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Galileo and Descartes on Copernicanism and the cause of the tides

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ABSTRACT

Galileo and Descartes were on the front lines of the defense of Copernicanism against theological objections that took on special importance during the seventeenth century. Galileo attempted to overcome opposition to Copernicanism within the Catholic Church by offering a demonstration of this theory that appeals to the fact that the double motion of the earth is necessary as a cause of the tides. It turns out, however, that the details of Galileo's tidal theory compromise his demonstration. Far from attempting to provide a demonstration of the earth's motion, Descartes ultimately argued that his system is compatible with the determination of the Church that the earth is at rest. Nonetheless, Descartes's account of the cause of the tides creates difficulty for this argument.

1. Introduction

Thomas Kuhn introduced the notion that the publication in 1543 of the *De Revolutionibus orbium coelestium* of Nicolaus Copernicus triggered a "Copernican Revolution" in astronomy, and in early modern scientific thought in general.[1] However, it is clear that Copernicus's work did not trigger a single revolution; recent historical work confirms Robert Westman's claim—in his massive new study of the history of "the Copernican question"—that "the Copernicans simply did not constitute a coherent movement."[2] There were in fact very different versions of Copernicanism in the early modern period, though, as Westman also notes, these versions can be seen as constituting a *via moderna* insofar as "they moved the debate over world systems to a new level of legitimacy and engagement."[3]

I want to illustrate both the diversity and the interconnectedness of different Copernicanisms by focusing on the reception of Copernicus in the work of Galileo Galilei and René Descartes.[4] Certainly these two intellectual giants can be considered to be prominent members of the early modern Copernican movement. After all, both were on the front lines of the defense of Copernicanism against theological objections that took on special importance during the seventeenth century. In the case of Galileo, of course, we have the iconic instance of the early modern conflict over Copernicanism in his 1633 trial by the Roman Inquisition, which issued in his conviction on the charge of "vehement suspicion of heresy." This conviction had a dramatic impact on Descartes, leading to his refusal to publish his *Le Monde*, as well as to his subsequent attempt to render his cosmology compatible with the Church's condemnation of Copernicus and Galileo. But as we will discover, the forms of Copernicanism that we find in these figures differ significantly from each other, as well as from what we find in Copernicus himself.

I begin my discussion with Galileo's defense of Copernicanism. His form of this theory in fact differs significantly from Copernicus's more robustly Ptolemaic version. Galileo is also distinguished from Copernicus in being concerned to overcome religious opposition to Copernicanism by offering a demonstration of this theory that is consistent with what is required for divine omnipotence. It is his concern to provide a demonstration of Copernicanism that led Galileo to emphasize the issue of the cause of the tides. However, we will discover that the details of Galileo's tidal theory in fact compromise his defense of Copernicanism.

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[1] See Thomas Kuhn, *The Copernican Revolution: Planetary Astronomy in the Development of Western Thought* (Cambridge, MA: Harvard University Press, 1957).

[2] Robert Westman, *The Copernican Question: Prognostication, Skepticism, and Celestial Order* (Berkeley: University of California Press, 2011), 425v.

[3] *Copernican Question*, 426r.

[4] Cf. the discussion of this topic in Michael Friedman, "Descartes and Galileo: Copernicanism and the Metaphysical Foundations of Physics," in Janet Broughton and John Carriero, eds, *A Companion to Descartes* (London: Blackwell, 2008), 69–83.

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What Descartes understood by Copernicanism differs from both Copernicus's Ptolemiac version and the more simplified version in Galileo. Moreover, in contrast to Galileo, Descartes was not concerned to offer a demonstration of Copernicanism, and indeed emphasizes the merely hypothetical nature of astronomical claims. Finally, Descartes did not share Galileo's concern to overcome religious opposition to the claim that the earth is in motion; indeed, he was eager to accommodate such opposition. Nonetheless, the issue of the cause of the tides turns out to be as relevant to Descartes's discussion of planetary motion as it is to Galileo's discussion. And as in the case of Galileo, what Descartes has to say about this issue creates difficulties for his defense of Copernicanism.

2. Galileo: demonstration and divine omnipotence

In his 1632 *Dialogo sopra i due massimi sistemi del mondo*, Galileo is concerned to address what his spokeman Salviati calls "strongest argument of all" against the motion of the earth, namely, the fact that a body falls perpendicular to the earth.[5] In the Second Day, Salviati offers the response that the falling body participates in the uniform circular motion of the earth. But Galileo also is led by his Copernicanism to add to this diurnal motion the annual motion of the earth around the sun, which—on his official view, at least[6]—is uniform and circular as well. This double motion of the earth is of crucial importance to Galileo since it is this feature that he takes to be necessary for the terrestrial phenomenon of the tides.

I will return to Galileo's tidal argument later in this section. However, it is important to recognize initially that the version of Copernicanism that Galileo presents in the *Dialogo* differs significantly from what we find in Copernicus's own *De Revolutionibus*. In particular, Copernicus's text does not endorse the sort of simple view in Galileo of nested circular planetary orbits around the sun. Indeed, Copernicus was concerned to reject a version of this view in Eudoxus that Aristotle later adopted. Though Eudoxus as well as Aristotle assumed that the earth is at rest in the center of a spherical universe, they also posited a set of homocentric spheres to explain the orbits of the other planets (and the sun). It was the inability of models involving such spheres to capture the celestial phenomena that led other ancient astronomers, including Ptolemy, to posit eccentric orbits that do not have the earth as their center, as well as epicyclic orbits that have centers that are themselves on deferents that constitute the circumference of larger circles.

On the point of rejecting nested homocentric spheres, Copernicus is entirely on Ptolemy's side. Thus he notes in *De Revolutionibus*:

> For although those who put their trust in homocentrics have shown that various different movements can be composed of such circles, nevertheless they have not been able to establish anything for certain that would fully correspond to the phenomena.[7]

And indeed, in the more technical portions of Copernicus's text there is extensive employment of the Ptolemaic devices of eccentrics and epicycles. Copernicus's use of these devices helps to explain the claim of Tycho Brahe, in his 1574 Copenhagen Oration, that Copernicus is "a second Ptolemy" whose innovations serve to reform Ptolemaic astronomy.[8]

In his *Dialogo*, Galileo presents a version of Copernicanism that eliminates these Ptolemaic elements and substitutes circular planetary orbits. In the third day of this text, Salviati claims that though Ptolemy "introduces vast epicyles" to save appearances, for the Copernican "all of these can be done away with by one very simple motion of the earth."[9] Here we have the familiar picture on which Copernicus purged astronomy of the monstrous Ptolemaic epicycles. In fact, however, Copernicus was aware of the need for epicycles as well as eccentrics in order to track the astronomical phenomena. Indeed, one reason that Kepler was able to provide a more empirically adequate version of Copernicanism than we find in Galileo is that he engaged the technical details of Copernican astronomy in a way Galileo never did. In particular, Kepler recognized the anomalies that had led earlier astronomers to posit epicycles and eccentrics, and he had the astronomer's concern to provide a model that dealt in a satisfactory way with these anomalies. To be sure, there is nothing in Kepler corresponding to the powerful critique in Galileo's *Dialogo* of the Aristotelian theory of motion, a critique that contributed to the increasing neutralization in the early modern period of the objection that Copernicanism is philosophically untenable.[10] Nonetheless, it remains the case that Kepler rather than Galileo is heir to Copernicus's role as "a second Ptolemy."

Though Galileo did not contribute much to the technical refinement of Copernicanism, he is distinctive in considering the possibility of providing a demonstration of this theory. The issue of demonstrability was in fact a central issue in the events leading up to the initial Roman condemnation of Copernicus. This condemnation involved the placement of *De Revolutionibus* on the *Index librorum prohibitorum* in 1616, after a review of the Copernican theory by the Congregation of the Inquisition that involved significant input from the prominent curial official, Robert Cardinal Bellarmine. Prior to these events, Bellarmine had an exchange with the Carmelite theologian Paolo Antonio Foscarini, the author of a treatise "in which it is shown that [the Copernican] opinion agrees

[5] *Dia*. II, in *Dialogue concerning the Two Chief World Systems*, trans. S. Drake (New York: Modern Library, 2001) [hereafter, *TCWS*], 146; original in *Le Opere di Galileo Galilei*, Edizione nationale, ed. Antoino Favaro (Florence: Barbèra, 1890–1909) [hereafter, EN], 7:151.

[6] See the complications for the assertion of the uniformity of the annual motion, considered toward the end of this section, introduced by Galileo's explanation of variations in the tides tied to the lunar orbit.

[7] *De. Rev*., pref. ad Paulum III, in *On the Revolutions of Heavenly Spheres*, trans. C. G. Wallis (Amherst, NY: Prometheus Books, 1995), 5.

[8] Quoted in Westman, *Copernican Question*, 244r–45v. The reform that Tycho emphasizes most is Copernicus's use of mathematical techniques to eliminate the Ptolemaic equant, the point around which an orbit has uniform motion, but which is not itself at the center of that orbit. Copernicus himself emphasized the need to eliminate the equant in his early *Commentariolis*; see N. M. Swerdlow, "The Derivation of the First Draft of Copernicus's Planetary Theory: A Translation of the Commentariolis with Commentary," *Proceedings of the American Philosophical Society* 117 (1973), 434–35.

[9] *Dia*. III, *TCWS* 397/EN 7:370. Admittedly, Galileo seems at times to recognize that Copernicus posits epicycles and eccentrics; see, e.g., his 1615 remarks on Bellarmine's letter to Foscarini translated in Richard J. Blackwell, *Galileo, Bellarmine, and the Bible* (Notre Dame, IN: University of Notre Dame Press, 1991) [hereafter, *GBB*], 269. (I consider both the letter and Galileo's commentary on it below.) However, in a letter written around the same time, Galileo claims that an epicycle is "nothing but a circle traced by the motion of a star and not enclosing the terrestrial globe," whereas an eccentric "a circle which indeed surrounds the earth, but has it on one side rather than at the center"; Galileo to Dini, 23 Mar. 1615, in M. A. Finocchiaro, *The Galileo Affair: A Documentary History* (Berkeley: University of California Press, 1989) [hereafter, *GA*], 61/EN 5:298–99. On the conceptions common to Ptolemy and Copernicus, however, an epicycle involves a motion around a deferent, whereas an eccentric involves a motion around some body not at the center. Galileo does not recognize in Copernicus epicycles and eccentrics conceived in this manner.

[10] In 1616, the judgment in the Curial report on *De Revolutionibus* was that the assertion in this work of the motion of the earth is not only "at least erroneous in faith" but also "foolish and absurd in philosophy"; *GA* 146/EN 19:320–21. The claim about the philosophical absurdity of Copernicanism was increasingly rejected by astronomers over the course of the seventeenth century; for documentation of this point, see John L. Heilbron, "Censorship of Astronomy in Italy after Galileo," in *The Church and Galileo*, 279–322.