted an almost pamphlet-like format, Zaccaria and Ximenes did not have to resort to any of the more extravagant strategies in order to achieve an easy conversational tone and keep the interest of their readers. They could ignore such innovations as the invented-letter strategy, which Johann Gaissel borrowed from some popular romances or from the *Pallade veneta* variety magazine of the last century for his abortive Venetian periodical *Lettere familiari sopra le novelle letterarie oltramontani*, and which Calogerà and Antonio Zanetti used later with extraordinary effectiveness and originality in the long-running *Memorie per servire alla storia letteraria*. The invented-letter strategy aimed to give readers the impression that they were practically talking to themselves—or at least to their closest intimates. "You will see whether I can satisfy your thirst, as long as you play by the rules. The first is," Calogerà and Zanetti began, "that you will never allow the news I will send you ever to leave your room."[45]

Science and the Public

Rather than intimacy, the *Storia* authors wished to provide guidance. Still, this permitted them considerable latitude for stylistic innovation; herein lay another of the *Storia*'s contributions. All they had to do was keep in mind the hysterical Swiftian rhetoric of their fellow journalist Lami, famous for spite and spunk. So they added whimsical interjections in the first person concerning the strange scientific culture of the times—strange, at least, from the point of view of male scientists. "Who would believe it? A woman among us has become a master of algebra," they exclaimed about the Milanese mathematician Gaetana Agnesi, adopting the first-person singular for effect. "I do not want this to lend further credit to the silliness of that 'true Dutch patriot' last year who claimed modern manners would turn men into women and women into men."[46] The same went for events in science seen from the point of view of European scientists: "Who would ever have believed it, that even in North America electricity had its learned connoisseurs?"[47] They even added occasional fake stories, as in the section on mathematics: "Problem concerning the lottery: Find a very easy way of winning any given amount of money in the ordinary game of the lottery." The answer: "Don't play."[48] But more often than not they let the material itself provide the humor, with a minimum of ironical prodding, as in the case of a manifesto by one Valentino Roveda, a hermit in Asti, who claimed to demonstrate the pointlessness of all geometry: "His learning is no less than his devotion. But it is so sublime that I confess I don't understand it at all. Who am I, to dare to fly behind this great eagle?"[49] And on the same occasion, they remarked: "While all these geometers have been trying to raise the great edifice of Geometry and analysis, they probably did not notice that their whole building was tumbling down and collapsing at its foundations. But I believe it is my duty to warn them not to build so high as to find themselves one day in ruins."[50] They lent literary continuity to the whole by fashioning elegant transitions from one matter to the next. "How could we better begin the present chapter than by giving our readers the news that a good pen"—as they dubbed one "P. Lettore Sandoni"—"has refuted the book [by Gregorio Bressani] against the philosophical method of the immortal Galileo mentioned in the last volume?" And the next material followed easily from this: "Now protected from the sophisms of the new Anti-Galileo, we can fearlessly proceed to report on some books concerning the philosophical method introduced by that most famous writer."[51] And after an anonymous work on the origins of rainfall written in the form of a dream, they described another one (with tongue in cheek?) by Jacopo Belgrado, "written with its author wide awake," concerning the physics of skipping stones.[52]

They took pains to make readers comfortable with unfamiliar material by gradually immersing them in the field rather than plunging them headlong. Mathematics, in case anyone had not yet heard, was "nobilissima e vasta"; and in recent times conspicuous for its important contributions to physics.[53] Physics, on the other hand, included fashionable subjects such as electricity, which—the strange scientific culture of the times required them to repeat—engaged even women.[54] Chemistry was especially necessary for the study of medicine.[55] And medicine, they explained, was a more respectable science than most people might think by reading Petrarch's denunciations of it, as long as it was based on the study of nature.[56] General criticisms of whole fields were occasionally in order, such as in geometry, where commentators on Euclid's *Elements* always "refried" the same old things.[57] And all fields in general sometimes deserved reproach for practicing the sorts of arguments "that dogs would even be ashamed of"—in spite of the abundant availability of works on the art of reasoning.[58]

For their readers' greater information, they provided laymen's summaries of the main issues behind complex scientific debates. For example, before going into a series of works on anatomy they explained in lengthy detail how putrefaction and fermentation in the stomach produced the nourishing substance called chyle, part of which subsequently passed into the mesenteric veins and eventually on to mix with the blood in the heart.[59] And before going into a series of works on mechanics they explained the problem of the "live forces" (*vis viva*). A little anachronistically, they told how in 1686 Leibniz had asked, for the first time, whether heaviness, magnetism, centrifugal force, and so forth acting on bodies at rest could be measured the same way as the force possessed by a body because of its motion. And he had answered no; the two situations were different in kind and the forces present in the first situation should be called "dead" and those in the second "live." "Since the manifestoes explain it little and the printed books do not treat it sufficiently, this question is therefore in the mouths of everyone but in the brains of few."[60] So into the brains of their readers they poured information about recent contributions by Vincenzo Riccati and Francesco Maria Zanotti.

To convey something of what might be called the drama of scientific discovery, the *Storia* authors showed exactly how experiments were constructed. The physician Giuseppe Vianelli had long been curious about the bright sparks that nightly seemed to illuminate the seawater just off the embankment in Chioggia, and one night he decided to find out what they were. He collected some of the water and passed it through a very fine linen cloth. And behold, the water that had passed through the cloth no longer glowed. Vianelli thereupon examined the cloth and noticed a certain flickering material, which he then he put under a microscope. After a series of tests, including minute anatomy, he concluded that the cause of the nocturnal light that made such a graceful appearance in the marine water was nothing other than a species of "insects never before observed."[61] What that insect might have looked like and what family it belong to, however, they left to the readers' imaginations.[62]

Other experiment narratives were perfect for demonstrating the Galilean model of scientific knowledge based on observation rather than on reading the signs and symbols hidden in nature to acquire a divine sort of knowledge. Raimondo di Sangro, prince of San Severo in Naples, had been working on his chemistry and put some of the results of his experiments away in jars. Noticing later that the material in the jars had begun to diminish, he opened one of them. In the course of examining the contents he accidentally brought a candle close by. The material caught fire and went on burning for the next four months. "If the Signor Prince manages to popularize this discovery," quipped the *Storia* authors, "the price of oil will collapse."[63] Exact measurements were an important component of an empirical science, so those formed part of the story; although there were still phenomena, such as light, that had to be measured by their relation to common everyday activities—closing the distance between science and the general reader. The accumulation of knowledge evidently progressed by tiny increments and produced many frustrations before yielding the satisfaction of a real discovery—which more often than not occurred purely by chance. In keeping with the Enlightenment conception of science, the next step was to find a practical use. But in this as well as the case of the little insects, so much of the narrative tension came from the process of discovery itself that the actual things discovered in the end seemed almost irrelevant.

Reluctant to allow the novelesque quality of such narratives to obscure the scientist's need for accuracy, Zaccaria and Ximenes produced plenty of technical information on other occasions. They provided minute-by-minute accounts of the solar eclipses of January 8 and June 19, 1750, observed from four different locations, and of the lunar one of June 8, 1751, observed from two locations. They described the transit of Mercury across the sun on May 5, 1753, observed from Bologna.[64] They reproduced Ximenes's calculations for deriving the correct difference in longitude between Pisa and Livorno. They reproduced Giuseppe Veratti's timely and exhaustive account of the successful attempt by members of the Bolognese Istituto to repeat Benjamin Franklin's experiments on electricity in clouds.[65] For those proficient enough to try, they provided a varied repertoire of geometrical problems, from Giuseppe Antonio Chautard Du Clos's method for inscribing an enneagon inside a circle, sent in from Turin, to Valentino Roveda's method, sent in from Asti, of squaring the circle by starting with a right triangle whose smallest side equaled the radius in length and whose hypotenuse equaled one-fourth of the circumference.[66] And for those interested in new instruments, they reported on the new Boylian air pump acquired by the Noble College in Naples, and, in Crema, Domenico Crespi's creation of a pendulum-and-spring-driven equation clock with internal adjustments, prefiguring the work of Ferdinand Berthaud, to lengthen the month of February automatically every leap year.[67]

By this approach, which extended to all the fields unconnected with their theological and ecclesiastical purposes, Zaccaria and Ximenes not only provided what has been called "the fullest and most exhaustive review of critical bibliography that Italy had yet possessed," and they not only fully succeeded in attracting readers to the rest of the journal; they also made it one of the all-time best-selling publications of its kind.[68] Its success abroad led the Marquis de Cursay, financier of the *Journal étranger*, to seek Zaccaria as his Italian correspondent, and French minister Pierre Guérin de Tencin to seek him as his bibliographical advisor, while Antoine Gachet d'Artigny excerpted the journal for his *Nouveaux mémoires d'histoire, de critique et de littérature*.[69] Its success in Italy convinced Scipione Maffei that his first lukewarm assessment had been wrong, and Apostolo Zeno that it ought to be printed in two yearly volumes instead of one.[70] And, the best compliment of all, its success drove Venetian printer Orazio Poletti to assume the production costs himself. Still, the first and second printings of the first volume failed to keep up with demand.[71] Soon its success far outran the capacities not only of the first printer but also of Bartolomeo Solani, the small-time local printer Zaccaria engaged upon moving the whole operation to Modena as the new librarian of the Estense. Accordingly, Giambattista and Giovanni Antonio

Remondini of Bassano, the fastest-growing printing firm in Northern Italy, took it over.[72]

That Italian cultural figures relied on their Transalpine colleagues for validating their work was by now a commonplace. "If ever one could write 'London' as the place of publication of an Italian book," noted Zaccaria and Ximenes, "oh how much respect would it not encouter in Italy?" The reasons, in a newly cosmopolitan intellectual environment, were not hard to find. "It adds so much luster to a work to be able to say that it is well-traveled," they remarked. "A book born in Florence could not possibly be any good. It must be brought in from overseas." The result was a devaluation of Italian contributions. "Oh miserable condition of Italians, once the masters and the lords of the world, and now considered by more than one nation as scholars and slaves."[73] Yet, did no one notice the remarkable number of plagiarists abroad, who passed off the discoveries of their Italian counterparts as their own? To ensure adequate coverage of matters at home, Zaccaria and Ximenes promised to limit their coverage to works written in Italy. And in so doing, they claimed to promote more than "the advantage of letters and the honor of the nation."[74]

The most original of all the contributions of Zaccaria and Ximenes was to organize, choose and interpret material in order to identify and encourage those currents in contemporary science they regarded as the best of a continuous Galilean tradition. Going back to the roots of that tradition seemed to them by no means a futile exercise, even in the middle of the eighteenth century. Everyone knew that Galileo's influence on Italian science had never abated since his works first appeared. But the first complete edition had only recently been published in Italy.[75] And remnants of the outmoded Aristotelian and scholastic physics against which Galileo battled still appeared in the textbooks now and then. Bringing the discussion of Galileo out into the open forum of the press was never unfashionable.

Zaccaria and Ximenes proclaimed the victory of empirical science by reexamining the accomplishments of Galileo. True, they occasionally got carried away—as when they wrongly credited him with having abandoned entirely the geometrical method of Eudoxian proportions in his mature work.[76] For the most part, however, their assessment was correct. They explained the novelty of his mathematization of physics. "Galileo was the first," they noted, "who left the philosophy of the ancients and introduced the new and different one prevailing in present times."[77] They defended his conclusions on motion, the planets, and the corruptibility of the heavens in the *Dialogo dei massimi sistemi*. They referred to his authority when assessing work treating odors and colors as mechanical effects on the senses rather than as accidents or qualities. And in his name, they threatened by a menacing array of air pumps, telescopes, and compasses anyone who tried to hold back progress.[78]

Again, in their account of the exploits of Galileo's direct and indirect disciples, the *Storia* authors made a few well-intentioned mistakes. For instance, they credited Domenico Guglielmini with the main principle of hydrodynamic measurement (that velocity differs between the surface and lower regions in any river)—a principle discovered in fact by Galileo's disciple Benedetto Castelli a hundred years before.[79] They were perfectly correct, however, in implying that Guglielmini profited from the continuation and development of the Galilean empirical method throughout the previous century. The pioneering Florentine Accademia del Cimento, with Giovanni Borelli, Francesco Redi, Lorenzo Magalotti, and the rest, fashioned new instruments for applying it.[80] Two of the members, Redi and Borelli, extended it to the life sciences; Marcello Malpighi, by relying exclusively on extensive comparative observations, followed in their steps. Paolo Boccone, Malpighi's Sicilian disciple, explored new ways of applying it to botany, subsequently followed by the Florentine Botanical Society and its members Giansebastiano Franchi and Pier Antonio Micheli and others.[81] It showed up again in the "great work" on human generation by another Malpighi disciple, Antonio Vallisneri, who improved on Anton Van Leeuwenhoek's theory about tiny pre-formed creatures in the semen.[82]

This interpretation of the Galilean tradition, of course, meant soft pedaling the various discordant notes within Italian science over the past century. It meant leaving out non-Galileans who nevertheless contributed something important, such as Giambattista Riccioli, Athanasius Kircher, and Sebastiano Bartoli—even though they were Jesuits. And even among the Galileans, it meant forgetting the battles between Borelli and Vincenzo Viviani in the Accademia del Cimento. It meant playing down the chemical philosophy of Lionardo Di Capua and the cabalism of Elio Astorini. It meant ignoring the scriptural literalism of Giambattista Hodierna and Pietro Mengoli. It meant ignoring the current of vitalism extending from Donato Rossetti in Galileo's time all the way up to the eighteenth-century naturalist Francesco Maria Nigrisoli. So instead of regarding as a symptom of a fractured tradition the most recent attempt, by Neapolitan philosopher Costantino Grimaldi, to resuscitate Della Porta's method of cryptology and resemblances and apply it to modern science, they simply left it out altogether.[83]

And on the basis of the supposed unity of the Galilean tradition, and not its fragmentation, the *Storia* authors registered their approval of current work. Michele Genorini, physiology instructor at the Florentine Studium, for instance, was perfectly Malpighian—i.e., Galilean—even though he aimed to disprove Malpighi's theory of the conversion of chyle into blood through the grinding action of the lungs. Emulating Galileo-style thought experiments, including a bag full of large and small glass balls to show that larger particles such as those of the blood would actually get ground up first, Genorini offered his own view that the conversion came about through the lungs' action of extracting and exhaling chyle acids. And Malpighian in their methodological approach, if not exactly in their therapeutic audacity, were several recent experiments to test the curative potential of mercury, on which they believed the physician Giuseppe Maria Saverio Bertini of Florence showed far more expertise than fashionable "desktop physician" Hermann Boerhaave of Leyden.[84] Finally, the *Storia* authors did not forget to salute the Galilean school's characteristic combination of scholarly and philological techniques with scientific ones by rewarding the Padua anatomist Giambattista Morgagni's authoritative edition of the works of two physicians of antiquity, Aulus Cornelius Celsus and Quintus Serenus, with two long reviews.[85]

Fully in the Galilean-Redian tradition of naturalistic description, they insisted, were the recently published *Reports on Some Travels Through Various Parts of Tuscany* by Giovanni Targioni Tozzetti. In volume IV, for instance, he provided the reader with explanations of everything geological in sight on a meandering trip along the hilly western margin of the grand duchy from Barga to Monterotondo. And squinting back through the mists of prehistoric times, he decided that horizontal cracks and fissures there visible could only be explained by the buildup of tension between land masses of different specific gravities compressed in different ways. Georges Buffon's suggestion in the *Histoire naturelle* that a settling of the ground at the base of the hills, Tozzetti pointed out, was only plausible for vertical features. Furthermore, drawing on Italian research on hydrodynamics, he showed the tremendous power of river currents to modify landscape morphology, and he criticized Buffon's theory tracing the origin of valleys and gorges solely to the action of marine currents before the land emerged. Something would have had to make those violent currents move in such irregular ways, he reasoned; but in the period hypothesized by Buffon there would have been no large land masses there protruding. Thus, Tozzetti explained the weirs of the river Torriti on the basis of an age-long process of erosion. And he added a powerful explanatory tool to the emerging science of paleontology. Citing the "excellent arguments and observations" whereby he proved his point, the *Storia* authors came surprisingly close to the modern assessment of the work.[86]

Newtonianism and Faith

While recommending local products with the same fervor as their predecessors on the *Giornale de' letterati d'Italia*, the *Storia* authors nevertheless paid due attention to the European context of the books they studied. For the greatest living example of the marriage between physics and mathematics, they turned again and again to Isaac Newton. True, they did not always faithfully portray Newton's position in contemporary physics. Perhaps to render the theories more palatable to many Italian readers who were likely to have Cartesian prejudices, they permitted themselves one wild oversimplification, saying that the main disagreement between Cartesians and Newtonians was over whether gravity was to be attributed to the effect of the vortex or to a property of matter.[87] However, in other résumés of Newton's greatest discoveries they cited passages from the *Principia* to show how he found the true causes of Kepler's laws of planetary motion. They showed how he managed to improve on Kepler's somewhat fanciful causal theories by comparing the elliptical orbits described in the first law to the motions bodies must make when circulating around each other with a centripetal force that varies inversely as the square of the distances. "Kepler . . . , trying to use his magnetic theory to give a mechanical explanation for such motions," they informed readers, "did not notice that the description of that curve was the result of a universal gravity."[88] They accounted for Newton's explanation of irregularities in the sun's movements on the basis of its position near the entire system's center of gravity.[89] And they outlined his discovery of the relation between the moon's gravity and the changing tides on earth.[90]

When measuring contemporary Italian contributions to astronomy, the *Storia* authors used Newton's work as a yardstick. They condemned anyone who denied the universality of the law of gravity to the "mercato vecchio."[91] They blamed the Bolognese astronomer Eustachio Manfredi's posthumous *Instituzioni astronomiche* (Bologna: 1749) for cutting short a discussion of the Newtonian system in order to prolong a useless and dated one comparing the heliocentric hypothesis with the now-defunct geocentric one.[92] On the other hand, they found Boscovich's contribution to contemporary efforts at clarifying Newton's own thoughts highly praiseworthy. His gloss marvelously clarified Corollary 4 of Newton's Third Law of Motion, establishing that common centers of gravities of bodies do not change their state of motion or rest by the actions of the bodies among themselves but either remain at rest or move uniformly in a right line, an important precondition of Newton's idea (book 3, proposition 11) that the center of the universe was at rest.[93] Likewise, Paolo Frisi added persuasive proof to Newton's outdated observations in the *Principia* (book 3, proposition 19) concerning the earth's bulging about the equator as a result of the forces generated by rotation. The ensuing quarrel between Newtonian bulging-equator theorists such as Pierre-Louis Maupertuis and Cartesian bulging-pole theorists such as Jacques Cassini brought about expeditions to Lapland and to Ecuador to get accurate on-the-spot measurements. Frisi set the Newtonian theory on an ever more secure foundation by correcting tiny mistakes in field measurements committed by Maupertuis through excessive zeal.[94]

Again, for the example of empirical science at its best, the *Storia* authors turned to Newton on optics. They outlined the problem he solved, starting with previous theories claiming color to be an intrinsic quality of a body, and they recounted the famous experiments dissecting white light and then reassembling it from its basic component colors. They showed how he arrived at his theory that colors come from rays of various types characterized by constant regular grades of refractibility and by the ability to produce different effects on the optic nerve. Objects therefore appear to show one color rather than another, they explained, because of different capacities for absorbing and reflecting the various wavelike rays of corpuscles. They then explained how the Tuscan Jesuit Pier Maria Salomoni further developed these ideas by suggesting that the maximum and minimum angles of the refracted rays producing the rainbow could be established by the differential calculus rather than by the "synthetic" method preferred by Newton in *Opticks* (book 1, proposition 9) and by Newton's followers Willem Jakob 'sGravesande, Pieter van Musschenbroek, and others, thus avoiding a long series of calculations.[95] Furthermore, they offered linguistic aids not available to Italian readers in Francesco Algarotti's popular *Neutonianismo per le dame* or in the recent translation of Henry Pemberton's *View of Sir Isaac Newton's Philosophy*, explaining what "indigo" might look like and how it differed from "violet" or "purple." "To do P. Salomoni justice," the *Storia* authors remarked, "he has not left out anything that whereby a valiant philosopher might illustrate the system of Newton on colors."[96]

However, the *Storia* authors were not so taken with Newton's optics as to be incapable of appreciating the debate surrounding them, both in Italy and in Transalpine Europe. Rather than the experimental results themselves, impugned by Scipione Maffei and others unable to repeat them because of defective instruments or fixed preconceptions, they impugned the interpretation of them, following the Venetian anti-Newtonian Giovanni Rizzetti. They expressed some dissatisfaction with Newton's agnostic response to the question of just how bodies could act at a distance on rays of light, causing all, some or none of them to be reflected.[97] Arighetti's simple mechanical explanation seemed promising: light literally struck the hard particles of bodies and either passed through the pores, producing translucency, or stopped dead, producing opacity. Furthermore, they seemed to share his difficulties in accepting an emission theory because of the way light traverses very great distances in a very short time.[98] They showed how he imagined instead that a very tenuous fiery substance equally distributed throughout all the spaces in all things served light in the same way that the air served sound; so, somewhat the same way as in Robert Hooke's wave theory, a very gentle impulse was propagated very quickly and successively throughout, perceptible only straight on and not from the side.[99]

Likewise, the *Storia* authors objected to the Newtonians' extension of the notion of attraction beyond the strict limits set for it by Newton himself everywhere except in the admittedly adventurous *Opticks* (query 31). As an example they cited Andrea Bina's "Newtonian" theory of electricity. "Since someone might suspect that I, who am neither Newtonian nor Cartesian, might contaminate the purity of Newtonian explanations by my own words," they began, "I will faithfully translate the sense of our author into our vernacular, without mixing in anything of my own, for greater satisfaction of these attractors."[100] So they included a long excerpt where Bina imagined that an electric vapor passed from an electrified body to the atmosphere between it and another body and built up there until the attractive force of the whole was able to overcome the inertia of the other body.[101] Of the same work, they recounted the theory that sunspots were simply clouds of objects that had been drawn to the sun by the force of attraction, like feathers to a glass rod. Whoever believed this, they said, could apply the same theory to the Aurora Borealis. "Anything is possible," they quipped, "when theorizing with the attraction and the mechanism of Bina."[102] The same went for "Newtonian" theories of medicine of John Keil, criticized by the Sienese physician Pietro Cornacchini for attributing the circulation of the blood and even the separation of the humors to an attractive force. "Its laws," they warned, "are now being extended to the point that it is fast becoming a ridiculous and very dangerous abuse."[103]

However, unlike the "Enlightened Catholics" explored in some recent historiography, the *Storia* authors did not balk at this widespread use of the concept of an invisible attractive force merely for fear of mixing physics and metaphysics or even science and theology. Following in Galileo's footsteps, it is true, they did everything they could to get the imaginary ghosts out of the world machine. They shunned literal interpretations of Genesis in favor of a creation scheme incorporating the geological evidence offered by Vallisneri and Giacinto de' Tonti.[104] On the basis of sociological evidence offered by Girolamo Tartarotti, They interpreted witchcraft as a social ill proceeding from popular ignorance and not a spiritual ill, at least in most cases, despite the ambiguous references in Deuteronomy.[105] However, while engaging in these efforts to get imaginary ghosts out, they engaged in others aimed at making sure the real ones stayed in. "The philosopher," they pointed out, "must concern himself with invisible beings no less than the theologian."[106] And in the investigation of invisible beings, philosophy could serve as the handmaid of theology far more than Galileo had ever dreamed. They encouraged efforts to use physics for studying levitation and other powers attributed to spirits, just when the Congregation on Rites under Benedict XIV was starting to use modern science for verifying miracles in the preliminary stages of the canonization process.[107] And they came down on the affirmative side in the great controversy over whether animals had souls. This was so, they argued, because the Cartesian position that animals moved and performed all their operations by purely automatic and mechanical actions came far too close to suggesting that man, too, might be a sort of automaton in spite of the orthodox view of man as a spiritual creature. And Lorenzo Barbieri's suggestion that animals, though entirely mechanical, were nonetheless directed in their actions by divine Providence, was no way out, since it seemed to sneak a Cartesian principle of aspiritual lifelessness right back in. They thus endorsed the position of Lorenzo Magalotti, later shared by Antonio Genovesi, that the animal soul is simply of an inferior sort to man's, even though experimental and observational evidence seemed useless to decide. Apparently, at least a few features of the mechanical philosophy could be sacrificed where dogmatic truth was at stake.[108]

What the *Storia* authors objected to in the extension of Newton's principle was the methodological sin of calling upon "Deus ex machina" —as they put it—whenever other explanations failed.[109] They understood as well as their fellow critic Maffei how great was the temptation to hide under the protection of an accredited and fashionable author.[110] They also understood the temptation to make broad claims for the significance of one's work—also for reasons associated with the social relations of science. "We ought to sympathize with our poor philosophers. They want to raise a hue and cry; they want to be applauded, and among most people this cannot be gained except by speaking about causes, and by putting together a huge machine of a system."[111] However, a new system explaining all phenomena could only be said to be established as true over a long period of time and through the general agreement of most of the practitioners in a particular field.[112] And at present, they believed, in spite of Newton's imposing achievement, there was no such system.

The *Storia* authors therefore made several recommendations for Italian scientists. The first was caution—exactly the opposite of what they observed in the field of electricity, where on slender evidence new systems and new theories were being erected every day.[113] The next recommendation was to avoid excessive hero worship. Newton and Descartes ought not to be looked upon as oracles to be consulted for inspiration even on matters they had never studied. Between the two, safe from the fashions and the passions of the moment, stood a middle ground, which Italian science, because of its traditions and because of its particular specialties, was ideally suited not just to occupy but even to dominate. "How desirable it would be," they exclaimed, "with the French transported by the spirit of Cartesianism and the English by that of Newtonianism, and the other nations lined up on one side or the other, to see the Italians look upon these battles with indifference, and meanwhile dedicate their time to more useful researches than those concerned with the causes of things."[114] The final recommendation concerned the publication of information on science in the press. As a collaborative effort, science required the testing of theses by everyone involved; submitting things to public judgment helped find truth.[115]

Having made these recommendations to all scientists, the *Storia* authors turned to Italians in general. Everywhere they looked, they saw indifference—especially among children, whose preparation in scientific fields was the only hope for future accomplishment. Little could be done about those whose modest means prevented them from advancing, but there was no excuse for the children of noble families. "How miserable is the state of Italian youth today."[116] Echoing Scipione Maffei's famous anti-noble diatribe in *La scienza chiamata cavalleresca* (1710), they poured scorn on nobles who squandered their good fortune on gambling, hunting, and other more sinful pastimes, leaving to others not only the cultivation of intellectual pursuits but even the management of their own estates. Instead, they announced, abundant wealth carried with it the moral imperative to benefit society and to educate children to do the same. To help direct some of this zeal toward the sciences, they paid particular attention to textbooks.[117] And to help provide new models for the young, they showered praise on contemporary nobles who dabbled in science—for example, the amateur mathematicians Count Giulio Carlo da Fagnano, Marquis de' Toschi e di S. Onorio and Count Giambattista Suardi.[118] With such recommendations, they hoped, Italians might be able to prove in the sciences what they had already proved in the military actions of the recent Austrian Succession war—namely, as they said quoting a famous canzone by Petrarch, that "the ancient valor in the Italian hearts is not yet dead."[119]

Such was the appeal of the original *Storia* authors' program in science that when Zaccaria admitted two of his subordinates at the Este library to take over the increasing burden of editorship in volumes VIII–XIV, they had no difficulty pursuing exactly the same policies as he and Ximenes had for the first eight volumes. Indeed, borne away in the general enthusiasm, even the new editor of the sections on "languages, poetry and eloquence," Gioacchino Gabardi, compared Newton's authority to Homer's.[120] However, Domenico Troili (a former Collegio Romano student of Boscovich's who assumed sole responsibility for scientific materials) continued to promote the work of Italian scientists who showed caution in their epistemological attachments and moderation in their conclusions—while taking every opportunity to heap ridicule on impostors who paid no attention to modern methods.[121] He continued to identify the marks of an Italian tradition, tracing the precursors of the calculus back to the so-called method of indivisibles created by Bonaventura Cavalieri and Galileo and developed by Evangelista Torricelli. And against opponents who viewed Boscovich as an uncritical Newtonian, Troili explained Boscovich's accomplishments on the basis of this long tradition, which he developed, criticized, modified, and extended to new applications.[122]

Troili continued to pursue a scientific approach that made sense of the theological and metaphysical ideas he shared with Zaccaria. Mathematics was the most obvious case, since it shared with religion the need for a belief in unquestioned first principles. Echoing the panegyrical tradition of Christopher Clavius, he saw mathematics as a lesson in faith:

> The term natural reason cannot refer to the mysteries of religion, because these mysteries are above natural reason—though they are no less true because of this; indeed, they are so evident in mathematics that they may seem absurd at first sight. Mathematicians therefore find little difficulty in believing these mysteries, which they may never completely understand, while they become ever more confirmed in faith.[123]

In the other exact sciences, Troili saw no use for unexplained axioms and every use for the kind of sensory experience explored by John Locke. But here too, everything he learned seemed to point to the God of his faith. Newton's theory of universal gravitation did not detract from it, provided it was understood in the proper theological perspective. And much less did John Turberville Needham's fanciful theories resuscitating the principle of spontaneous generation disproved decades before by Vallisneri. Troili thus prefigured Lazzaro Spallanzani's somewhat tendentious interpretation of Needham's research as suggesting an independent life-giving principle in nature apart from God.[124] "The necessity for a first independent and most perfect cause is openly demonstrated by the nature of bodies, which are deprived of any living principle."[125] Thus, once again, religion in the service of science brought both toward a higher truth.

One effect of the *Storia* may well have been to lend further weight to what had become an authoritative interpretation of science in Italy. It may be true that journals devoted more exclusively to scholarship, such as the *Commentarii* of the Bolognese Istituto, did more to further actual discoveries, and specialized journals such as the Venetian *Giornale di medicina* and the Lucchese *Memorie sopra la fisica e la scienza naturale* did more for particular disciplines, just as technical publications such as the Venetian *Giornale d'Italia* did more for the practical application of scientific knowledge to fields such as agriculture. But encyclopedic journals always performed the important function of situating discoveries into their wider cultural framework and clarifying methodological and philosophical points not covered in monographic articles. And if the *Storia* encountered considerable agreement with its campaign against undue confidence in shaky structures elevated to the status of systems by their hopeful inventors and for a rigorously empirical and experimental approach, this was largely because previous publications paved the way. The same went for its effort to identify an Italian scientific tradition and coordinate this tradition with a firm stance against contemporary currents of deism and unbelief. One predecessor, the *Giornale de' letterati d'Italia*, made a deliberate mission of propagating exactly the same ideas, which in turn informed the modest scientific revival of the Age of Vallisneri. And when the *Giornale* stopped publishing, the former collaborators Vallisneri, Morgagni, and Giovanni Poleni made sure that their convictions about these matters shone through in their specialized works, all of which received honorable mention in the *Storia* from time to time.

By its appealing format and style, far easier and more conversational than that of the more stodgy *Giornale*, the *Storia* may have been particularly effective at helping win wide acceptance among the public at large for its interpretation of science. Unlike Giovanni Baldasseroni and his collaborators in Livorno, who loosely patterned their exactly contemporary *Magazzino italiano* on Edward Cave's *Gentleman's Magazine*, the *Storia* did not promise instant and effortless erudition.[126] However, even to those readers who were unlikely ever to purchase the ponderous Latin tomes it reviewed, it did offer enough information to give readers a rudimentary grasp of some of the basic issues of contemporary science. And furthermore, it offered an indispensable guide to the reader bewildered by the volume of contemporary book production. "The portentious multitude of printed works imposes from every country, and weighs down so much, that if the good God should not rain down a plague on paper, capable of destroying useless and malevolent writings, and get some of these books out of the way, we will in a short time have to go out of our houses to make room for these honored guests, who however for their multitude are beginning to be indiscreet."[127] And by praising works that conformed to its program and damning others, guiding the purchases of its readers along the lines it suggested, and insinuating the principles of correct method in exciting scientific narratives, it could be a "plague" to "malevolent" books—or ideas—and a boon to good ones.

Far from merely administering Jesuit propaganda, as current scholarship supposes, the *Storia* may well have contributed to the cultural ambience that prepared the late-eighteenth-century Italian scientific renaissance. True, many other causes collaborated to bring about this result. Cultural policies dating back to the early part of the century were to some extent responsible for the Austrian government's sponsorship of well-equipped laboratories and copiously furnished museums, which were important in encouraging Alessandro Volta, Spallanzani, and Antonio Scarpa at Pavia. The same went for the Habsburg-Lorraine government (which kept Felice Fontana and Giuseppe Fabbroni active at Florence), the papal government (which did not hesitate to ensure that Luigi Galvani and Marcantonio Caldani at Bologna had everything they needed to pursue their work), and Venice (which was not far behind in maintaining Marco Carburi and Giuseppe Toaldo at Padua in the same fashion). And in the Savoy state, says recent research, military necessity gave added impetus to government sponsorship of culture so that Louis Lagrange, Francesco Domenico Michelotti, and eventually Amedeo Avogadro could keep the scientific and technological faculty at the university at least on a par with the rest of Europe. An "Italian revolution," Spallanzani's publisher called it, both in the sciences and in politics.[128] Nevertheless, the periodical press, by increasing public awareness of scientific accomplishment and by widening the pool of applicants and bringing them to the attention of those in power, was a chief instigator and inspiration for determining the particular projects that enjoyed government sponsorship. And it was Andrea Rubbi's *Nuovo giornale letterario d'Italia*, one of the successors to the *Storia*, that declared in the last 20 years of the century that Italian scientists, science having "lost its primacy," had finally taken over genuine leadership.[129]

Twilight of a Tradition

Hard as they tried to please their readers and great as was their commercial success, Zaccaria and his collaborators nonetheless failed to silence their most vociferous critics. For example, Gian Vincenzo Patuzzi in Verona and Giovan Battista Macchi in Piadana complained about the *Storia*'s treatment of rigorist morals and Church government.[130] Giuseppe Frova in Vercelli complained about its views concerning sacred images.[131] Concina complained that its scrappy style provoked the urgent self-defense of the people it had criticized in every field.[132] Giovanni Lami accused it of "distorted reasoning" and recommended it only to experts who could see through its "many errors."[133] And among scientists, Gaetano Fabbri impugned its coverage of medicine as amateurish and as unbecoming ecclesiastics.[134] Janus Plancus thought it neglected important works—namely, his own.[135] In Lucca, Gianlorenzo Berti began a veritable anti-*Storia* industry, with a counter-journal called *Supplement* that ran for three volumes, followed by an *Anatomy of all the volumes*, criticizing its positions on everything from morals to theology to magic to the causes of lightning while excoriating it for excessive praise of sloppy scientific work by Jesuits (especially Federico Sanvitale, professor at the College of Brescia).[136] Even Tanucci was amazed by it all—although not unpleasantly. "So much anger, so much persecution. . . . But we want truth in the world and we will crucify."[137]

So vociferous were these critics, indeed, that they dampened the enthusiasm of Zaccaria's ecclesiastical superiors. Already in the third year of publication, Ignazio Visconti, the Jesuit General, demanded that volumes be sent to Rome for pre-publication censorship, thus limiting the considerable freedom in which Zaccaria, like his fellow Jesuits elsewhere, had recently become accustomed to operating.[138] As the journal's reputation for making trouble continued to spread, Pope Clement XIII is reported to have exclaimed "Oh that *Storia*; that *Storia letteraria*!"[139] And when no amount of warning and counseling seemed sufficient to blunt the work's polemical weapons, Visconti's successor Lorenzo Ricci finally pleaded with Zaccaria to suspend the journal in 1758 "for the better interest of the Order."[140] Thus, in spite of the continuous efforts of Francesco III d'Este, duke of Modena, to deflect the onslaught from Rome, Zaccaria finally gave up the prospect of a continuation of the journal under another name until four years later—although for the moment, other concerns were foremost in his mind.

Worse yet, the *Storia* authors' pro-Jesuit intentions, of which their contribution to scientific culture was apparently a very significant by-product, were completely undone by events out of their control. Standard complaints about moral lassitude, philosophical immaturity, pedagogical obtuseness, and political meddling had by now been merged into a new conspiracy theory far more potent than the many ones announced in the previous century.[141] It first emerged in Portugal, where João I's minister Sebastião João de Carvalho e Melo (later marquis de Pombal) sought to use the Jesuits as symbols of the opposition to his program of state modernization, economic reorganization, and educational reform. And it first took the form of accusations about fomenting popular political discontent during the reconstruction after the Lisbon earthquake. It flourished with charges against all of them of exploiting a privileged position in the colonies to compete commercially on unfair terms with state companies. It finally escalated into allegations against several of them for complicity in the Távora-Aveiro assassination plot against the king, sufficient to justify the expulsion of the order in 1758—from the schools, from the missions, and from the state. And soon it was stretched back into an inquiry about what the Jesuits had been doing all along in Portuguese lands and elsewhere.

In Italy, where the Jesuit debate had already been brought before the tribunal of public opinion through the works of Zaccaria and the other *Storia* authors, their supporters, and their opponents, the conspiracy theory spread quickly. Along with news of the subsequent expulsion of the Order from France and Spain, it became the subject of an unprecedented pamphlet war to which Italian Enlightenment philosophers such as Tommaso Antonio Contin contributed. "The poor read them," apostrophized the writer, reputedly Gioacchino Faranca, "and learn to cry vendetta for the blood that you [Jesuits] have sucked from their veins in your insatiable greed. The merchants read them and conceive mortal jealousy for their usurped commerce. The plebs read them, and horrified by your numerous excesses, begin to point their fingers at you, whistling loudly, as they do on Saturdays against the Jews."[142] Amid the general uproar, the conspiracy theory became a main component of the Enlightenment-led anti-clerical movement of the 1760s. To stop the onslaught was far beyond even the considerable polemical gifts of Zaccaria, which he employed to the best possible effect in a pamphlet counterattack. And governments responded to the growing pressure by abolishing mainmort, suppressing local offices of the Inquisition, dissolving ecclesiastical courts, confiscating and redistributing Church property, and, in Parma, Naples, Milan, and Venice, expelling the Jesuits.

Among the various conspiracy theories the Italian Enlightenment philosophers examined was the theory of Jesuit complicity in the destruction of Italian science. The Milanese philosopher-mathematician Paolo Frisi was exemplary in this respect. He inserted his digression on the subject in the midst of a biography of Bonaventura Cavalieri, who was often mistaken for a Jesuit because of his affiliation with the nearly homonymous Jesuates. Such an occasion perfectly suited the exigencies of a philosophical historian seeking, on the model of Voltaire, to demonstrate the positive power of individual choice and commitment in a figure such as Cavalieri when not diverted by the sinister operations of a collective evil will embodied in the Jesuits. Elaborating on themes previously explored by Pascal and Louis-René de la Chalotais, Frisi wondered why the Jesuits had over the centuries produced such a modest return in epoch-making accomplishments in spite of almost unlimited patronage, convenient buildings, sophisticated equipment, and powerful influence even in institutions of learning that they did not entirely control. The answer, Frisi claimed, was not the obvious one—namely, that they viewed themselves mainly as teachers. The answer was that they were inveterate enemies of science. Over the decades, their power and resources had been entirely directed to a continuous secret effort to undermine, attack, and suppress the most important discoveries—not only those of Galileo and Copernicus but also those of Cavalieri, Huygens, Newton, Descartes, Gassendi, and the rest—and to replace them with the ancient opinions of Avicenna and Ptolemy. New entrants were simply inducted into the imperatives of the order as members of a transsecular historical community united to the forces of darkness against the spread of knowledge. And in Italy they almost had their way. It was no wonder, then, that Italy had to struggle to regain its position among the scientific cultures of Europe. "Those countries where the [Jesuit] institute reigned," Frisi insisted, "[have] remain[ed] for a long time below the level of other places."[143]

To Frisi, as to the other Italian Enlightenment philosophers, the suppression of the Order in 1773 was no simple diplomatic coup by the marquis de Pombal, in spite of all appearances.[144] It was the inevitable, logical, and just consequence of an epochal struggle for freedom from a pernicious episteme and a meddlesome Church. So it seemed, at least—until plans for secular systems of public education in Milan, Turin, and elsewhere foundered, until Pius VII reestablished the Jesuits, and until the events of the next decades smudged the Enlightenment blueprint for the project of modernity beyond all recognition. Meanwhile, the main monuments of the Jesuit side of the quarrel, from the *Storia letteraria d'Italia* to the former Jesuit Girolamo Tiraboschi's monumental *Storia della letteratura italiana*, quietly took their place on library shelves not as polemics but as indispensable reference works on the Italian culture of their troubled times.

Notes

1. Quoted in Maria D. Collina, *Il carteggio letterario di uno scienziato del Settecento (Janus Plancus)* (Florence, 1957), p. 80, letter dated Ravenna, January 31, 1750.

2. Scipione Maffei, *Epistolario* (Milan, 1955), volume II, p. 1273, letter to Jacopo Maria Paitoni dated May 28, 1750.

3. Circulation figures are from a letter by Zaccaria dated June 6, 1752, quoted in Mario Infelise, "Gesuiti e giurisdizionalisti nella pubblicistica veneziana di metà Settecento," in *I gesuiti e Venezia. Momenti e problemi di storia veneziana della Compagnia di Gesù*, ed. M. Zanardi (Padua, 1994).

4. I refer to the work by Simonetta Santucci, Martino Capucci, and Carolina Gasparini, exhaustively annotated by Giovanna Gronda, in *La biblioteca periodica*, ed. M. Capucci et al. (Bologna, 1985–87), volume II.

5. Marino Berengo, "Introduzione," in *Giornali veneziani del Settecento*, ed. M. Berengo (Milan, 1962).

6. Giuseppe Ricuperati, "Politica, cultura e religione nei giornali italiani del Settecento," in *Cattolicesimo e lumi nel Settecento italiano*, ed. M. Rosa (Rome, 1981), p. 65; Ricuperati, "Giornali nell'Italia dell' 'ancien regime,'" in *La stampa italiana dal Cinqecento all'Ottocento*, ed. V. Castronovo and N. Tranfaglia (Bari, 19863), p. 251.

7. All are listed in Carlos Sommervogel, *Bibliothèque de la Compagnie de Jesus* (Bruxelles, and Paris, 1890–1909), volume VII, pp. 1381–1435. The standard work on Zaccaria is Donato Scioscioli, *La vita e le opere di Francesco Antonio Zaccaria, erudito del secolo XVIII* (Brescia, 1922), which is updated in several articles by E. Rosa: "Gli scritti e il carteggio di F. A. Zaccaria in un archivio della Guipuzcoa," *Civiltà cattolica* 80 (1929): 118–130; "La vita e le opere di Francesco Antonio Zaccaria," *Civiltà cattolica* 81 (1930): 339–351; "Nuovi documenti sulla vita e le opere di F. A. Zaccaria," *Civiltà cattolica* 81 (1930): 509–517; "Pubblicazioni e tribolazioni del p. F. A. Zaccaria," *Civiltà cattolica* 81 (1930), pp. 3, 27–40, 121–130.

8. On these aspects of his career see Infelise, "Gesuiti e giurisdizionalisti"; Luigi Balsamo, "Editoria e biblioteche della seconda metà del Settecento negli stati Estensi," in *Reggio e i Territori Estensi dall'Antico Regime all'età Napoleonica*, ed. M. Berengo and S. Romagnoli (Parma, 1979), volume II.

9. Franco Venturi, *Settecento riformatore*, volume 2: *La chiesa e la repubblica dentro i loro limiti, 1758–1774* (Turin, 1976), p. 22.

10. E. Appolis, *Entre jansénistes et zelanti. Le "Tiers parti" catholique au XVIIIe siècle* (Paris, 1960), p. 570.

11. Giuseppe Pignatelli, "Le origini settecenteschi del Cattolicesimo reazionario. La polemica antigiansenista del Giornale ecclesiastico di Roma," *Studi storici* 11 (1970), p. 759n.

12. *Storia letteraria d'Italia* [hereafter *SLI*] 12 (1758), p. 310. The comment concerned Muratori's *Della regolata divozione*. Zaccaria's treatises of this period include the following: *Lettere al signor Antonio Lampridio intorno al suo libro nuovamente pubblicato, "De superstitione vitanda"* (Palermo, 1741); *Lettere . . . sul libro: "De eruditione apostolorum"* (Venice, 1741); *Osservazioni sopra i primi cinque capitoli dell' Esame teologico* (Bastia, 1745).

13. From a letter dated June 6, 1752, cited in Infelise, "Gesuiti e giurisdizionalisti."

14. "Ancor il minuto popoletto, il rivendugliolo, e il barbiere sa in qual piaggia sieda Peterburg, Memel, Stetino, Stockholm, e il mar Baltico," *SLI* 13 (1758), p. 12.

15. *SLI* 5 (1753), pp. 430–444; 12 (1758), pp. 310–312. I refer to Zaccaria's "Dissertatio prolegomena" to Liguori's *Theologia moralis* (Rome, 1757). For examinations of this issue see Jean Delumeau, "S. Alfonso dottor della fiducia," in *Alfonso M. De Liguori e la società civile del suo tempo*, ed. P. Giannantonio (Florence, 1990), volume I, pp. 205–221; Giorgio Petrocchi, "Sant'Alfonso scrittore mariano," in ibid, volume II, pp. 445–461. On the wider context of Muratori's views, see Claudio Donati, "Dalla 'regolata devozione' al 'giuseppinismo,'" in *Cattolicesimo e lumi nel Settecento italiano*, ed. M. Rosa (Rome, 1981); but also see Pietro Stella, "Preludi culturali e pastorali alla Regolata divozion de' cristiani," in *Ludovico Antonio Muratori e la cultura contemporanea* (Florence, 1972).

16. *SLI* 1 (1750): 49–55; 5 (1754): 146; 12 (1758): 325–329, 329–342. The standard study of Concina is Alberto Vecchi, *Correnti religiose nel Sei-Settecento Veneto* (Venice and Rome, 1962), pp. 307–400. For present purposes, see ibid., pp. 375–382.

17. *SLI* 1 (1750): 41–42; 4 (1753): 404–422. The authority on Lami is still Eric Cochrane; see book 5 of his *Florence in the Forgotten Centuries* (Chicago, 1973); for present purposes, see p. 338.

18. Giannone got his revenge in *History of the Kingdom of Naples* (Naples, 1723); I quote from book 40, chapter 4. See also Luciano Osbat, *L'Inquisizione a Napoli. Il processo agli ateisti, 1688–97* (Rome, 1974).

19. See Vincenzo Ferrone, *Scienza natura religione. Mondo newtoniano e cultura italiana nel primo Settecento* (Naples, 1982), p. 35; Paolo Casini, "Le Newtonianisme en Italie," Dix-huitième siècle 10 (1978), p. 98; Mauro De Zan, "La messa all'Indice del Newtonianismo per le dame di Francesco Algarotti," in *Scienza e letteratura nella cultura italiana del Settecento*, ed. R. Cremante and W. Tega (Bologna, 1984). The best description of the opposition appears to be that of Algarotti's correspondent Eustachio Manfredi, who cites the work's excessive "liberty" and use of

"French expressions" (Algarotti, *Opere inedite*, Venice, 1796, volume I, p. 139, letter dated August 11, 1738).

20. Epistolario di Angelo Calogerà, Soltykov Library, Leningrad, consulted in microfilmothèque of Fondazione Giorgio Cini in Venice (volume 29, dated December 5, 1727, c. 10).

21. Zaccaria makes fun of them on this account in *SLI* 2 (1751), p. 151.

22. [Giovanni Lami], *I pifferi di montagna, che andarono per suonare e furono suonati* (Leyden [but Florence]: 1738], p. 7. For a translation see Eric Cochrane, *Florence in the Forgotten Centuries*, pp. 385–386.

23. Bernardo Tanucci, *Epistolario*, volume 3, ed. A. Migliorini (Rome: Edizioni di storia e letteratura, 1982), p. 79, letter dated April 24, 1753.

24. This point is clarified in a note on pp. 316–317 of *Saggio critico della corrente letteratura straniera antica e moderna* 2, pt. 2 (1758): "Ora è da avvertire che incominciando dal tomo IX l'opera [*Storia letteraria d'Italia*] è di due altri autori, cioè, del p. Domenico Troili e del p. Gioacchino Gabardi. Il primo lavora i capi che alla filosofia, alle matematiche e alla medicina appartengono (benchè nel tomo IX il numero 7 del capo V del primo libro sino alla fine del capo sia d'altra mano, cioè del primario autore di quest'opera); l'altro i capi delle lingue, della poesia, dell'eloquenza e qualche altro, come nel t. IX il capo IX e nel t. X il capo della Storia profana. Tutti gli altri capi sono del primario autore; il che si avverte acciocchè ognuno sappia cui debba gli estratti delle sue opere. Per altro anche nel t. VIII il p. Troili ebbe qualche mano, e più negli altri ebbela il dottor p. Lionardo Ximenes, del quale benchè non tutti, son tuttavia parecchi estratti o di filosofia o di matematica, e quello massimamente pel quale i pp. Frisio e Bina han fatto tanto rumore." The account seems exact, as Zaccaria forewarned readers about the advent of a collaborative work already in the preface to *SLI* 5 (1754): "Non è da temere, che il diverso stile ostacolo sia ad aver nell'avvenire, quando che sia, compagni all'opera." Federico Sanvitale is mentioned as one of the "correspondents" in *SLI* 2 (1751), p. xii.

25. Information on Ximenes is from the following: Luigi Palcani, "Elogio di Leonardo Ximenes," in *Le prose italiane di Luigi Palcani* (Milan, 1817); Luigi Brenna, "Elogio del signor abate Leonardo Ximenes," *Giornale de' letterati* (Pisa) 64 (1786): 91–141; Sommervogel, *Bibliothèque de la Compagnie de Jesus*, volume VII, pp. 1341–1357. On where his path crossed Boscovich's, see Gino Arrighi, "Quarantaquattro lettere inedite di G. De la Lande, Ruggiero Giuseppe Boscovich, e Leonardo Ximenes," *La provincia di Lucca* 5 (1965); Germano *Paoli, Ruggiero Giuseppe Boscovich nella scienza e nella storia del Settecento* (Rome, 1988), chapters 7 and 31. On Borgondio, see Paolo Casini, "Orazio Borgondio," in *Dizionario biografico degli italiani* [hereafter *DBI*] 12 (1970), p. 779. Borgondio explained his method in a letter to Antonio Vallisneri in Venice (Biblioteca Nazionale Marciana, cod. it. 148 (=6685), c. 11, January 24, 1716): "L'osservazione e sperienze saranno sempre il fondamento insieme e il contrassegno della vera fisica, appunto come l'osservazioni celesti sono l'appoggio insieme, e l'indizio della sussistenza nei calcoli astronomici."

26. On the Tuscan projects see Danilo Barsanti and Leonardo Rombai, *La "Guerra delle acque" in Toscana: storia delle bonifiche dai Medici alla riforma agraria*

(Florence, 1986), from which I quote p. 14. On the Roman project see Hanns Gross, *Rome in the Age of Enlightenment* (Cambridge, 1990), pp. 172–173. Ximenes's reports were collected in *Raccolta delle perizie ed opuscoli idraulici del Signor Abate Leonardo Ximenes* (Florence, 1785–86).

27. *SLI* 10 (1757), pp. 142–143 (Benvenuti); 2 (1751), pp. 156–159, 3 (1752), p. 262 (Plata); 3 (1752), pp. 268ff.; 6 (1754), p. 130; 8 (1755), p. 69 (Arrighetti); 7 (1755), pp. 131ff.; 8 (1755), p. 46 (Lecchi); 7 (1755), p. 589 (Caraccilo); 8 (1755), p. 476 (Mangini).

28. *SLI* 3 (1752), p. 245; 5 (1754), p. 86.

29. SLI3 (1752), p. 276.

30. *SLI* 6 (1754), p. 136.

31. *SLI* 1 (1750), p. 128.

32. *SLI* 1 (1750), p. 133. In their assessment of the importance of the work, they were at least as enthusiastic as Ivica Martinovic ("Boscovich's 'model of the atom' from 1748," in *Bicentennial Commemoration of Ruggiero Giuseppe Boscovich*, ed. M. Bossi and P. Tucci, Milan, 1988). And they were on the mark as far as Boscovich's later claims were concerned, at least according to Paolo Casini ("Ruggiero Giuseppe Boscovich," *DBI* 13, 1971, pp. 225–226).

33. *SLI* 3 (1752), p. 271.

34. On the Mémoires de Trévoux, see my "From Literary Criticism to Systems Theory in Early Modern Journalism History," *Journal of the History of Ideas* 51 (1990), p. 482.

35. All references to that journal are based on my *Science, Politics and Society in Eighteenth-Century Italy: The "Giornale de' letterati d'Italia" and Its World* (New York, 1991). We have incontrovertible evidence of a circulation of at least 1500 (Venice, Ashb. 1788, no. 256, Zeno to Nicola Saverio Valletta, July 21, 1714, asking for copies of the portrait of Giuseppe Valletta) and reason to believe that it was one of the largest-circulation periodicals of its time.

36. On his early friendships see Scioscioli, *La vita e le opere di Francesco Antonio Zaccaria*, p. 13.

37. For reviews of this work and the other major work of this period, see *Bibliotheca Pistoriensis a Francisco Antonio Zacharia . . . descripta*, Turin, 1752; *Göttingische Anzeigen* (1755), pp. 1368 and 1425. Muratori's text is in *Anecdota, quae ex Ambrosiana bibliothecae codicibus nunc primum eruit* (Milan, 1697–1713), volume II, p. 212ff. Mario Rosa evaluates the productions of these years in "Le 'vaste ed infeconde memorie degli eruditi': momenti della erudizione storica in Italian nella seconda metà del Settecento," in *Erudizione e storiografia nel Veneto di Giambattista Verci*, ed. P. Del Negro (Treviso, 1988), pp. 19–23. Gori included work by Zaccaria in his *Symbolae litterarie* (Florence, 1748–1753), volume IV, pp. 143–175.

38. "Lettera del Padre Francesco Antonio Zaccaria al sig. Lorenzo Covi cavaliere Bresciano sopra gli studi che da lui desidera intrapresi," *Raccolta d'opuscoli scientifici e filologici* 41 (1749), p. 89.

39. Ibid, p. 90: "Crederebbesi mai, che dove nella filosofia, nelle matematiche vantano i loro professori nuove terre per così dire discoperte, e nuovi mari, pur non avessimo un tolerabile corso di filosofia ed un pieno e sicuro trattato di matematica, che pressochè in ogni fisica question di qualche conto sperienze dovessimo vedere opposte a sperienze? Che in assai punti pro e contro recarsi dimostrazioni matematiche a gran meraviglia di chi penetra la forza e l'uso di questo termine 'dimostrazione' in fatto di matematica?" Compare *Storia* 8 (1755), p. 59.

40. *SLI* 3 (1752), p. 211.

41. Ibid., p. 223.

42. For details on specific journals I relied to some extent on the following: Ricuperati, "Giornali nell'Italia dell"ancien regime'"; Ricuperati, "Giornali e società nell'Italia delle riforme," in *La stampa italiana dal Cinqecento all'Ottocento*, ed. Castronovo and Tranfaglia; Capucci, Cremante, and Gronda, eds., *La biblioteca periodica.*

43. *SLI* 12 (1758), p. 13.

44. *SLI* 1 (1750), preface: "Saggio consiglio fu senza dubbio quello, che da certo scrittore è stato preso di dare alla fine di ogni anno la storia civile di quell'anno stesso, nella quale i precipui avvenimenti pe' Mercurii e per le pubbliche gazzette di già narratici con ordine e con qualche critica o politica riflessione si contenessero. Ma perchè di ciò, che alla Repubblica delle lettere appartiene, non far similmente?"

45. *Memorie per servire alla storia letteraria* 1 (1753), no. 1, p. 6.

46. *SLI* 1 (1750), p. 114.

47. *SLI* 6 (1754), p. 689.

48. *SLI* 3 (1752), p. 237.

49. Ibid., p. 243.

50. Ibid., p. 242.

51. *SLI* 8 (1755), p. 58.

52. Ibid., pp. 59, 62.

53. *SLI* 1 (1750), p. 113; *SLI* 5 (1754), p. 70: "Non si corruccino i filosofi, se prima di parlare della lor facoltà disccoriamo della matematica. Basti per ogni ragione sapersi, quanto alla buona fisica necessarie sieno le nozioni geometriche, e cento altre cose, le quali dalla sola matematica si possan prendere."

54. *SLI* 3 (1752), p. 258.

55. *SLI* 5 (1754), p. 151: "Se coll'aiuto del fuoco e delle ritorte non venisse a discoprire, quale, e quanta parte di sali, d'olii, d'acidi o d'alcaliche particelle è racchiusa ne' corpi, che a noi in varie maniere adoperati servono di medicina, come mai se ne potrebbono prescrivere le giuste dosi?"

56. *SLI* 6 (1754), p. 166: "Celebre è il detto di Francesco Petrarca, che non pure niente siavi a sperare da' medici, ma sì molto a temere. . . . Ma troppo esagerato è un tal sentimento. Perciocchè è veramente la medicina un arte di congetture, ma tuttavia ha ella i suoi sodi principii, da' quali un uomo d'ingegno e di sapere può utilissime conseguenze trarre a particolari bisogni degli uomini. Sopra ogni altra cosa dee un valoroso medico studiare la natura."

57. *SLI* 7 (1755), p. 128.

58. Ibid., p. 144.

59. *SLI* 3 (1752), p. 205.

60. *SLI* 5 (1754), p. 71. More recently, light has been cast on this quarrel by Thomas L. Hankins ("Eighteenth-Century Attempts to Resolve the *Vis viva* Controversy," *Isis* 56, 1965: 281–297) and by Kathleen Okruhlik ("Ghosts in the World Machine: A Taxonomy of Leibnizian Forces," in *Change and Progress in Modern Science*, ed. Joseph C. Pitt, Boston, 1985).

61. *SLI* 2 (1751), volume II, p. 165.

62. *SLI* 2 (1751), p. 165. The information was from Vianelli's *Nuove scoperte intorno le luci notturne dell'acqua marina spettanti alla naturale storia* (Venice, 1749).

63. *SLI* 7 (1755), p. 200. The work in question was *Lettere del Sig. Raimondo di Sangro Principe di S. Severo di Napoli, sopra alcune scoperte chimiche* (Florence, 1754).

64. *SLI* 8 (1755), 477; 2 (1751), pp. 502–512; 3 (1752), pp. 651–656.

65. *SLI* 6 (1754), pp. 686–694; 2 (1751), p. 512.

66. *SLI* 6 (1754), pp. 684, 670.

67. *SLI* 7 (1755), pp. 584, 589. Crespi's work is not mentioned in the standard study (G. H. Baille, *Watchmakers and Clockmakers of the World*, London, 1963) or in *DBI*. I used information from Ferdinand Berthoud, *Histoire de la mesure du temps* (Paris, 1802), volume I, p. 188. On the equation clock as a technological feat, see David S. Landes, *Revolution in Time* (Cambridge, 1983), p. 123.

68. The comment is Vecchi's (*Correnti religiose*, p. 375).

69. All this appears on p. 58 of Scioscioli, *La vita e le opere di Francesco Antonio Zaccaria*.

70. For Zeno's view, see *SLI* 2 (1751), p. vii. For Maffei's, see Scipione Maffei, *Epistolario*, ed. C. Garibotto (Milan, 1955), volume II, p. 1311: "Sappia che ammiro e lodo con tutti gli amici l'opera sua; e di quanto spetta a me, le rendo distinte grazie. Proseguisca pure, e procuri d'ottenere di non attender ad altro."

71. Infelise, "Gesuiti e giurisdizionalisti," quoting a letter of June 6, 1752, to Father Domenico Turano in Rome: "Il negozio è sicuro. Il libraio alle cui spese sinora si è stampata ha fatto incredibile guadagno, appena bastano le 1200 copie ch'egli ne ha tirate: è passata l'opera oltramonti ed è stata tradotta a Ginevra in franzese. Vuol dire che continuandosi e stampandosi a spese nostre il guadagno è certo."

72. On the role of the Remondini, see Mario Infelise, *L'editoria veneziana nel Settecento* (Milan, 1989), pp. 281–283. Zeno's endorsement is mentioned in the preface to *SLI* 2.

73. *SLI* 5 (1754), p. 113.

74. *SLI* 10 (1757), preface.

75. Ferrone (*Scienza, natura religione*, p. 136n.) discusses *Opere di Galileo Galilei*, ed. Giuseppe Toaldo (Padova, 1744).

76. *SLI* 3 (1752), p. 234. Compare Stillman Drake, *Galileo at Work* (Chicago, 1978), p. 58.

77. *SLI* 7 (1755), p. 46.

78. *SLI* 1 (1750), p. 101: "Qualcuno potrebbe . . . muovergli contro tutti i moderni coltivatori della fisica naturale, o sia della buona filosofia, e non so come volesse passarla, quando questi contro di lui rivolgessero e compassi e macchine pneumatiche, e telescopi, ed altri innumerabili strumenti loro." See also *SLI* 8 (1755), p. 58; 2 (1751), pp. 152–153.

79. *SLI* 6 (1754), p. 100. Castelli's work was *Della misura dell'acque correnti* (1628).

80. *SLI* 1 (1750), p. 122.

81. Ibid., p. 108.

82. *SLI* 8 (1755), p. 72.

83. On Grimaldi's role, see Vincenzo Ferrone, *I profeti dell'Illuminismo. Le metamorfosi della ragione nel tardo Settecento italiano* (Bari, 1989), p. 46. Other material in this paragraph is from the following sources: articles by Marco Ferrari and Paolo Galluzzi in *Scienze, credenze occulte, livelli di cultura* (Florence, 1982), pp. 21–30, 31–62; Marta Cavazza, "Introduzione" and Gabriele Baroncini, "L'Arithmetica realis di Pietro Mengoli," in *La corrispondenza di Pietro Mengoli*, ed. Baroncini and Cavazza (Florence, 1986), pp. 1–22, 155–188; Paolo Galluzzi, "Il dibattito scientifico in Toscana, 1666–86," in *Nicola Stenone e la scienza toscana alla fine del Seicento* (Florence, 1986), pp. 113–130; Galluzzi, "L'Accademia del Cimento: 'gusti' del principe, filosofia e ideologia dell'esperimento," *Quaderni storici* 16 (1981): 789–843; Maurizio Torrini, "Uno scritto sconosciuto di Lionardo di Capua in difesa dell'arte chimica," *Bollettino del Centro di Studi Vichiani* 4 (1974): 126–139; Eugenio Garin, *Dal Rinascimento all'Illuminismo* (Pisa, 1970), pp. 135–144; Walter Bernardi, *Le metafisiche dell'embrione: scienze della vita e filosofia da Malpighi a Spallanzani, 1672–1793* (Florence, 1986), pp. 68–70, 112–119; Paolo Galluzzi, Maurizio Torrini, Ugo Baldini, Elvezia De Angeli, and Luigi Belloni, in *La scuola galileiana*, ed. G. Arrighi (Florence, 1979); Baldini in *Storia d'Italia, Annali 3*, ed. G. Micheli (Turin, 1980).

84. *SLI* 5 (1754), p. 181: "Nell'esaminare le materie mediche gioverà sempre oltremodo lo star lontani dalle ipotesi e l'accostarsi il più che possible sia alla sicurissima via delle sensate e giudiziose sperienze"; *SLI* 1 (1750), pp. 100–101: "il Boerhaave era più valente medico a tavolino che per esperienza di molte cure."

85. *SLI* 2 (1751), p. 132ff. Zaccaria referred to the following work of Morgagni: *Jo: Baptistae Morgagni in A. Cornelium Celsum et Quintum Serenum Samonicum epistolae decem, quarum sex nunc primum prodeunt* (Padua, 1750). Some of the correspondence on which this work was based appeared in Quintus Serenus Sammonicus, *De medicina praecepta saluberrima* (Padua, 1722) and in Aulus Cornelius Celsus, *De medicina libri octo* (Padua, 1722). For detailed discussions of the works, see Dante Nardo, "Scienza e filologia nel primo Settecento padovano. Gli studi classici di Giambattista Morgagni, Giovanni Poleni, Giulio Pontedera e Leone Targa," *Quaderni per la storia dell'Università di Padova* 14 (1981): 1–40.

86. *SLI 5* (1754), p. 27. Compare Francesco Rodolico, "Giovanni Targioni Tozzetti," *Dictionary of Scientific Biography* 8 (1970): 257–258.

87. *SLI* 3 (1752), p. 271: "La dissensione tra Cartesiani e Newtoniani versa solamente in questo, che i primi questa gravità vogliono che sia un effetto del Vortice, ed i secondi vogliono che sia una legge primaria della natura. Ma gli uni e gli altri accordano la gravità."

88. *SLI* 2 (1751), p. 139: "Il sig. Newton fu, che meglio penetrando il meccanismo celeste, dimostrò generalmente che, se un corpo qualunque graviti verso un centro per modo, che tal gravità sia in ragion reciproca duplicata delle distanze, e sia spinto con qualunque velocità, e con qualunque direzione (purchè non passi pel centro delle forze) esso sarà obbligato a descrivere una delle sezioni coniche, cioè, o una elisse o una parabola o un'iperbola, o un cerchio, considerando il cerchio come una sezione del cono. Da questa generalità venne il signor Newton a determinare per una costruzione geometrica la spezie dell'orbita medesima, distinguendo quali sieno que' casi, ne' quali il corpo sarà astretto a descrivere un'elisse, una parabola, un iperbola."

89. *SLI* 5 (1754), p. 82: "I Newtoniani hanno col loro maestro stabilito che il centro delle rivoluzioni de' primarii sia il centro comune di gravità de' primarii e del sole. Ma superando il sole di gran lunga nella sua massa le masse di tutti i pianeti uniti insieme, ne viene, che questo centro comune di gravità non è molto lungi dal sole medesimo. Indi è, che il sole medesimo diviene come un pianeta, il qual si rivolge intorno al centro comune di gravità; e siccome questo centro, che dipende dalle posizioni di tutti i corpi mondani sempre varianti, patisce una gran varietà, così non v'è orbita più irregolare dell'orbita, benchè piccolissima del sole."

90. *SLI* 7 (1755), p. 156.

91. *SLI* 3 (1752), p. 327: "Questo è un modo di ragionar di mercato vecchio. Questi argomenti e dicerie popolari non hanno luogo presso agli uomini dotti. . . . Oggi non vi è filosofo, che colla scorta di una buona e legittima induzione, e con certi raziocini, che in mercato non si vendono, tengono per certa la gravità de' corpi rispettivi di Marte, di Venere, e degli altri Pianeti."

92. *SLI* 2 (1751), p. 37.

93. *SLI* 3 (1752), p. 271. They referred the reader to Boscovich, *De centro Gravitatis Dissertatio* (Rome, 1751).

94. *SLI* 5 (1754), p. 113. On these efforts, see Charles Coulston Gillispie, *Science and Polity in France at the End of the Old Regime* (Princeton, 1980), pp. 112–113.

95. *SLI* 3 (1752), p. 257: "Perchè dunque da' sopraddetti autori con questo metodo non è stato sciolto?" The work in question was *Compendiaria Dissertatio de coloribus . . . pars prima* (Florence, 1749).

96. *SLI* 2 (1751), p. 156. Pemberton's work was translated as *Saggio della filosofia del signor cav. Isaaco Newton* (Venice, 1733; reprinted in 1745).

97. *SLI* 3 (1752), p. 212. The issue is covered in Newton, *Opticks*, book 2, part 3, proposition 8. On the Italian side of the quarrel, see pp. 250–256 of Ferrone, *Scienza natura religione*. On the Transalpine debate, see pp. 78–164 of Henry Guerlac, *Newton on the Continent* (Ithaca, 1981).

98. *SLI* 6 (1754), p. 130: "I Newtoniani ormai non degnansi più di provare, che la luce sia un effluvio da' corpi lucidi mandato fuori; lo suppongono siccome indubitata cosa, e quindi passano a spiegare i curiosi e vari fenomeni della luce. Eppure di grandissimo incomodo è l'esplicare in questa sentenza la successiva, ma oltre ogni credere velocissima, propagazione della luce in spazi sì vasti, e lontani; al che sarebbe necessaria cosa o mettere nel corpo lucido forze maggiori di quelle che sogliono o possono da' corpi cacciare cotali particelle, o nelle trasmesse particelle fingere un affatto incredibile tenuità, per la quale ancora con leggerissimo impeto potessero con tutta celerità a tanto immensi spazi venir mandate." The work in question was Niccolò Arrighetti, *Lucis Theoria* (Siena, 1752).

99. On Hooke's theories and their relation to Newton's, see Patri Jones Pugliese, The Scientific Method and Mechanical Investigations of Robert Hooke, Ph.D dissertation. Harvard University, 1982, pp. 592–617.

100. *SLI* 3 (1752), p. 263. The work in question was *Electricorum effectuum explicatio, quam ex principiis Newtonianis deduxit, novisque experimentis ornavit D. Andreas Bina Mediolanensis* (Padua, 1751).

101. *SLI* 3 (1752), p. 264: "Scorrendo per tanto il fiume della materia elettrica da' pori del corpo elettrico successivamente, la condensazione della medesima accanto all'ostacolo riceverà accrescimento sempre maggiore, e finalmente giungerà a tale, che la superficie dell'atmosfera elettrica confinante coll'ostacolo colla forza propria dell'attrazione venga a poter superare la forza attraente dell'ostacolo, ed anche la sua gravità."

102. Ibid., p. 267.

103. *SLI* 5 (1754), p. 181. The work in question was Pietro Cornacchini, *Lettere fisico-mediche* (Siena, 1751).

104. *SLI* 8 (1755), pp. 70–72.

105. *SLI* 1 (1750), pp. 57–58. On the witch debate, see Venturi, *Settecento riformatore*, pp. 355–410.

106. *SLI* 8 (1755), p. 73: "l trattar degli Enti invisibili appartiene non meno al filosofo, che al teologo, mentre la pneumatica parte della metafisica è destinata a un simile trattato, e che quando in tal materia questi due sono tra di loro discordi, se il teologo produce dottrine dubbie, e il filosofo dottrine manifeste, quest'ultimo è in diritto di pretendere, che il primo debbasi seco lui accordare." Compare Ferrone, *Scienza natura religione*, p. 273.

107. *SLI* 8 (1755), p. 73. On the scientific interests of Benedict XIV, see Gross, *Rome in the Age of Enlightenment*, pp. 239–241.

108. *SLI* 3 (1752), p. 221: "Sino a tanto che fiateremo, viva Dio, non lascerem mai di condannare gli errori che la Chiesa Romana riprova, e d'opporci a chiunque e' sia, e 'n qualunque modo il faccia, il quale cercasse di promuoverli e di ristabilirli." On Ludovico Barbieri, *Nuovo sistema intorno l'anima delle bestie* (Vicenza, n.d.), see *SLI* 3 (1752), pp. 275–278. Genovesi explained his position in *Elementa metaphysicae* (Naples, 1743). For a fine examination of the whole quarrel, see Maria Teresa Marcialis, "Macchinismo e unità dell'essere nella cultura italiana Settecentesca," *Rivista critica di storia della filosofia* 37 (1982): 3–38.

109. *SLI* 3 (1752), p. 209.

110. Scipione Maffei, *Epistolario*, volume II, p. 805, letter to Giovanni Poleni, November 27, 1737, concerning the opinion on colors: "Io per verità la tengo per opinion falsa e bizzarra; e forse sarebbe tenuta tale da molti altri, se l'idolatria odierna al nome di quel filosofo e la passione che abbiamo per tutto ciò ch'è straniero non ci trasportasse."

111. *SLI* 1 (1750), p. 122.

112. Ibid., p. 123: "Quando i fisici si accorderanno e si troveranno tali, allora si potrà oltrepassare a cercar mezzi propri per sollevare in alto corpi dell'aria più pesanti."

113. Ibid., p. 122: "Credendo ciascuno di aver diritto di filosofare su tali sperimenti, forma da se' nuovi sistemi, inventa nuove ipotesi, e involge in maggior oscurità la ricerca de' veri principi."

114. Ibid., p. 122.

115. *SLI* 6 (1754), p. 128: "Furono fatte all'autore alcune obbiezioni. . . . Ma forse le nuove difficoltà che potrannoglisi fare gli serviranno perchè meglio si spieghi e frenando i trasporti del fervido suo ingegno disamini anche con maggior cura le materie, che restangli a trattare."

116. *SLI* 3 (1752), p. 233.

117. One such textbook was Gaetana Agnesi's *Instituzioni analitiche ad uso della gioventù italiana* (1748).

118. *SLI* 6 (1754), p. 109; 9 (1756), p. 51. For an explanation of Maffei's ideas, see Claudio Donati, "Scipione Maffei e la *Scienza chiamata cavalleresca*: saggio sull'ideologia nobiliare al principio del Settecento," *Rivista storica italiana* 90 (1978): 30–71; but see my comments on pp. 29–32 of *Science, Politics and Society*.

119. *SLI* 1(1750), p. 120.

120. *SLI* 12 (1758), p. 15.

121. *SLI* 10 (1757), p. 105: "Non possiamo da grave imprudenza scusar[e], [coloro che] senza intendere i moderni autori, e senza tanto sapere, che possano tenerli, pongansi arditamente a impugnarli." He mentions his lessons with Boscovich on p. 43 of *SLI 9* (1766).

122. *SLI* 10 (1757), p. 126: "Segue egli è vero in molte cose il Newton, e si gloria di seguire un filosofo, a cui molto deve la matematica e la fisica, ma seguelo solo dove conosce, che gagliarde sono le ragioni, da lui addottate. Del rimanente lo abbandona in altre cose, e gli sbagli suoi, benchè piccoli, non dissimula in parecchie delle dissertazioni." In addition, see ibid., p. 116.

123. Ibid., p. 106: "Non possono colla naturale ragione intendersi i misteri della religione, perchè sono alla naturale ragione superiori; ma non saranno meno veri per questo; essendo nella Matematica assai cose evidenti, che assurde possano sembrare a prima vista, onde non è difficile a un Matematico credere i rivelati misteri, benchè non possa giungere a ben capirli, e confermarsi sempre più nella fede." Compare Clavius (William Wallace, *Galileo and His Sources*, Princeton, 1984, p. 139).

124. *SLI 9* (1766), p. 48: "A Locke unitisi altri Moderni Autori, la nostra ignoranza intorno alla essenza de' corpi con questa ragione han confermato, che dopo le moltissime dispute non si è essa ancora trovata. Alcuni Fisici finalmente l'attività della materia, e della gravità a tutti i corpi comune hanno dedotta, e da que' movimenti, che in molte infusioni de' liquidi ha col microscopio osservato il Needham e dall'attrazione Newtoniana . . . Certissima cosa è pertanto, che 'l corpo non ha di sua natura alcun attivo principio, e che il movimento delle minime particelle della materia non nasce da un principio intrinseco." For an examination of Spallanzani's position, see Bernardi, *Le metafisiche dell'embrione*, p. 323. On the theological background of Needham's position, see Renato Mazzoleni and Shirley Roe, *Science against the Unbelievers: The Correspondence of Bonnet and Needham, 1760–1780* (Oxford, 1986), especially pp. 62–76.

125. *SLI 9* (1766), p. 47.

126. *SLI* 12 (1758), p. 1: "Che è che è, eccone una col titolo di filosofia, ora di nuovo metodo, e facile, ora di saggio, ora di che so io, promettitrice quale in un anno, quale in 6 mesi, e taluna anche in 4 mesi di addottorare chi che sia nella lingua latina." Compare the following, from the preface to *Magazzino italiano* 1 (1752): "Noi scriviamo per quelle persone, che distratte da impieghi, o da cure più utili alla società, non possano consacrare, che una piccola parte del tempo alla lettura. Scriviamo per quelli che non hanno potuto darsi alle scienze, che si lamentono di non possederle, e che ne sospirano qualche notizia."

127. *SLI* 1 (1750), p. vi.

128. Quoted by Franco Venturi in "Postilla," *Annali della fondazione Luigi Einaudi* 19 (1985), p. 454. Here I follow the interpretation of Ferrone, *I profeti dell'Illuminismo*, pp. 57–60.

129. "Lo stato presente della letteratura italiana," *Nuovo giornale letterario d'Italia* 1 (1788): 60–64. (This was the beginning of an article that extended over several numbers; for a transcription, see *Giornali veneziani*, ed. Berengo, pp. 618–626.)

130. Gian Vincenzo Patuzzi, Lettere teologico-morali in continuazione della difesa della storia del probabilismo e rigorismo (Trent [Venice], 1751); Giovan Battista Macchi et al., *Lettere di ragguaglio di Rambaldo Norimene al suo dilettissimo amico D. Luigi Bravier intorno ad alcune controversie letterarie suscitatesi in varie città dell'Italia* (Trent [Lugano], 1754).

131. *Novelle letterarie* 12 (1751), pp. 291–297.

132. *Theologia christiana dogmatico-moralis* (Rome, 1751), p. lxi.

133. *Novelle letterarie* 11 (1750), pp. 139, 567.

134. *Appendice al trattato dell'uso del mercurio sempre temerario in medicina in giustificazione di Lorenzo Gaetano Fabbri, lettore di medicina nel gran ospedale di* Firenze (Lucca, 1751), p. 228.

135. *Novelle letterarie* 13 (1752), p. 360.

136. *Supplemento* 1 (1753), p. 225 (magic), p. 251 (lightening); 2 (1754), p. 228 (Sanvitali). For Sanvitali's response, see *Annali letterarie d'Italia* 1 (1762), p. 90.

137. *Epistolario* 3, p. 79, letter to Bottari dated April 24, 1753.

138. Scipione Maffei recorded the incident in a letter to Benedetto Bonelli dated August 5, 1753 (*Epistolario*, volume II, p. 1369): "Il generale de' Gesuiti fu talmente uffiziato alcuni mesi fa da quello de' Dominicani, che proibì al p. Zaccaria di continuar la sua Storia; ma egli si difese e la proibizione svanì." Zaccaria complained about these restrictions (*Difesa della Storia letteraria d'Italia e de suo autore contro le Lettere teologico-morali di certo P. Eusebio Eraniste. . .*, Modena, 1755, p. 114). On the freedom of fellow Jesuits elsewhere, see Antonio Acerbi and Massimo Marcocci, eds., *Ricerche sulla Chiesa di Milano nel Settecento* (Milan, 1988).

139. Rosa, "Pubblicazioni e tribolazioni," p. 40, reported by Ricci in a letter dated July 22, 1758.

140. Rosa, "Pubblicazioni e tribolazioni," p. 38, letter dated July 1, 1758.

141. The exhaustive work on Jesuit conspiracy theories is Alexandre Brou, *Les Jésuites de la Legende* (Paris, 1906).

142. *Lettera d'un cavaliere amico fiorentino al reverendissimo padre Lorenzo Ricci, generale de' Gesuiti esortandolo ad una riforma universale del suo ordine* (Lugano [Venice], 1762), quoted in Franco Venturi, *Settecento riformatore*, volume 2: *La chiesa e la repubblica dentro i loro limiti, 1758–1774* (Turin, 1976), p. 20 (my source for this and the previous paragraph).

143. *Elogio del Cavalieri* (Milan, 1778), pp. 37–38. Pascal explored similar themes in *Lettres Provinciales*, letter 18, which I read in H. F. Stewart's edition (Manchester, 1920), p. 244; La Chalotais explored them in *Compte rendu des Constitutions des Jésuites* (Rennes, 1762), pp. 177–181.

144. On this point, the interpretation of Franco Venturi (*La chiesa e la repubblica dentro i loro limiti, 1758–1774*) agrees with that of Ludwig von Pastor (*The History of the Popes*, London, 1951, volume XXXVIII). For critiques of the positivist account of eighteenth-century science and religion, see Gianvittorio Signorotto, "La devozione settecentesca. Tradizione e mutamento," in *L'editoria del Settecento e i Remondini*, ed. M. Infelise and P. Marini (Bassano, 1992); Ferrone, *I profeti dell'Illuminismo*, passim.

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