BRILL

Early Science and Medicine 14 (2009) 265-289

Early Science and Medicine
www.brill.nl/esm

Conjecture, Probabilism, and Provisional Knowledge in Renaissance Meteorology

Craig Martin*
Oakland University

Abstract
For Renaissance Aristotelian natural philosophers, ideally knowledge was certain and based on syllogistic demonstration. Many Italian scholars, such as Agostino Nifo, Pietro Pomponazzi, and Niccolò Cabeo, considered this ideal as inapplicable to the field of meteorology. Rather, because of the accidental nature of meteorological phenomena and the inherent irregularity of the weather, they believed that causal explanations of meteorology were largely conjectural, provisional, and probabilistic. Several of these natural philosophers applied the standard of "saving the appearances" to the field of meteorology because of the difficulties involved in making accurate observations. This lower epistemological standard contributed to the willingness of Aristotelians to revise meteorological theories and deviate from Aristotle's own positions.

Keywords
meteorology, imperfect mixtures, Pietro Pomponazzi (1462-1525), earthquakes, demonstration, conjecture, dialectic, probabilism, "saving the appearances," Aristotelian natural philosophy, Renaissance

Introduction

The two dominating views of Renaissance Aristotelian epistemology or "scientific methodology" entail positions that are incompatible,

* History Department, Oakland University, 372 O'Dowd Hall, Rochester, MI 48309, U.S.A. (martin@oakland.edu). I thank Matt Klemm, Bill Newman, Darrel Rutkin, and Edith Sylla for their advice, comments, and corrections. Research and writing of this article was supported by a Gladys Krieble Delmas Foundation Fellowship, an Oakland University URC Faculty Fellowship, and a Dibner History of Science Program Fellowship at the Huntington Library.

DOI: 10.1163/157338208X362■■

if not contradictory. The first view holds that Aristotelians believed that their knowledge was complete and certain. Holders of this position believe that Aristotle, and his later medieval and Renaissance commentators, equated natural philosophical knowledge with the logical methods found in the analytics, that used syllogism for a model of unequivocal demonstration. These accounts begin with analyses of Aristotle,[1] extend from Aristotle's supposed view to his scholastic followers,[2] and find that the rejection of belief in the certainty of knowledge of the natural world to be crucial to the Scientific Revolution.[3] Thus according to this view, seventeenth-century English experimentalists, in a climate of latitudinarianism, overturned their predecessors' epistemology that used the demonstrative sciences as a model "to attain to the kind of certainty that compelled absolute assent."[4] Moreover, the insistence on certainty purportedly endorsed by Aristotelian natural philosophers is considered opposed not just to the new natural philosophies of the seventeenth century but also to the rhetorical traditions of Renaissance humanists that emphasized observation and contingent knowledge.[5]

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1) James Franklin, *The Science of Conjecture* (Baltimore, 2001), 166: "Aristotle argued for a rational search for certain causes in medicine as everywhere else."

2) Peter Dear, *Revolutionizing the Sciences: European Knowledge and Its Ambitions, 1500-1700* (Princeton, 2001), 5-6: "The lure of demonstrative certainty drew scholastic natural philosophers to believe that they could make knowledge that was analytically solid." Richard G. Olson, *Science and Religion, 1450-1900: From Copernicus to Darwin* (Baltimore, 2004), 90: "According to most Christian Aristotelian philosophers including Thomas Aquinas, one should demand absolute certainty of any religious or natural scientific statement that commands assent."

3) James R. Jacob, *The Scientific Revolution: Aspirations and Achievements, 1500-1700* (Atlantic Highlands, NJ, 1998), xiii: "The shift from an Aristotelian theory of knowledge, which was confident of the truth of what we perceive, to a modern skepticism that doubts our capacity to know truth but nonetheless finds the resources, intellectual and cultural to overcome pessimism and to insist that scientific knowledge is still attainable … ."

4) Steven Shapin and Simon Schaffer, *Leviathan and the Air-Pump: Hobbes, Boyle, and the Experimental Life* (Princeton, 1985), 23-24

5) Barbara Shapiro, *Probability and Certainty in Seventeenth-Century England: A Study of the Relationships between Natural Science, Religion, History, Law, and Literature* (Princeton, 1983), 3-14.

The second view, which stems from the groundbreaking work of first Ernst Cassirer and then John Herman Randall, Jr., stresses the importance of the method called *regressus*, which combined new observationally based discovery of causes (*demonstratio quia* or *methodus resolutiva*) with the certainty of syllogism in producing theoretical explanations (*demonstratio propter quid* or *methodus compositiva*).[6] Using this model of method, natural signs, experience, and observations lead to the hypothetical determination of the causes of effects, by what Averroes termed *demonstratio signi* or "demonstrations from signs." Then by an intellective *negotiatio*, confidence in the hypothetical causes increases. Finally, the causes can then be utilized to explain the effects in a certain demonstration. Thus, *regressus* method allows for the possibility of change and progress in natural philosophical knowledge and a place for hypothetical understandings of nature without rejecting the possibility of syllogistic demonstration. The possibility of change means that the results are not certain but rather provisional, especially for knowledge that has resulted only from the first stage of the procedure, the *demonstratio signi*.

While the combination of all three parts of the *regressus* was intended to bring about certainty or near certainty, the realization of this goal was not always possible because of the contingent, i.e., accidental, nature or difficulty of the subject. Paolo Palmieri notes for example that Giacomo Zabarella, one of the leading proponents of and contributors to the *regressus* theory, did not apply the theory in his textbook, *De rebus naturalibus*.[7] Zabarella, however, and many other Renaissance natural philosophers followed the first stage of the *regressus* in their discussions of meteorology, a field that recommended itself to *demonstratio signi* because of Aristotle's explicit use of signs in his own considerations of meteorological phenomena. The first stage of the *regressus* was not taken to be definitive or certain but rather was provisional. Agostino Nifo, a natural philosopher

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6) Ernst Cassirer, *Das Erkenntnisproblem in der neueren Zeit* (Berlin, 1922), 136-144; John Herman Randall, Jr., "The Development of Scientific Method in the School of Padua," *Journal of the History of Ideas*, 1 (1940), 177–206; John Herman Randall, Jr., *The School of Padua and the Emergence of Modern Science* (Padua, 1961).

7) Paolo Palmieri, "Science and Authority in Giacomo Zabarella," *History of Science* 45 (2007), 404-427, esp. 418.

who wrote on logic as well as meteorology, described the discovery of causes through natural effects, a method he took to be typical of the natural philosophy, as "conjectural."[8]

An examination of Italian Renaissance Aristotelian meteorology, from Agostino Nifo to Niccolò Cabeo, demonstrates that Aristotelians saw many theories about nature as provisional and at times instrumental. Just as Robert Boyle and other later experimentalists are said to have believed, they thought that their "physical hypotheses were provisional and revisable" in addition to being "removed from the realm of the demonstrative."[9] Thinkers including Nifo, Pietro Pomponazzi, and Lodovico Boccadiferro applied the ideal of "saving the appearances" not just to astronomical theory but also to explanations of changes within the sublunary region. While epistemic goals and standards varied among thinkers, a number of them consciously followed at least the first stage of the *regressus* theory, the demonstration of the fact, in their attempts to establish hypothetical understandings of the causes of weather. Many were fully aware of the uncertainty of their findings and enunciated the provisional nature of their theories. This does not mean, however, that they were anticipating or applying the modern scientific method or Baconian induction. Rather their views were firmly based in Renaissance ideals of demonstration and dialectic based on experience, Aristotelian textual analysis, and the utilization of signs.

Aristotle's Meteorology

Aristotelian meteorology, as opposed to astro-meteorology, was primarily causal in its goals, not predictive. For Aristotle, knowledge of the causes of many meteorological subjects was based not on syllogistic deduction but was the result of interpreting signs that helped to confirm the hypothesis that meteorological phenomena result from two exhalations that circulate in the sublunary region.

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8) Agostino Nifo, *Expositio super octo Aristotelis Stagiritae libros de physico auditu,* (Venice, 1552), fol. 6v.

9) Shapin and Schaffer, *Leviathan and the Air-pump*, 24.

Aristotle himself was aware of the impossibility of a unified method for all learning, and proposed a prohibition on μετάβασις, the use of content from one field to explain another.[10] Thus, he contended that while mathematics was appropriate for discussions of astronomy and optics, in other messier fields, the objects of science could not be known through such tools. In the *Nicomachean Ethics*, Aristotle specified that all fields of philosophy cannot be expected to achieve the same level of precision (τὸ ἀκριβής). Rather, the degree of certainty is determined, at least partially, by the nature of the subjects under scrutiny. Thus fields that rely on opinion and uncertain premises can at best provide probable conclusions and approximations to the truth (τύπῳ τἀληθὲς).[11]

While in the *Ethics* Aristotle urged investigators to expect degrees of exactness proportional to the subject at hand, in the *Topics* he detailed two kinds of logical proof that differ in terms of certainty: demonstration (ἡ ἀπόδειξις) and dialectic. Demonstration, the more certain of the two, is a deductive argument based on "true and primitive" premises that are convincing in and of themselves; dialectic starts with reputable opinions, that is, opinions that if not acceptable to everyone at least are endorsed by most wise people. Demonstration provided *scientia*, proven knowledge, while dialectic yielded verisimilitude. In the words of recent commentators, dialectic "could offer only conjectural premises and probable conclusions," no matter how accurate or truthful they seemed.[12] Thus Renaissance thinkers typically understood dialectic as a discussion of probability, that is, a consideration of likelihoods. By the sixteenth century, scholars had added a third category of argument, namely persuasion, which was rhetorical in its nature and even less certain than dialectic. Acknowledgement of these three categories, demonstration, probability, and persuasion, was so widespread that it was common to, in the words of Richard Serjeantson, "every natural

[10] Aristotle, *Posterior Analytics*, 75a38-75b6.

[11] Aristotle, *Nicomachean Ethics*, 1094b13-27.

[12] Jean Dietz Moss and William A. Wallace, *Rhetoric and Dialectic in the Time of Galileo* (Washington, D.C., 2003), 16.

philosopher educated to any level beyond that of rudimentary Latin grammar."[13]

While recognition of the categories of demonstration, probability, and persuasion was nearly universal, it was less clear which category should be applied to which subjects. Meteorology, however, was a particularly good candidate for dialectical or probable arguments for a number of reasons. For one, Aristotle's approach was dialectical throughout the *Meteorology*. He considered and largely rejected the opinions (τὰ ἔνδοξα) of the Presocratics in addition to admitting the relative strengths of the adopted positions.[14] Second, some Renaissance Thomists believed that certain knowledge (*scientia*) was restricted to metaphysical topics while opinion (*opinio*) applied to the physical world, and thus also to meteorology.[15] The lower epistemic standard was used for natural knowledge in part because the regularity of nature is only "for the most part," according to Aristotle. In particular, matter and its accidents, as opposed to substances, are contingent, that is, are not necessary, accidental, and "capable of being otherwise than as it for the most part is."[16] Aristotle went on to explain in the *Posterior Analytics* that non-essential attributes, or accidental qualities, because of the absence of their necessity, are not subject to necessary proofs or demonstrative knowledge (ἐπιστήμη ἀποδεικτική).[17] The contention that the non-essential does not admit to demonstration but rather to dialectic or probable argumentation is crucial to Renaissance meteorology because of the widely-held belief that most meteorological phenomena involve not substances or essential natures *per se* but rather imperfect mixtures of the elements. If meteorology deals with

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13) R.W. Serjeantson, "Proof and Persuasion," in *The Cambridge History of Science: Volume 3 Early Modern Science*, ed. Lorraine Daston and Katharine Park (Cambridge, 2006), 139-140.
14) Cynthia Freeland, "Scientific Explanation and Empirical Data in Aristotle's *Meteorology*," *Oxford Studies in Ancient Philosophy* 8 (1990), 62-107.
15) Serjeantson, "Proof and Persuasion," 139.
16) Aristotle, *Metaphysics*, VI.2, 1027a12, Trans. W.D. Ross.
17) Aristotle, *Posterior Analytics*, I.6, 75a19-22.

accidental formations of the elements then it stands to reason that any understanding of the field is only probable.[18]

Aristotle realized the difficulty of making comprehensive and accurate determinations of meteorology. According to Aristotle, meteorology strives to explain changes in the sublunary world, including the area above the earth as well as below. The key word is "strives." The phenomena of this region are natural, but necessarily irregular, particularly in comparison to the celestial region.[19] Because of their natural irregularity, a limited confidence in the ability to give true explanations is called for. Aristotle wrote: "Of all these phenomena, some we find inexplicable, others we can to some extent understand."[20] Gaining a good account of meteorological phenomena is hampered not only by their irregularity but also by their inaccessibility to the senses. Before giving his explanation for comets, Aristotle, in a statement that can reasonably be thought to apply to large portions of the *Meteorology*, wrote: "We consider that we have given a sufficiently rational explanation of things inaccessible to observation by our senses if we have produced a theory (λόγος) that is possible."[21] Thus the goal was to provide a "possible" account rather than a "certain" one.

Matter Theory, Uncertainty, and Meteorology

A number of Renaissance treatments of Aristotle's *Meteorology* not only accepted his claims that meteorological knowledge is limited but used matter theory to explain why. These explanations were based on two principles: 1) meteorological phenomena result from imperfect mixtures, which do not possess substantial forms; and 2) the matter of the terrestrial or sublunary realm is unstable and relatively unknowable.

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18) For similar arguments as applied in Renaissance medicine see Ian Maclean, *Logic, Signs and Nature* (Cambridge, 2002), 132.

19) Aristotle, *Meteorology*, 338b1-3.

20) Ibid., 339a3-4. Tr. H.D.P. Lee (Cambridge, MA, 1952), 5.

21) Ibid., 344a5-7. Tr. Lee, 49.

The idea that the first three books of the *Meteorology* treated imperfect mixture goes back at least to Albertus Magnus who described the subject of these books as phenomena that are in the state of becoming a simple substance.[22] John Buridan was one of the earliest to use the term "imperfect mixtures" to categorize meteorological substrata in contrast to "perfect mixtures" such as flesh, blood, milk, and metals, for which *Meteorology* IV gives an account.[23] Renaissance Aristotelians followed Buridan's phrasing almost uniformly. The acceptance of meteorological substrata as "imperfect" contributed to the idea that meteorological knowledge is probable. If meteorology considers objects that are without their own substantial forms, knowledge of formal causes will be limited. Indeed meteorology most often referred to the forms of the elements that composed the two exhalations, which were the material and efficient causes of meteorological effects. Francesco Piccolomini, a professor at Padua during the last decades of the sixteenth century, explicitly expressed this view: "The form that is a substance is not properly suited to meteors, because they are imperfect mixtures, which are of such a type, that they will not create new forms; therefore their substantial form is not distinct from those of the elements."[24] As a result, scholars were limited in the kinds of formal and final causation that could be used to understand meteorology.

Although Renaissance commentators did not uniformly claim there were no formal or final causes for meteorological phenomena, the rejection of the existence of those causes was frequent. For example, Francesco Vimercati and Jacob Schegk specifically argued that the two causes of meteorological phenomena are efficient and material causes; and the Coimbrans' commentary contended that "meteors" do not have their own formal causes and made little mention

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22) Albertus Magnus, *Liber quartus meteororum,* in *Opera,* ed. A. Borgnet (Paris, 1890), IV: 705.

23) John Buridan, *Expositio libri meteororum*, Ms. Vaticana lat. 2162, f. 103r.

24) Francesco Piccolomini, *Librorum ad scientiam de natura attinentium pars quarta. In qua Meteorologica explicantur et connexa cum eis* (Venice, 1596), fol. 4v "Forma, quae Substantia sit, proprie Metheoris non competit, quia sunt mixta imperfecta, quae huius sunt conditionis, ut nova non prodierint, ideo forma Substantialis non est distincta ab ea Elementorum."

of final causes.[25] Effectively, the idea that the end of a substance was the realization of its form was ruled out, leaving only external final causes available for meteorology for those who believed that final causes do indeed exist for meteorology. The character of meteorological phenomena thus eliminated the possibility of a deep knowledge of their formal and final causes, the two most privileged types of causes for Aristotelians.

The Renaissance conception of the imperfection of meteorological phenomena was an amalgam of the Aristotelian ideas of potency and act and Platonic views of matter, that had held currency throughout the Middle Ages. In the *Timaeus*, Plato contrasted the matter of the sublunary world with the forms. Forms are perfect, unchanging, and the source of knowledge. To the contrary matter is the source of imperfection in the world because of its instability. Material necessity is the "errant" cause.[26] As a result, understandings of the material world are necessarily as transitory as its contents, and the *Timaeus* puts forth only a "likely" explanation, which is the best we can hope for.[27] Plato's belief that matter is the source of uncertainty or natural imperfection ran through the Augustinian tradition and emerged in other *loci* of medieval and Renaissance scholasticism. Averroes in his commentary on the *Posterior Analytics* wrote, "matter is the reason that that which is *per accidens* is found in the sciences. And what is *per accidens* is a great distance from truth … Therefore, it is necessary that the matter is less true."[28] Thomas Aquinas expressed a similar view in his commentaries on Aristotelian logic, where he contended that uncertainty is correlative

25) Jacob Schegk, *In reliquos naturalium Aristotelis libros Commentaria* (Basel, 1550), 335; Francesco Vimercati, *In quatuor libros Aristotelis Meteorologicorum commentarii* (Paris, 1556), 18; Collegium Conimbricense, *In libros Meteororum Aristotelis Stagiritae* (Cologne, 1603), 5.

26) Plato, *Timaeus*, 47e-48e.

27) Plato, *Timaeus*, 29b-c.

28) Averroes, *In librum Aristotelis de demonstratione maxima expositio*, in *Aristotelis Opera cum Averrois Commentariis* (Venice, 1572-1576 ; reprt. Frankfurt am Main, 1962), I, 2, fol. 375r: "materia est causa, quod inveniatur in scientiis id, quod est per accidens: et quod est per accidens est magna elongatio a veritate … oportet igitur ut materia sit minus vera … ."

to matter's instability: "Uncertainty is caused by the transmutability of sensible matter; thus however much it approaches it [matter], knowledge (*scientia*) is less certain."[29] These views were influential in logical works even up to the 1590s, when Zabarella cited them to give authority to his similar position.[30] The practical ramifications of this Platonic conception of matter, however, are evident not in the works on logic and method but in meteorological discourse, because of its overwhelming concern with material causes.

Simone Porzio, a professor at Pisa in the 1540s and 50s best known for his defense of the materiality of the human intellect,[31] gave an account of the epistemological basis for the natural sciences in his treatise, *De rerum naturalium principiis*. In the section that considers meteorology, Porzio considered the immediate efficient causes of simple and composite substances. Simple substances can be known according to a formula (*ratio*) because they are constant by nature. Difficulties, however, emerge in attempting to explain particular composites or mixtures because they arise out of matter that is indeterminate. These mixtures are accidental and lack a specific cause; their necessity is internal rather than the necessity of universal efficient causes, such as the sun. Thus, Porzio contended that natural philosophical arguments that move "from efficient causes to their effects are not the most powerful (*potissimae*) because the effects can be impeded by the indetermination of the matter, which can receive multiple and various forms."[32] For Porzio, the plasticity

29) Thomas Aquinas, *In Aristotelis Peri Hermeneias et Posteriorum analyticorum expositio*, ed. Raimondo M. Spiazzi (Rome,1964), lib. I, lect. 41, n. 358: "… incertitudo causatur propter transmutabilitatem materiae sensibilis; inde quanto magis acceditur ad eam, tanto scientia est minus certa."

30) Luigi Olivieri, *Certezza e gerarchi del sapere: Crisi dell'idea di scientificità nell'aristotelismo del secolo xvi* (Padua, 1983), 67-69.

31) Simone Porzio, *De humana mente, disputatio* (Florence, 1551).

32) Simone Porzio, *De rerum naturalium principiis* (Naples, 1553), fol. Riiv-Riiir: "Verum respectu aliquorum, ut puta quarundam elementorum affectionum, quas in libro Meteorum alias enarravimus, est causa particularis, hoc est, est proxima & immediata efficiens causa: … Atque iccirco in rebus naturalibus demonstrationes a causis efficientibus ad suos effectus non sunt potissimae: quia effectus impediri queant, ob materiae indeterminationem, quae varias multiplicesque formas recipere potest."

of matter makes knowledge of composites uncertain and proofs stemming from efficient causes are less than certain. Even though Porzio's conclusion potentially applies to many fields within natural philosophy, it is especially pertinent to meteorology because of the significant role that matter holds in explanations of this field.

Saving the Appearances: Probable, Possible, and Provisional Knowledge

The lack of certainty about meteorological phenomena did not render the field hopeless. Rather honest assessments of the character of meteorological theory were needed, as was recognized well before the Renaissance. Avempace (Ibn Bājja), for example, compared the field of meteorology to mathematical astronomy, which he believed had progressed in recent years, "we have now more principles from mathematical astronomy than in any preceding time." In comparison, meteorological subjects are "difficult" because "the principles we have are not sufficient," but that should not lead us to reject natural science altogether, rather "there is no reason to give no account at all; therefore, let us give an account insofar as we are enabled to do it by the principles we have found."[33] A modest assessment of the possibility and degree of knowledge in meteorology is required until better principles are uncovered. While a critic of a number of aspects of Avempace's natural philosophy, Averroes in his meteorological works agreed concerning the limited epistemic character of meteorology. In his discussion of the Milky Way, Averroes argued that because there are doubts about the *genus* of the Milky Way, our knowledge of its causes should be considered "possible" and our understanding diminished (*cognitio diminuta*).[34] The acceptance of limitations was no hindrance to speculation about

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33) Paul Lettinck, ed. and trans., *Aristotle's Meteorology and its Reception in the Arab World: With an Edition and translation of Ibn Suwār's Treatise on Meteorological Phenomena and Ibn Bājja's Commentary on the Meteorology* (Leiden, 1999), 399

34) Averroes, *In quatuor Meteorologicorum Aristotelis libros* in *Aristotelis Opera,* V, fol. 414r: "Accidit autem huic cognitioni in substantia Galasiae esse cognitionem diminutam: propterea quod genus illius est ignotum esse per se."

causes as long as we recognize that they are only possible; thus, Averroes offered two separate possibilities for the causes of the flickering Milky Way: the weakness of our eyes causes it because of the distance of small stars; or, a place in the skies receives and multiplies the light of the stars.

The views of Averroes resonated during the Renaissance. Pietro Pomponazzi expressed skepticism about the possibility of complete knowledge of the natural world, using our inability to understand meteorological phenomena as evidence for the limitation of human knowledge. In his *De incantationibus*, a work dedicated to giving potential explanations for strange and seemingly miraculous events, for prodigies, including fountains and statues that drip blood, or for bizarre meteorological events chronicled in histories, such as the time it rained wool, he conceded that an epistemological standard below certainty was appropriate. In the introductory pages of *De incantationibus*, he claimed that some Peripatetics used demons to explain the intractable, not only because demons are posited by "ecclesiastical decrees," but also because their presumed existence allows us to "save many phenomena."[35] The employment of demons in natural philosophy is thus instrumental, parallel to epicycles and eccentrics that save the phenomena in astronomy. While Pomponazzi rejected demons, he did not reject the idea that naturalistic explanations are meant to save the appearances. Citing Averroes' commentary on the *De caelo* and Aristotle's *Topics,* Pomponazzi argued "that in difficult and hidden matters, the answers more removed from inconveniences, and more consonant with sensations and reason, are to be better received than contrary arguments."[36] As a result, Pomponazzi's controversial claim that the miraculous events

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35) Pietro Pomponazzi, *De naturalium effectuum causis sive de incantationibus* (Basel, 1567; reprint Hildesheim, 1970), 6. For saving the appearances in Pomponazzi see Ian Maclean, "Heterodoxy in Natural Philosophy and Medicine: Pietro Pomponazzi, Guglielmo Gratarolo, Girolamo Cardano," in *Heterodoxy in Early Modern Science and Religion,* ed. John Brooke and Ian Maclean (Oxford, 2005), 1-29, esp. 15-16; Franco Graiff, "I prodigi e l'astrologia nei commenti di Pietro Pomponazzi al *De caelo,* alla *Meteora* e al *De generatione*," *Medioevo* 2 (1976), 331-361, esp. 331-332.

36) Pomponazzi, *De incantationibus*, 130-131. For raining wool see Pliny, *Historia naturalis*, II, 57.

recounted in scripture "can on the surface be reduced to natural causes"[37] need not be taken as an endorsement of the view that the events actually were the result of natural causes alone but rather as support of the more modest claim that natural causes can give an explanation that potentially conforms to our experiences and reasoning.

Pomponazzi further considered epistemology and the natural world in his *In libros Meteororum* (ca.1522), a work that discusses these difficult and hidden matters. In this work he contended that Aristotle at times adopted the epistemological standard of verisimilitude and employed rhetorical arguments in natural philosophy. As a result, Pomponazzi conceded that saving the appearances was an appropriate ideal for natural philosophy.

In a *dubium* dedicated to *Meteorology* 2.1, he addressed the degree of knowledge and certainty that can be ascribed to meteorological subjects as he tried to make sense of a passage of the *Meteorology* that confounded and contradicted his own experience of the natural world. In this passage, Aristotle attempted to explain the sources that create various kinds of bodies of water. He divided the kinds of bodies of fresh water into two types: standing and running. Running water, such as rivers and streams, comes from sources that are higher than the stream or river. Standing water, however, is of two types. Typically, standing water naturally comes from the accumulation of rain water and is static; the relevant examples are lakes and swamps. According to Aristotle, standing water that comes from underground sources only does so when artificially created, such as in the case of wells. This last statement, which Pomponazzi found problematic, does not appear to have been a slip of the Stagirite, as it appears twice. Aristotle wrote: "Some [standing water] springs from sources, but is always made to do so artificially (χειρόκμητα), as for instance the water in wells." And two lines later wrote: "Hence water in streams and rivers runs of its own accord (αὐτόματα), but well-water needs an artificial construction (τέχνης ἐργασομένης)."[38]

[37] Pomponazzi, *De incantationibus,* 81.
[38] Aristotle, *Meteorology,* 353b25-29. Trans. Lee, 127.

Pomponazzi found the contention that all standing springs or wells must be artificial untenable: "this is *contra experimentum*, as many from the schools have told me they have seen, and I myself have seen, many springs and natural wells."[39] After rejecting the interpretation attributed to Thomas Aquinas, which was shared by Gaetano of Thiene and "all of the Latins [he] had seen," because this view, although in agreement with Aristotle, was not in accordance with reason and experience, and after dismissing Alexander's view, which he said was also false, Pomponazzi tried to determine why Aristotle believed as he did. He speculated that perhaps "in Aristotle's country all stationary bodies of water are man-made," although in his own "regions this is not the case."[40] But his conclusion was that Aristotle's view is "probable and does not demonstrate."[41] More strongly he contended that "in my judgment Aristotle's theory is without value." The only way Pomponazzi found to make sense of Aristotle was to lower the epistemological standard that Aristotle used to reach this theory. It is not one of demonstration as found in the *Analytics* but rather closer to the standards of a rhetorical argument:

> I do not wish to seem rash for I do not say this because I wish to reprehend the words of Aristotle, yet without blaming it is conceded to me and licit to doubt about this matter. For in my view Aristotle's position is without value. I know how to respond to this position [i.e., Aristotle's] even if I do not know it [i.e., the correct position] and I would like to respond to it. Perhaps it should be said that Aristotle does not proffer this position as a demonstration and necessary proof but in order that it be some likely persuasion. For it seems that the sea could not arise from springs by the method that Aristotle posits but does not demonstrate. I should say that Aristotle did not posit it as a demonstration. [His position] is valid according to verisimilitude, not by [his] advancing [it] absolutely. For in advancing

39) Pomponazzi, *In libros Meteororum* , Ms. Biblioteca Ambrosiana R. 96 sup., fol. 49r: "Et hoc est contra experientiam; nam, ut multi ex scolaribus mihi dixerunt vidisse, et ego ipse vidi multos fontes et puteos stantes naturales naturaliter neque aliquo artis ministerio."

40) Ibid., fol. 50r: "sed forsan in patria Arist[otelis] ita erat quod omnes aquae stationariae erant manufactae. In nostris tamen regionibus non ita est."

41) Ibid., fol. 49v: "Hoc autem est probabile, et non demonstrat."

> it absolutely, it would be false. But Aristotle has assumed it not absolutely, but for the most part.[42]

Pomponazzi thus contended that Aristotle for many topics argued not absolutely but with likely persuasion or according to verisimilitude. These many topics included others discussed in the *Meteorology*, where Aristotle seems to have made the claim that he could not use demonstrative proof because of the inaccessibility and irregularity of many meteorological effects.

Pomponazzi resumed this discussion of the epistemology of meteorology in another *dubium* in which he addressed Aristotle's theory of the formation of typhoons. According to this theory typhoons result when two winds collide in a cloud. The weaker wind is thrust aside and begins to move in circular motion, just as an eddy does in water. Pomponazzi asked simply: How did Aristotle know typhoons are formed in such away "when he was neither above the clouds nor was he able to see them generated?" The answer depends on the relatively lower standard of demonstration for natural phenomena inaccessible to the senses. Citing the first book of the *Nicomachean Ethics*, where Aristotle held that one cannot expect the same level of demonstration in ethical matters as one finds in mathematics, Pomponazzi suggested "that as much should be expected by the auditor as the treated material allows." The natural world defies complete explanation, while metaphysics can admit certain demonstration:

> In natural things we cannot have demonstration *semper sic* … since no one can know these *diurna superiora*. For we are like manual workers, and God truly is as

42) Ibid., fol. 50r: "Nollem ego videri temerarius. nam haec non dico ut velim dicta Arist. reprehendere. sed tamen circa illa absque reprehensione mihi concessum et licitum est dubitare; nam meo iudicio ratio Aristo. nullius est valoris. Ad hanc rationem scio ego respondere nec eam novi, et [ut written above] respondere velim. forsan dicendum est, quod Ar. non protulit hanc rationem pro demonstratione et necessaria probatione, sed ut esset quaedam persuasio. Verisimile enim videtur quod non possit mare a fontibus ortum trahere. Ratione illa quam ponit Ar[istoteles] non autem demonstrat. id dicerem Aristotelem non potuisse pro demonstratione. Valet ergo a verisimili, non absolute proferendo. absolute enim proferendo falsa esset. Sed Ar[istoteles] assumpsit eam ut in pluribus non absolute."

> Architect, we can make artificial things and not natural, and in this science [i.e., meteorology] we can have demonstration and certitude in so far as we can, not however as [we can] in metaphysics.

Rather the standard for much of the impermanent natural world is "saving the appearances." Pomponazzi thus concluded that: "but because Aristotle is further from contradiction, therefore his words are tested in natural things."[43] Many discussions of the natural world and therefore discussions of meteorology are evaluated not by strict standards of syllogistic proof but rather by their consistency with experience and free from internal contradiction.

Agostino Nifo agreed with Pomponazzi, his rival and contemporary, that theories in meteorology should attempt only to save the appearances because of the indetermination of matter combined with concerns over the possibility of accurate sensation and the limits of human comprehension of natural subjects. In a short treatise on the causes of catastrophes printed in 1505, he considered and rejected the possibility of accurately predicting meteorological catastrophes through diagnoses of air because of the near infinite number of mixtures, each with a different temperament. "To explain how so many signs from mixtures occur is laborious and perhaps beyond human capabilities." Thus only an empiricism based on observation, not on matter theory, can aid in predicting future natural

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[43] Ibid., fol. 84r: "Alia dubitatio satis trivialis: quomodo scivit Aristoteles tiphonem illo modo contrarium, cum non fuerit supra nubem, nec viderit eum generari. Notetis quod tantum petendum est ab auditore, quantum concedit materia tractata: et clare habetur primo Aethic. [i.e., *Nicomachean Ethics*] et in meth. [i.e., the *Metaphysics*]. In rebus naturalibus non possumus habere demonstrationem semper sic, ut diximus in lib. de Anima, meth., autem prius, Quoniam nemo possit scire illa diurna superiora. Nos enim sumus ut manuales, Deus vero ut Architectus, possumus enim nos facere artificialia non autem naturalia, unde in hac scientia possumus habere demonstrationem, et certitudinem eo modo quo possumus, non autem ut in meth. Sed quia Aristoteles remotior est a contradictione, ideo sua dicta in naturalibus probantur." For Pomponazzi's claims of using an uncertain method in other works see: Stefano Perfetti, "Docebo vos dubitare. Il commento inedito di Pietro Pomponazzi al *De partibus animalium* (Bologna 1521-24)," *Documenti e studi sulla tradizione filosofica medievale* 10 (1999), 439-66; Francesco Paolo Raimondi, "Pomponazzi's Criticism of Swineshead and the Decline of the Calculatory Tradition in Italy," *Physis* n.s. 37 (2000), 311-358, esp. 326.

disasters.[44] Similar doubts were common to critiques of medical diagnosis and astrological prediction, fields that potentially considered an infinite number of combinations of complexions and influences.[45] In any case, in his commentary on the *Meteorology* that was first printed in 1523, Nifo went even further, conceding that the field of meteorology is not a science in itself (*in se*) because of the irregularity of meteorological phenomena and "also because the elementary causes, from which these [meteorological] phenomena arise, act contingently and are acted upon contingently."[46] The indeterminate nature of matter coupled with the difficulty of observing many meteorological phenomena led Nifo to conclude that the standard of meteorological knowledge required that the accounts were coherent rather than certain in a strict sense.

> Because we think we have sufficiently given demonstration about effects unclear to the senses according to theory (*secundum rationem*) if we reduce those appearances to the possible, that is, to such a certainty to which what is impossible does not follow.[47]

In his treatment of Aristotle's *Physics*, Nifo, basing himself on his reading of the *Meteorology*, expanded this judgment to all of natural science, which he says is not a *scientia simpliciter* such as mathematics because "it does not treat the true causes of natural effects, but only in so far as they are possible through conjecture."[48]

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44) Agostino Nifo, *De nostrarum calamitatum causis liber ad Oliverium Carafam* (Venice, 1505), fol. 18r: "Explicare quot e mixtionibus contingant significationes laboriosum est: et fortasse supra captum humanum: quapropter observatoribus pensitanda relinquimus."

45) For medicine, see Maclean, *Logic, Signs and Nature*, 134.

46) Agostino Nifo, *In libris Aristotelis Meteorologicis commentaria* (Venice, 1540), fol. 2r: "Tum etiam quia cause elementarie e quibus, hec proficiscuntur, contingenter agunt, et contingenter patiuntur."

47) Nifo, *In Meteorologicorum,* fol. 26v: Quoniam autem de effectibus sensui immanifestis putamus sufficienter demonstrasse secundum rationem si ostensa de his reduxerimus ad possibilem, hoc est ad talem certitudinem, ad quam non sequantur impossibilia."

48) Agostino Nifo, *Expositio super octo Aristotelis Stagiritae libros de Physico auditu* (Venice, 1552), fol. 6v: "Dicendum, scientiam de natura non esse scientiam simpliciter,

A similar skepticism toward the possibility of certain knowledge of meteorology is found in Tiberio Russiliano's *Apologeticus adversus culcullatos* (1519), a work that applied physical causes to both the foundations of Christian dogma and to what was traditionally understood as miraculous. Russiliano, a former student of Nifo, in a *quaestio* in which he put forth the argument that according to philosophical arguments there must have been an infinite number of universal floods, considered his argument "demonstrative and unassailable," but only if his suppositions are accepted. He admitted that not all of his suppositions were necessarily true even if they were clear in themselves (*ex se patent*); rather they were conjectural, based on common agreement and sensible signs.

> The suppositions are clear of themselves; first they derive out of common agreement and experience, since signs and traces of an inundation appear in mountainous regions, such as seashells and oysters, so that we should reasonably arrive at the conjecture that when there was a universal flood it covered and surpassed all of the mountains.[49]

The key is that signs and traces, based on experience, lead to conjectures that then become the basis for premises in deductive arguments. The deductive arguments, however, are only as sound as the conjectures upon which they are based.

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qualis est scientia mathematica, est tamen scientia propter quid: quia inventio causae, quae habetur per syllogismum coniecturalem, est propter quid effectus. Per haec delentur obiectiones, quae contra haec fieri solent: Prima quidem delentur ex eo, quia non est circulus in demonstratione, cum primus processus sit tantum syllogismus, secundus vero demonstratio propter quid. Deletur etiam secunda obiectio, quia effectus semper est notior ipsa causa in genere notitiae quia est. Nunquam enim causa potest esse ita certa quia est, sicut effectus, cuius esse est ad sensum notum. Ipsum vero quia est causae, est coniecturale, utrum tale esse coniecturale est notius ipso effectu, in genere notitiae propter quid. Nam posita inventione causae, semper scitur propter quid effectus. unde & Aristo[teles], in libro *Meteororum* concedit se non tradidisse veras causas effectuum naturalium, sed quo erat sibi possibile coniecturabiliter."

49) Tiberio Russilano, *Apologeticus adversus cucullatos*, ed. Luigi De France (Cosenza, 1991), 154: "Suppositiones autem ex se patent; prima quidem ex communi consensu et experientia, cum in locis montuosis signa adhuc inundationis appareant atque vestigia, ut conchae et ostrea, ut deveniamus iure in coniecturam quandoque diluvium fuisse universale, montuosa quaecumque cooperiens ac tegens."

Since the time of Pierre Duhem, the epistemological standard of "saving the appearances" has been used to distinguish the astronomical science from cosmology and terrestrial physics.[50] As Peter Barker and Bernard Goldstein have argued, the epistemological goal of "saving the appearances" was meant to give *demonstratio quia* while admitting the impossibility of *demonstratio propter quid*.[51] While for astronomy the limitations on certainty result from the mathematically indistinguishable nature of starting principles and the inability to observe accurately celestial bodies, for meteorology the limitation comes from the accidental nature of meteorological phenomena. Lodovico Boccadiferro, a professor of natural philosophy at Bologna in the period 1527-1545, who had studied with Pomponazzi, perhaps gave the clearest summation: "This law must be observed: that when the causes of some effects are unknown to us, we must accept suppositions, or principles, from which nothing impossible, nothing contrary to the senses, and nothing repugnant to the appearances follows." Boccadiferro admitted that this "contingent possible proposition is that which is not true, but could be true."[52] Thus the epistemological standard for meteorology fell far below that of certain truth; and the goal of "saving the appearances" should not be taken to be characteristic only of astronomy but for some parts of natural philosophy as well.

50) Pierre Duhem, *SOZEIN TA PHAINOMENA, essai sur la notion de théorie physique de Platon à Galilée* (Paris, 1908).

51) Peter Barker and Bernard R. Goldstein, "Realism and Instrumentalism in Sixteenth-Century Astronomy," *Perspectives on Science* 6 (1998), 232-258.

52) Lodovico Boccadiferro, *Lectiones super primum librum Meteorologicorum Aristotelis* (Venice, 1565), fol. 45v-46r: "Et lex observanda est ista, quod cum causae alicuius effectus sunt nobis ignotae, debemus accipere suppositiones, aut principia, ex quibus nihil impossibile sequatur, neque contra sensum, neque apparentibus repugnans … . Propositio possibilis contingens est illa quae non est vera, sed potest esse vera, ut habetur primo priorum. & Averr. hoc contingens appellat inventum, & contingens & possibile … ."

Observations, Theory, and Revisions

The contention that meteorological theory was conjectural and at times only capable of saving the appearances was widely known among those concerned with this field in the sixteenth century. Moreover, this contention justified the application of new observations to the field, which could be used as signs to correct Aristotle's own theory. For example, a number of Aristotelians as early as the 1520s used the observations of sailors to amend Aristotle's position that there was an uninhabitable torrid zone in the area around the equator.[53] Moreover, Vimercati contended that, contrary to Aristotle, Portuguese sailors and Columbus had observed flows in the Atlantic Ocean, which had caused their return trips to be of different lengths than their departing voyages.[54] Zabarella utilized his experience of being upon Monte Venda, outside of Padua, on a day when it rained in the lowlands but did not on the mountaintop to conclude that he had observed the "middle region" of air, i.e., the region above the clouds. From his observations, he concluded, against Aristotle, that this region is composed of normal air, not exhalations.[55]

One of the most common topics where authors took into account the application of newly observed signs was in explanations of earthquakes. Not only had Aristotle's treatment included an extremely lengthy discussion of signs, but a number of his observations and generalization did not conform to the experiences of those who lived in the sixteenth century. Lucio Maggio, a self-described Bolognese *gentil'huomo* who authored a dialogue dedicated to explaining the

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[53] Craig Martin, "Experience of the New World and Aristotelian Revisions of the Earth's Climates during the Renaissance," *History of Meteorology* 3 (2006), 1-15.

[54] Aristotle, *Meteorology,* 354a20; Francesco Vimercati, *In quatuor libros Aristotelis Meteorologicorum commentarii* (Paris, 1556), 176: "Observatus vero est & alius in mari fluxus, tum in Mediterraneo, tum in Oceano, quo videlicet fluit ab ortu ad occasum, & in Mediterraneo rursus ad ortum refluit, quomodo etiam in sinu illius Adriatico. Quem fluxum, etsi non evidentem, observaverunt tamen nautae ex itineribus, quae breviori tempore conficiunt, cum ab ortu ad occasum navigant, quam cum ab occasu ad ortum, aquae fluxu navium motum aut adiuvante, aut impediente."

[55] Giacomo Zabarella, *De rebus naturalibus libri xxx* (Venice, 1590), 386-387. See Charles B. Schmitt, "Experience and Experiment: A Comparison of Zabarella's View with Galileo's in *De Motu*," *Studies in the Renaissance* 16 (1969), 80-138, at 98-100.

earthquakes that struck Ferrara in 1570, followed Aristotle's general explanation based on underground exhalations and winds but disagreed with particular details of Aristotle's account. He credited Aristotle himself with having developed a limited epistemological goal for meteorology: "Aristotle did not tell a lie saying that of those things that are hardly clear to the senses, we demonstrate appropriately if by reasoning about these matters we deduce some causes that are not contrary to the effects."[56] Maggio's primary intention was to demonstrate the natural origins of the Ferrarese earthquakes in order to dispute Pope Pius V's claim that the earthquakes resulted from divine anger over Ferrara's hospitable treatment of its large Jewish population,[57] so he attempted to demonstrate that all of the particulars of this earthquake were not beyond the understanding of natural philosophy even if they did not correspond to exactly what was found in Aristotle. The fact that the Ferrarese earthquakes began in November is taken as evidence that Aristotle's contention that earthquakes most often occur in winter during tranquil weather at night should not be understood as a uniform rule.[58] Other observations were put to the service of upholding Aristotle's contention that earthquakes occur in locales where the earth is porous and hollow.[59] Maggio asserted that the Ferrarese terrain contains "holes, pores, caverns, and subterranean passages" that are typically filled with water. The untypically warm summer and autumn, however, dried out these pores, which Maggio wrote he had observed. The heat rendered the passages "deprived of their usual humor," thereby allowing the earthquake-inducing exhalation to enter and subsequently to cause tremors.[60]

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56) Lucio Maggio, *Del terremoto dialogo del Signor Lucio Maggio gentil'huomo bolognese* (Bologna, 1571), fol. 56v: "ho havuto sommo piacere di vegghiare, & considerare, che Aristotele non disse la bugia dicendo che di queste cose poco manifeste al senso convenientemente demostriamo se ragionandone adduciamo alcune cause che non siano agli effetti contrarie."

57) Emanuela Guidoboni, "Riti di calamità: Terremoti a Ferrara nel 1570-1574," *Quaderni Storici,* n.s. 55 (1984), 107-135.

58) Maggio, *Del terremoto*, fol. 44r.

59) Aristotle, *Meteorology,* 366a24-26.

60) Maggio, *Del terremoto,* fol. 34v-35r: "Ma tornando là donde ci partimmo dico, che il terreno Ferrarese come molti altri, contiene in se meati, pori, caverne, & vie sotter-

Discussions such as Maggio's remained present within the commentary tradition on Aristotle's *Meteorology* during the seventeenth century. Niccolò Cabeo, a Jesuit originally from Ferrara, emphasized experience and chymical experimentation in his 1646 commentary on Aristotle's *Meteorology*.[61] Similarly to Maggio, he noted approvingly that Aristotle used the first stage of the *regressus* method in the analysis of earthquakes, "He [Aristotle] began well, as I have said, in trying to show *a posteriori*, or rather by the *methodus resolutoria,* what is the cause assigned to earthquakes."[62] For Cabeo, however, Aristotle's attempts were insufficient and his theory was unable to explain the real cause of earthquakes. Experience and observations taken from recent earthquakes support a chymical explanation. Instead of maintaining that winds or the eruption of subterranean exhalations provoked tremors, Cabeo believed that earthquakes result when veins of flammable substances such as sulfur, bitumen, and niter ignite.[63] This theory is supported by a number of observations, or arguments *a posteriori*. The earth in the area around Ferrara, which had been struck by earthquakes again in 1625 and 1636, for example, is full of niter, confirmed by the red

ranee, dove si generano l'acque, & per le quali l'acque delle pioggie, & del Pò, vanno penetrando, & lo rendono humido… . Hora essendo stato grandissimo caldo, & siccità del mese di Luglio fino à i dodici di Novembre, che non cadde mai tanta acqua dal cielo, che se bagnasse la polvere, & essendo passato tutto queltempo, senza che mai piovesse, si come in quei tempi essendo il Signor Mattio in Ferrrar per servigio dell'Illustrissimo Signor Cardinale Paleotti, & io del Signor Prencipe osservammo insieme, & più volte discoremmo sopra quel la straordinaria sicittà, per la quale erano secchi i fiumi, i pozzi, & ogni humore, si sono sempre per lo secco fatte maggiori le caverne, i pori, & meati della terra, & restando asciute, & prive del solito humore, doveano empirsi di alcuna cosa, percha la natura, come sapete, non comporta il vacuo … ."

61) Craig Martin, "With Aristotelians like These, Who Needs anti-Aristotelians? Chymical Corpuscular Matter Theory in Niccolò Cabeo's Meteorology," *Early Science and Medicine* 11 (2006), 135-161.

62) Niccolò Cabeo, *Commentaria in libros Meteorologicorum* (Rome, 1646), II, 246: "Incipit, ut dixi, probare a posteriori, seu potius Methodo resolutoria, ostendere, bene assigatam esse causam terraemotus."

63) Ibid., II, 243. The idea that the causes of earthquakes were chymical did not originate with Cabeo, see: Georgius Agricola, *De ortu et causis subterraneorum libri V* (Basel, 1558), 31-32.

color of the local well-water.[64] The 1636 earthquake provided Cabeo the opportunity to witness the flow of these waters that were accompanied by burning fumes.[65] No winds, however, were seen escaping from the newly created gashes in the ground. Moreover the numerous earthquakes that occur in the region around Vesuvius, a region famed for volcanic eruptions, spontaneous fires, and bituminous soil, are signs of the correctness of Cabeo's general theory.[66] Thus according to Cabeo, Aristotle's general method of arguing from effects to causes leads to chymical theories that Aristotle himself did not endorse.

Conclusion

The distinction between theories of scientific knowledge and practice is necessary for historical understandings of Renaissance natural philosophy. While epistemological ideals played a role in the presentation of concepts and guided the direction of natural philosophy, they should not be mistaken for actual methods of research. Palmieri rightfully distinguishes Zabarella's logic from the paths followed in his treatises on cosmology and nature. Nevertheless, the *methodus resolutiva*, with its emphasis on using experience to modify and create provisional theories, guided Renaissance thinkers. While certainty was the ideal for syllogistic knowledge, Renaissance commentators on the *Meteorology* recognized that the intractable nature of the field, the difficulty of accurate observations, the inaccessibility of many of the subjects, and the accidental nature of material causes rendered much of meteorology conjectural. Observations could lead to new theories, departures from Aristotle's own positions, which would not be certain but strive to correspond to observable natural effects.

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64) Cabeo, *Commentaria,* II:243.

65) Ibid., II:248.

66) Ibid., II:249. The sulfuric, bituminous, and nitric nature of the area around Vesuvius was widely noted by observers of its 1631 eruption and before. E.g., Giovanni Francesco Porrata Spinola, *Discorso sopra l'origine de' fuochi gettati dal Monte Veseuo* (Lecce, 1632), 4; Simone Porzio, *De conflagratione agri Puteolani… Epistola* (Florence, 1551), 6.

The intractability of meteorology led authors to proofs within the field, not as demonstrative in a strict sense, but as dialectical, or, for Pomponazzi, even as rhetorical. Recognition that Aristotle's arguments were probable or approached verisimilitude extended not just to the portions of the field that were especially difficult but its foundations as well. For example, two Franciscans, Bartolomeo Mastri and and Bonaventura Belluti, while agreeing with Aristotle that there were four elements, found Aristotle's arguments not demonstrative but rather probable in their 1640 disputations on meteorology.[67] Natural philosophers in the Aristotelian tradition realized that while *scientia* required syllogism, the probable arguments of dialectic were at times the only available solution for discussions of the natural world.

While natural philosophers of the sixteenth and seventeenth centuries might have found new impetus in humanism and latitudinarianism for endorsing the belief that natural philosophy was composed of probable knowledge, that belief was not foreign to Aristotelian natural philosophy. When Claude Bérigard, a professor at Pisa and then Padua, wrote in his 1661 *Circulus pisanus* that Aristotle spoke correctly that every opinion of natural philosophy was "nothing other than a hypothesis," that could help solve difficulties just "as was the custom in the science of the stars, which puts forth epicycles, concentrics, and eccentrics," he was following a long Aristotelian tradition rather than undermining it by casting doubts.[68] Thus Athanasius Kircher's probabilism found in the *Mundus*

67) Bartolomeo Mastri and Bonaventura Belluti, *Disputationes in libros de celo et Metheoris* (Venice, 1640), 203: "Numerus elementorum, quamvis varius fuerit apud Antiquos, ut dicitur in Phys. communiter tamen censetur esse quaternarius; verum est tamen, quod non datur ratio aliqua evidenter demonstrans elementa non esse plura, nec pauciora, & praesertim rationes Arist. sunt probabiles… ."

68) Claude Bérigard, *Circulus pisanus… veteri et peripatetica philosphia in Aristotelis libros de octo Physicorum. Quatuor de Coelo. Duos de Ortu & interitu. Quatuor de Meteoris, & tres de Anima* (Padua, 1661), 19: "Haec ratio iam nihil concludit, sed nos remittit ad discutiendas totius Physicae difficultates, ut tandem constet an eas dirimat accuratius Aristoteles, an antiqui: & vere opinio cuiuscunque philosophi nihil est aliud quam hypothesis, qua posita videndum est an facilius enodentur omnes difficultates scientiae naturalis, ut fieri solet in Astrologia quae varios statuit epicyclos, concentricos & eccentricos, ut iis quae apparent in coelo respondeatur: sic arbitrandum est de

subterraneus (1665), a work that is largely meteorological, at least partially exhibits continuity with the Aristotelian tradition in addition to being an example of Jesuit endorsement of this epistemic standard.[69] Aristotelians recognized that natural philosophy dealt with contingencies and that its theories were dialectical and therefore uncertain. The imperfections of the matter of the sublunary regions and our inability to observe accurately the effects of this matter, made Aristotelians recognize that knowledge of nature was incomplete and probable. If indeed there was a major shift during the seventeenth century, it was the broader endorsement of the uncertainty or inconclusiveness of metaphysics rather than the adoption of the idea that natural philosophy provided probable knowledge.

opinione Aristotelis & antiquorum, nec ante sententiam ferre oportet, quam praecipuis dubitationibus responsum fuerit." Cf. Paolo Marangon, "Aristotelismo e cartesianesimo: Filosofia accademica e libertini," in *Storia della cultura veneta* (Vicenza, 1984), IV.2, 95-114.

69) Mark A. Waddell, "The World as it Might Be: Iconography and Probabilism in the *Mundus subterraneus* of Athanasius Kircher," *Centaurus* 48 (2006), 3-22.