Reading Galileo's *Discorsi* in the Early Modern University

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This article examines the scholarly practices with which readers at three universities read select passages from Galileo's 1638 Discorsi, *a work depicted by Galileo as one that eschewed the goals and methods of Aristotelian natural philosophy in favor of the quantitative and experimental ones characteristic of modern science. The article reveals that a group of readers — diverse in terms of institutional affiliation, disciplinary identity, geography, and attitude toward Galileo — approached Galileo's text using the tools of what Ann Blair has termed "bookish" natural philosophy. It argues that, contrary to Galileo's rhetoric, these readers saw old and new methods as interchangeable.*

INTRODUCTION

HISTORIANS AND THEIR historical actors have spilled much ink detailing what it was like to experience the upheavals in early modern science once commonly referred to as the Scientific Revolution. The period's innovators, Galileo Galilei (1564–1642), René Descartes (1596–1650), Francis Bacon (1561–1626), and others, described it as a great struggle, one pitting new methods and insights against the sterile learning and stubbornness of university-trained Aristotelians committed to Scholastic and humanist textual methods. One example to consider is Galileo's criticism of his Jesuit rival Orazio Grassi (1583–1654), addressed by the pseudonym Lotario Sarsi, in his 1623 *Saggiatore*: "I seem to detect in Sarsi the firm belief that in philosophizing one must rely upon the opinions of some famous author. . . . Perhaps he thinks that philosophy is the creation of a man, a book like the *Iliad* or *Orlando Furioso*. . . . Mr. Sarsi, that is not the way it is. Philosophy is written in this all-encompassing book that is constantly open before our eyes, that is the universe. . . . It is written in

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mathematical language."[1] Galileo's criticism in this passage and elsewhere focuses on the methodological differences between his approach to the study of the natural world and that of his opponents. He claims to be describing the world quantitatively and to be relying on sensory experience to verify his speculations. Sarsi, in his view, carries out an exercise in textual exegesis where the veracity of a claim is measured by its agreement with the opinions of established textual authorities.

Galileo's vision, one shared by other period innovators, encouraged their peers and successors to value novelty and reject traditional textual learning. So, too, as historians have argued, did such visions shape the historiography of early modern science.[2] This article seeks a new perspective on contemporaries' evaluations of novelty and tradition by asking how the period's transformations were perceived by the receivers, rather than the generators, of novelty. In a field dominated by histories of the genesis of new ideas, it tackles the question of how to tell the history of early modern science, a question central to historians of science, by employing the methods of historians of reading and reception.[3] In particular, it examines the reading and teaching of Galileo's 1638 *Discorsi e dimostrazione matematiche intorno à due nuove scienze*.

The *Discorsi* was Galileo's final published text, in which he shared key findings on mechanics and local motion. Written as a dialogue in Italian between three interlocutors that takes place over four days, the work is often described as addressing two new sciences. Days 1 and 2 present Galileo's science of materials, focusing specifically on the resistance of bodies to breakage. Days 3 and 4 contain Galileo's science of motion and consist of a discussion in Italian of a Latin treatise written by the "Academician" (Galileo), which contains Galileo's well-known results on local motion, including the fact that all bodies fall at the same speed and that projectiles follow a parabolic path.

The *Discorsi* occupies a privileged position in the historiographical tradition. The text has been considered a key step in the transition from Scholastic Aristotelian natural philosophy to classical physics because of the mathematical, mechanical, and experimental approach to the study of local motion Galileo

[1]Galilei, 1890–1909, 6:232: "Parmi, oltre a ciò, di scorgere nel Sarsi ferma credenza, che nel filosofare sia necessario appoggiarsi all'opinioni di qualche celebre autore . . . e forse stima che la filosofia sia un libro e una fantasia d'un uomo, come l'Iliade e l' Orlando Furioso. . . . Sig. Sarsi, la cosa non istà così. La filosofia è scritta in questo grandissimo libro che continuamente ci sta aperto innanzi a gli occhi (io dico l' universo). . . . Egli è scritto in lingua matematica."

[2]Grafton, 1991, 1–5. For an analysis of varying attitudes toward innovation in the period, see Roux.

[3]It thus builds on several pioneering studies that have married the fields of early modern history of science and the histories of books and their readers. For key examples, see Blair, 1997; Gingerich, 2002 and 2004; Guicciardini; Frasca-Spada and Jardine; Johns. On the need to study the reception of science, see Secord, 660–64; Osler, 6.

advocated in place of Aristotle's causal, descriptive science.[4] Galileo himself portrayed the *Discorsi* in this light. He announces at the start of day 3 that he was "bringing forth a very new science on a very old subject," an allusion to his quantitative approach to the study of motion, a topic central to Aristotelian natural philosophy.[5] In another passage, he explicitly states his intention to set aside Aristotle's question of the causes underlying such motion to concentrate on quantitative description.[6] Scholarship on the *Discorsi* has focused primarily on its genesis. The smaller number of studies dedicated to the text's reception has reinforced its reputation as a key step in the development of modern science by analyzing the reactions of readers interested in the elements of the work associated with the development of classical physics.[7]

This piece questions the received view of Galileo's reception by considering readers of the *Discorsi* thus far overlooked in the Galilean historiography. Specifically, it examines how professors of natural philosophy at the Jesuit Collegio Romano and University of Pisa incorporated aspects of the *Discorsi* in their teaching and note-taking.[8] It compares their responses to annotations made in surviving copies of the *Discorsi* by the Oxford mathematicians and founding members of the Royal Society Seth Ward (1617–89) and Christopher Wren (1632–1723), two readers of the text largely unknown (or overlooked) by

[4]For Koyré, 201, Galileo should be seen as the "father of classical science" for his idea of a mathematical physics, which he put forth in his *Dialogo* and *Discorsi*. For A. Rupert Hall, the *Discorsi* was Galileo's most important work, one whose "induction of fundamental principles . . . henceforth dominate[d] a whole field of science": Hall, 75–76. For a more recent discussion of the importance of the *Discorsi*, consider Dear, 2001, 49–64.

[5]Galilei, 1890–1909, 8:190.

[6]Ibid., 8:202. Note that Galileo did not avoid the question of causes completely, for he discussed the causes of the adherence of bodies in day 1; but the generalization is often made. See, for example, Bertoloni Meli, 2006, 662.

[7]On the development of Galileo's science of motion through studies of his surviving manuscripts, see Drake; Renn, Damerow, and Rieger; Renn. On the role of experiment in shaping Galileo's thought, see Settle, 1961 and 1968; Palmieri. On the conceptual ideas appropriated by and developed by Galileo, see Galluzzi, 1979; Damerow et al. On the cultural context in which Galileo developed his ideas, see, among other works, Valleriani; Camerota and Helbing; Helbing. The most substantial body of scholarship on the reception of the *Discorsi* has focused on debate over the validity of Galileo's findings on motion occasioned by the publication of Pierre Gassendi's 1642 *Epistolae Duae de Motu Impresso a Motore Translato*, which involved, among others, Marin Mersenne, Christiaan Huygens, Pierre Le Cazre, and Honoré Fabri. See Galluzzi, 2001 and 1993; Palmerino, 1999, 2004, and 2003; Elazar. Other scholarship has focused on the reception and extension of Galileo's work by his supporters and followers, a group often designated as the *scuola galileiana*. To cite a few key examples, consider Garber; *Galileo e la Scuola*; Soppelsa.

[8]While one of these professors, Claude Bérigard, is a well-known reader of Galileo, the other readers analyzed in the article are not. On Bérigard, see Favaro, 59–60; Stabile, 1975; Bottin; Ragnisco; Stabile, 1984.

Galileo scholars. This diverse group of contemporary readers approached the text using the methods of traditional textual natural philosophy. Their approach and responses challenge the current narrative of Galileo's reception.

Drawing on recent scholarship, Domenico Bertoloni Meli has argued that readers of Galileo were most interested in the sections of the *Discorsi* that treated Galileo's new science of motion (days 3 and 4). In their responses to these sections, Bertoloni Meli claims, readers followed three main approaches. Some readers, including Galileo's students Evangelista Torricelli (1608–47) and Vincenzo Viviani (1622–1703), concerned themselves with formalizing and extending Galileo's science of motion in imitation of Archimedes's work on the equilibrium of the balance. Another group of readers, which included Gianbattista Baliani (1582–1666) and Marin Mersenne (1588–1648), were not convinced of the validity of Galileo's propositions and questioned his specific empirical claims; they undertook to perform experiments that at times challenged Galileo's statements and results. Finally, a third group of readers expressed doubts about the specific and general philosophical propositions underlying his science of motion. These readers, who included Honoré Fabri (1607–88), Pierre Le Cazre (b. 1589), and Pierre Gassendi (1592–1655), sought to provide a more solid metaphysical underpinning for a science of motion.[9] Other readers, both inside and outside the university, sought to validate, extend, or modify the findings of the *Discorsi*. A number of readers, including François Blondel (1618–86) — architect, engineer, and member of the French Academy of Sciences — and the Pisan professors of mathematics Alessandro Marchetti (1633–1714) and Guido Grandi (1671–1742), debated the correctness of Galileo's findings in day 2 and argued for their priority in correcting and extending his ideas.[10] Others, including Galileo's student Benedetto Castelli (1578–1643) and the Jesuit mathematician Paolo Casati (1617–1707), attempted to apply Galileo's quantitative approach to the study of motion to the subject of hydrostatics.[11]

The analysis that follows reveals that a significant group of period scholars read Galileo's *Discorsi* in ways thus far not recognized in the historiography. They judged the *Discorsi* as contiguous with, rather than in opposition to, traditional natural philosophy. It may be tempting to dismiss their reactions as anomalous, yet this diverse group includes individuals of Italian, English, Irish, and French origins. They comprise Catholic natural philosophers at the Collegio Romano and the University of Pisa, and Protestant mathematicians at the University of Oxford who made important contributions to the development of the New Science and were members of the Royal Society. That such a diverse group, some supportive of Galileo, others critical or indifferent, approached the *Discorsi* using similar traditional methods suggests that Galileo's readers, on the

[9]Bertoloni Meli, 2006, 651–53.

[10]Benvenuto, 1:235–61.

[11]Fiocca; Gavagna, 2002 and 2011.

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whole, may have employed comparable reading practices and seen the *Discorsi* as less of a break with past scholarship than the current historiography implies.

Some recent historians of early modern scholarly methods have argued for the continuing relevance of traditional methods of scholarship into the seventeenth and even eighteenth century.[12] This article suggests that traditional methods continued to exist alongside and shape the direction of new methods and scholarly production. Moreover, the reading, reception, and appropriation of new methods and conclusions were themselves dependent on older forms of scholarship. In this discussion, the term *traditional scholarship* will signify an approach to natural philosophy shaped by Scholastic and humanist practices. It builds specifically on the notion of a "bookish" natural philosophy that Ann Blair has ascribed to Renaissance natural philosophy before the Scientific Revolution.[13] According to Blair, Renaissance natural philosophy melded Scholastic and humanist practices in an enterprise that consisted largely of textual criticism. It was an exercise in exegesis that involved the extraction and reusing of material from texts. Its goal was not the discovery of new knowledge but the systematization of an existing body of scholarship, whose parameters were set by the writings of Aristotle and his commentators. Its activities were directed at defining, describing, dividing, ordering, and causally explaining this body of knowledge. In keeping with the Scholastic tradition, the method of determining the truth was the same as the method of discovering it. Both proceeded by means of the quaestio, in which set questions were raised in connection with a given section of Aristotle's writings and then resolved in reference to the writings of Aristotle and his commentators.

The textual tools and output produced within this tradition included not only the commentaries and Scholastic pedagogical treatises of quaestiones, but also new genres encouraged by humanist pedagogues. Of particular importance to the reading and writing of natural philosophy was the commonplace book, a method of keeping notes encouraged by Desiderius Erasmus, Rodolphus Agricola, and Philip Melanchthon, among others, which drew on ancient and medieval antecedents. Students were instructed to keep notebooks in which they recorded passages from their reading under appropriate headings (commonplaces) for later retrieval and use, notably in their own compositions.[14] While this humanist practice is best known for its application to classical and moral subjects, recent scholars have drawn attention to its role in the realm of natural learning through the seventeenth century. Through her study of Jean Bodin's 1596 *Universae Naturae Theatrum*, Blair has argued that natural-philosophical writers in the sixteenth and early seventeenth

[12]See, for example, Blair, 1992; Grafton, 1991, 5; Yeo, 2004 and 2007.

[13]For an explicit discussion of the bookish nature of this textual enterprise, see Blair, 1997, 49–115; Blair, 1992. On the fusion of Scholastic and humanist methods by the late sixteenth century, see Costello, 14–31; Cochrane, 1055–57; Grendler, 199–248.

[14]Moss, 101–214.

centuries relied on books of natural commonplaces. These natural commonplaces derived from one's reading and even personal experience and were collected according to heads, following the guidelines set forth by earlier humanist educators for the reading of literature, theology, and other subjects.[15] Though the commonplace method was increasingly criticized in the seventeenth century, Richard Yeo has argued for its continuing vitality and its adaptation and transformation, from a tool of memory to one of storage and retrieval; Francis Bacon (1561–1626) and John Locke (1632–1704) were among the authors who relied on and transformed this traditional method.[16] Blair's description of a bookish natural philosophy has enriched the more general terms in which historians of early modern science have compared the textual, exegetical methods associated with Scholastic and humanist approaches with the empirical, quantitative, and mechanical methods of the New Science.[17] The former involved the close reading, note-taking, and commenting on authoritative texts with the goal of explicating them. The latter used experiment and mathematics to describe, predict, and (at times) control what happened in nature.

Reading and writing about a text with pen in hand, of course, is a common feature even of modern reading. What sets Galileo's readers apart from today's readers is that their reading was carried out with the methods, goals, and content of traditional natural philosophy. Some read using the tools of humanist scholarship (e.g., the commonplace book). Others did not necessarily put their notes into commonplace books but paid specific attention to the aspects of Galileo's text that touched on the topics and questions of Aristotelian natural philosophy as taught in the early modern university. These were the same topics and questions that likely would have served as the heads of natural-philosophical commonplace books. Finally, others incorporated Galileo's *Discorsi* into textual productions characteristic of bookish natural philosophy, including teaching texts on Aristotle and pedagogical dialogues.

The analysis that follows considers three separate case studies that reveal how diverse groups of readers approached the *Discorsi* using the tools of traditional natural philosophy. The second section, "Jesuit Natural Philosophers Teach the *Discorsi*: Using New and Old in Tandem," examines how professors of natural philosophy at the Collegio Romano incorporated Galileo's empirical measurement of the heaviness of the air in their commentaries on Aristotle. The next section, "Pisa: A Dialogue between Old and New," discusses Claude

[15]Blair, 1992; Blair, 1997, 65–77.

[16]On specific critiques of the commonplacing method, see Moss, 255–81; Yeo, 2004, 6. On the transformation of the method, see Yeo, 2004, 9; Yeo, 2007, 10–12. On discussions of Bacon that emphasize, to varying degrees, his differences rather than reliance on the method, see Blair, 1992, 550–51; Moss, 268–72.

[17]On the contrast between new and old, see, for example, Dear, 2001, 49–100; Shapin, 65–118.

Bérigard's treatment of the *Discorsi* in successive editions of his *Circulus Pisanus*; through consideration of the reading notes of Lorenzo Bellini, it argues that Bérigard and others saw old and new in dialogue because they relied on traditional note-taking methods, such as commonplacing. The marginal annotations of Oxford mathematicians Seth Ward and Christopher Wren are considered in the fourth section, "Ward and Wren: Textual Scholarship in the Service of the New Science." These annotations reveal that Ward and Wren annotated the *Discorsi* with many of the same concerns and methods as did their counterparts who taught natural philosophy in Italian universities. Finally, the conclusion demonstrates how these findings of Galileo's readers might reshape current understanding of the *Discorsi*, its period reception, and Galileo himself.

JESUIT NATURAL PHILOSOPHERS TEACH THE *DISCORSI*: USING NEW AND OLD IN TANDEM

Founded in 1551 by Ignatius Loyola (1491–1556), by the seventeenth century the Collegio Romano stood at the center of a vast international network of Jesuit colleges that aimed to provide a rigorous and orthodox education, offered free of charge. The order's high standards of scholarship — as well as its commitment to sound and orthodox teaching — were enforced both through an internal system of censorship and through ordinances promulgated with regularity throughout the period.[18] This case study inquires into the methods with which these readers approached the *Discorsi* and the relation they saw between the text and their own scholarly projects. This focused examination of how three obscure Jesuit professors at the Collegio Romano presented one passage from the *Discorsi* in their natural-philosophical teaching reveals that these professors relied on old and new approaches and conclusions in tandem, using Aristotle and his commentators to evaluate Galileo's findings and vice versa. That is, these professors not only defy Galileo's description of them as traditionalists, but they call into question the very binary categorization Galileo offered of his contemporaries. While these particular professors did not go on to engage more extensively with Galileo's work in subsequent publications, their treatment of the *Discorsi* in their teaching parallels the way other, more prolific Jesuit authors interacted with texts of the New Science in the period.[19]

The passage in question is found in day 1 of the *Discorsi*, in which Galileo describes two procedures for measuring the heaviness of air compared to that of

[18]For an overview of recent scholarship on the Jesuits that focuses on their intellectual and cultural activities, see O'Malley, Bailey, Harris, and Kennedy, 1999 and 2006. On the censorship system, see Hellyer, 1996.

[19]For specific observations on the way other Jesuits relied on old and new in assessing Galileo, see Elazar, xv–xviii; Palmerino, 2003, 214–18.

water. Using these methods, Galileo claimed to have determined that water is about 400-times heavier than air.[20] The responses of the Jesuit readers considered here are similar to those of other Jesuit professors of natural philosophy at the Collegio Romano. In general, these readers focused on specific passages of the *Discorsi* in which Galileo treated a topic central to their own discussions of Aristotle (e.g., the heaviness of the air, rarefaction and condensation, the question of the void), and they discussed Galileo's claims, either rejecting or accepting them on the basis of their reading of Aristotle and his commentators. Most scholarship on the reception of the *Discorsi* has emphasized contemporaries' interest in days 3 and 4, yet Jesuit natural philosophers drew most heavily on passages in day 1. Only a few individuals mentioned Galileo's findings on local motion contained in these later days, and those who did so followed the approach found in their discussions of other passages from the *Discorsi*, folding Galileo's findings into topics and questions standard in early modern commentaries and teaching texts on Aristotle's natural-philosophical writings.[21] Galileo's discussion of the heaviness of the air is thus a suitably representative passage to choose when analyzing the response of Jesuit readers.

Jesuit readers were interested in this passage in the *Discorsi* because the question of the heaviness of the air had a long history in medieval Scholasticism and even antiquity. Galileo, who himself was educated in natural philosophy at the University of Pisa and was a serious student of Aristotle in his younger days, was familiar with this tradition: in fact, he wrote the *Discorsi* with an eye toward it. In his description of his two methods for measuring the heaviness of the air, Galileo references this tradition specifically through the comments of his interlocutor Simplicio, who cites Aristotle's *De caelo* directly, calling attention to Aristotle's example of leather pouches, which are found to be heavier when inflated with air than when they are empty.[22] This example of the inflated pouches, or bags, was commonly cited by Aristotle's ancient, medieval, and early modern commentators. Aristotle's ancient commentator Simplicius (ca. 490–ca. 560) of Cilicia discussed the example at length in his own commentary on Aristotle's *De caelo*, and later medieval commentators, including Peter of

[20]Galilei, 1890–1909, 8:123–24. Today this question would be phrased in terms of a comparison of the densities of water and air or the specific weights of water and air, which depend on pressure and temperature. Galileo's estimate is roughly half of the value accepted today.

[21]For a more detailed discussion of this pattern of response, see Raphael, 2009, 95–164; Raphael, 2011, 487–88. For a discussion of a similar response to elements of the New Science in the writings of another Italian university professor, see Baldini, 2011.

[22]Galilei, 1890–1909, 8:121. The example of the inflated pouches cited by Galileo is found in Aristotle, 60 (book 4 of *De caelo*, 311b.10–11).

Auvergne (d. 1304), drew on Simplicius's treatment in their discussions of the heaviness and lightness of the elements.[23]

The question of the heaviness of air continued to be discussed in detail by later medieval and early modern commentators. In his commentary on book 4 of *De caelo*, for example, Jean Buridan (ca. 1300–after 1385) poses the question, "Whether air is heavy or light in its own region, or whether it is neither heavy nor light." Buridan describes the example of the inflated pouches twice in his discussion, both times as an example of Aristotle's conclusion that air does have heaviness in its region.[24] Because Buridan argues that air does not have heaviness or lightness in its region, he accounts for Aristotle's example of the pouches by appealing to the commentary of Ibn Rushd (Averroës, 1126–98), who had argued that the air in the inflated pouches was heavier only because it was more condensed than the outside air.[25] Albert of Saxony (ca. 1316–90) offered a similar presentation of the question and example as did Buridan. He discusses the pouches in a quaestio on *De caelo* entitled, "Whether some element in its place is heavy." He cites the example as evidence of air's heaviness in its own region but dismissed the evidence, as had Buridan, by appealing to the explanation that its apparent heaviness is only due to its being condensed and compressed within the pouch.[26]

In the commentary on *De caelo* produced by the Jesuits at Coimbra — published in multiple editions and often cited in textbooks and teaching notes of professors at the Collegio Romano — the example of the pouches was also singled out for discussion. The Coimbra commentary consisted of Aristotle's Greek text alongside a Latin translation, followed by an explanation and various quaestiones pertinent to the passage in question. The commentary on *De caelo* was, in turn, followed by a treatise on various problems relating to the four elements. The second of the problems relating to the element air elaborated on the difficulties posed by the pouches. It asks the question, "If pouches filled with wet air are heavier than empty ones, as we admitted above; why do those float on water, [while] the others sink?"[27] The commentators respond to their question by ignoring the behavior of the empty pouches and arguing that the lightness of the air contained within the pouches filled with the "aqueous water" made the said filled pouches lighter than water, especially given the tendency of the light air to impel itself above water.[28]

[23]Galle, 113, 257–60. For Simplicius's discussion, see Simplicius of Cilicia, 710–11.

[24]Buridan, 265, 268.

[25]Ibid., 268.

[26]Albert of Saxony, 464, 469.

[27]*Commentariorum Collegii Conimbricensis*, 542.

[28]Ibid., 542–43.

Jesuit readers who encountered this passage in Galileo's *Discorsi* thus undoubtedly were drawn to it by Galileo's own explicit references to this textual tradition, one that would have been familiar to them as expositors of Aristotle's works on natural philosophy. But aspects of Galileo's description also would have seemed unusual in this context, for Galileo appeared to provide specific details of an actual procedure and a quantitative result obtained by it. The question to consider here is how these readers negotiated these different claims to knowledge, both the textual claims (of Aristotle, his commentators, and even Galileo himself) and Galileo's more experimental, hands-on, quantitative claim that provided a measure of the air's heaviness.

In the earliest surviving records of teaching on the subject at the Collegio Romano, Galileo's measurement was evaluated using textual methods but not afforded demonstrative weight in traditional proofs. That is, Jesuit readers discussed Galileo's measurement in their Aristotelian commentaries, but they did not include it as part of their proof or demonstration of the air's heaviness. The lecture notes of Silvestro Mauro (1619–87), shepherded into print in 1658 by one of his students under the title *Quaestionum Philosophicarum . . . Libri Tres*, serve as an example of such a response. Born in Spoleto, Mauro had studied philosophy and theology at the Collegio Romano from 1639 to 1648.[29] After teaching first at the Jesuit school at Macerata and then at the Collegio Germanico in Rome, Mauro was appointed a professor at the Collegio Romano, where he taught theology, ethics, and sacred scripture in addition to the three-year philosophy sequence, comprising logic, natural philosophy, and metaphysics.[30] Mauro remained at the Collegio Romano until his death in 1687, serving both as prefect (1682–84) and then rector (1684–87). In addition to his *Quaestionum Philosophicarum . . . Libri Tres*, Mauro also published a six-volume paraphrase of Aristotle's writings (*Aristotelis Opera Quae Extant Omnia*, 1668) and a three-volume theology course (*Opus Theologicum*, 1687). In his *Quaestionum Philosophicarum . . . Libri Tres*, Mauro argues that while fire had the quality of lightness, it was probable that other elements, including air, did not have positive lightness.[31] He then offers a variety of proofs based on Aristotle's writings and experiences commonly cited by Aristotle and his commentators to establish that air was positively heavy.

[29]Zanfredini.

[30]Information on positions held at the Collegio Romano for Mauro and other professors is taken from Garcìa Villoslada, 321–36.

[31]Mauro, 3:404: "It is probable that other elements, even air, and similarly mixtures, in which fire does not predominate, do not have positive lightness, but only less heaviness" ("Probabile est alia elementa, etiam aerem, & similiter mista, in quibus non prædominatur ignis, non habere positiuam leuitatem, sed solum gravitatem minorem").

An examination of Mauro's word choice reveals his conception that his argument — the heaviness of the air — is proved via an appeal to generalized experience, textual authority, and logical argument. According to Mauro, it is proved that air has positive heaviness, "because leather bags, as Aristotle remarks in Book 4 of *De Caelo*, text 30, weigh more inflated than when they are not inflated; therefore the enclosed air in the leather bags adds weight; therefore it is weighty and heavy." While "Adversaries can respond that our air is heavy, because it is vaporous and contains many aqueous parts," Mauro asserts that "we find by experience that our air adds heaviness," and "since other experiences agree, and since we are not able to acquire any experience of that pure air, we ought to say that air is absolutely heavy, even if it is light with respect to earth and to water."[32] In this passage, Mauro proves his assertion of the air's heaviness by reference to textual authority (Aristotle's *De caelo*) and appeals to general experience, notably the example of the leather pouches cited by Aristotle and many of his commentators. No reference is made to a specific experimental procedure, nor, aside from Aristotle's, is a specific experience mentioned. It is Aristotle's text, affirmed by Mauro's and others' "experiences," that allowed Mauro to claim that the second part of his conclusion (the air's heaviness) was proven.

Following his demonstration of air's positive heaviness, however, Mauro departs from this purely textual debate. Moving beyond the examples and textual proofs that characterized his discussion thus far, Mauro follows his demonstration with a reference to Galileo's procedure, noting that, "At this point, indeed, we may add a means, [derived] from Galileo for weighing the air and for testing what proportion the heaviness of air has to the heaviness of water of the same volume. Take a shallow dish made of glass with a very narrow mouth, and a continuous shell or outer covering."[33] Mauro goes on to describe a procedure that closely resembled that which Galileo had included in his *Discorsi*. He closes his description of the procedure by noting that, "By this calculation, Galileo held that he discovered that air weighs around four hundred parts less than does water of equal quantity."[34]

[32]Ibid., 3:406–07: "quia utres inflati, ut etiam advertit Aristoteles 4. de Cœlo text. 30. magis ponderant, quam non inflati; ergo aer inclusus in utribus addit pondus; ergo est ponderosus & gravis. Et licet adversarij respondeant aerem nostrum esse gravem, quia est vaporosus, & continet plures partes aqueas, tamen cum nos experiamur nostrum aerem addere pondus; cum consonent aliæ experientiæ; & cum de aere illo puro sumere non possimus ullum experímentum debemus dicere aerem esse absolute gravem, licet respectu terræ, & aquæ est levis."

[33]Ibid., 3:407: "Hic vero libet ex Galilaeo apponere modum ponderandi aerem, & explorandi, quam proportionem habeat pondus aeris ad pondus aquæ aequalis in mole. Sumatur phiala vitrea oris angustissimi, & corio contexti."

[34]Ibid. "Hac ratione restatur Galilæus se deprehendisse aerem ponderare quadringentis circiter partibus minus, quam ponderet aqua molis æqualis."

Mauro's text reveals that he was careful to assign little epistemic value to Galileo's experiment. While Mauro agreed with Galileo that the air was heavy, he did not incorporate Galileo's measurement in his proof of its heaviness. Rather, Mauro completed the demonstration by relying on a logical proof filled with textual references and universal experiences commonly reported in other texts. In Mauro's commentary, then, Galileo's measurement was merely an addendum to his argument that air was heavy and not light. As the report of an experiment, the procedure was an interesting aside, not suitable for inclusion in a demonstration undergirded by textual evidence. Mauro's reliance on the Aristotelian-Scholastic commentary tradition to formulate his proof of the air's heaviness reveals that, for him, traditional textual arguments continued to serve as the foundation for natural-philosophical demonstration. Mauro clearly considered Galileo's experimental procedure to be epistemologically inferior to that of Aristotle and his commentators. This impression is supported further by the asymmetry underlying Mauro's proof and presentation of Galileo's result. In the course of his proof, Mauro responds to the potential objection against Aristotle's example of the heavy leather pouches filled with air: the pouches are heavy not because air is heavy, but because they are filled with a mixture of pure air and earthly vapors. Though this argument was easily applicable to Galileo's procedure, Mauro did not address the relationship between them. Galileo's reported experience and the generalized experience and logical arguments of textual authorities remained separate in Mauro's account.

In subsequent decades, professors began to integrate Galileo's experimental results more fully into the traditional curriculum. This may indicate increasing acceptance of experimental evidence as part of natural-philosophical demonstration.[35] Alternatively, professors may have been more likely to accept and cite the claims and evidence of authors when they were reported in the texts of others.[36] One indication of such a transformation can be seen in a set of manuscript teaching notes that follow a natural-philosophical course offered in 1660 by Ignatius Tellin (1623–99). Born in Armagh, Tellin joined the Jesuit order in 1642 and taught philosophy, mathematics, and theology in Venice and Rome.[37] Tellin's word choice and sentence structure indicate that he may have developed his course using Mauro's printed textbook as a model.[38] If so, Tellin perhaps never consulted the *Discorsi* directly, but judged Galileo's claims reliable because they were reported by Mauro.

[35]On the difficulties of integrating experimental evidence in natural-philosophical demonstration, see Dear, 1985, 32–62.

[36]For a similar argument, consider Blair's claim that Bodin's use of the commonplace method allowed him to make "a 'matter of fact' out of someone else's evidence": Blair, 1997, 75.

[37]Sommervogel, 7:1920.

[38]Like Mauro, Tellin deemed the opinion that all elements except fire and other mixtures were heavy as "probable." Tellin's initial statement regarding the behavior of these elements and mixtures, as well as the four proofs upon which he relies, were also found in Mauro's text.

Like Mauro, Tellin claims that fire is positively light and that the rest of the elements and mixtures are heavy. However, in place of a demonstration of the air's heaviness, Tellin offers an argument for its probable heaviness. In Tellin's words, "It is probable that they [the other elements and mixtures, aside from fire] do not have positive lightness, but only less heaviness." Tellin then goes on to list evidence in support of his assertion. For one, he notes that "bodies never rise above those heavier in species unless when an impetus is impressed on them by a heavier one forcing them out."[39] As an illustration of this principle, Tellin points to another instance of generalized experience reported in Aristotle's *De caelo*, namely the behavior of a pouch filled with air and submerged in water. According to Aristotle, such a pouch will attempt to ascend, but when the water is frozen, the pouch is forced to remain under the frozen water unless it manages to break the ice. Such a scenario, argues Tellin, is analogous to the behavior of air trapped in stones and metals, which would also be inclined to ascend. Tellin claims that more evidence supported his contention of the air's heaviness. He first points to the same example noted by Mauro and derived from Aristotle's *De caelo* of the inflated leather pouches. The increased heaviness of the pouches when inflated "is evidence . . . that simple, unmixed air is heavy and weighty." Such behavior is analogous to Galileo's recognition "that the heaviness of water to the heaviness of air is in the proportion of 400 to 1."

Though Tellin reached the same conclusion as Mauro, the role he assigned to Galileo's measurement was very different. For one, he included Galileo's procedure as evidence in support of his claim of the air's heaviness, unlike Mauro, who had relegated Galileo's measurement to the status of an addendum. In addition, Tellin's word choice suggests that he judged Galileo's recently reported measurement to be on equal footing with the textual examples drawn from Aristotle. Tellin divides the four examples described above into pairs, which he connects by the Latin words "his accredit" ("to these it is added"). He then equates the two members of each pair by the Latin words "sicut" ("just as" or "in

[39]Archivio Storico della Pontificia Università Gregoriana (hereafter APUG), Fondo Curia (hereafter FC) 1344, 162. The following is the passage in its entirety: "7th proposition, with regards to the other elements and mixtures, it is probable that they do not have positive lightness, but only less heaviness. This is clear from the fact that a body never rises above another heavier in species unless when an impetus is impressed on [it] by a heavier one forcing [it] out. This indeed is evident from Book 4 of *De caelo*, t. 39, for when a pouch inflated with air is submerged in water, it tries to ascend with a great impetus. If that water in which it is submerged is frozen, because it is not thrust out, it remains at rest under the heavier water, and it does not have an impetus for ascending. Rather more correctly, the impulse forces and breaks the ice, just as air buried and enclosed in the concavities of stones and metals exercises an impetus for ascending. To [this evidence] it is added that inflated pouches, as is described in Book 4 of *De caelo* t. 30, weigh more than those which are not inflated. Therefore, this is evidence that simple, unmixed air is heavy and weighty, just as Galileo recognized, that the heaviness of water to the heaviness of air is in the proportion of 400 to 1."

the same way as") and "ita ut" ("in the same way as"). That is, the behaviors of the leather pouches noted by Aristotle are equivalent, in Tellin's writing, to the general observation of air trapped in stones and Galileo's specific observation of the heaviness of air compared to water. By thus equating Galileo's measurement to Aristotle's examples, Tellin implies that Galileo's measurement was neither an extraneous example designed merely to illustrate Aristotle's point, nor endowed with a truth status of lesser or greater value than Aristotle's textual examples.

By the end of the seventeenth century, some Jesuit authors began privileging evidence from recent experiments over the textual tradition. This is evidenced in the manuscript teaching notes composed by Giovanni Iacopo Panici (1657–1716), who taught natural philosophy at the Collegio Romano from 1698 to 1701. Born in Macerata, Panici joined the Society of Jesus in 1673. While he spent most of his teaching career at the Collegio Romano, where he served at various times as professor of rhetoric, natural philosophy, and theology, he taught canon law from 1700 to 1705 in Germany.[40] Panici's notes reflect his attention to experiments carried out with inverted tubes of mercury and air pumps, which were themselves inspired by Galileo's claim in the *Discorsi* that water could not be pumped by suction to a height of more than eighteen braccia.[41] Though much of the debate focused on the nature of the apparently void space above the mercury or in the evacuated vessel of the air pump, various authors, including Torricelli, Robert Boyle (1627–91), and the German Jesuit mathematician Kaspar Schott (1608–66), had argued that the behavior of the mercury (which always came to rest at a determined height) could be explained by the weight of atmospheric air.[42] While earlier Jesuit professors, including Mauro, had discussed these experiments in their natural-philosophical teaching, most separated their discussion of the experiments from that of the air's heaviness, treating the former in sections of the curriculum that dealt with Aristotle's *Physics* and the latter in sections of the curriculum dealing with the terrestrial elements.[43] Panici, in contrast, included his discussion of the air's

[40]Sommervogel, 6:166.

[41]On these experiments, see Dear, 1985, 180–209; Hellyer, 2005, 142–58; Shea, 17–127.

[42]On Schott's endorsement of this explanation following that of Otto van Guericke (the inventor of the air pump) and Robert Boyle, see Hellyer 2005, 153–58. On Torricelli's attribution of the behavior to the weight of the air, see Shea, 32–36.

[43]Mauro included Galileo's device to measure the heaviness of the air in a quaestio entitled "Utrum aliquod elementum sit positive leve" ("Whether some element is positively light"): Mauro, 3:400. He discussed the recent experiments with the inverted tubes of mercury in a quaestio entitled "Utrum detur vacuum" ("Whether a void is given"): ibid., 2:414. Tellin's teaching text consists of only the third year of the philosophical sequence. As a result, it does not contain his commentary on Aristotle's *Physics*, so it is unclear whether he described the experiments to his students.

heaviness in the section of the curriculum that dealt with the question of the void.[44]

For the purposes of the present article, however, what is of interest is how Panici presented Galileo's experiment in comparison with his predecessors. Panici begins his discussion of the air's heaviness by declaring that "the heaviness of the air cannot be explained more appropriately than by comparison with the heaviness of other bodies, whose heaviness is perceived by the senses." After asserting his preference for quantitative comparison, he refers directly to contemporary experiments, noting that, "If air therefore would be compared with water through a ratio of heaviness, it will have [the ratio] of one to 500, if we believe Galileo; or if we believe Mersenne, Fabri, and others, of one to 1000."[45]

Like his predecessors, Panici addresses the traditional question of the heaviness of the air, but he does so by beginning not with Aristotle but with recent experimental, quantitative measurements of the heaviness of the air. In Panici's words, the air's heaviness cannot be explained "more appropriately" than by comparing it quantitatively to the heaviness of other bodies, like water. Furthermore, while Panici does cite Aristotle's *De caelo* as confirmation of his supposition that air was, in fact, heavy, he at no point provides a traditional, Scholastic proof of its heaviness.[46] In many ways, Panici seems to have abandoned the bookish tools of traditional natural philosophy and turned to new experimental evidence to answer the long-standing questions derived from the textual tradition.

Yet further examination of Panici's text reveals that elements of the commentary tradition continued to inform his thinking. He follows the bold statement about the air's heaviness with a cautionary note, informing his readers that the quantitative results he previously quoted were not universally applicable. The measurements cited by Galileo, Fabri, and Mersenne, "must be understood of common elementary air; for it cannot be denied that some part of air, on account of mixing with vapors and exhalations, would weigh more, and some [part of air], on account of a lesser mixing, would weigh less."[47] Panici reminds

[44]Panici's discussion is found in a section of his text entitled "De vacuo": APUG, FC 1093, 406v.

[45]Ibid., 412v: "Gravitas aeris non potest commodius explicari quam per comparationem ad gravitatem aliorum corporum, quorum gravitatem per sensum experimur. Si aer igitur comparetur cum aqua in ratione ponderis, se habebit ut unum ad quingenta, si credimus Galilæo, vel si credimus Mersennio, Fabrio, aliisque, ut unum ad mille."

[46]Ibid.: "Aristotle's words on this matter are very clear in Book 4 of *De caelo*, text 29. In its region everything has heaviness, except fire, even air itself whose indication is that an inflated pouch weighs more than an empty one."

[47]Ibid., 413r: "Hoc tamen intelligendum de communi aere elementari; nam negari non potest, quod aliqua pars aeris propter maiorem permixtionem cum vaporibus, et exhalationibus, magis ponderet: aliqua propter minorem permixtionem ponderet minus."

readers that the air around them mixes with vapors and exhalations and, on account of this mixing, sometimes weighs more or less. This draws directly from the commentary tradition, in particular the objections posed in previous texts to the commonplace example of the inflated leather pouch. As Mauro had noted, the greater heaviness of the inflated leather pouch over an empty one could be explained by the mixing of heavy vapors with pure air. While pure air (according to this interpretation) was light, this mixing made it seem heavy. Panici draws on this interpretive tradition, not to discount the heaviness of the air, but to qualify the experimental results he reported. That is, he relies on the textual commentary apparatus of traditional natural philosophy to qualify and comment upon the experimental results of the New Science. In Panici's text, elements of the New Science and the Aristotelian tradition come together in a new way. Unlike in previous teaching texts, the New Science together with the commentary tradition forms the evidence for Panici's conclusion regarding the heaviness of the air.

The response of these readers to Galileo's measurement evinces a general pattern that suggests the increasing importance of a Galilean style of evidence being employed to answer traditional questions established by Aristotle and his commentators. This pattern, however, cannot — and indeed should not — be distilled into a simple narrative of a triumph or adoption of the New Science in the Collegio Romano. Instead, the most important conclusion to be drawn from it is that this process of transformation first and foremost involved a process of appropriation and integration by which new claims and methods were folded into traditional styles of scholarship by means of traditional, bookish methods. Professors were comfortable with and receptive to taking part in this mixing of old and new, even if they were not always in agreement on how it should be done. Some used the old to evaluate the new, others the new to evaluate the old; in other texts, the old and new pointed separately to the same conclusion. The teaching texts of these three readers suggest that — in contrast to Galileo's own rhetoric — his readers did not view old and new methods and conclusions as opposing and mutually contradictory, but as interchangeable tools applicable to their own scholarly projects, namely an exposition of Aristotle.

PISA: A DIALOGUE BETWEEN OLD AND NEW

A similar attitude toward old and new styles of scholarship is evidenced in the publications and notes of two professors at the University of Pisa. While scholars have varied in their portrayals of Pisa, on the whole they depict the Tuscan university as offering a different intellectual atmosphere and attitude toward Galileo (and other novel currents in scholarship) than Jesuit institutions. Some have argued for the declining intellectual rigor and reputation of traditional universities like Pisa in favor of newer institutions, like the Jesuit colleges. Others have pointed to the close association between the university and Galileo's students and followers in Tuscany during the period, claiming that these individuals promoted a new Galilean-style science within and outside the university. Others have highlighted the conflict-ridden nature of the intellectual community at Pisa, one divided between conservatives eager to maintain the status quo and those who embraced Galilean and atomistic doctrine.[48] Such depictions reveal the intellectual and cultural context in which Galileo's *Discorsi* was read, and highlight differences between the university and the Collegio Romano. This article avoids classing readers according to Galileo's categories of innovator versus traditionalist. Instead, the analysis presented here focuses on the relationship that two professors at Pisa saw between old and new approaches by examining, on the one hand, two editions of a published exposition of Aristotle's doctrine, and, on the other, a set of surviving reading notes.

In 1643, the French scholar Claude Bérigard (ca. 1590–1663) published a text entitled *Circulus Pisanus*. It was written as a dialogue between two interlocutors, one of whom was intended to represent Aristotle's views and the other those of Aristotle's ancient opponents rolled into one. Bérigard's text, which clearly appealed to humanist aspirations to recover and revive the works of ancient writers, was intended as a tribute to his teaching at Pisa. Its title alludes to the practice of circular disputations, a type of informal disputation required by Pisan university statutes, in which students and professors seated in a circle debate the material recently presented in lecture.[49] Bérigard had studied natural philosophy and medicine in Aix before being summoned to the Tuscan court in 1626 to serve as a secretary to the Grand Duchess Christina. The following year, at the urging of Christina's confessor, Bérigard was appointed an extraordinary professor of natural philosophy, and subsequently assigned to the post of ordinary professor, a position he held until 1639 when he moved to Padua.[50] A post at the prestigious University of Padua was clearly a move up for Bérigard, but part of his desire to leave Pisa may have arisen from more personal reasons. In 1632, he had penned the first published critique of Galileo's 1632 *Dialogo*.

[48]For examples of these views, see Grendler, 477–83; Gomez Lopez, 1997, 14–19, 234–35; Gomez Lopez, 2011, 232; Galluzzi, 1995, 1318–19. With the exception of Grendler, these scholars have avoided direct comparisons with Jesuit institutions. The comparison articulated in the present article derives from these scholars' depictions of avowed followers of Galileo and open conflict between those who embraced novel doctrine and those who did not, in comparison with the Jesuits' desire to maintain (outward) uniformity of doctrine. See, for example, Baldini, 1992, 19–119.

[49]On these mandated disputations, see Marrara, 616–17. For descriptions of them at Pisa, see Spagnesi, 222–25; Mango Tomei, 61; Verde, 117. On circular disputations in Italian universities more generally, see Grendler, 156. On their origins, see Maierù, 64.

[50]On Bérigard, see Favaro, 59–60; Stabile, 1975; Bottin; Ragnisco; Stabile, 1984.

While Bérigard may have written at the instigation of the Medici to diffuse a tense political situation between Florence and Rome, his text permanently soured his relations with the Tuscan intellectual community, many of whom remained ardent supporters of Galileo.[51]

Like professors at the Collegio Romano, Bérigard integrated sections of Galileo's *Discorsi* in his *Circulus* where they complemented his discussion of Aristotle's writings on natural philosophy. One such passage is found in his presentation of the question, standard in university classroom teaching and derived from Aristotle's *Physics*, as to whether it is possible for a void to be found in nature. In the 1643 edition of his text, an image accompanied Bérigard's text (fig. 1). Bérigard gave no source for his image, but claimed it had been proposed by "younger writers" as evidence for the existence of a void. These writers argued that a void could be created in nature if a glass vessel, denoted by the letters A and B, was filled with water. The void would be made in the space indicated by BA when the cover, designated by C, was dragged open by force.[52] In the subsequent discussion, Bérigard's interlocutors discuss the merits of this proposed experiment. To improve the experiment, they propose adding a heavy weight, shown by the letter D in the diagram, to force the cover to remain extended. While they agree that such an experiment would provide the opportunity to test the void, they conclude, in agreement with Aristotle, that a void can never be found in nature. If the experiment were really carried out, they argue, thin bodies would enter through the pores of the contraption, filling the supposed void space with matter.[53]

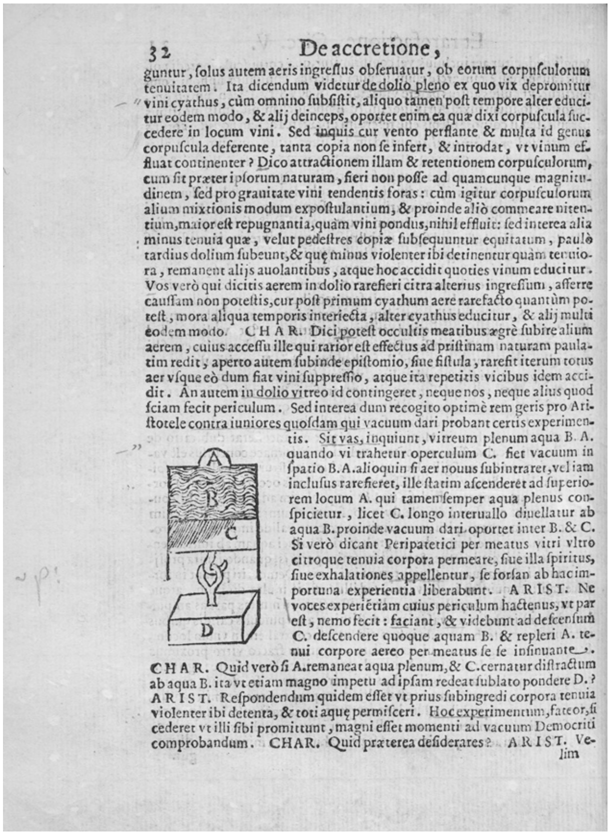
Though no source is cited for this image, this argument made by "younger writers" was almost certainly taken from day 1 of Galileo's *Discorsi*. In day 1, Galileo describes a very similar device. The set-up of the device was exactly the same (fig. 2). Here a cylinder is first filled with water, closed up, and turned upside down. Weights are added to the bucket until the inner cylinder separated from the water above it. Galileo, however, intended the device as a way of measuring quantitatively nature's abhorrence of the void, not as a means (necessarily) to create one.

Through the characters in his dialogue, Bérigard effectively put this section of the *Discorsi* into conversation with Aristotle and his ancient interlocutors. Bérigard's intellectual project was an exposition of Aristotle, an exercise that had

[51]Stabile, 1984.

[52]Bérigard, 1643, 4:32. Bérigard illustrated and described this device and its proposal to measure the force of the void both in his commentary on Aristotle's *Physics* (in a section on the void) and in his commentary on Aristotle's *On generation* (in a section on rarefaction). His description and treatment of the example are common in both sections. The quotation included in the text comes from the latter part (with subtitle "In Aristotelis lib. de ortu & interitu").

[53]Berigard, 1643, 4:32–33.



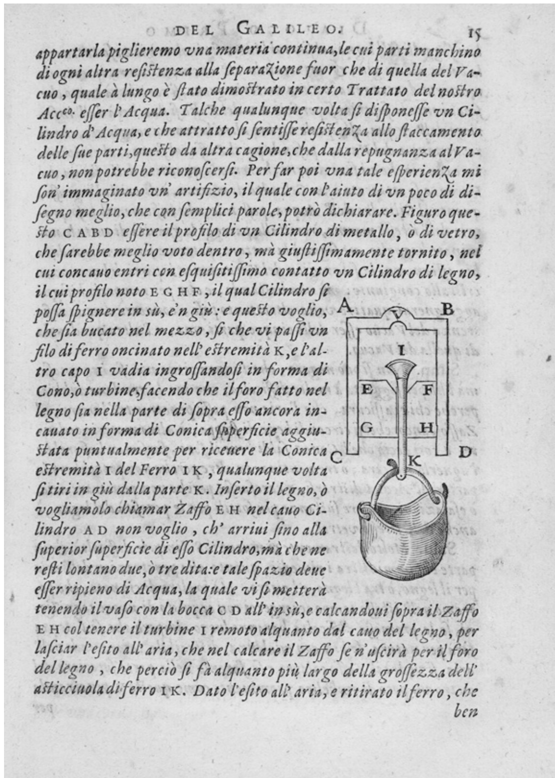
32 De accretione,

guntur, ſolus autem aeris ingreſſus obſeruatur, ob eorum corpuſculorum tenuitatem. Ita dicendum videtur de dolio pleno ex quo vix depromitur vini cyathus, cùm omnino ſubſiſtit, aliquo tamen poſt tempore alter educitur eodem modo, & alij deinceps, oportet enim ea quæ dixi corpuſcula ſuccedere in locum vini. Sed inquis cur vento perflante & multa id genus corpuſcula deferente, tanta copia non ſe infert, & introdat, vt vinum effluat continenter? Dico attractionem illam & retentionem corpuſculorum, cum ſit præter ipſorum naturam, fieri non poſſe ad quamcunque magnitudinem, ſed pro grauitate vini tendentis foras: cùm igitur corpuſculorum alium mixtionis modum expoſtulantium, & proinde aliò commeare nitentium, maior eſt repugnantia, quàm vini pondus, nihil effluit: ſed interea alia minus tenuia quæ, velut pedeſtres copiæ ſubſequuntur equitatum, paulò tardius dolium ſubeunt, & quę minus violenter ibi detinentur quàm tenuiora, remanent alijs auolantibus, atque hoc accidit quoties vinum educitur. Vos verò qui dicitis aerem in dolio rarefieri citra alterius ingreſſum, afferre cauſſam non poteſtis, cur poſt primum cyathum aere rarefacto quantùm poteſt, mora aliqua temporis interiecta, alter cyathus educitur, & alij multi eodem modo. CHAR. Dici poteſt occultis meatibus ægrè ſubire alium aerem, cuius acceſſu ille qui rarior eſt effectus ad priſtinam naturam paulatim redit, aperto autem ſubinde epiſtomio, ſiue fiſtula, rarefit iterum totus aer vſque eò dum fiat vini ſuppreſſio, atque ita repetitis vicibus idem accidit. An autem in dolio vitreo id contingeret, neque nos, neque alius quod ſciam fecit periculum. Sed interea dum recogito optimè rem geris pro Ariſtotele contra iuniores quoſdam qui vacuum dari probant certis experimentis. Sit vas, inquiunt, vitreum plenum aqua B. A. quando vi trahetur operculum C. fiet vacuum in ſpatio B. A. alioquin ſi aer nouus ſubintraret, vel iam incluſus rarefieret, ille ſtatim aſcenderet ad ſuperiorem locum A. qui tamen ſemper aqua plenus conſpicietur, licet C. longo interuallo diuellatur ab aqua B. proinde vacuum dari oportet inter B. & C. Si verò dicant Peripatetici per meatus vitri vltro citroque tenuia corpora permeare, ſiue illa ſpiritus, ſiue exhalationes appellentur, ſe forſan ab hac importuna experientia liberabunt. ARIST. Ne voces experiētiam cuius periculum hactenus, vt par eſt, nemo fecit: faciant, & videbunt ad deſcenſum C. deſcendere quoque aquam B. & repleri A. tenui corpore aereo per meatus ſe ſe inſinuante. CHAR. Quid verò ſi A. remaneat aqua plenum, & C. cernatur diſtractum ab aqua B. ita vt etiam magno impetu ad ipſam redeat ſublato pondere D.? ARIST. Reſpondendum quidem eſſet vt prius ſubingredi corpora tenuia violenter ibi detenta, & toti aquę permiſceri. Hoc experimentum, fateor, ſi cederet vt illi ſibi promittunt, magni eſſet momenti ad vacuum Democriti comprobandum. CHAR. Quid præterea deſiderares? ARIST. Velim

Figure 1. Bérigard's device for creating a void. "In Aristotelis lib. de ortu & interitu" in *Circulus Pisanus*, 1643, page 32. Image courtesy of the University of Glasgow Library, shelfmark: Sp Coll Veitch Eg6-d.15.

long involved the juxtaposition of Aristotle's and contrary opinions, and the subsequent resolution of the resulting contradictions. Despite Galileo having dismissed the aims and methods of this style of natural philosophy, Berigard saw this section of Galileo's *Discorsi* as relevant to this enterprise, an example to be folded in and analyzed because it touched on the very Aristotelian topic of the void.

This point is made more forcefully through examination of the changes made to this passage in the second edition of the *Circulus*. In the 1661 edition, Bérigard excised the diagram and its description and inserted in its place the claim that "the same must be said of the living silver (mercury), which is said by modern writers to leave a void space in a glass tube, and [they say] that it is made greater with fire having been brought near, and smaller with ice brought near." Bérigard goes on to cite specific experiments that negated the possibility that the space contains a void: "since gnats fly about in it, sound is heard [in it], according



DEL GALILEO. 15

*appartarla piglieremo vna materia continua, le cui parti manchino di ogni altra reſiſtenza alla ſeparazione fuor che di quella del Vacuo, quale à lungo è ſtato dimoſtrato in certo Trattato del noſtro Acc*co. *eſſer l'Acqua. Talche qualunque volta ſi diſponeſſe vn Cilindro d'Acqua, e che attratto ſi ſentiſſe reſiſtenza allo ſtaccamento delle ſue parti, queſto da altra cagione, che dalla repugnanza al Vacuo, non potrebbe riconoſcerſi. Per far poi vna tale eſperienza mi ſon' immaginato vn' artifizio, il quale con l'aiuto di vn poco di diſegno meglio, che con ſemplici parole, potrò dichiarare. Figuro queſto* C A B D *eſſere il profilo di vn Cilindro di metallo, ò di vetro, che ſarebbe meglio voto dentro, mà giuſtiſſimamente tornito, nel cui concauo entri con eſquiſitiſſimo contatto vn Cilindro di legno, il cui profilo noto* E G H F, *il qual Cilindro ſi poſſa ſpignere in sù, e'n giù: e queſto voglio, che ſia bucato nel mezzo, ſi che vi paſſi vn filo di ferro oncinato nell' eſtremità* K, *e l'altro capo* I *vadia ingroſſandoſi in forma di Cono, ò turbine, facendo che il foro fatto nel legno ſia nella parte di ſopra eſſo ancora incauato in forma di Conica ſuperficie aggiuſtata puntualmente per riceuere la Conica eſtremità* I *del Ferro* I K, *qualunque volta ſi tiri in giù dalla parte* K. *Inſerto il legno, ò vogliamolo chiamar Zaffo* E H *nel cauo Cilindro* A D *non voglio, ch' arriui ſino alla ſuperior ſuperficie di eſſo Cilindro, mà che ne reſti lontano due, ò tre dita: e tale ſpazio deue eſſer ripieno di Acqua, la quale vi ſi metterà tenendo il vaſo con la bocca* C D *all' in sù, e calcandoui ſopra il Zaffo* E H *col tenere il turbine* I *remoto alquanto dal cauo del legno, per laſciar l'eſito all' aria, che nel calcare il Zaffo ſe n'uſcirà per il foro del legno, che perciò ſi fà alquanto più largo della groſſezza dell' aſticciuola di ferro* I K. *Dato l'eſito all' aria, e ritirato il ferro, che ben*

Figure 2. Galileo's device for measuring the strength of the void. *Discorsi*, 1638, page 15. This item is reproduced by permission of the Huntington Library, San Marino, California. Shelfmark RB 701317.

to the witness Kircher, and light is produced [in it], these things demonstrate that a very subtle body is contained in that space . . . evidently very thin substances are dragged through passage-ways of the glass."[54] In place of Galileo's device, Bérigard describes the reports of modern writers who claimed that a void can be created in a glass tube filled with mercury, a void that grows greater when the contraption is heated and smaller when it is cooled. He gives little information about how such experiments were carried out, but does provide further details, including that gnats can fly in the space, light can be produced in it, and — citing the experiments of the Jesuit mathematician Gasparo Berti

[54]Berigard, 1661, 1:55. Bérigard substituted the description of Galileo's device with similar references to the experiments with mercury. The instance quoted here comes from part 1 of the second edition, subtitled "De veteri et peripatetica philosophia in Aristotelis libros octo physicorum."

(ca. 1600–43), as reported in Athanasius Kircher's (1601/02–80) 1650 *Musurgia Universalis* — that sound is heard in it. These phenomena were evidence that the space above the mercury is not empty but, in fact, contains very thin substances that arrive through passages of the glass, effectively dismissing the new mercury experiments using the same reasoning he had employed to explain Galileo's device.[55] Bérigard's response was a rejoinder commonly employed by those contemporaries, including the Jesuits at the Collegio Romano, who believed that nature did not allow a void space.

Bérigard continued comparing established and novel hypotheses in the 1661 edition of his *Circulus Pisanus*. Though he rejected the vacuist interpretation of the mercury tubes, he accepted both the premise of experimentation and the reported phenomena. He believed, moreover, that both were relevant to his explanation of Aristotle. What is most interesting is that Bérigard edited the passage on Galileo to keep his text abreast with the most up-to-date speculation. This change indicates Berigard's view that the old and new are in a continually evolving dialogue, one in which the latest experiments should be brought to bear on the discussion. Bérigard's decision to replace Galileo's apparatus with a reference to the mercury experiments also reveals his own familiarity with the state of natural-philosophical investigation. Substitution of Galileo's proposed procedure with a description of the recent mercury experiments was a sound one, because both experiments were understood as being a means of creating a void, thus violating Aristotle's provision that a natural void was impossible. They were also related because Galileo's apparatus was the intellectual inspiration for the mercury experiments. The first experiments with inverted tubes filled with liquid were those of Galileo's student Evangelista Torricelli, who filled such tubes with water following Galileo's description in his *Discorsi*. He then turned to filling the tubes with the heavier liquid mercury, whose maximum height in inverted tubes was significantly shorter than that of water.[56] By replacing his description of Galileo's apparatus with references to these mercury experiments, Bérigard was thus updating his text by reporting on the next generation of experimental attempts to succeed Galileo's proposal.

Both Bérigard and the three Jesuit professors considered above incorporated material from Galileo's *Discorsi* into their texts when the subject matter addressed by Galileo corresponded with a central theme of Aristotelian natural philosophy. This pattern of reception suggests that these readers approached Galileo's text with the categories and framework of traditional natural philosophy in mind. The extant notes of one of Bérigard's successors at Pisa offer a glimpse into the reading methods that may have encouraged professors to read Galileo through the lens of their university teaching.

[55]For the experiment, see Shea, 24–29.

[56]Ibid., 32–36.

Lorenzo Bellini (1643–1704) taught natural philosophy and anatomy at the University of Pisa in the second half of the seventeenth century. Bellini studied at Pisa under self-proclaimed followers of Galileo, including Alfonso Borelli (1608–79) and Alessandro Marchetti (1633–1714), and he himself achieved wide acclaim during his lifetime for his publications on anatomy, which applied the latest experimental and physicomathematical techniques to explain the structure and function of the kidneys and sense organs. Bellini's own writings indicate his familiarity with a wide variety of ancient and early modern authors, from Democritus (ca. 460–ca. 370 BCE) and Anaxagoras (ca. 510–428 BCE) to Galileo, Pierre Gassendi (1592–1655), and René Descartes.[57]

Bellini's extant papers, now held at the Biblioteca Laurenziana in Florence, indicate that while he read, discussed, and oftentimes embraced novel hypotheses in his publications, he continued to employ traditional textual practices in his working methods. Specifically, these extant papers contain three different collections of reading notes taken according to the commonplace method, the method of note-taking advocated by humanist pedagogues and applied to the textual enterprise of bookish natural philosophy.[58] Bellini's commonplace notes follow a slightly different format than that described by Erasmus and other sixteenth-century humanists. Rather than devoting each page to a different topical heading, as earlier humanists had advised, Bellini organized his notes loosely topically and alphabetically. At times Bellini included a heading on each page corresponding to a specific topic, such as "Mixtio" or "Motus" or "Anima," but the entries on each page (labeled or not) often addressed a variety of topics, all of which began with the same first letter. Thus on the page lacking a heading but whose first entry is "anima" (fig. 3), Bellini took notes on a variety of heads that began with the letter *a*, from "Aqua," to "Aer," to "Anima mundi."

Moreover, Bellini took notes on these topical headings nonconsecutively. In the same section under the heading "Anima," Bellini took multiple notes on the topics of *aer* (air) and *aqua* (water). He notes, for example, that Aristotle had asserted in book 4 of *De caelo* that water is heavy. Bellini then turns to the subject of air, indicating both Aristotle's and Plutarch's opinions on its qualities. He

[57]Iofrida, 316–22; Bertoloni Meli, 2011, 160.

[58]One devoted primarily to medical and anatomical topics is organized alphabetically with letter tabs cut out on the margin of the pages for easier finding: Biblioteca Medicea Laurenziana, MS Ashburnham (hereafter Laur., MS Ashb.) 638.1:164^{r}–235^{v}. The second, which is titled "Excerpta philosophica ex variis Auctoribus," focuses on topics related to natural philosophy: Laur., MS Ashb. 638.4:182^{r}–313^{r}. The last, entitled "Studia et Citationes," is more detailed and less organized. It can be found at Laur., MS Ashb. 638.6:39^{r}.

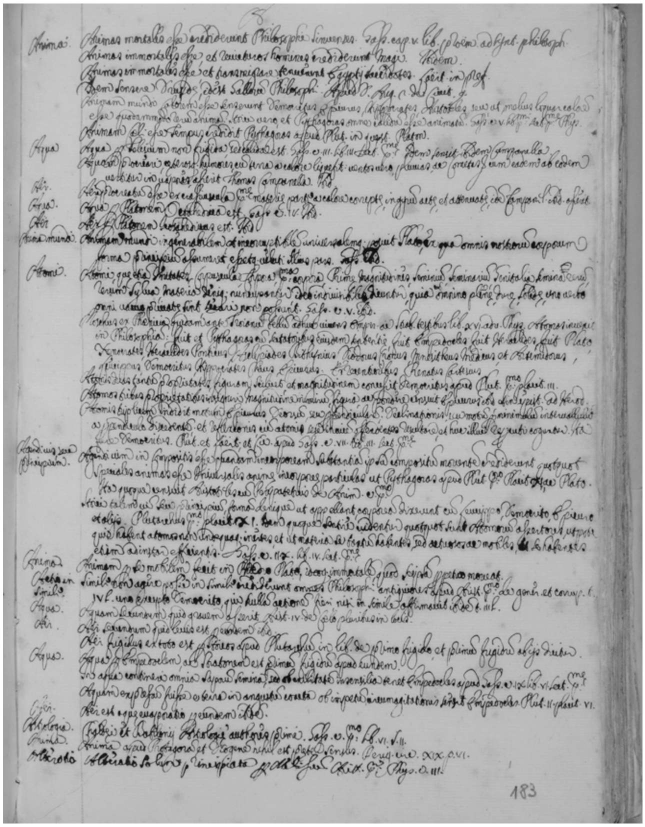


Figure 3. A page of Bellini's reading notes, Biblioteca Medicea Laurenziana, MS Ashb. 638.4, 183r. Image courtesy of the Biblioteca Medicea Laurenziana, Florence.

then turns back to water again, noting various opinions by Empedocles, Strato, and Gassendi.[59] This organization bears some resemblance to the "new method" of commonplacing described by John Locke in the *Bibliothèque universelle et historique* of 1686, in which Locke relied on an alphabetized index to order his collection of commonplace notes.[60]

[59]Laur., MS Ashb. 638.4:183r: "Water. Aristotle asserts with qualification in many passages of Book 4 of *De caelo* that water is heavy // Air. Air is light with qualification according to the same / Air is in all cold [*unreadable*] according to Plutarch in his book *De primo frigido*, and it is said [*unreadable*] the first cold. // Water. Water is the first cold according to Empedocles and Strato in their writings on the same. Empedocles holds that all seeds of flavors are contained in water, but [*unreadable*] imperceptible, according to Gassendi."

[60]Yeo, 2004, 9–17.

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Bellini's juxtaposition of ancient writers with Gassendi in his notes on water highlights a more general feature of his commonplace notes, namely his tendency to put old and new sources in dialogue. Just as Mauro, Tellin, Panici, and Bérigard had seen Galileo as relevant to their expositions of Aristotle, Bellini's reading notes reveal his view that these ancient and modern sources all speak to standard, shared topics of interest. A brief examination of Bellini's commonplace entry entitled "Motion and Mover[s]" demonstrates more fully this aspect of his reading.[61] In his notes, which run for over four pages, Bellini collected the ideas of a diverse group of authors, from Aristotle to Galileo. As was the practice in commonplace books, Bellini jotted down the ideas of different authors, even when their approaches or conclusions are, to modern sensibilities, contradictory. Bellini, for example, described and provided textual references for Aristotle's distinction between natural and violent motion, as well as Aristotle's notion that all motion was the result of the action of a mover.[62] Bellini interspersed with these notes devoted to Aristotle's qualitative approach to motion Galileo's quantitative rules on the behavior of accelerated and projectile motion.[63] Similarly he juxtaposed Galileo's findings on the quantitative rules for accelerated motion with Gassendi's speculations on the cause of such motion, despite the fact that Galileo argued in his *Discorsi* that such a query was beyond the scope of his investigation.[64]

Bellini's commonplace notes reveal that one of the reasons why seventeenth-century readers — in contrast to modern scholars — saw Galileo's *Discorsi* as in dialogue with traditional natural philosophy was because of the tools they used to read it. The bookish practices of traditional natural philosophy encouraged readers to sift the contents of a text through the standard heads of a commonplace book or traditional natural-philosophical course. Because the

[61]Laur., MS Ashb. 638.4:280^r: "Motus and Motor."

[62]Ibid., 638.4:281^r: "Motion is divided into natural and violent. Natural is that which is produced by nature or without resistance. Violent, to be sure, is that which [is produced] contrary to nature, or with some resistance." Ibid., 638.4:280^r. "It cannot . . . be moved, unless also the mover itself is moved (in speaking of secondary and finite movers, not of the Prime and infinite) because whatever moves, drives, but action is motion and passion likewise [is] motion, indeed, action and passion are identified with motion itself by Aristotle in his *Physics* t. XVI and XVII."

[63]Ibid., 638.4:280^v–281^r: "Hence the acceleration of motion is made according to the proportion of odd numbers growing from unity or, what is the same, according to their squares to such a degree that if in the first arterial pulse one space is run through by the moveable in the second, three [spaces] will be run through, in the third, five, in the fourth, seven, etc. This Galileo shows in his dialogue 'On uniformly accelerated motion.' . . . Indeed the line which will be described by a projectile in descent is parabolic, as Galileo, Cavalieri, and Torricelli show."

[64]Ibid., 638.4:280^v: "The cause of this acceleration . . . as is said, is in the attraction of the Earth, which is explained very clearly thus by Gassendi v.III Book V, first section."

goal of such an enterprise was the juxtaposing of authors' opinions on a standard set of topics, the process encouraged readers to put the texts they read — both those of traditional natural philosophy and those of the New Science — in dialogue. Galileo had claimed at the beginning of day 3 of the *Discorsi* that he was putting forward a whole new science concerning a very old subject, a reference to the primacy of motion in Aristotle's writings and to the very different quantitative and experimental approach he himself espoused. The two Pisan professors showed otherwise. Bérigard, by using Galileo to explicate Aristotle, and Bellini, by relying on the traditional textual tool of the commonplace book, put Galileo's work in dialogue with the very tradition he ostensibly rejected.

WARD AND WREN: TEXTUAL SCHOLARSHIP IN SERVICE OF THE NEW SCIENCE

Perhaps it should be anticipated that university professors of natural philosophy, a group portrayed by Galileo (and often modern historians) as of limited intellectual horizons, read the *Discorsi* through glasses tinted by the methods and aims of traditional textual natural philosophy. The existence of two heavily annotated copies of the *Discorsi*, one previously unknown, the other overlooked, in the Savilian collection at the University of Oxford's Bodleian Library suggests otherwise. The first is a copy that will be shown to have been annotated by Seth Ward, founding member of the Royal Society, Savilian professor of astronomy from 1649 to 1660, and later bishop of Salisbury. The second is a copy annotated by Christopher Wren, the architect responsible for the reconstruction of St. Paul's Cathedral in London following the Great London Fire of 1666, member and president of the early Royal Society, and Savilian professor of astronomy at Oxford from 1661 to 1673. These copies show how two mathematicians who actively participated in and promoted the seventeenth-century New Science similarly brought the tools and concerns of traditional bookish natural philosophy to bear on their readings of the *Discorsi*.[65]

In 1619, Sir Henry Savile (1549–1622) created two Oxford professorships (the Savilian chairs) in astronomy and geometry, and donated his own books to form a library for use by the appointed professors. Later professors added their own volumes to the collection, which now numbers around 1,180 volumes. The Savile collection contains two copies of Galileo's final published work; the first (shelfmark Bb.13) is a copy of the first edition of the *Discorsi*, published in Leiden in 1638, while the second (shelfmark A.19) is a copy of the *Discorsi* contained in the first edition of Galileo's collected works, his 1655–56 *Opere*,

[65]On the teaching of mathematics and science more generally at Oxford, and the universities' openness to novel ideas, see the following and the sources cited therein: Feingold, 1984 and 1997.

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published in Bologna. Both of the volumes are heavily annotated, with extensive marginalia and notes written on the inside covers and fly leaves, as well as on additional sheets inserted into the books. These volumes are some of the first heavily annotated copies of the *Discorsi* to have been identified outside of Italy.[66] Wren has been identified as the owner and annotator of the Savile A.19 by J. A. Bennett, on the basis of the book's physical features (a note on the title page indicates the book was donated by Wren and its spine is monogrammed with the initials "CW") and the handwriting contained within it.[67] The 1638 volume, one apparently unknown to modern scholars, appears to be annotated by Seth Ward.

Close examination reveals that the annotations in the two volumes are nearly identical. Furthermore, it is clear that those found in the A.19 Wren volume (1655–56 *Opere*) were copied from those found in the Bb.13 Ward volume. The inserted pages often contain references to page numbers. In the latter edition (fig. 4), these references are all clean, but in the former edition (fig. 5), they are almost without exception crossed out. At one point, the reader of the 1655–56 edition (Wren) accidentally wrote the page number as 137, which corresponds to the 1638 reader's notes, and subsequently corrected it to 101.

It is the marginal annotations corresponding to these additional sheets that indicate that the annotator of the 1638 copy is Ward. The annotator of the 1638 volume referred readers to these additional sheets with marginal annotations that read, for example, "See the empty page at the beginning of the book for another demonstration."[68] The corresponding annotations of the 1655–56 edition consistently cite not the additional sheets inserted in the book (which are identical to those found in the 1638 edition), but instead the work of "D. Ward," a reference that appears to be to Dr. Seth Ward.[69] These annotations suggest that Wren copied his annotations from the 1638 edition, and that the annotations in that earlier edition were written by Seth Ward. In his studies of Wren's mathematics, Bennett made brief mention of Wren's annotated copy. He posited on the basis of these annotations that Wren had had access to "some kind of discussion, or perhaps a course conducted by Ward, [which] had centred round the *Discorsi*."[70] Comparison with the corresponding annotations of the 1638

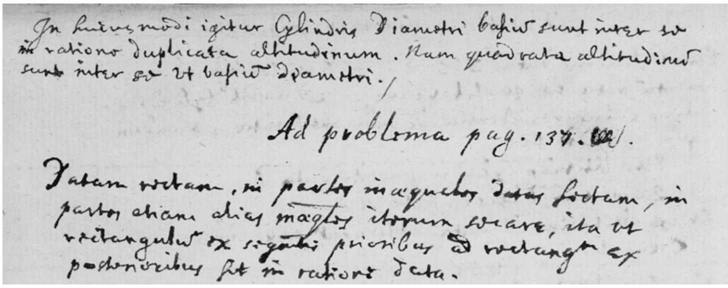
[66]Two heavily annotated copies are held at the Biblioteca Nazionale Centrale di Firenze (Gal. 79 and 80). Those in Gal. 79 have been published in Galilei, 1990. Marin Mersenne's annotated copy of the *Discorsi* has also been identified and described in Buccolini.

[67]Bennett, 1975, 38; Bennett, 1982, 61–62.

[68]Bodleian Library (hereafter Bodleian), Savile Bb.13, 118: "Aliam . . . demonstrationem, vide in pag. vacua ad initium libri."

[69]Bodleian, Savile A.19, 89: "Vide Demonstrationem aliam D. Wardi" ("See D. Ward's other demonstration").

[70]Bennett, 1975, 38.

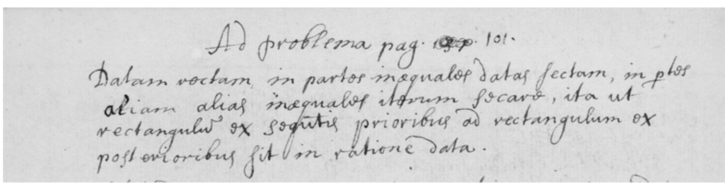


In huiusmodi igitur Cylindris diametri basis sunt inter se in ratione duplicata altitudinum. Nam quadrata altitudinum sunt inter se ut basium diametri.

Ad problema pag. 137.

Datam rectam, in partes inaequales datas sectam, in partes etiam alias magis iterum secare, ita ut rectangulum ex sequentibus prioribus ad rectangulum ex posterioribus fit in ratione data.

Figure 4. Ward's page-number references. Savile Bb.13, fly 3v (detail). Courtesy of the Bodleian Library, University of Oxford.



Ad problema pag. 101.

Datam rectam in partes inaequales datas sectam, in plures alias inaequales iterum secare, ita ut rectangulum ex sequentibus prioribus ad rectangulum ex posterioribus fit in ratione data.

Figure 5. Wren's page-number references. Savile A.19, loose slip 2v between pages 88 and 89 (detail). Courtesy of the Bodleian Library, University of Oxford.

edition reveals that the source of Wren's solutions was most likely Ward's own annotations. The 1638 edition is thus the "course" or "discussion" that Bennett had foretold in his 1975 article.

Ward's and Wren's annotations suggest that they came to the text with multiple goals and read the text in a variety of ways, from working through Galileo's mathematics to taking note of Galileo's conclusions. The present section highlights the similarities between Ward's and Wren's approaches to the *Discorsi* and those of Galileo's Jesuit and Pisan readers, not because Ward and Wren only read the *Discorsi* through the lens of traditional natural philosophy, but because the fact that they did so in a consistent and thorough way reinforces the argument that multiple readers from different perspectives and backgrounds considered the methods and concerns of traditional textual natural philosophy as suitable for application to Galileo's text. In the discussion that follows, Ward is named as the reader of Galileo, except in instances in which it is important to note an aspect of Wren's response that differs from Ward's.

First, Ward paid close attention to the parts of the *Discorsi* that treated subjects central to Aristotelian natural philosophy. For example, he noted Galileo's discussion of such subjects as "the resistance of the void," "on infinite indivisibles," and "examples of rarefaction and condensation."[71] He also recorded Galileo's conclusions regarding these topics, noting Galileo's opinion that the continuum consists of indivisible atoms, that the velocity of a descending body does not depend on its heaviness, that air is heavy, and that a heavy body in motion differs from one at rest.[72] These topics were central to period expositions of Aristotelian natural philosophy and were from the same sections of the *Discorsi* that university readers tended to incorporate into their discussions of Aristotle.[73] Ward indicated his particular attention to this aspect of the *Discorsi* by including on the inside cover of his copy a more extensive summary of Galileo's explanation of rarefaction and condensation under the title, "Condensation and rarefaction from the opinion of Galileo." In this note, copied by Wren in his own exemplar, Ward summarized Galileo's claim that the two processes could be explained by supposing that bodies were composed of infinite indivisibles.[74]

Noting Galileo's discussion of topics central to the Aristotelian tradition could be seen as inconsequential — active readers, to be sure, would have taken note of Galileo's main points of discussion — were it not for additional annotations that point to Ward's interest in another central concern of traditional natural philosophy explicitly set aside by Galileo, namely a search for the causes underlying motion. In day 3, Ward included the marginal note, "The cause of accelerated motion in the descent of heavy bodies."[75] In the corresponding passage, Galileo's interlocutor Sagredo briefly mentions some common speculations on the cause of accelerated motion. Salviati quickly interrupts, declaring that such a topic lies outside Galileo's intended aims to describe motion quantitatively. Ward's

[71]Bodleian, Savile Bb.13, 12, 25, 61; Bodleian, Savile A.19, 9, 19, 46: "Resistentia vacui," "De Indivisibilibus Infinitis," "Exempla Rarefactionis et Condensationis."

[72]Bodleian, Savile Bb.13, 49; Bodleian, Savile A.19, 37: "Continuum constare ex Atomis Indivisibilibus" ("That the continuum consists of indivisible atoms"). Bodleian, Savile Bb.13, 74; Bodleian, Savile A.19, 56: "Velocitatem descensus non pendere a gravitate mobilis" ("That the velocity of descent does not depend on the heaviness of the moveable"). Bodleian, Savile Bb.13, 64; Bodleian, Savile A.19, 48: "Grave in motu differt a Gravi in quiete" ("A heavy body in motion differs from a heavy body at rest"). Bodleian, Savile Bb.13, 78: "Aer gravis" ("heavy air").

[73]The Jesuit professors in this article focused on Galileo's discussion of the heaviness of the air, while Bérigard focused on his opinions on the void. On the standardization of topics set by Aristotle's text and his commentators in the period, see Baldini, 1999, 252; Brockliss, 1996, 580; Brockliss, 1987, 337; Grendler, 277.

[74]Bodleian, Savile Bb.13, inside front cover; Bodleian, Savile A.19, loose slip 4^r between pages 88 and 89: "Condensatio et Rarefactio ex sententia Galilei"; "Condensation and rarefaction according to Galileo's opinion. All bodies consist of infinite indivisibles, some a plenum, others void; condensation arises from their compression; rarefaction from their dilation."

[75]Bodleian, Savile Bb.13, 161; Bodleian, Savile A.19, 122: "Causa accelerationis motus in gravium descensu."

annotation suggests that he read this passage as Galileo's summary of possible causes of accelerated motion, not as a statement of Galileo's intent not to treat of this subject. An additional annotation in day 4 confirms that, despite Galileo's admonition to readers that he rejected the causal physics advocated by Aristotle, Ward read the *Discorsi* with this concern in mind.

In the relevant passage, Sagredo compares Galileo's conception of the horizontal and vertical components of the projectile's parabolic trajectory to Plato's idea that God had started all planets moving toward the sun from the same point in the universe and later converted their rectilinear motion into a uniform circular one. In the margin of his copy, Ward noted that if the Platonic hypothesis to which Galileo refers is true, it would be necessary "that the Earth and other planets respect some heavenly body (perhaps the sun) as a center in their proper motion (just as our heavy bodies are carried to the Earth as a center) or by a different route some certain thing must be assigned as a cause of accelerated motion."[76] Whatever Ward's thoughts were regarding the possible causes of accelerated motion and that of planetary motions, his annotation reveals — contrary to Galileo's own professed intentions — that he was interested in the causes underlying projectile, accelerated, and planetary motion and that he brought this concern with him as he read the *Discorsi*. In this sense, Ward's approach to the *Discorsi* can be seen to parallel Bellini's, for both find nothing amiss in reading and annotating Galileo's quantitative, experimental findings on motion (which were accompanied by Galileo's decision to reject such a causal study of motion), while simultaneously remaining interested in understanding the causes underlying such motion.

Finally, Ward's marginal annotations and inserted note sheets reveal his interest in the relationship between the *Discorsi* and other textual sources. The process of textual citation and attribution was, of course, the very feature of bookish natural philosophy that Galileo criticized in Sarsi in the quotation with which this article began. Many of Ward's annotations reference the works of other authors, including Christoph Clavius (1538–1612), Bonaventura Cavalieri (1598–1647), and Galileo's own previous publication on floating bodies.[77] At times, Ward signals Galileo's relationship to Aristotle through his marginal notes.

[76]Bodleian, Savile Bb.13, 254; Bodleian, Savile A.19, 193: "Si vera esset hypothesis haec Platonica, oportuit terram caeterosque planetas centrum aliquid coelestem (solem fortasse) in motu eorum recto respexisse (sicut gravia nostra ad terram centrum feruntur) aut alia quaedam assignanda est causa motus accelerati."

[77]Bodleian, Savile Bb.13, 42: "Speculum ustorium Bonaventuri Cavalieris" ("Bonaventura Cavalieri's *Speculum ustorium*") (Ward only). Bodleian, Savile Bb.13, 48; Bodleian, Savile A.19, 36: "vid. Clavium in Scalig. Cyclometr" ("See Clavius about *Scaliger's Cyclometrica*") (Savile A.19, 36 has "adv" in place of "in"). Bodleian, Savile Bb.13, 58: "Clavium videtur intelligere" ("He seems to understand Clavius") (Ward only). Bodleian, Savile Bb.13, 71; Bodleian, Savile A.19, 53: "Galilei tract. de Aqua nulla ei tenacitate inesse" ("In Galileo's treatise on water it has no tenacity").

When Galileo criticizes Aristotle's opinions on the relative velocities of falling bodies, for example, Ward includes a marginal annotation that reads "Aristotle's error."[78] Wren includes a separate annotation, not found in Ward's text, that reads, "this is characteristic of Aristotle," in the section of day 1 in which Galileo explains that the coherence of bodies can be explained by nature's repugnance to the void acting between the minimal particles of bodies.[79] Ward confirmed his interest in Galileo's relationship to other textual authorities by including a "list of authors cited by Galileo" on the verso side of the errata sheet (fig. 6); Wren copied the list into his own book (fig. 7), but left out the relevant page numbers, perhaps because it would have been too much trouble for him to translate Ward's page numbers (for the 1638 edition) into the corresponding numbers for his 1656 edition. This list includes Aristotle, Guidobaldo, Euclid, Plato, and Galileo himself. This pattern of annotations reveals that Ward (and subsequently Wren) believed the traditional categories of analysis and agenda of bookish natural philosophy were applicable to Galileo's text.

In addition, that Wren copied Ward's annotations suggests that the two men read the *Discorsi* as a pedagogical text. The glossing and commenting on texts and the copying of such explications — via student lecture notes or through marginalia — was an activity central to both Scholastic and humanist educational practice.[80] While this teaching is often associated with the texts of classical authors, the use of such a technical mathematical text in early modern pedagogy is not unknown. Owen Gingerich has shown that many of Nicolaus Copernicus's readers responded similarly — using marginalia and copying marginalia from one copy to another — as they responded to the first two editions of his *De Revolutionibus*, first published in 1543.[81] Wren first joined the scholarly community at Oxford in 1650 as a gentleman commoner at Wadham College, where Ward was then living.[82] If Wren purchased his copy of Galileo's *Opere* when it was published in 1656, it is possible that he copied the annotations in Ward's 1638 copy as part of his introduction to and training in the community there. It is not surprising, of course, that Wren would have been familiar with the *Discorsi* and even owned and annotated his own copy of the text as part of his introductory training. What makes Wren's use of the *Discorsi* in keeping with the methods of bookish natural

[78]Bodleian, Savile Bb.13, 65; Bodleian, Savile A.19, 49: "Aristotelis error."

[79]Bodleian, Savile A.19, 15: "est Aristotelis propria." Galileo's argument and its relationship to Aristotle's assertion of nature's abhorrence of the void are addressed in Galilei, 1989, 27n8.

[80]Blair, 1997, 90–97; Blair, 2010, 62–116. On how such texts were employed in pedagogy, see Grafton, 2008. On glossing, commenting, and note-taking in Jesuit pedagogy, see Nelles, 86–92, 95–106.

[81]Gingerich, 2002, xvi–xxiii; Gingerich, 2004, 154–66, 170–79.

[82]Bennett, 1982, 14–25.

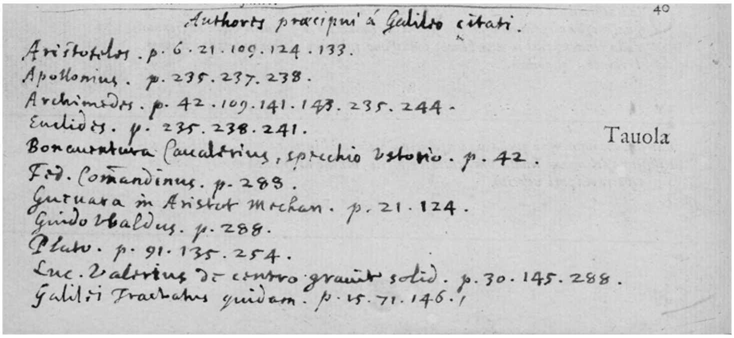


Figure 6. Ward's list of authors cited by Galileo. Bodleian, Savile Bb.13. Table of printing errors (detail). Courtesy of the Bodleian Library, University of Oxford.

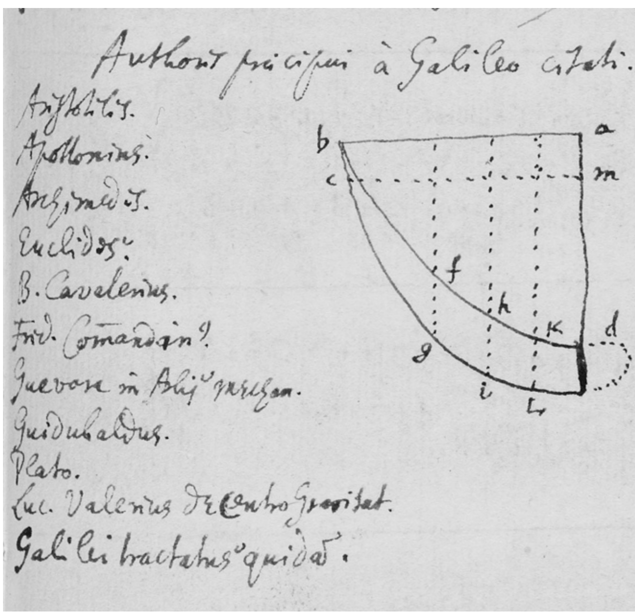


Figure 7. Wren's copy of Ward's list of authors cited by Galileo. Bodleian, Savile A.19, loose slip 4r between pages 88 and 89 (detail). Courtesy of the Bodleian Library, University of Oxford.

philosophy is the fact that the transmission took place through the copying of his teacher's extensive marginalia, which treated not only Galileo's main ideas and mathematics, but explored multiple aspects of the text, from its mathematics to its reliance on other textual authorities.

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CONCLUSIONS

The traces of reading examined here suggest that some seventeenth-century readers read Galileo's *Discorsi* — a canonical text in the history of early modern science, one usually celebrated for its embrace of quantification and experimentation — using the tools and categories of traditional scholarship. These included the note-taking and commonplacing methods and the attention to textual authorities, standard topics, and causal explanation associated with Scholastic and humanist approaches to natural philosophy. The approach was consistent across geographic, religious, and disciplinary boundaries. It was used by Jesuit natural philosophers based in Rome but who came from across Europe (Mauro from Spoleto, Tellin from Armaugh, and Panici from Macerata); the native Florentine Bellini, known primarily for his innovative work in anatomy; the French Bérigard interested in the writings of the pre-Socratics; and Ward and Wren, two Oxford scholars who made important contributions to mathematics and English experimental philosophy. That this diverse group of readers approached the *Discorsi* using a common set of methods suggests that this textual approach to the *Discorsi* was widespread. It reflected scholarly practices shared across early modern Europe, practices that shaped the way the *Discorsi* was read and — given Galileo's participation in the community — the way it was written.

Taking Galileo at his word, one might be inclined to dismiss this textual response to his *Discorsi* as a sign that many of Galileo's readers radically misinterpreted his aims and methods. Galileo is well known for his outspoken criticism of the textual methods of his contemporaries. The type of response to Galileo's text analyzed in this article — marginal annotations, note-taking, commonplacing, putting Galileo as a textual authority in dialogue with other writers — seems to be exactly the type of response Galileo hoped to avoid in his own scholarly practices, and that he encouraged his readers to abandon as well. Under this interpretation, the readers who followed such practices may be the very readers for whom Galileo expressly did not write, readers whose reactions modern scholars should dismiss because Galileo himself claims he would do the same. It might be tempting, therefore, to argue that the readers considered above misinterpreted Galileo because they were so steeped in the textual tradition he came to eschew.

Such a line of reasoning, however, ignores the most valuable insight that a study of reception can bring. Theorists of reader reception have argued that the interpretation of an author's ideas is not fixed on the printed page (or other medium) but arises (and is continually in flux) in the act of reading itself. Because a text's meaning is malleable, the notion of misinterpretations and uncorrupted transmission is irrelevant.[83] Hans Robert Jauss's notion of a horizon of

[83]For a discussion of reception theory and its usefulness in avoiding anachronism, see Darnton, 98–100.

expectations — of expectations about genre, knowledge claims, and approaches — shared by authors and their readers enters in here.[84] This notion privileges the interpretations of texts provided by period readers, readers infinitely more well versed than modern historians in the intellectual, social, and cultural context in which the author operated. In the case of the *Discorsi*, that so many readers of Galileo from diverse backgrounds, institutional affiliations, and disciplinary traditions thought the tools of traditional textual scholarship were appropriate ones for applying to his text suggests that, despite his rhetoric, Galileo retained strong ties to the world of traditional scholarship. That is, these readers who approached Galileo's text using traditional textual methods did not misread Galileo by evaluating the *Discorsi* through their interpretations of Aristotle or through the traditional topics of natural philosophy. Rather, they were picking up on elements of the text that modern scholars have not been trained to see.

Galileo's surviving papers and books support such a view. Galileo himself was an avid student of Aristotle and Aristotelian natural philosophy (at least in his early days).[85] He annotated his own books and those of his contemporaries, and he relied on these annotations in his own compositions.[86] Furthermore, as scholars of Galileo's library have emphasized, despite Galileo's and his students' insistence to the contrary, he owned and worked with a very large library filled with ancient, medieval, and contemporary works.[87] While Galileo thus may have hoped that modern scholars would discount this textual approach to his texts as unimportant, the fact remains that period readers of diverse backgrounds and interests thought his *Discorsi* could be studied using traditional methods. To make sense of their response, it is necessary to go beyond Galileo's rhetoric — his ostensible commitment to experimentation, quantification, sensory experience, instruments, and new techniques of visual representation — to see how he himself combined new and old. Such an approach is not new to Galileo studies — many previous Galileo scholars have engaged in just such an enterprise — but the notion that traditional methods shaped not only the genesis of the *Discorsi*, but also its *fortuna* and contributions to later developments, is.[88]

[84]On the horizon of expectations, see Jauss, 20–32.

[85]Scholars have emphasized Galileo's study of natural philosophy as taught at the Collegio Romano and Pisa. For key examples of such work, see Camerota and Helbing; Carugo and Crombie; Crombie and Carugo; Wallace.

[86]As one example, Galileo's response to Antonio Rocco's 1633 *Esercitazioni filosofiche* shaped his writing of day 1 of the *Discorsi*. For Galileo's annotations, see Galilei, 1890–1909, 7:569–750. For the relationship between Rocco's text and the *Discorsi*, see Galilei 1958, 626–28, 637–38, 640, 642, 659–60, 692.

[87]See Camerota, 84–87.

[88]For examples, see Schmitt, 1969 and 1981; Crombie; Carugo and Crombie; Wallace; Camerota and Helbing.

Galileo scholar Stillman Drake once described the *Discorsi* as "Galileo's last and scientifically most enduring work . . . a book on physics that opened the road for Newton's immortal *Mathematical Principles of Natural Philosophy*."[89] The examination here does not negate this assessment of the *Discorsi* so much as it provides a window into how and why the text came to play such a pivotal role. To assert that seventeenth-century readers across Europe read the *Discorsi* using the tools of bookish natural philosophy shows how traditional methods facilitated the dissemination and understanding of texts of the New Science. These findings confirm the conclusions of scholars who have argued for the continuing relevance of the textual tradition to seventeenth-century scholarship. In fact, they go beyond them to show that it is not only that the two cultures of humanism and science "coexisted and often collaborated," but that, in many ways, the dissemination and transformative power of the latter depended on the tools and methods of the former.[90] As narratives of early modern science continue to be reassessed, reformulated, and rewritten, one of the most pressing tasks that awaits is the study of the reception of key texts and ideas in the period. Reading the *Discorsi* through the eyes of contemporary readers provides a glimpse — perhaps the closest modern scholars will ever get — into what it meant to live through and experience the transformations in early modern science once termed the Scientific Revolution.

[89]Drake's comment is found in his introduction to the translation of the *Discorsi*: Galilei, 1989, xiii.

[90]Grafton, 1991, 5.

BIBLIOGRAPHY

Archival Sources

Archivio Storico della Pontificia Università Gregoriana (APUG), Rome, Fondo Curia (FC) 1093. Panici, J. J. "In Libros Aristotelis de Physico Auditu." Cited as APUG, FC 1093.

APUG, FC 1344. Tellin, I, "Tertia pars Philosophiae Peripateticae."

Biblioteca Medicea Laurenziana (Laur.), Florence, MS Ashburnham 638. Bellini, Lorenzo. "Opere Varie." Cited as Laur., MS Ashb. 638.

Bodleian Library (Bodleian), University of Oxford, Oxford, Savile Bb.13. Galilei, Galileo. *Discorsi e dimostrazioni matematiche: Intorno à due nuoue scienze, attenenti alla mecanica & i movimenti locali*. Leiden, 1638. Cited as Bodleian, Savile Bb.13.

Bodleian, Savile A.19. Galilei, Galileo. *Opere di Galileo Galilei Linceo nobile fiorentino*. 2 vols. Bologna, 1655–56. Cited as Bodleian, Savile A.19.

Printed Sources

Albert of Saxony. *Quaestiones in Aristotelis* De Caelo. Ed. Benoît Patar. Louvain, 2008.

Aristotle. *On the Heavens*. Ed. J. L. Stocks. Blacksburg, VA, 2001.

Baldini, Ugo. *Legem Impone Subactis: Studi su Filosofia e Scienza dei Gesuiti in Italia, 1540–1632*. Rome, 1992.

———. "The Development of Jesuit 'Physics' in Italy, 1550–1700: A Structural Approach." In *Philosophy in the Sixteenth and Seventeenth Centuries: Conversations with Aristotle*, ed. Constance Blackwell and Sachiko Kusukawa, 248–79. Aldershot, 1999.

———. "Tra due paradigmi? La *Naturalis Philosophia* di Carlo Rinaldini." In *Galileo e la Scuola Galileiana* (2011), 189–222.

Bennett, J. A. "Hooke and Wren and the System of the World: Some Points toward an Historical Account." *The British Journal for the History of Science* 8.1 (1975): 32–61.

———. *The Mathematical Science of Christopher Wren*. Cambridge, 1982.

Benvenuto, Edoardo. *An Introduction to the History of Structural Mechanics*. 2 vols. New York, 1991.

Bérigard, Claude. *Circulus Pisanus . . . De Veteri & Peripatetica Philosophia in Priores Libros Phys. Arist*. 4 parts in 1 vol. Udine, 1643.

———. *Circulus Pisanus Claudii Berigardi . . . De Veteri et Peripatetica Philosophia in Aristotelis Libros Octo Physicorum*. 6 pts. Padua, 1661.

Bertoloni Meli, Domenico. "Mechanics." In *The Cambridge History of Science*. Vol. 3, *Early Modern Science*, ed. Katharine Park and Lorraine Daston, 632–72. Cambridge, 2006.

———. *Mechanism, Experiment, Disease: Marcello Malpighi and Seventeenth-Century Anatomy*. Baltimore, 2011.

Blair, Ann. "Humanist Methods in Natural Philosophy: The Commonplace Book." *Journal of the History of Ideas* 53.4 (1992): 541–51.

———. *The Theater of Nature: Jean Bodin and Renaissance Science*. Princeton, 1997.

———. "Note Taking as an Art of Transmission." *Critical Inquiry* 31.1 (2004): 85–107.

———. "The Rise of Note-Taking in Early Modern Europe." *Intellectual History Review* 20.3 (2010): 303–16.

Bottin, Francesco. "Claude Guillermet Bérigard (c. 1590–1663)." In *Models of the History of Philosophy*. Vol. 1, *From Its Origins in the Renaissance to the* Historia Philosophica, ed. Giovanni Santinello, C. W. T. Blackwell, and Philip Weller, 147–49. Boston, 1993.

Brockliss, L. W. B. *French Higher Education in the Seventeenth and Eighteenth Centuries: A Cultural History*. Oxford, 1987.

———. "Curricula." In *A History of the University in Europe*. Vol. 2, *Universities in Early Modern Europe (1500–1800)*, ed. H. de Ridder-Symoens, 563–620. Cambridge, 1996.

Buccolini, Claudio. "Opere di Galileo Galilei Provenienti dalla Biblioteca di Marin Mersenne." *Nouvelles de la République des Lettres* 2 (1998): 139–42.

Buridan, Jean. *Quaestiones Super Libris Quattuor de Caelo et Mundo*. Ed. Ernest Addison Moody. Cambridge, MA, 1942. Reprint, New York, 1970.

Camerota, Michele. "La Biblioteca di Galileo: Alcune integrazioni e aggiunte desunte dal carteggio." In *Biblioteche Filosofiche Private in Età Moderna e Contemporanea: Atti del Convegno Cagliari, 21–23 Aprile 2009*, ed. Francesca M. Crasta, 81–95. Florence, 2010.

Camerota, Michele, and Mario Helbing. "Galileo and Pisan Aristotelianism: Galileo's *De Motu Antiquiora* and *Quaestiones de Motu Elementorum* of the Pisan Professors." *Early Science and Medicine* 5.4 (2000): 319–65.

Carugo, Adriano, and Alistair C. Crombie. "The Jesuits and Galileo's Ideas of Science and of Nature." *Annali dell'Istituto e Museo di Storia della Scienza di Firenze* 8 (1983): 3–67.

Cochrane, Eric W. "Science and Humanism in the Italian Renaissance." *American Historical Review* 81.5 (1976): 1039–57.

Commentariorum Collegii Conimbricensis Societatis Iesu, in Quatuor Libros de Coelo, Meteorologicos et Parva Naturalia Aristotelis Stagiritae. Cologne, 1603.

Costello, William T. *The Scholastic Curriculum at Early Seventeenth-Century Cambridge*. Cambridge, MA, 1958.

Crombie, Alistair C. "Sources of Galileo's Early Natural Philosophy." In *Reason, Experiment and Mysticism in the Scientific Revolution*, ed. M. L. Righini Bonelli and William R. Shea, 157–75. New York, 1975.

Crombie, Alistair C., and Adriano Carugo. "Sorting Out the Sources." *The Times Literary Supplement* (22 November 1985): 1319–20.

Damerow, Peter, G. Freudenthal, P. McLaughlin, and Jürgen Renn. *Exploring the Limits of Preclassical Mechanics*. New York, 2004.

Darnton, Robert. "Toward a History of Reading." *Wilson Quarterly* 13.4 (1989): 86–102.

Dear, Peter. *Discipline and Experience: The Mathematical Way in the Scientific Revolution*. Chicago, 1985.

———. *Revolutionizing the Sciences: European Knowledge and Its Ambitions, 1500–1700*. Princeton, 2001.

Drake, Stillman. *Galileo's Notes on Motion Arranged in Probable Order of Composition and Presented in Reduced Facsimile*. Florence, 1979.

Elazar, Michael. *Honoré Fabri and the Concept of Impetus: A Bridge between Conceptual Frameworks*. Dordrecht, 2011.

Favaro, Antonio. "Oppositori di Galileo: IV. Claudio Berigardo." *Atti del Reale Istituto Veneto* 79.1 (1919): 39–92.

Feingold, Mordechai. *The Mathematicians' Apprenticeship: Science, Universities, and Society in England, 1560–1640*. Cambridge, 1984.

———. "The Mathematical Sciences and New Philosophies." In *The History of the University of Oxford.* Vol. 4, *Seventeenth-Century Oxford*, ed. Nicholas Tyacke, 319–448. Oxford, 1997.

Fiocca, Alessandra. "Galileiani e Gesuiti a Ferrara nel Seicento." In *Galileo e la Scuola Galileiana* (2011), 292–309.

Frasca-Spada, Marina, and Nick Jardine. *Books and the Sciences in History*. Cambridge, 2000.

Galilei, Galileo. *Le Opere di Galileo Galilei: Edizione Nazionale sotto gli auspicii di Sua Maestà il Re d'Italia*. Ed. Antonio Favaro. 20 vols. in 21. Florence, 1890–1909.

———. *Discorsi e Dimostrazioni Matematiche intorno a Due Nuove Scienze*. Ed. Adriano Carugo and Ludovico Geymonat. Turin, 1958.

———. *Two New Sciences Including Centers of Gravity and Force of Percussion*. Trans. Stillman Drake. Toronto, 1989.

———. *Discorsi e Dimostrazioni Matematiche*. Ed. Enrico Giusti. Torino, 1990.

Galileo e la Scuola Galileiana nelle Università del Seicento. Ed. Luigi Pepe. Bologna, 2011.

Galileo in Context. Ed. Jürgen Renn. Cambridge, 2001.

Galle, Griet, ed. *Peter of Auvergne: Questions on Aristotle's* De caelo: *A Critical Edition*. Leuven, 2003.

Galluzzi, Paolo. *Momento: Studi Galileiani*. Rome, 1979.

———. "Gassendi e l'affaire Galilée delle Leggi del Moto." *Giornale Critico della Filosofia Italiana* 72 (1993): 86–119.

———. "La Scienza davanti alla Chiesa e al Principe in una Polemica Universitaria del Secondo Seicento." In *Studi in Onore di Arnaldo d'Addario*, ed. L. Borgia, 1317–44. Lecce, 1995.

———. "Gassendi and *l'Affaire Galilée* of the Laws of Motion." In *Galileo in Context* (2001), 239–75.

Garber, Daniel. "On the Frontlines of the Scientific Revolution: How Mersenne Learned to Love Galileo." *Perspectives on Science* 12.2 (2004): 135–60.

García Villoslada, Riccardo. *Storia del Collegio Romano dal suo Inizio (1551) alla Soppressione della Compagnia di Gesù (1773)*. Rome, 1954.

Gavagna, Veronica. "I gesuiti e la polemica sul vuoto: Il contributo di Paolo Casati." In *Gesuiti e università in Europa*, ed. Gian Paolo Brizzi and Roberto Greci, 325–38. Bologna, 2002.

———. "Paolo Casati e la Scuola Galileiana." In *Galileo e la Scuola Galileiana* (2011), 311–26.

Gingerich, Owen. *An Annotated Census of Copernicus'* De Revolutionibus *(Nuremberg, 1543 and Basel, 1566)*. Leiden, 2002.

———. *The Book Nobody Read: Chasing the Revolutions of Nicolaus Copernicus*. New York, 2004.

Gomez Lopez, Susana. *Le Passioni degli Atomi. Montanari e Rossetti: Una Polemica tra Galileiani*. Florence, 1997.

———. "Dopo Borelli: La Scuola Galileiana a Pisa." In *Galileo e La Scuola Galileiana* (2011), 223–32.

Grafton, Anthony. *Defenders of the Text: The Traditions of Scholarship in an Age of Science, 1450–1800*. Cambridge, MA, 1991.

———. "Textbooks and the Disciplines." In *Scholarly Knowledge: Textbooks in Early Modern Europe*, ed. Ernidio Campi, 11–36. Geneva, 2008.

Grendler, Paul F. *The Universities of the Italian Renaissance*. Baltimore, 2002.

Guicciardini, Niccolo. *Reading the* Principia: *The Debate on Newton's Mathematical Methods for Natural Philosophy from 1687 to 1736*. Cambridge, 1999.

Hall, A. Rupert. *The Scientific Revolution, 1500–1800*. Boston, 1966.

Helbing, Mario. *La Filosofia di Francesco Buonamici, Professore di Galileo a Pisa*. Pisa, 1989.

Hellyer, Marcus. "'Because the Authority of My Superiors Commands': Censorship, Physics and the German Jesuits." *Early Science and Medicine* 1.3 (1996): 319–54.

———. *Catholic Physics: Jesuit Natural Philosophy in Early Modern Germany*. Notre Dame, 2005.

Iofrida, Manlio. "La Filosofia e La Medicina (1543–1737)." In *Storia dell' Università di Pisa* (1993), 1:289–338.

Jauss, Hans Robert. *Toward an Aesthetic of Reception*. Trans. Timothy Bahti. Minneapolis, 1982.

Johns, Adrian. *The Nature of the Book: Print and Knowledge in the Making*. Chicago, 1998.

Koyré, Alexandre. *Galileo Studies*. Trans. John Mepham. Hassocks, Sussex, 1978.

Maierù, Alfonso. *University Training in Medieval Europe*. Leiden, 1994.

Mango Tomei, Elsa. *Gli Studenti dell' Università di Pisa sotto il Regime Granducale*. Pisa, 1976.

Marrara, Danilo. "Gli Statuti di Cosimo I: Il Progetto e il Testo Definitivo." In *Storia dell' Università di Pisa* (1993), 1:577–645.

Mauro, Sylvester. *Quaestionum Philosophicarum Sylvestri Mauri Soc. Iesu. in Collegio Romano Philosophiæ Professoris. Libri Tres Pro Laurea Philosophica Andreae Portner Collegij Germanici, & Hungarici Alumni*. 3 vols. Rome, 1658.

Moss, Ann. *Printed Commonplace-Books and the Structuring of Renaissance Thought*. Oxford, 1996.

Nelles, Paul. "*Libros de Papel, Libri Bianchi, Libri Papyracei*: Note-Taking Techniques and the Role of Student Notebooks in the Early Jesuit Colleges." *Archivium Historicum Societatis Iesu* 76 (2007): 75–111.

O'Malley, John W., Gauvin Alexander Bailey, Steven J. Harris, and T. Frank Kennedy, eds. *The Jesuits: Cultures, Sciences, and the Arts, 1540–1773*. Toronto, 1999.

———. *The Jesuits II: Cultures, Sciences, and the Arts, 1540–1773*. Toronto, 2006.

Osler, Margaret J. "The Canonical Imperative: Rethinking the Scientific Revolution." In *Rethinking the Scientific Revolution*, ed. Margaret J. Osler, 3–39. Cambridge, 2000.

Palmerino, Carla Rita. "Infinite Degrees of Speed: Marin Mersenne and the Debate over Galileo's Law of Free Fall." *Early Science and Medicine* 4 (1999): 269–328.

———. "Two Jesuit Responses to Galileo's Science of Motion: Honoré Fabri and Pierre Le Cazre." In *The New Science and Jesuit Science: Seventeenth Century Perspectives*, ed. Mordechai Feingold, 187–228. Dordrecht, 2003.

———. "Gassendi's Reinterpretation of the Galilean Theory of Tides." *Perspectives on Science* 12.2 (2004): 212–37.

Palmieri, Paolo. *Reenacting Galileo's Experiments: Rediscovering the Techniques of Seventeenth-Century Science*. Lewiston, 2008.

Ragnisco, Pietro. "Da Giacomo Zabarella a Claudio Berigardo ossia prima e dopo Galileo nell' Università di Padova." *Atti del Reale Istituto Veneto* 52.1 (1893–94): 474–518.

Raphael, Renée. "Galileo as a Commentator on Aristotle?: The Reception of Galileo in the Jesuit Collegio Romano and University of Pisa, 1633–1700." PhD diss., Princeton University, 2009.

———. "Making Sense of Day 1 of the 'Two New Sciences': Galileo's Aristotelian-Inspired Agenda and His Jesuit Readers." *Studies in History and Philosophy of Science* 42 (2011): 479–91.

Renn, Jürgen. "Galileo's Manuscripts on Mechanics: The Project of an Edition with Full Critical Apparatus of Mss. Gal. Codex 72." *Nuncius* 3.1 (1988): 193–241.

Renn, Jürgen, Peter Damerow, and Simone Rieger. "Hunting the White Elephant: When and How Did Galileo Discover the Law of Fall?" In *Galileo in Context* (2001), 29–149.

Roux, Sophie. "An Empire Divided: French Natural Philosophy (1670–1690)." In *The Mechanization of Natural Philosophy*, ed. Daniel Garber and Sophie Roux, 55–95. Dordrecht, 2012.

Schmitt, Charles B. "Experience and Experiment: A Comparison of Zabarella's View with Galileo's in *De Motu*." *Studies in the Renaissance* 16 (1969): 80–138.

———. "The Faculty of Arts at Pisa at the Time of Galileo." In *Studies in Renaissance Philosophy and Science*, 243–72. London, 1981.

Secord, James A. "Knowledge in Transit." *Isis* 95.4 (2004): 654–72.

Settle, Thomas B. "An Experiment in the History of Science." *Science* 133 (1961): 19–23.

———. "Galileo's Use of Experiment as a Tool of Investigation." In *Galileo, Man of Science*, ed. Ernan McMullin, 315–37. New York, 1968.

Shapin, Steven. *The Scientific Revolution*. Chicago, 1998.

Shea, William. *Designing Experiments and Games of Chance*. Canton, MA, 2003.

Simplicius of Cilicia. *Commentaria in Aristotelem Graeca*. Vol. 7 of *De Caelo commentaria*. Ed. I. L. Heiberg. Berlin, 1894.

Sommervogel, Carlos. *Bibliothèque de la Compagnie de Jésus*. 12 vols. Brussels, 1890–1932. Reprint, Louvain, 1960.

Soppelsa, Marialaura. *Genesi del Metodo Galileiano e Tramonto dell' Aristotelismo nella Scuola di Padova*. Padua, 1974.

Spagnesi, Enrico. "Il Diritto." In *Storia dell' Università di Pisa* (1993), 1:191–257.

Stabile, Giorgio. *Claude Bérigard (1592–1663): Contributo alla Storia dell' Atomismo Seicentesco*. Rome, 1975.

———. "Il Primo Oppositore del Dialogo: Claude Berigard." In *Novità Celesti e Crisi del Sapere*, ed. Paolo Galluzzi, 277–82. Florence, 1984.

Storia dell' Università di Pisa. 2 vols. in 5 parts. Pisa, 1993.

Valleriani, Matteo. *Galileo Engineer*. London, 2010.

Verde, Armando. "Il Secondo Periodo de Lo Studio Fiorentino (1504–1528)." In *L'università e la sua Storia. Origini, Spazi Istituzionali e Pratiche Didattiche dello Studium Cittadino*, ed. Paolo Renzi, 105–31. Siena, 1998.

Wallace, William A. *Galileo and His Sources: The Heritage of the Collegio Romano in Galileo's Science*. Princeton, 1984.

Yeo, Richard. "John Locke's 'New Method' of Commonplacing: Managing Memory and Information." *Eighteenth-Century Thought* 2 (2004): 1–38.

———. "Between Memory and Paperbooks: Baconianism and Natural History in Seventeenth-Century England." *History of Science* 45 (2007): 1–46.

Zanfredini, M. "Mauro, Silvestro." In *Diccionario Histórico de la Compañia de Jesús Biográfico-Temático*, ed. Charles E. O'Neill and Joaquin M. Dominguez, 3:2583. Madrid, 2001.