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THEN & NOW

The 'Impiety' of Kepler's shift from mathematical astronomy to celestial physics

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In the early modern period, the age of the "Scientific Revolution," theological and metaphysical concerns played a decisive role in scientific debates. In a time in which physics was a synonym for natural philosophy, it could be very hard to challenge the Aristotelian framework in which issues such as planetary motion, falling bodies and the trajectory of projectiles were inserted and explained. Astronomy was specially loaded with ethical and religious meanings as it related to questions such as the place of humankind in the cosmos and the meaning of life, as well as the revelation of God through His Creation. Such constraints hindered in many ways the dissemination and acceptance of novel theories such as the heliocentric system, as terrestrial motion and solar centrality appeared to contradict some Biblical passages. Astronomical and physical theses could even become a matter of faith and dogma, as witnessed by the prohibition of the Copernican theory by the Catholic Church in 1616 and the famous condemnation of Galileo Galilei in 1633. However, theological and widely-held philosophical argumentations were not external to the scientific debates. Rather, they were used, appropriated and refined by mathematicians and scholars in the natural sciences. It is less well-known that Galileo's contemporary, the imperial mathematician Johannes Kepler, also met with severe philosophical and theological criticism against his seminal work in celestial physics. In the following, I will briefly recount some of his colleagues' reactions and the manner in which he replied to their objections.

On 6 June 1638 the elderly and reputed Copenhagen professor of astronomy Christianus Severinus Longomontanus (1562–1647) communicated to his correspondent, the town physician to Stettin and calendar maker Laurentius Eichstadius (future town physician and Gymnasium professor of Gdańsk) (1596–1660), his disappointment with Johannes Kepler's (1571–1630) astronomical tables, owing to the physical theory they rested upon:

> "Although the incredible efforts of the illustrious Mr. Kepler contributed much to the restoration of astronomy; nonetheless he admitted that he relied upon physical and too uncommon speculations [...]. Therefore [...] I could not approve his *Rudolphine Tables* in all respects (and I have not changed my mind). In fact, I am certain that astronomy rests on principles that are much loftier than such a physics."[1]

The *Rudolphine Tables* (1627), named after the magnificent patron of the sciences and the arts, Rudolph II (1552–1612), were actually the coronation of Kepler's work as Imperial Mathematician in Prague. They were the tangible result of his innovative planetary theory, which he had first devised for Mars and presented in his *New Astronomy* (1609). The 'newness' of his approach to astronomy resided in the idea of a *physica coelestis* (celestial physics). According to Kepler, this unheard-of discipline should substitute the purely geometrical science of ancient and modern astronomers for a theory in which the geometry of planetary motions and their variations in velocity were derived for the first time from the action of physical forces. Regrettably, Kepler's *physics* infringed on widely accepted disciplinary separations and *metaphysical principles* of astronomy. First and foremost, his approach invalidated the traditional distinction between mathematical astronomy representing heavenly phenomena and the natural philosophy 'explaining' their causes. Moreover,

[1] Laurentius Eichstadius, *Tabulae harmonicae coelestium motuum tum primorum, tum secundorum, seu doctrinae sphaericae et theoriae planetarum. Innitentes potissimum exactissimis observationibus et hypothesibus Nobilissimi Tychonis Brahei, solertissimi Astronomiae instauratoris* (Stetini: Typis Georgii Rhetii, 1644), pp. 148 and 151.

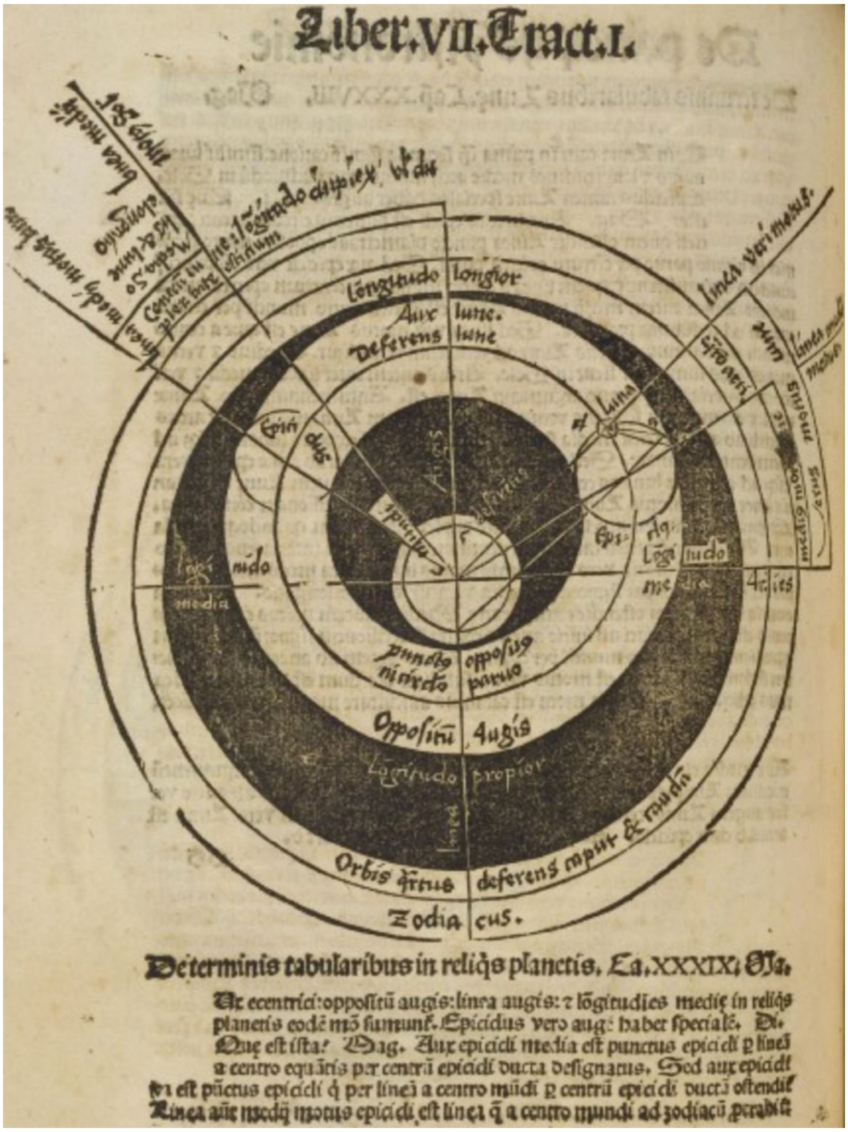

Figure 1 Example of Ptolemaic devices for the modeling of planetary motions from the Renaissance encyclopedic work of Gregor Reisch, *Margarita philosophica* VII,1 (Strassbourg, 1508). Courtesy of the Max-Planck-Institut für Wissenschaftsgeschichte, Library.

he abandoned the Aristotelian assumption that the heavens, owing to their perfection and closeness to the divine, follow physical laws which are different than those ruling the terrestrial (or sublunary) realm.

The perceived contrast between Kepler's theory and the astronomical tradition is particularly true for his elliptical orbits and the law of areas (his so-called 'first' and 'second' laws). Generations of astronomers before him had modeled planetary motions on epicycles in such a way that celestial appearances could be represented as the composition of circular uniform motions (see Fig. 1). Nicholas Copernicus (1473–1543) in his *chef d'oeuvre*, *The Revolutions of the Celestial Orbs* (1543), had substituted Ptolemy's equants (a geometrical device implying the variability of the linear speed of a planet to which Kepler's theory most closely resembles) for epicyclical models securing the respect of the so-called *axioma astronomicum.* According to such an 'axiom of astronomy,' planetary motions are uniformly circular about their centers or result from the composition of circular uniform motions. It was derived from classical philosophical sources, especially from the second book of Aristotle's *On the Heavens* (from the third century BC) and from the metaphysically oriented *Draft of Astronomical Hypotheses* (Latinized as *Hypotyposis orbium coelestium*) by the neo-Platonist Proclus (5th century AD). The metaphysical soundness of such a principle, which informed Copernicus's geometrical devices, was very much appreciated by his early followers beginning with the Wittenberg mathematician Erasmus Reinhold (1511–1553), compiler of the most successful astronomical tables of the sixteenth century (*Prussian Tables*, 1551). Reinhold and most astronomers of his time assumed that circular uniformity was the proper expression of the eternal perfection that God communicated to the heavens, contrary to the imperfection of the terrestrial (or, rather, 'sublunary') realm, marked by sin, alteration, and death.

Moreover, since Copernicus had not persuaded them of the astronomical, physical, and theological acceptability of the heliocentric hypotheses, his early German readers implanted his geometrical models resting on the 'astronomical axiom' into a geocentric framework. The most astounding compromise these astronomers made between their general assumptions and the Copernican legacy was the implementation of geo-heliocentric planetary systems. Geo-heliocentrism was a sort of 'third way' between Ptolemy and Copernicus, according to which the Earth remains the center of the cosmos and of the solar and lunar deferents, whereas the Sun, traveling about the Earth, is the movable

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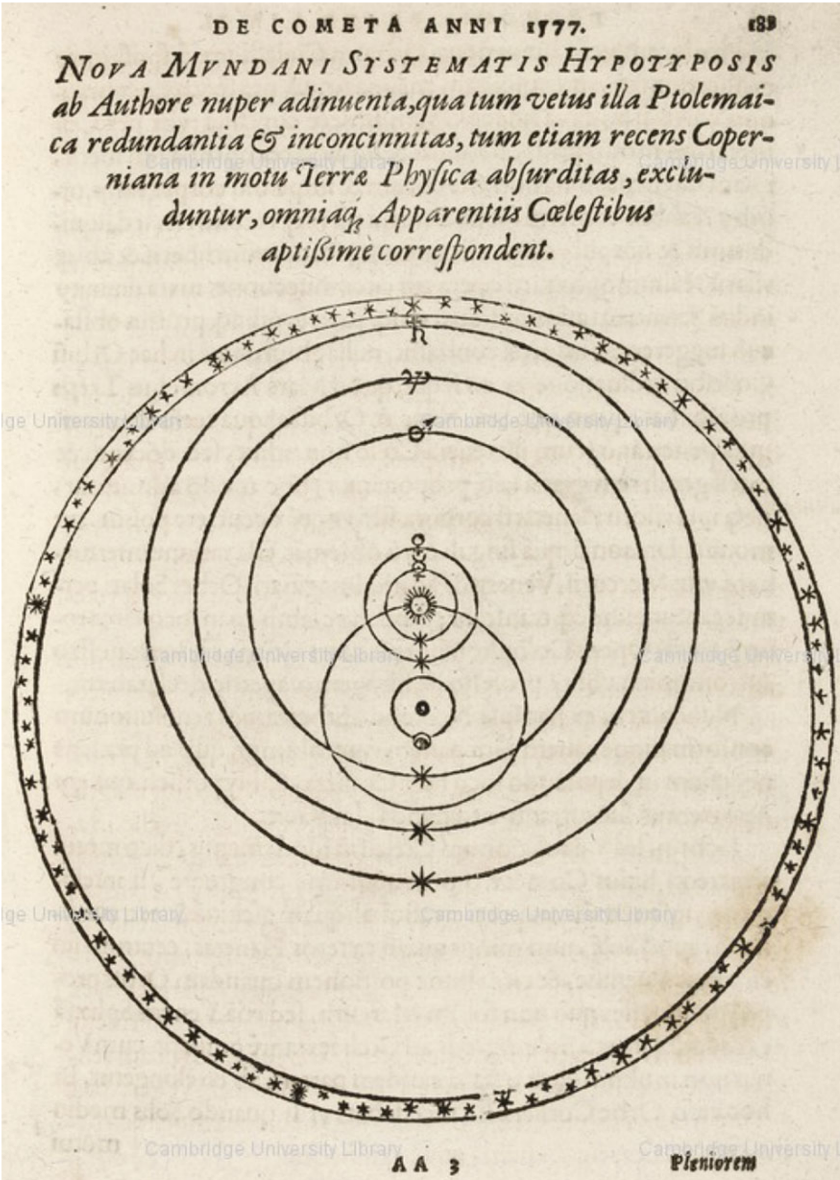

Figure 2 Tycho Brahe's geo-heliocentric planetary system as presented in *De mundi aetherei recentioribus phaenomenis* (1588). Provenance: Staats- und Stadtbibliothek Augsburg.

center of the planets (Fig. 2). Danish scholars held a sort of primacy in the invention of such systems: Nicolaus Raimarus Ursus of Hennstedt (then part of the Kingdom of Denmark) (1551–1600) and the Lord of the marvelous castle-observatory of Uraniborg, Tycho Brahe (1546–1601), independently arrived at the geo-heliocentric solution, communicated it in two competing publications in 1588, and entered a bitter controversy over priority and plagiarism. Brahe's pupil Longomontanus later brought the geo-heliocentric theory to its perfection in a work that carried the quite patriotic title *Danish Astronomy* (1622). Considering this context, we should not be surprised that scholars from Denmark and the Baltic area were among those who most decidedly opposed Kepler's celestial physics as contrary to the pillars of their conception, that is, geocentrism, the metaphysics of circular uniformity and the distinction between celestial and terrestrial physics.

Yet, these scholars were facing the same theoretical problem motivating Kepler's inquiry into celestial physics, namely the need for a new explanation of planetary motions following the dissolution of the Aristotelian cosmology. According to the Scholastic followers of Aristotle, the heavens were made out of ethereal spheres that rotated mechanically and transported celestial bodies. But since Renaissance optical considerations on light refraction and observations of comets had forced astronomers to renounce material spheres, the most varied doctrines began circulating as possible accounts of planetary motions through the fluid medium of cosmic space. They mostly rested on analogies. For instance, the Copernican philosopher Giordano Bruno (1548–1600) regarded planets as living beings moved by animal and intelligent souls, while the neo-Platonic philosopher Francesco Patrizi (1529–1597) equated heavenly bodies with fish and birds travelling through water and air. Brahe and his correspondent, the court mathematician at Kassel, Christoph Rothmann (c.1555–1601), postulated that every planet was guided on its course by a "science infused by God." Among the followers of Brahe, a detailed treatment of the metaphysical principles making celestial dynamics possible was attempted by the philosopher and theologian Daniel Cramer (1568–1637), professor at the Gymnasium in Stettin. Cramer dedicated to Brahe an *Introduction to Aristotelian Metaphysics* (1594, revised 1601), in which he adapted the principles of Aristotle to

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a geo-heliocentric system renouncing material spheres:

> "Just as it was once believed that no sphere is moved by itself—actually, nothing moves itself—but it was assumed that a special intelligence or mover assisted the sphere, similarly you should assume that heavenly bodies are not moved by some instruments by analogy with terrestrial beings moving with their feet, water animals with their fins, and birds with their wings. Rather, they are moved by the proper and regular [...] impetus of their own mover. We must believe that, in the same manner in which this [mover] assisted a solid sphere according to the opinion of the ancients, it assists any star moving without spheres. We have insisted on this aspect, to manifest the reason why it is not necessary to abandon the movers, although the spheres have vanished."[2]

Cramer called the metaphysical principles securing planets' motions 'movers,' 'divine substances,' or 'separate intelligences.' Although all these terms stem from Aristotle's *Metaphysics*, in a Christian context separate intelligences were identified with angels. In Stettin and Gdańsk, half a century later, Longomontanus's correspondent Eichstadius refined and rearticulated such Aristotelian premises of astronomy and explained that "those motions of the heavens that are produced by intelligences or angels are not physical but hyperphysical."[3] He and the other Tychonics shared the conviction that celestial geometries rest on principles that are higher than those accounting for sublunary phenomena. According to them, it was metaphysics and not physics that should offer the principles ruling the motions in the loftiest spheres of the Divine Creation. Kepler's vision of a celestial physics looked suspicious if not impious to them, because it downplayed a mathematical discipline dealing with perfect bodies to the rank of a physical discipline blemished by the material imperfection of the lowest realms in nature. As Longomontanus put it, "I am certain that astronomy rests on principles that are much loftier than such a physics."

Kepler sensed the reluctance of his colleagues entrenched in the Tychonic paradigm. He dealt with the foundational problems of their views in the *New Astronomy* to show their incapacity to offer any plausible physical account for their paradoxical system, in which a small Earth is the center around which the great bulk of the solar body accomplishes its revolutions. The Sun, in turn, exerts an attractive force investing all the planets travelling around it, with the sole exception of our petty globe, inexplicably unaffected by its action.[4] However, as Kepler could not persuade his adversaries of the correctness of his mathematical and physical arguments, he did not miss an opportunity to teach them a lesson in theology. He deemed their plurality of separate intellects, one for each celestial motion, as a vain attempt to revive Greek polytheism. On this account, he reproached the Tychonics for neglecting the unity of the Creation mirrored by the unitary principle of planetary motions. Kepler eventually pitted the *piety* of his physics against the *irreverence* of their cosmology. In his eyes, the solar force communicating to the planets their motions with variations linked to their distance from the Sun offered a unitary physical explanation of celestial motions mirroring the wisdom of the one and only God of his monotheistic creed.

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[2] On Kepler and the Tychonics: James R. Voelkel, *The composition of Kepler's Astronomia nova* (Princeton: UP, 2001), Chap. 7, "The Tychonics," and Miguel A. Granada, "'A quo moventur

[2] Cramer, *Isagoge in Metaphysicam Aristotelis* (Witebergae: Impensis Bechtoldi Raben Bibliopol., 1601), p. 182.

[3] Laurens Eichstadius, *Collegi Physici Generalis Disputationes XXVII* (Gedani: Typus Viduae Georgii Rhetii, s.a.), p. 354b.

[4] Cf. Johannes Kepler, *New Astronomy*, transl. William H. Donahue (Cambridge: UP, 1992), pp. 169–170.

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[3] For Kepler's celestial physics, see Bruce Stephenson, *Kepler's Physical Astronomy* (New York: Springer, 1987). On the context of the geo-heliocentric controversies, cf. Nicholas Jardine and Alain Segonds, *La guerre des astronomes: La querelle au sujet de l'origine du système géo-héliocentrique à la fin du XVIe siècle*, (Paris: Les Belles Lettres, 2008). Concerning the Renaissance debates on astronomy following the publication of Copernicus's *De revolutionibus*, see my *Copernicus in the Cultural Debates of the Renaissance: Reception, Legacy, Transformation* (Leiden: Brill, 2014).