

AT THE ORIGINS OF MODERN SCIENCE:
Demythologizing Pythagoreanism

Ptolemy, who was a great man, had established the limits of our world; all the ancient philosophers thought they had its measure, except for a few remote islands that might escape their knowledge. It would have been Pyrrhonizing, a thousand years ago, to cast in doubt the science of cosmography, . . . The question is, if Ptolemy was once mistaken on the grounds of his reason, whether it would not be stupid for me now to trust what these people [Copernicus and others] say about it; and whether it is not more likely that this great body that we call the world is something quite different from what we judge.

Montaigne, *Apology for Raymond Sebond*¹

MANY philosophers of science, most notably Kuhn and Feyerabend have examined the rationality of Galileo's case for the heliocentric theory of Copernicus in terms of a rationalist model of a hypothetical-deductive method of testing a scientific claim. And they have found the case wanting.² In reading their assessment of the rationality, one comes away with a sense that Galileo fell short of a compelling argument, or even that he failed. In contrast to Kuhn and Feyerabend, I shall try to show that Galileo's case was unfinished rather than failed and that Descartes actually completed the argument for a new world system. Thus, a full assessment of the rationality of the Copernican revolution must include Descartes's part in the unfolding argument. Accordingly, I want to display the need for re-contextualizing any assessment of the Copernican revolution by establishing two claims: one, that Galileo's case for the Copernican theory was incomplete in part because it failed to provide a needed philosophical argument for what I have called a "demythologized Pythagoreanism;"³ and two, that Descartes developed a subtle argument for this "demythologized Pythagoreanism," which began to emerge with his *Le Monde* and which becomes fully discernible in the *Meditations*.⁴

I. THE CIRCLE OF RETROSPECTIVE AND PROSPECTIVE STANDPOINTS

Some remarks about an historical philosophy of science are in order. My argument depends upon a historically accommodative philosophy of science, one which lies somewhere between Karl Popper's methodological rationalist account by a logic of conjecture and refutation and Thomas Kuhn's historical narrative account.⁵ Admittedly, even the early Popper was sensitive to the demand history makes on an intellectually honest philosophy of science. Such a theory has the responsibility to recover the rationality we feel is implicit in the practice of science. In spite of Popper's contributions toward moving philosophy beyond the ahistorical, positivist epistemology, it was Kuhn's seminal work, *The Structure of Scientific Revolutions*,⁶ that effectively established as a requirement for any adequate philosophy of science that it accommodate history. Thus, what Popper had always held as the central task of a philosophy of science, viz., a putative account of the historically situated growth of scientific knowledge, is now a *sine qua non*.

Popper's theory explains the historical development of science as a process of bold hypotheses conjectured, then subjected to severe critical examination in a sophisticated method of falsification. As a logic of falsification, it is a method of discovering that a theory fails. At best it can insure only that we might learn

⁵Michel de Montaigne, *The Complete Essays of Montaigne*, trans. Donald M. Frame, (Stanford: Stanford University Press, 1965), 430. In this paper, I have bracketed the problem of skepticism posed by Montaigne for the "new science." Obviously, Descartes addressed this challenge. To incorporate this as another dimension of the complex situation of the problem of the new science in the early seventeenth century would take us far beyond the space of this paper. I also note that I have left out consideration of Kepler's role in the case for the Copernican revolution. Suffice it to say that there were strong Hermetic tendencies in Kepler's astronomical work which would not weaken our argument for our thesis regarding Descartes and Pythagoreanism.

⁶Thomas Kuhn, *The Copernican Revolution* (Chicago: University of Chicago Press, 1959). Paul Feyerabend, *Against Method* (Atlantic Highlands, NJ: Humanities Press, 1975). The specific analysis of Galileo's case are in chapters 6-13.

⁷See my "Galileo's Unfinished Case and Its Cartesian Product," *International Philosophical Quarterly* 34 (1994): 318-19.

⁸Unless otherwise indicated, references to the English translations of Descartes's writings are *Philosophical Writings of Descartes*, trans. J. Cottingham, R. Stoothoff, & D. Murdoch

(Cambridge: Cambridge University Press, 1985). Further references will refer to this collection as PWD, followed volume & page.

⁹The best introduction to Popper's theory of science is his essay "Science: Conjectures and Refutations," in *Conjectures and Refutations*, (New York: Harper & Row, 1963), ch. 1.

¹⁰Thomas Kuhn, *The Structure of Scientific Revolutions*, 2nd ed., (Chicago: University of Chicago Press, 1970). Hereafter referred to as SSR in parenthesis in the text. An excellent critical presentation of the views of Popper and Kuhn can be found respectively in Chapters III and V of W. H. Newton-Smith, *The Rationality of Science* (Boston: Routledge & Kegan Paul, 1981).

¹¹Briefly, the problem of Whiggish history of science, sometimes called "presentism," is that of understanding past "science" in terms of our present-day meanings and senses of key terms such as space, motion, or force, and even methodological terms such as evidence, proof, or casual explanation. The classic criticism is found in Herbert Butterfield, *The Whig Interpretation of History* (London: G. Bell and Sons, 1931). For a succinct presentation of Butterfield's position see Hugh Kearney, *Science and Change 1500-1700* (New York: McGraw-Hill, 1971), 17-22.

which among our competing theories are mistaken. To the extent that the history of science discloses its progress through building on a succession of "failed" theories, Popper's approach holds some prospect for a rationalist account of scientific change. It does so, however, from the standpoint of a fixed methodological norm, that of "greater falsifiability" and "increasing verisimilitude." Insofar as these norms are currently operative scientific norms, this way of retrieving the rationality of science in the history of its practice runs a serious risk of being too Whiggish.⁷ Just as important for a historically adequate philosophy of science is the recognition of the nature of the **problem-situation** at that time. Though Popper recognized the historically situated dimension of the problem-situation, his theory accommodates it from an almost exclusively retrospective contemporary standpoint. Such a standpoint inhibits an appreciation of the full nature of the problem-situation from its lived prospective standpoint and thereby prevents retrieving the history of science as rational. This paper hopes to show that this is especially the case for the so-called Copernican revolution at the origins of modern science.

In contrast to Popper's "rationalist" history via a logic of conjecture and refutation, Thomas Kuhn — at least the Kuhn of *The Structure of Scientific Revolutions* — turned to a discourse of historical narrative to get at the rationality of scientific change. The most striking case of such resistance is that of the Copernican thesis and Galileo's arguments in support of it. It was because of his careful and rather thorough study of the Copernican revolution that Thomas Kuhn was lead to his thesis of the development of science by revolutionary paradigm change and its correlate thesis that scientific rationality is paradigm relative. Kuhn concluded, for example, that in the 1632 debate between the Aristotelian-Ptolemaic geocentric system and the would-be Galilean-Copernican system, there could be no logical appeal to theory-neutral evidence to test objectively and decide between the rival theories. The fact of the sun's daily rising and setting was not in question. But the significance, the meaning, of this "fact" was. In offering what seemed a plausible alternative, Copernicus's theory put in question whether the sun **really** revolved around the earth, or the earth around the sun. The issue of a realist interpretation of the Copernican theory was paramount in the discussions between Galileo and Bellarmine. Later we shall see that the question of realism goes to the heart of a subtly complex question of the Pythagorean philosophy of nature. Kuhn's study of the Copernican revolution, in his book *The Copernican Revolution*, joined with the epistemological findings of Wittgenstein, Michael Polanyi, Jean Piaget, and W. V. O. Quine convinced him that in the final analysis there is no objective, theory-independent logic of testing our most fundamental

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assumptions about nature. For it is only by making commitments to paradigmatic assertions about nature, cognitive norms, and values that a logic can have legitimate authority over the scientist. When debate occurs across paradigms, Kuhn argued, "there is an incomplete logical contact" (SSR, 110) due to an incommensurability of the meaning of fundamental terms, sometimes an incommensurability of methodological norms, and on rare occasions, of epistemic values. This view is that of the early, revolutionary Kuhn, which provoked charges of irrationality, relativism, and historicism.⁸

Whether Kuhn's subsequent conservative retreat to present day, fixed epistemic characteristics of good scientific theory (accuracy, consistency, broad scope, simplicity, and fruitfulness) as values guiding, rather than as rules determining, theory choice⁹ adequately answer such criticisms is still debatable. Notwithstanding this, it is clear that such values must be seen as functioning in the historical case of scientific change which the philosopher of science attempts to explicate. Obviously, this requires getting back to the context of the problem situation at that time, in terms of its lived prospective standpoint. In the tension between the back-and-forth play of the retrospective and prospective standpoints, the problem of the hermeneutic circle bears on our judgment of the rationality of scientific change. If we take present day meanings of key terms such as 'attraction,' 'force,' 'hypothesis,' or even 'science' to select the relevant concepts, norms, or theories in an important case of scientific change, we are always at risk of missing significant factors at that time. In the past thirty years, the development and expansion of the functional unit of rational assessment from that of the isolated hypothesis to Kuhn's paradigm or Imre Lakatos's "research program" has shown that the question of rationality, of the rational choice at a given moment, is larger than a logic of any instant test or test situation. As Lakatos has argued so convincingly, the decision to accept or reject a hypothesis can not avoid an element of risk

⁸See Imre Lakatos and Alan Musgrave, *Criticism and the Growth of Knowledge*, ed. Imre Lakatos and Alan Musgrave (Cambridge: Cambridge University Press, 1970), for the Popperian responses and criticisms of Kuhn. A good example of a logical empiricist criticism is Israd Scheffler, *Science and Subjectivity* (Indianapolis, IN: Bobbs-Merrill, 1967).

⁹Thomas Kuhn, "Objectivity, Value Judgment, and Theory Choice," *The Essential Tension* (Chicago: University of Chicago Press, 1977), 320-39.

¹⁰The concept and potential uses of such re-contextualization are displayed in Stephen Toulmin, *Cosmopolis: The Hidden Agenda of Modernity* (Chicago: University of Chicago Press, 1990).

¹¹See Stillman Drake, *Galileo Studies* (Ann Arbor: University of Michigan Press, 1970),

ch. 10, for a detailed analysis and presentation of Galileo's argument from the tides, as well as Galileo's *Dialogue Concerning the Two Chief World Systems*, trans. Stillman Drake (Berkeley: University of California Press, 1967), "The Fourth Day." And see E.A. Burtt, *The Metaphysical Foundations of Modern Sciences* (New York: Doubleday, 1954) for a discussion of the Pythagorean influences on Galileo as well as Copernicus and Kepler.

¹²See Clive Morphet, *Galileo and Copernican Astronomy* (London: Butterworths, 1977), ch. 5 for a reliable, succinct presentation of Galileo's empirical case. The major source for this is Galileo's *The Starry Messenger in Discoveries and Opinions of Galileo*, trans. Stillman Drake (New York: Double Anchor, 1957), hereafter cited as DOG.

for the rationality of the theory choice can only be disclosed in the light of history. There is no instant rationality. But not even the sophisticated programmatic, historical structures of Lakatos, Larry Laudan, or the like succeed in eliminating the problem of the hermeneutic circle, unless we arrive at the end of history. Until that time, the best we can do is counter the problem. Once history enters the core of our philosophy of science, the best we can do is to counter the problem of history by turning back again, and then again in order to re-contextualize the problem-situation.¹⁰ But how does the philosopher achieve this? By turning to the honest, competent, and insightful studies by philosophically-sensitive historians like Frances Yates and John Headley and historically-minded philosophers like Richard Blackwell. The results of their work provide us a prospective standpoint to counterbalance the Whiggish tendencies of the more dominant retrospective history of most contemporary philosophers of science.

II. GALILEO'S CASE FOR COPERNICUS: THE STANDARD STORY

With the above remarks in mind, let us consider Galileo's case for Copernicus. The more familiar is the retrospective story wherein science is understood as modern. In the early seventeenth century, Galileo's case for the preferability of the heliocentric Copernican thesis (1543) to the Ptolemaic theory is comprised of a three phased defense: the first kind of argument is empirical; the second is a type of "inference to the best explanation" of the tides as due to the earth's double motion of rotation and revolution; and the third, which is the motivation behind the struggle, is Galileo's mathematical essentialism.¹¹

Over a period of years (c.1609–1615), Galileo discovered what he believed to be significant "observational, empirical evidence" in support of the Copernican thesis as a rival to the Ptolemaic theory.¹² This evidence included the following observations:

- (i) "imperfect" phenomena (at least as judged from the rival Aristotelian-Ptolemaic world system) such as the bulges of Saturn and the craters and valleys on the moon;
- (ii) the moons of Jupiter, which provided the basis of an argument by analogy for an orbiting earth and with its own moon; and
- (iii) the phases of Venus, which was the best evidence for the preferability of the Copernican theory over the Ptolemaic theory, because it presented a new and serious problem for the Ptolemaic framework.

It is essential to note that Galileo obtained his *observational evidence* via a new instrument, the "spyglass." Defenders of Ptolemy insisted on questioning the legitimacy of the empirical evidence, demanding that Galileo justify his use of the

telescope before its evidence was judged admissible. Galileo briefly explains the workings of the telescope in *The Starry Messenger*, but since he knows that it is not adequate he promises "on some other occasion we shall explain the entire theory of this instrument" (DOG, 31). Galileo never produced the work on optics, whereas Descartes did. So were his critics unreasonable and dogmatic in raising the question of the "admissibility" of the "instrumental observations" of the telescope? I think not, for they had quite understandable reasons for suspecting the evidence. On an empirical level, the telescopic image was known to have been a distortion of the object image. It was a rather crude instrument back then. More significant on a theoretical level, the legitimacy of the use of the telescope for distant observations requires an explanation of how it works, i.e., an optics, a theory of light. Thus, all of Galileo's empirical evidence is instrument-laden and by an instrument that presupposed a theory not yet available.¹³

Moreover — and this is most crucial — when one extends the use of the telescope to observe the heavens, one is crossing the boundary between the two domains of the long-standing Aristotelian-Ptolemaic system. This is, in effect, to beg the question at issue — Ptolemy or Copernicus. It is a classic and actual instance of the theory-ladenness of observation and evidence. In the case of Galileo, it shows that an intellectually open and honest opponent was indeed reasonable in withholding assent on the basis of Galileo's empirical evidence at that time, 1600–1632. At least according to the canons of an hypothetical-deductive-model of scientific method, the logic of Galileo's argument is:

1. $(T \ \& \ H_{Aux-L}) \supset (C \supset E)$
2. $C \ \& \ E$
3. $\therefore T$

where E is the reported observations put forth as empirical evidence by Galileo, H_{Aux-L} are auxiliary hypotheses regarding the behavior of light through the lenses of his telescope (then called a "spyglass") and across the two domains, C the actual experimental or observational set up and conditions under which he observes the reported findings such as mountains and valleys on the moon, and T the hypothesis under consideration which in this case is that of Copernicus. It is crucial to note that the legitimacy of E as inductive evidence depends upon H_{Aux-L} i.e., a warranted theory of light. (Although Newton's system finally solves the theoretical prob-

¹³As the dependence of modern scientific theory upon instrumental technologies has increased there has emerged a developmental dynamic of a *theoria* and *techne* interaction that tends to transform modern science as *theoria* (pure science with a disinterested goal of truth) into a *techne* whose interest is in maximum efficiency in the advancement of knowledge, the goal of *theoria* notwithstanding. In this regard the epistemology of modern science

is, indeed, that of Kant which implies that we can only know what we can make.

¹⁴For an excellent presentation of the various objections presented against the Copernican theory at the time of Galileo, see Maurice A. Finocchiaro, *The Galileo Affair* (Berkeley: University of California Press, 1989), 15–25.

¹⁵See William A. Wallace, *Prelude to Galileo* (Boston: D. Reidel Publishing Co., 1991), cf. fn. 19.

lems, the first instance of solid, unproblematic, and generally accepted empirical corroboration was the measurement of stellar parallax in 1838.)

But even if we admit the telescopic observations, for the sake of argument in the spirit of a Lakatosian historical rationality, Galileo's case is far from a compelling demonstration. For there were significant recalcitrant results which at the time provided strong reasons for rejecting the Copernican theory, and perhaps for accepting Tycho's Compromise if not for retaining the Ptolemaic theory. In particular, two failures were pointed out by opponents:¹⁴ the tower argument and the failure to observe stellar parallax. The tower argument is an objection based upon the vertical free fall of heavy objects. If the earth is rotating at the high speed required by the Copernican hypothesis, then we should observe that objects dropped from the west side of a high tower land much farther west than they do. Whether Galileo's retort to the tower objection, which was to offer more theory (a theory of circular inertia) in order to explain away the recalcitrant result, was at that time *ad hoc* — and, therefore illegitimate — may depend on the framework of one's philosophy of science. (Galileo made the problem of inertia the center of a research program which was continued by Descartes through Huygens and resolved by Newton). Yet from the standpoint of a Ptolemaic astronomer, it would initially have appeared so. The second objection argues that if the Copernican thesis were true, astronomers should observe a stellar parallax due to the annual revolutionary motion of the earth about the sun, if one makes the appropriate observations at six month intervals. But no stellar parallax was observed, not even by Tycho Brahe who over a period of years had amassed an astounding amount of the most trustworthy observational data available at that time. These objections posed formidable problems for accepting the double motion of the earth — its diurnal rotation and its annual revolution.

The second phase of Galileo's argument is a theoretical argument with a hypothetical deductive structure,¹⁵ which is advanced as the best explanation of the well-known periodic motions of the tides. Though Galileo knew of Kepler's explanation of the tides as an effect of the moon's attraction, Galileo dismissed it as astrological superstition. At the end of the Fourth and last day of the Dialogue, we read Galileo's spokesman, Salviati, expressing astonishment as he rejects Kepler's opinion regarding the effect of the tides:

But among all the great men who have philosophized about this effect, I am more astonished at Kepler than at any other. Despite his open and acute mind, and though he has at his fingertips the motions attributed to the earth, he has nevertheless lent his ear and his assent to the moon's dominion over the waters, to occult properties, and to such puerilities.¹⁶

Galileo's theory of the tides asserted that the tides are caused by the periodic double motion of the earth — its annual revolution around the sun and its daily rotation on its axis. When revolution and rotation reinforce one another at night causing low tide, and oppose one another at midday causing high tide. It follows from this theory that there should be only one high tide at a given location about noon per day. Moreover, it was well known that there were two tides per day and that the time of daily occurrence varies from day to day. At best in his own methodological terms, Galileo has "demonstrated" the Copernican thesis as probable. Galileo attempted to explain away this divergence of his theory from the fact of the tides by attributing it to the action of "secondary causes" such as the irregular depth of the sea and the shape and location of the coastline. Because of his insistence on mechanical causes in natural philosophy, Galileo was convinced that his theory of the double motion of the earth was the best explanation of the tides. Accordingly, he took it as convincing.

As he proceeded through his arguments, Galileo gradually backs away from attempts to "prove" the Copernican theory as a whole and shifts to specific uses of hypothetical reasoning to the best explanation of well known phenomena. Galileo also used a combination of quantifiable mechanical models in actual experimental set ups or in thought experiments and mathematical descriptions, of problematic but observable phenomena. Of course, the motivation for this approach to the study of nature is Galileo's belief that nature is an embodied mathematical structure, his mathematical essentialism or Pythagoreanism which takes us to the third phase of his case for Copernicus.

Not long after Galileo had published his first work in support of the heliocentric theory of Copernicus, *The Starry Messenger*,¹⁷ he continued to marshal the results of his astronomical observations through improvements of his telescope. He published these in a series entitled "Letters on Sunspots" (1612). In the first letter, after reporting his observations of the phases of Venus and thereby establishing its orbit, Galileo expresses in rather strong and confident language his belief in a Copernicus allied with a Pythagoreanism. He says:

¹⁶Galileo, *Dialogue*, 462. Also see Drake's insightful note at 491.

¹⁷Galileo indicates his support indirectly by suggesting a response to the objection that the Copernican theory must place the moon alone in a revolution about the earth as the earth is in an annual orbit about the sun. Referring to his discovery and carefully described observations of the four moons of Jupiter, which Galileo named after soon to be court patron, the Medicean planets: "Here we have a fine and elegant argument for quieting the doubts of those who, while accepting with tranquil mind the revolutions of the planets about the sun in the Copernican system, are mightily disturbed

to have the moon alone revolve about the earth and accompany it in an annual rotation about the sun." Galileo, *The Starry Messenger*, in DOG, 57.

¹⁸Galileo Galilei, "Letter on sunspots," in DOG, 94.

¹⁹See William A. Wallace, *Prelude to Galileo* ch. 8, "Galileo and Reasoning *ex suppositione*," for a clear presentation of the two major senses *ex suppositione*: one, an axiomatic sense of reasoning from first principles of nature, and the other a hypothetical reasoning from a conjectured reasonable explanation; especially 132-32 and 139-42.

With absolute necessity we shall conclude, in agreement with the theories of the Pythagoreans and of Copernicus, that Venus revolves about the sun just as do all the other planets.¹⁸

In resorting to the hyperbolic, rhetorically stunning phrase of "absolute necessity" Galileo, as Italy's leading mathematician at the time, was positioning himself through (in Richard Blackwell's words) a rhetoric of the "authority of logic" as the leading advocate of the heliocentric theory of Copernicus. Nevertheless, the phrase is intended to express Galileo's conviction that he has "demonstrated" the Copernican thesis as a truth of natural philosophy. From a retrospective standpoint today, Galileo's phrase might be taken to mean "scientifically proven." But without careful qualification such a translation warps our historical understanding of the case under the stresses and strains of a too Whiggish historiography. Indeed, Galileo contributed toward transforming the scholastic sense of reasoning *ex suppositione* into something more similar to the modern sense of reasoning hypothetically.¹⁹

The most moving and memorable expression of this Pythagoreanism is found in his 1623 work, *Il Saggiatore*:

Philosophy is written in this grand book, the universe, which stands continually open to our gaze. But the book cannot be understood unless one first learns to comprehend the language and letters in which it is composed. It is written in the language of mathematics, and its characters are triangles, circles and other geometric figures without which it is humanly impossible to understand a single word of it; without these one wonders about in a dark labyrinth (DOG, 238).

Though Galileo held this position, presumed it, and advocated it with rhetorical flourish, he did not argue a philosophical case that could rival an Aristotelian natural philosophy that physical nature is an embodied mathematical structure, that it is a *res extensa*.

Without the philosophical argument, Galileo's case had to work in a piecemeal and indirect fashion. His arguments could only chisel and chip away at the Aristotelian-Ptolemaic world system, and its qualitative, two domain teleological physics of motion. Though it effectively damaged the outer periphery, it could not dislodge allegiance to the hard core and easily replace it with a new, Pythagorean philosophy of nature of the kind which Galileo pursued with a quantitative, mechanistic physics of motion. To become effective as evidence — even indirectly — it needed to be embedded in an alternative world system. The title of Galileo's most famous work, *Dialogues on the Two Chief World Systems*, refers to the Aristotelian and the would-be Galilean-Copernican world system. In this work

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Galileo does argue for the plausibility of replacing the Aristotelian laws of natural motion by a Galilean law of circular inertia. But it does so only with respect to the rival, technical astronomies. Galileo never quite articulated a complete, alternative system with a realist defense. To be sure, he envisioned a key feature (circular inertia) of a Galilean-Copernican system of nature, but he never made the effective philosophical argument for a realist view of this new Pythagoreanism. In the absence of the philosophical argument for realism, we do not think that the rationality of the shift of allegiance from the Aristotelian-Ptolemaic system to the beginnings of our modern systems can be retrieved.

III. RE-CONTEXTUALIZING GALILEO'S CASE FOR COPERNICUS

So why didn't Galileo make the argument for Pythagoreanism? Is it due to his early, more Aristotelian period and formation? William Wallace's contention that Galileo retained an Aristotelian philosophy of nature even during his later, Pythagorean period might explain why he did not take up the philosophical phase of the argument for Copernicanism. Pietro Redondi's work suggests fear of the Church because of a new, mechanistic atomism. I do not think that these explain the silence, for it is clear that Galileo rejects the Aristotelian philosophy of nature for a mathematical machine model of nature. One answer is that Galileo was impatient with metaphysical philosophy and simply chose to exhibit the value of the new mechanical, mathematical approach in the study of nature by using it. But this is not convincing. We may note with Stillman Drake that Galileo "publicly expressed doubt that any phenomenon in nature, even the very least that existed, could ever be completely understood by any theorist."²⁰ Indeed, in his third "Letters on Sunspots," Galileo proclaims in quite explicit terms: "I know no more about the true essences of earth or fire than about those of the moon or sun, for that knowledge is withheld from us, . . . until we reach the state of blessedness" (DOG, 124). We surmise that Galileo's doubts were in part due to the Gordian knot which the prospect of the grand program of the new mechanical philosophy of nature presented. To appreciate the entanglement in this knot, we must shift to a strong prospective consideration of the problematic at that time.

In our Whiggish tendency regarding a history of science, we construe Galileo's reference to the theories of the Pythagoreans and Copernicus as an historically simple and straightforward matter. So most of us interpret Galileo's Pythagoreanism as a simple shift to a mathematical physics of nature. But such a view suffers from the lack of a prospective reading of the problematic which con-

²⁰See Stillman Drake, "Introduction," in Galileo Galilei, *Discourses & Mathematical Demonstrations Concerning Two New Sciences* trans. Stillman Drake (Madison: University of Wisconsin Press, 1974), xxi.

²¹Richard Blackwell, "Introduction" in

Thomas Campanella, O.P., *A Defense of Galileo, the Mathematician from Florence*, trans. Richard J. Blackwell (Notre Dame: University of Notre Dame Press, 1994), 34. Hereafter cited as DG.

fronted the mathematician and natural philosopher in the early seventeenth century. Galileo's own reference to his agreement with the Pythagoreans discloses another dimension in understanding the deeper problematic at the origins of modern science.

At the end of the introduction to his most recent contribution to the Galileo scholarship, a translation of Thomas Campanella's *Defense of Galileo, the Mathematician from Florence*, Dr. Blackwell reminds his reader that "when Copernicanism was condemned by the Catholic Church, there were three defenders against that decision, each with a different emphasis . . ." ²¹ They were Galileo, Foscarini, and Campanella. Galileo's defense was based on an argument for the independence of scientific truth from religious truth; Foscarini's was based on an actual reinterpretation of the problematic passages in Scripture; and Campanella's set out the requirement of a "competent philosopher and faithful knower." About halfway through his defense of Galileo, Campanella encapsulates his position in the third hypothesis of the Defense, which is worth reading in full:

Whoever would wish to be a judge in this case must understand that our previous remarks are fundamental. And since the present dispute concerns the physical knowledge contained in the Sacred Scriptures, whoever wishes to be a judge must, as said earlier, thoroughly understand the methods of explaining all the literal and mystical senses of Sacred Scripture according to the commentaries of the holy Fathers, and must also understand the book of nature as found in all the sciences and especially the observations made by physicists and astronomers (DG,80).

After remarking that Sacred Scripture does not contradict that other book of God, i.e., nature, Campanella closes the chapter by criticizing theologians who have yoked themselves with a "crude zeal for Aristotle rather than for Moses or St. Thomas" (DG,82).

Campanella initiates the second half of the book by aligning Galileo with the neo-Platonic thinking of the Church Fathers including Augustine, Ambrose, and Basil (p.84) in order to set up his theological replies. In the short, last chapter Campanella makes three telling claims: one, that "[t]he theory of Copernicus and Galileo . . . is probable but not certainly true" (DG,118); two, that "it seems that Pythagoras derived these [various anti-Aristotelian theses including heliocentrism] teachings from Moses, for he could not have had such wisdom without a previous revelation" (DG,120); and three, that Copernicus was led to his heliocentric theory through his Pythagorean teacher at the University of Bologna, Domenico Maria Novara of Ferrara (DG, 120). These direct us away from the Aristotelian tradition in the "sciences," and to the Pythagorean sources which,

from our modern standpoint, are construed as a mathematical approach to the study of nature and nothing more.

Campanella stands at a watershed. Looking forward, he seems to recognize the stronger sense of a probable truth arrived at through a more empirically based reasoning *ex suppositione*. Looking backward, he presses, like Giordano Bruno²² twenty years before, to strongly link Copernicus to a Hermetic tradition of Pythagoreanism. The latter only deepens the difficulty for our historical understanding to appreciate the nature of the crisis which confronted theologians and philosophers at that postmedieval moment.

Despite how easy his graceful writing makes it seem, Blackwell's works on Galileo, Foscarini, Campanella, science, and the church alert us to the complex methodological subtleties which underlie any attempt to sort out and separate the theological from the scientific content of sixteenth century theories of the cosmos for the Christian thinker. Likewise the work of Frances Yates compels us to recognize that Renaissance Pythagoreans, were deeply immersed in a Hermetic approach to the study and understanding of nature. "Like Bruno," Yates says, "Campanella was a magician-philosopher, in line of the Renaissance Magi descending from Ficino. . . . Yet — also unlike Bruno — Campanella very nearly succeeded in bringing off the project of magical reform within a Catholic framework, or, at least in interesting a number of very important people in it."²³

Thus, in addition to the Aristotelian philosophy of nature, so incompatible with any realist interpretation of the Copernican theory, there was at least one other — the Hermetic philosophy of nature. Because of its compatibility with heliocentrism, it offered itself as an ally to Galileo. But as we have seen in his astonishment at Kepler's appeal to "occult qualities," Galileo rejected any appeal to the occult. Indeed, at the outset of the *Dialogue*, he has Salviati distance himself from both the likes of Campanella and the Pythagorean mystery cult.²⁴ The question of "competent judge" in the sciences becomes complicated as soon as we acknowledge the Hermetic tradition in the Renaissance as a strong rival to the Aristotelian philosophy of nature. As deeply rooted in Hermeticism,

²²See Frances Yates, *Giordano Bruno and the Hermetic Tradition* (Chicago: University of Chicago, 1964) ch. XX, "Giordano Bruno and Tommaso Campanella."

²³Yates, *Bruno and the Hermetic Tradition*, 360. Indeed Campanella actually performed anti-eclipse magic for Pope Urban VIII in Rome in 1628 (388). In a very recent impressively thorough study of Campanella, John M. Headley expands and extends beyond the nascent ideas of Yates's chapter. See Headley, *Tommaso Campanella and the Transformation of the World* (Princeton University Press, 1997), especially ch. IV, "The Controversy

with Aristotle," and ch. VII, "Universal Theocracy and the Ecclesiastical State: The Figure of Melchisedech."

²⁴Galileo, *Dialogue Concerning the Two Chief World Systems*, 11. Yates holds this view as well, see Yates, *Bruno*, 358–59.

²⁵Kearney, *Science and Change*, 47. For a succinct presentation of the three distinct traditions, see ch. 1.

²⁶Descartes, *The World or A Treatise on Light*, in PWD, I:81–98.

²⁷Descartes, *Discourse on Method, Optics, Geometry, and Meteorology*, trans. Paul J. Olscamp (Indianapolis: Bobbs-Merrill, 1965).

Pythagoreanism delivered a mystical message with its mathematics. Though these findings complicate matters, they help clarify the nature of the challenge at that time. In addition to defeating an Aristotelian philosophy of nature, Galileo or any other mechanist and realist defender of Copernicus' theory would also have to establish their "world system" as preferable to a Hermetic-Copernican rival as well. To the extent that the new philosophy of nature was both mathematical and mechanical, its advocates needed to show how nature could be realistically construed as mathematical without being magical. Furthermore, to insure that no occult contraband could work behind the mathematical descriptions, a mechanistic model of the causal workings of nature needed to be incorporated and fused with the distilled mathematics. In sum, there were three distinct somewhat competing approaches to the study of nature in the sixteenth century: the organic philosophy of Aristotle, the Hermetic mystical approach of the neo-Platonists, and the Archimedean mechanistic approach which was carried forward from the Italian engineer Niccolo Tartaglia to Galileo in the work of Guidobaldo's *Libri Mechanicorum* (1577).²⁵ Among Descartes's epoch-making projects was precisely this extraction and fusion of the mathematical and the mechanical into a new synthesis.

IV. DESCARTES'S DEMYTHOLOGIZING OF PYTHAGOREANISM

At the same time that Galileo completed his *Dialogues*, Rene Descartes had begun to respond to the lacuna in a deep and compelling way. In 1632 Descartes completed his work entitled *Le Monde* or *Treatise on Light*²⁶ which held the contours of a world system with a heliocentric astronomy. He continued to work on problems in optics, on motion, and in mathematics. These results were published in three treatises, the *Optics*, the *Geometry*, and the *Meteorology*, introduced by the *Discourse on Method*.²⁷ Because Descartes the philosopher understood that a new philosophy of nature and the method appropriate to it should be propaedeutic to the new "quantitative, non-teleological physics of motion," he had introduced the scientific works to his readers through his well-known *Discourse on Method*. Descartes understood that a realist construal of these new, mathematical methods, concepts, and structures for a "science" of nature required a fundamental shift in the philosophy of nature. The *Discourse* was intended to prepare the reader for this. As a "discourse," it was only an informal sketch and discussion of the method and view of nature within which the new treatises made sense. As such, it did not constitute the philosophical argument for the new philosophy of nature, the new Pythagoreanism. That argument is one of the major tasks of Descartes's *Meditations*.

Though Descartes waits until the end of chapter five of *Le Monde* to

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announce that he wants "to clothe part of it in the guise of a fable" (PWD,I:10), it is clear from the outset that the work presents a conjecture of how the world might be a mathematical structure very much like Galileo's "Great Book of Nature." Its goal is to show the reader that its proposed "world system" is a real possibility. In sanctioning a heliocentric universe and critiquing the Aristotelian hylomorphic theory of the five elements (earth, air, fire, water, and the fifth element) and its teleological notion of potentiality in nature, it emerges as a rival to the Aristotelian-Ptolemaic world system. In its positive task, it constructs the framework for a system of nature which is at once mathematical, mechanical, and knowable. *Le Monde* postulates Nature as a system constituted by a homogeneous matter everywhere in motions governed by three laws of Nature: a law of inertial state (PWD,I:93), a law of the conservation of the quantity of motion (PWD,I:94), and a law of linear inertia of a body's parts (PWD,I:96). Descartes was well aware of the Hermetic thinking of Bruno, Campanella, and others. In introducing his laws of the motion of matter, he carefully distinguishes his sense of 'nature' from any Hermetic one: "Note, in the first place, that by 'nature' here I do not mean some goddess or any other sort of imaginary power" (PWD,I:92). To insure further that his matter conceals no "occult qualities," Descartes insists that it is fully and transparently knowable: "Now since we are taking the liberty of fashioning this matter as we fancy, let us attribute to it, if we may, a nature in which there is absolutely nothing that everyone cannot know as perfectly as possible" (PWD,I:90). In addition to eliminating the mystical, Descartes also distinguished his notion from the prime matter of the Aristotelian philosopher of nature. In differentiating his matter from the Aristotelian and Hermetic senses, Descartes has cleared the way to explain matter, and all of its qualities and properties, in terms of purely quantitative descriptions of "motion, size, shape, and arrangement of its [bodies] parts" (PWD,I:89). He also believes that he has prepared the Aristotelian philosopher at the least to understand this new system of the world. Referring to them he remarks, "Nor should they find it strange if I conceive its [matter's] extension, or the property it has of occupying space, not as an accident, but as its true form and essence" (PWD,I:92).

Finally, this conjectured world is composed of parts moving parts, like the mechanisms of a clockwork. Insofar as Descartes's system includes a heliocentric universe generated by a vortex motion of matter regulated by the three laws of motion, *Le Monde* succeeds in presenting a rival, alternative to the Aristotelian-Ptolemaic world system. It is interesting to notice that it is somewhat asymmetrical to the Galilean-Copernican world system. Whereas the Galilean system includes a detailed and complete mathematical astronomy, but little in the way of principles of nature, Descartes' system lacks the technical astronomy while offer-

²⁸See Headley, *Campanella and the Transformation of The World*, 119-38, for an

insightful account of Campanella's last years in the Paris of Mersenne.

ing a much more promising philosophy of nature. This is important, because it affords Descartes a much stronger position from which to argue for a realist mathematical philosophy of nature, something Galileo never did. *Le Monde* offers only a possible world system. Descartes' three works, the *Optics*, the *Geometry*, and the *Meteorology*, which are introduced by his *Discourse on Method*, exhibit the fruitful results and future promise that a purely mathematical, which is to say, a distilled Pythagorean philosophy of nature can offer. The *Optics* and the *Meteorology* display the use of mathematically described mechanical models for the study of light. And the latter's explanation of the colors of the rainbow leave no question about Descartes' realism: it extends to the nonobservable theoretical entities which his new world makes available. However possible, plausible, useful, and promising this "scientific realism" would be compelling only if Descartes could show that *Le Monde's* conception of matter as *res extensa* is an essentially true description of the real, external world. This claim — the realist thesis about Galileo's "great Book of Nature" — must await the cunning argument of Descartes's *Meditations* with its subtle, demythologized Pythagoreanism.

In 1634 the last of the Renaissance Magus, Campanella, had arrived in Paris where Fr. Mersenne was the chief architect of its emerging Republic of Letters, a champion of the new mechanistic view of nature, and the close correspondent and friend of Rene Descartes.²⁸ Could it be that the talk of madmen, dreams, and demons was Descartes's somewhat contemptuous way of dealing with Hermetic thinkers, such as Campanella? And was his expansion of the method of doubt to its hyperbolic extremes part of a cunning strategy not only for answering Montaigne's skeptical challenge, but also for exorcising the Hermetic element from the science of nature?

In the beginning of the *Meditations* (PWD,II:15), Descartes does doubt and reject the existence of the external world, but it is the world of common sense experience and of the Aristotelian natural philosophy. It is that world which countenances the secondary sense qualities of things, their sounds, colors, and fragrances to be as real as the motions, shapes, and sizes of things. It is that Aristotelian world for which *Le Monde* constructed a quite different possible world, one readily amenable to another construction of Descartes, his analytic geometry. Armed with a powerful phenomenological method of the analysis of ideas, designed to direct the attentive mind to the self-evident clarity and distinction of intuition, Descartes sustains an analysis upon the idea of a wax ball as a prototypical body in order to arrive at an intuition of its true essence, which is to be spatially extended (PWD,II:20–21). If extension is the essential attribute of matter, then motion and shape (geometric form) are its possible modifications.

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Thus, not only is a world of such *res extensa* amenable to analytic geometry, the latter is the perfect instrument for the study of this world. The last step for Descartes to secure this harmony between method and content, between mathematics and nature, is to retrieve the external world. But it can not be and will not be that common sense world thrown out in *Meditation I*. Rather when Descartes arrives at the question of "proving" the existence of the external world, he has transformed the task into that of proving his "scientific realism."

If we briefly consider Descartes's philosophy of mathematics, at least as implicit in his theory of ideas, we can see how he is purging mathematics of its Hermetic dimension. Descartes's distinction between the formal and the objective reality of an idea applied to the mathematical idea (for example, the idea of a triangle) insures the "objectivity" of the mathematical entity. As available to the analysis of an attentive mind, the mathematical entity can be distinguished from other mathematical entities so that what is present to the mind is the objective reality of the mathematical idea in its fully transparent clarity. As such, there is nothing hidden, nothing else concealed behind or within the idea. In this sense, Descartes has made available a mathematics without an occult or magic dimension to it. Inasmuch as he has also used analysis to arrive at a clear and distinct conception of the essential form or nature of matter as spatial extension, as *res extensa*, he has prepared a mathematical conception of physical nature. Finally, his argument of *Meditation VI* for the existence of the physical world is in effect an argument for a realist interpretation of his fabled nature as a *res extensa*. The argument initially appears unnecessarily complicated in its forestalling manner of proceeding through three successive theses: first, that as objects of mathematics (i.e. as *res extensa*), material things could exist (PWD,II:32); second, that my natural power to image bodies inclines me to believe that bodies exist, and so, they probably exist (PWD,II:52); and third, that bodies as *res extensa* do exist (PWD,II:55).

My aim here has been to show that the argument of *Meditation VI* is Descartes's way of epistemically assuring us that the essence of a world of *res extensa*, an essence of mathematical attribute devoid of any Hermetic traces of Pythagoreanism, indeed has existence. As such the argument of the last *Meditation* is the end of a mythic Pythagoreanism. To the extent that it succeeded in dislodging the grip of an Aristotelian theory of nature, it completed the unfinished case of Galileo, not so much for the Copernican thesis as for its Pythagoreanism.