The Persistence of Tychonism

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Abstract: Tychonism, if it is considered at all in histories of the Copernican Revolution, is briefly acknowledged as an alternative cosmic scheme, but seldom mentioned as an active tradition extending into the seventeenth century. I will make a case that it lasted into the eighteenth century. In this paper I will consider astronomers, almanac makers and natural philosophers who adopted and spread Tychonism. I will summarize and supplement the accounts of Carolino (2023) and Kallinen (1995) who document sequences of Tychonists in Lisbon, Portugal and Turku, Finland, respectively. I will then argue that Maria Cunitz (1610-1664) declares herself a Tychonist in her celebrated book *Urania Propitia* (1650). The same considerations emphasize the importance of Christian Longomontanus' (1562-1647) *Astronomia Danica* (1622) as a resource for Tychonism. I will conclude by examining a few almanac makers who adopted Tychonism, some of whom used Longomontanus. I offer corrections to earlier accounts of Tychonism, especially Schofield (1984). In conclusion I will suggest that the historical longevity of Tychonism has been considerably underestimated and also that Tychonists were not generally restrained from public endorsement of heliocentrism by religious pressure. On the contrary, I suggest that the continued acceptance of Tychonism was conditioned by its congruence with scientists' religious beliefs.

Keywords: Tycho Brahe (1546-1601); Tychonic system; Christian Longomontanus (1562-1647); Maria Cunitz (1610-1664); Christine J. Schofield; early modern almanacs; Jesuit scientists; Lutheran scientists; science and religion.

1. Introduction

My aim in this paper is to present a preliminary survey of Tychonism as a research tradition,[1] from the publication of *De mundi aetherii recentioribus phaenomena* in 1588 to the end of the next century.[2] By 'Tychonism' I mean the astronomical system introduced by Tycho in that book, developed in *Astronomiae instauratae progymnasmata* published 1603, and appearing in fully mathematical form in Christian Longomontanus' *Astronomia Danica* in 1622.[3] Tycho postulated a cosmos with a stationary central Earth, which the Moon and Sun revolved around while all the other planets revolved around the Sun. The orb of fixed stars was still the boundary of the cosmos and still concentric to the earth. Adoption of this scheme required the abandonment of solid celestial orbs as the causes of planetary motion. Longomontanus endowed the Earth with a daily rotation, and this innovation was adopted by many later adherents of Tychonism. Later writers also sometimes made only the inner planets and Mars revolve around the Sun, with Jupiter and Saturn again taking the Earth as the center of their motions. Consequently, I take the main markers of adherence to Tychonism to be acceptance of the overall cosmic scheme in either the original or modified form, a central Earth which may rotate or not, and the abandonment of celestial orbs.

Tychonism, if it is considered at all in histories of the Copernican Revolution, is usually acknowledged as an alternative cosmic scheme, but seldom mentioned as an active tradition extending into the seventeenth century. I will make a case that it lasted into the eighteenth century. In this paper I will consider astronomers, almanac makers and natural philosophers who adopted and spread Tychonism. I will summarize and supplement the accounts of Carolino (2023) and Kallinen (1995) who document sequences of Tychonists in Lisbon, Portugal and Turku, Finland, respectively.[4] I will then argue that Maria Cunitz (1610-1664) declares herself a Tychonist in her celebrated book *Urania Propitia* (1650). These considerations emphasize the importance of Christian Longomontanus' (1562-1647) *Astronomia Danica* (1622) as a resource for Tychonism. I will conclude by examining a few almanac makers who adopted Tychonism, some of whom used Longomontanus. I offer corrections to earlier accounts of Tychonism, especially Schofield (1984). More importantly, I suggest that the historical longevity of Tychonism has been considerably underestimated and also that Tychonists were not generally restrained from public endorsement of heliocentrism by religious pressure. On the contrary, I suggest that the continued acceptance of Tychonism was conditioned by its congruence with scientists' religious beliefs.[5]

2. Jesuit Tychonists

The strongest reaction to Tycho's work seems to have been from Jesuit scientists. As early as the 1610/11 academic year Otto Catenius (1582-1635) lectured on the Tychonic system at Mainz. The following academic year another Jesuit, Christophoro Borri (1583-1632), lectured on the Tychonic system at the College of Brera in Milan.[6] His unpublished treatise on astrology records the content of these lectures. Borri presented the cosmic schemes of Ptolemy, Copernicus and Tycho and chose Tycho for religious and physical reasons. In 1612 Borri was removed from his teaching position for views that were "non-orthodox." The Order sent him to Macao in 1615, and to Vietnam in 1617-22.[7] He took his Tychonic convictions with him and wrote books on astronomy while abroad. On

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the way back to Europe, he met the Italian traveler Pietro della Valle in Goa, on the east coast of India. At della Valle's request he wrote a summary of the Tychonic system (*Compendium ...de nova mundi constitutione iuxta systema Tichonis Brahae aliorumque recentiorum mathematicorum*) which Della Valle himself translated into Persian and then Italian.[8] On returning to Europe Borri taught in Portugal. Towards the end of his life, he composed another Tychonic text *Doctrine of the Three Heavens*, that formed part of his *Astronomical Collection* published in Lisbon in 1631.

Borri carried Tychonic doctrines over a large part of the world, before returning to teach in Portugal, but other Jesuits closer to home were active Tychonists, especially those involved with Galileo's telescopic discoveries, and Galileo himself, in 1610-11. One famous outcome of Galileo's visits to Rome was the statement added by Christopher Clavius to the last edition of his celebrated *Sphaera*, listing Galileo's discoveries, and concluding, "Since things are this way, Astronomers should consider how the celestial orbs ought to be arranged so they are able to explain these phenomena."[9] This has been read as an endorsement of Tychonic astronomy, or at least an encouragement to consider it, but Baldini (1992) and Lattis (1994) argue convincingly that Clavius was seeking a reformulation of the solid celestial orbs which he had always used, rather than a revolutionary replacement of the orb system; he never accepted Tycho's idea of fluid heavens. His successor Christoph Grienberger (1561-1636) wrote to Giuseppe Biancani (Josephus Blancanus, 1566-1624) in 1618: "...when he [Clavius] advised that other spheres should be considered, it seems he hoped more for an explanation of the new observations by the old theory than for a complete replacement."[10]

At the *Collegio Romano* Orazio Grassi (1583-1654) described the Tychonic system to students in his course on astronomy, as shown in the notebooks for the years 1617 and 1623 examined by Kraig Bartel. Grassi was circumspect on which of the four systems was preferable. He accepted that observations of the phases of Venus and the moons of Jupiter showed that they were satellites of the Sun and Jupiter respectively, but he continued to maintain the incorruptibility of the heavens in discussing the nature of the Moon and the spots on the sun.[11]

Grienberger's correspondent Biancani, however, did see an opportunity to reject solid celestial spheres, and despite Grienberger's worst efforts as censor, published a *Sphera Mundi* at Bologna in 1620, endorsing Tycho's system. He followed Iohannes Baptist Cysat (1586/7-1657), who one year earlier had adopted the Tychonic system to explain the comets of 1618, in his *Mathemata astronomica* (Ingolstadt, 1619).[12]

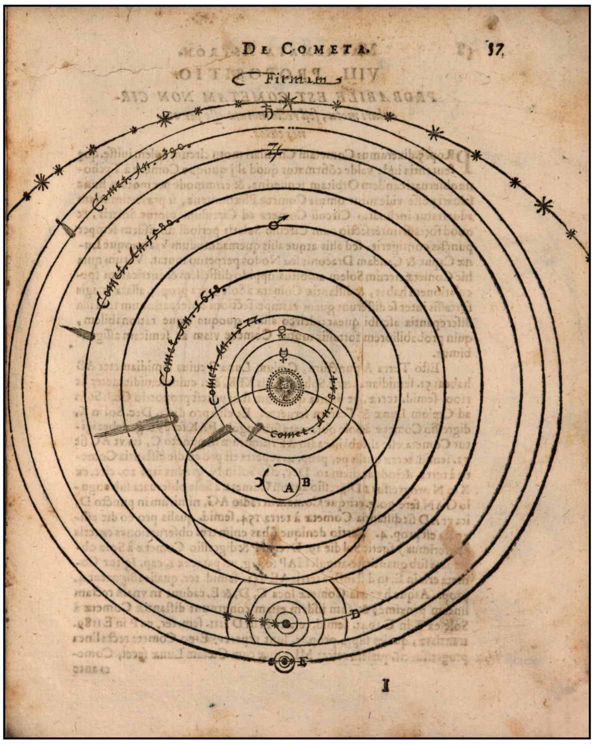

Figure 1: *Cysat (1619) page 57. How comets fit into the Tychonic system: The Earth, A, circled by the Moon, B, is the center of the cosmos and the orb of fixed stars. The sun is the center of all other motions, including comets. Note the comets of 1577 and 1618, on the left side of the Sun, between the paths of Venus and Mars. Note also the conspicuous rings of small objects immediately surrounding the sun – a common Jesuit explanation for sunspots that preserved the incorruptibility of the heavens. München, Bayerische Staatsbibliothek -- 4 Diss. 3786,26.*

Returning to Biancani, his support of Tycho is vigorous and extensive. In his preface he quotes the entire passage in which Clavius lists Galileo's discoveries and suggests finding new combinations of spheres.[13] Not only does Biancani support the Tychonic system as an alternative to Ptolemy and Copernicus, but he also accepts the unmodified form, arguing strongly for a stationary, non-rotating earth. Everything else revolves around the Sun, starting with the sunspots, which are small objects in stable orbits, as in Cysat. He gives mean motion tables for all the other planets and includes a Tychonic analysis of the moons of Jupiter. Last, he concludes that the epicyclic motions of the planets as they are carried around the sun create paths that are spirals.[14]

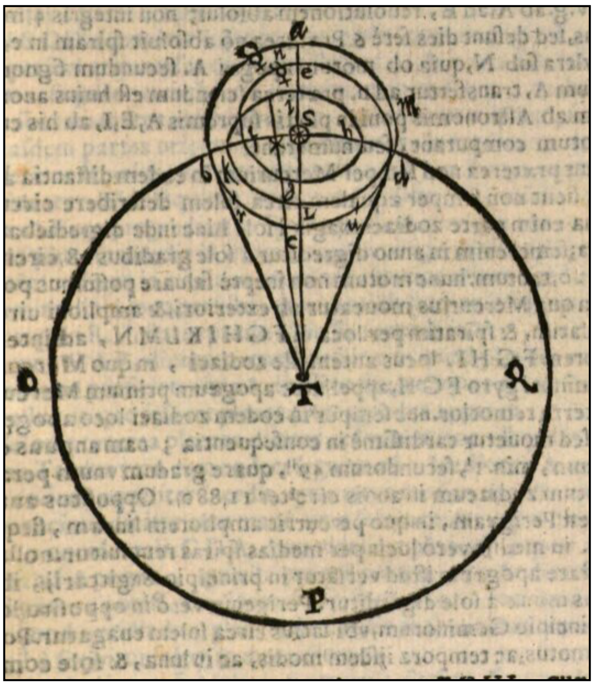

Figure 2 (right column, on the page before): *Biancanus (1620) page 255: The spiral path of the planet Mercury: The Earth, T, is the center of motion for the Sun, S, on its path SOPQ. Mercury follows a spiral path a,b,c,d,e,f,g,h,i,K,L,m,n. The effect of this motion over time is shown in the next figure. München, Bayerische Staatsbibliothek -- 4 Astr.u. 29.*

– an idea found in many later Jesuit astronomers. He reproduces Kepler's famous 'pretzel' diagram of the geocentric motion of Mars from the 1609 *Astronomia nova*

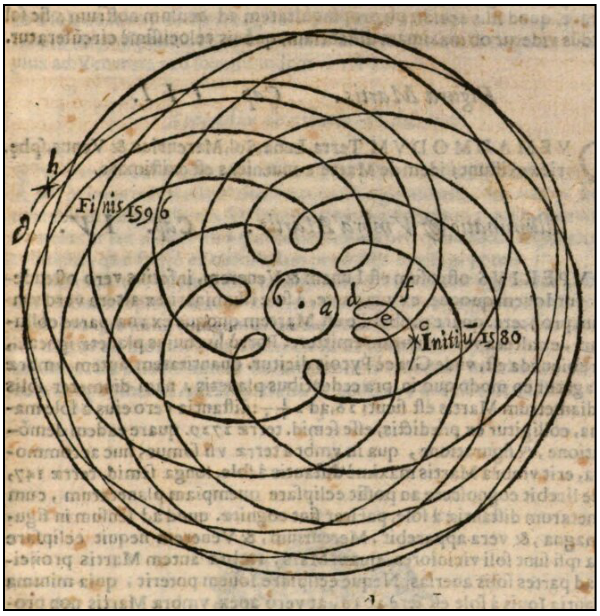

Figure 3: *Biancanus (1620) page 275: The motion of Mars from 1589 (c,d,e,f) to 1596 (h,g). Compare Kepler (1609) page 4. München, Bayerische Staatsbibliothek -- 4 Astr.u. 29. 309.*

but, unlike Kepler, does not conclude that such a motion is impossible; rather he gives it as an example of what he means by a spiral path.[15]

In a series of papers and now a book, Luis Miguel Carlino, presents a succession of Jesuit mathematicians who taught various versions of Tychonism in the introductory astronomy course at the College of Santo Antão in Lisbon. The book also contains valuable transcriptions and translations of primary sources.[16] The first in Carlino's list is Giovanni Paolo Lembo (1570–1618) from Italy, a student of Clavius and perhaps the first Jesuit to construct a telescope. He was also a participant in the Jesuit reception of Galileo in 1610-1611. He taught in Lisbon from 1615 to 1617. Next came Johann Chrysostomus Gall (1586–1643), from Germany who studied astronomy at Ingolstadt with Christoph Scheiner and, significantly, Cysat. Gall taught the *Sphaera* course from 1620–1627 and was succeeded by the Cristoforo Borri whose world travels I have already mentioned. Borri, however, taught in Lisbon for just one year (1627–8), before moving to Coimbra. The next Jesuit mathematician to teach the course was an Englishman, Ignacio Stafford (1599–1642), who taught from 1630–1636. He was followed by an Irish Jesuit, Simon Fallon (1604–42) who taught from 1638–1641.

There is considerable diversity among these Jesuit teachers of Tychonism. Lembo advocates a limited Tychonic system on the pattern introduced by Martianus Capella in antiquity.[17] For him only Venus and Mercury circle the Sun, and he retains celestial orbs as the path of Mars does not intersect the orb of the sun in this arrangement. Carlino's second figure, Gall, accepts Tycho as an authority in mathematics but not natural philosophy; although he presents the Tychonic system he does not endorse fluid heavens, but says he should not decide such questions.[18] As Carlino points out, this reinforces the traditional division between mathematics and natural philosophy.[19] However, this division was being erased by[20] other Jesuits elsewhere, for example Grassi in Rome.[21] The later Jesuits described by Carolino all adopted both some version of Tychonism, and the correlative doctrine of a fluid heavens, perhaps with a rotating central earth. In addition, Borri, Stafford, Fallon, and later Riccioli, all endorse the idea of spiral paths for the planets. Carlino traces the idea to a treatise on comets by Manuel Bocarro Francês (d.1668) published in Lisbon in 1619.[22] However, Victor Navarro Brotons calls this the doctrine "of remote origins" noting its adoption in sixteenth-century Spain by Jerónimo Muñoz (1515-1591) and Diego Pérez de Mesa (1563-1632). Later authors, for example Riccioli, the next Jesuit to be considered, attribute the origins of this doctrine to al-Biṭrūjī (fl. 1185-1192). Riccioli, incidentally, also reproduces an image of the spiral path in Figure 3.[23]

Later Jesuits modified the original Tychonic system in various ways. Perhaps the most celebrated is the Italian Giovanni Battista Riccioli (1598-1671), who in the *Almagestum novum* (1651) adopts a system in which the central earth has a daily rotation, the Moon and Sun rotate around the Earth, Mercury, Venus and Mars rotate around the Sun, but Jupiter and Saturn rotate about the earth.[24] However, fourteen years later in his *Astronomia reformata,* he reverted to the Sun as center of motion for all five planets.[25] Both Riccioli's books were written at Bologna. In the time between them another Jesuit, Melchior Cornaeus (1598-1665) at Würzburg defended the unmodified Tychonic system. In *Curriculum philosophiae peripateticae* (1657), he rejected Ptolemy as presented by Clavius, and also rejected Copernicus, denied the rotation of earth and fully supported the Tychonic arrangement of planets.[26]

Members of the Jesuit Order showed consistently strong support for Tychonism in both its original and modified forms. This support may be traced to two main reasons. The first is a genuine desire to accommodate the celestial novelties that appeared at the end of the sixteenth century and the beginning of the seventeenth. These included novae and comets (as we saw in the case of Cysat) as well as new discoveries made with the telescope (shown for example by the wide adoption of the explanation of sunspots as minor planets). The second reason is religious and has often been misunderstood. It is, of course, true that after the 1616 condemnation, Copernicanism was not an available option for Catholic cosmologists. However, Catholics did not adopt Tycho as a second best to Copernicus. Almost everyone understood and agreed with the reasoning of the 1616 decree. More fundamentally all natural philosophers at this moment in history expected that their religious and philosophical, or physical, ideas would interpenetrate and mutually reinforce; it was inconceivable that science would contradict religion. This was true even for Copernicans like Kepler and Galileo, who went out of their way to prove the compatibility of their cosmological ideas with their religion.[27] For Catholics like the Jesuits, Tychonism was a way of accommodating celestial novelties in accord with their personal religious ideas, as it had been for Tycho himself. Any implausibility the modern reader feels, when asked to consider a planetary system dragged by the sun around a central earth, needs to be balanced by a recognition of the religious commitments that were central to the lives of all early modern Europeans. As we will see in the next section, this same reasoning explains the adoption of Tychonism even among scholars who were not subject to the 1616 prohibition.

3. Lutheran Tychonists

Carolino's list of Tychonists ends in 1641. Maija Kallinen has described a very similar series of academics, who taught Tychonism at the University of Turku, formerly part of Sweden but today part of Finland, between 1640 and 1720. Turku had been founded as a Gymnasium in 1630 and elevated to a university in 1640.[28] In contrast to the Catholic scholars of Lisbon, the academics at Turku were all Lutherans. By this time the internal strife between followers of Phillip Melanchthon and Mattias Flaccius had been resolved in favor of the latter, who now practiced an orthodox Lutheranism that, as Kallinen succinctly puts it, "…was characterized by fundamentalism, literal reading of the Bible and quarrelsome opposition to other religious confessions."[29] Despite a general intellectual environment hostile to earlier Philippists like Caspar Peucer, Michael Maestlin, and Johann Kepler, a variety of professors of mathematics and other disciplines at Turku endorsed Tychonic cosmic schemes, seemingly because they offered an intellectually respectable way of retaining a geocentric reading of the Bible.

The first entry in this series of Tychonists is Simon Svenonis Kexlerus (1602-1669), although it is difficult to date his adoption of Tychonism precisely. Kexlerus served as professor of mathematics from 1640 until his death in 1669. In 1649 he published a vernacular *Almanac* and in 1666 a Latin *Cosmography*, both at Turku.[30] Some time between 1648 and 1651 he was commissioned to write an introduction to astronomy, which despite its Latin name, the *Astronomia*, was written in Swedish, and is now counted as the earliest endorsement in Swedish of the daily motion of earth. The book survives in manuscript and is complete up to the heading for chapter 13. As for date, all we can say is that the draft we have must be from no later than 1669, the year of the author's death.[31]

Oddly, the manuscript begins with a title page that identifies the author as Andreas Thuronius (1632-65), professor of physics and botany from 1660 to 1665. From his publications Thuronius is a plausible candidate; he published almanacs for 1661 and 1664 in Turku and for 1665 in Stockholm.[32] This sequence likely indicates that he prepared other almanacs that have not been preserved or come to light. Moving the venue of publication from Turku to Stockholm would also have given him a larger and more lucrative market, and suggests serious plans to produce more almanacs, although, sadly, he was not able to capitalize on this success, as he died in 1665. In late 1664 and early 1665 he made observations of a comet, and located it in the celestial realm not the terrestrial realm.[33] He also adopted fluid heavens.[34] He published Latin texts on logic and metaphysics in Turku, and supervised many dissertations.[35] One of these, defended by J. G. Alanus in 1664, was on the universal influence of the heavens on the sublunar world.[36] So on this evidence Thuronius is a plausible candidate for Tychonism, although we lack decisive evidence.

However, Thuronius did not write the *Astronomia*. The handwriting throughout the main draft is consistent with what would be expected from Kexlerus, while the handwriting on the title page is different. Most importantly, in 1987 Jaakko Lounela found the correspondence between the patron who commissioned the work and Kexlerus, and later reports from Kexlerus on progress towards completing the book.[37]

The manuscript of the *Astronomia* consists of twelve complete chapters and the title page for chapter thirteen, and is written throughout in Swedish. It begins conventionally by rehearsing the geometrical tools needed for astronomy. After discussing the status of astronomy as a science distinct from astrology, Kexlerus addresses the reality of celestial orbs, and discusses the systems of Copernicus and Tycho in detail. He concludes, with Tycho, that there are no real spheres in the heavens, except as useful boundaries defined by mathematics, although he mistakenly attributes the same view to Copernicus.[38] In subsequent pages he endorses the Tychonic system on the grounds that is accords better with everyday experience and Scripture. However, he strongly favors modifying Tycho's system by giving the Earth a daily rotation, which he finds simpler and more physically plausible than having the entire cosmos rotate each day. He answers Tycho's physical and Scriptural objections to the daily motion. However, Kalinnen notes that he carefully avoids a direct endorsement of the motion of the earth, despite rehearsing a series of arguments that support the idea. These arguments are repeated in the *Cosmography* published in the year of his death.[39] So, in summary, Kexlerus appears to be a Tychonist who accepts the fluid heavens required by the cosmic scheme, with the addition of a rotating central earth.

Kexlerus died in 1669 and was succeeded by Johann Flachsenius (1633-1694) who served as professor of mathematics until 1692. Flachsenius published on pneumatics and logic, and 1679 sponsored a defense by J. Grimsteen on astronomical hypotheses.[40] Although, typically, there is no outright statement of which system is correct, Flachsenius presents the Ptolemaic, Copernican and Tychonic systems, and refutes the Copernican system. As the Ptolemaic system was generally agreed to be no longer defensible, by default this leaves Tychonism as the preferred view.[41]

At the same time Flachsenius held the chair in mathematics, the Bishop and Chancellor of the University was

Johannes Gezelius (1615-1690), a polymath who wrote students' editions of Cicero, and a Greek textbook, as well as theological works. In 1672 he published an *Encyclopedia Synoptica*, which describes five cosmic schemes corresponding to Ptolemy, the 'Egyptians', Copernicus, Tycho, and Riccioli. Following the pattern we have already noted he fails to state directly which scheme is best, Kallinen regards him as a geocentrist from other evidence. Given this additional information, then, the inclusion of Riccioli's scheme is best explained by the author's preference for it over the unmodified Tychonic scheme, which is in turn preferable to any of the others.[42] The preference for Riccioli is even clearer in another writer from the same period, Daniel Achrelius.

Daniel Achrelius (1644-1692) held the chair in Eloquence (or Latin Literature) from 1679-1692 and directed dissertations on natural philosophy between at least 1681 and 1689.[43] In 1682 he published *Contemplationum mundi dissertatio quinta*, which Kallinen counts as a textbook.[44] Here Achrelius clearly states a preference for a Tychonic system in the form modified by Riccioli, and even provides a picture.[45] The Earth is shown as the center of motion for the Moon and Sun, which in turn is the center of motion for Mercury, Venus and Mars. However, the outer planets Jupiter, with four moons, and Saturn, with two, are shown moving concentric to the Earth just inside the Sphere of Fixed Stars which is also concentric to the Earth. The Sphere of Fixed Stars is itself surrounded by the Biblically required "water above the heavens" in a final sphere, which is the boundary of the cosmos; beyond is "an imaginary space which is nothing."[46] The sphere of fixed stars is shown to be of finite depth with a "New Star" at one o'clock. In the intervening space two comets are shown with tails longer than the distances between planets. Oddly, although Achrelius acknowledges the important contemporary result that the tails of comets always point away from the sun, the tails of the comets in the picture are conspicuously not antisolar.[47]

Flachsenius retired from the professorship in mathematics in 1692, two years before his death, and was replaced by Magnus Steen (d.1697), until his own death. Steen is unusual for holding the chair for only half a decade, and even more unusual in being a heliocentrist and a Cartesian. In a dissertation defended in the year of his death, Steen described the Ptolemaic, Copernican, and Tychonic systems as well as a Tychonic system with a rotating Earth.[48] However, the Sun was placed at the center of a vortex, which carried the planets around it, making a Tychonic system impossible. He also adopted Descartes' explanation of the origin of comets. But again, he stopped short of a simple declaration in favor of one system over another, leaving the decision to the reader.[49]

From the death of Magnus Steen in 1698 until 1717 the professor of mathematics was Laurentius Gabrielis [Lars Gabriel] Tammelin (1669-1733).[50] He made almanacs that survive for the years 1700, 1705, and 1717-1725 inclusive.[51] It may well be that the run from 1717 to 1725 survived because they were all published in Stockholm, while the existing earlier almanacs appeared in Turku. Hence, it is possible that he made almanacs for the intervening years that have not survived because they were also published in Turku. According to Kallinen, Tammelin made a clear endorsement of Tychonism no later than 1707.[52] The almanacs and the endorsement of Tychonism may be connected, if, like Achrelius, Tammelin used his cosmology to support the practice of astrology.

With Tammelin it is clear that Tychonism was endorsed at Turku well into the eighteenth century, often in the form of the "improved" version introduced by Riccioli, with geocentric paths for Jupiter and Saturn, and perhaps a rotating earth. This commitment corresponded to an abandonment of solid celestial spheres to move the planets and the adoption of some form of fluid heavens. Tychonists at Turku were eager to regale their audiences with other astronomical novelties such as the moons of the outer planets, and do not seem to have defended the Aristotelian division between the celestial and terrestrial realms, which partially motivated the Jesuits. Achrelius, for example, considers the Sun to be made of fire.[53] At Turku, motivations seem to be balanced between keeping up with innovations in astronomy and retaining their geocentrist reading of the Bible. As Kalinnen puts it, in cosmology, "Most convincing of all arguments was … the authority of the Bible, which was interpreted as disproving Copernicanism."[54] It would be interesting to know whether the Turku Tychonists who wrote almanacs used the *Astronomia Danica*, but this is a matter for further research.

4. Was Maria Cunitz a Copernican?

What was going on in the rest of Europe, while all these Jesuits and Lutherans were employing variations on Tycho? According to Schofield, "Lutheran Germany ... displayed little interest in the planetary system of their fellow Lutheran Tycho,"[55] apart from the early interest by Ursus, Roeslin and Marius (who each claimed they had invented something like it).[56] I have to report a rather startling counterexample to this generalization, from the period of Riccioli: Maria Cunitz (1610-1664).

Kepler had developed a heliocentric system based on elliptical orbits announced in the *Astronomia nova* of 1609, but, according to the usual account, it made little headway until he published the *Rudolphine Tables* in 1627. As word of their accuracy spread, these became widely used, supposedly adding support to heliocentrism, which grew in acceptance through the next century. Kepler had presented the tables with the aid of logarithms – he had been an early adopter – but the logarithms were an obstacle to the use of the tables for many potential readers.[57] In 1650, Maria Cunitz published *Urania Propitia,* providing a simplified method for calculating positions from the *Rudolfine Tables,* and extending the audience for Kepler's heliocentrism. Except, she didn't. Yes, she simplified the use of the *Rudolphine Tables* by eliminating the logarithms. No, she did not endorse heliocentrism; she was a Tychonist.

Maria Cunitz spent her entire life in the Protestant parts of Germany. Born in Wohlau, her family lived in Schweidnitz, but the Thirty Years War obliged them to flee to Liegnitz and then Pitschen, and finally Lubnitz across the border in Poland. They were able to return to Pitschen as her main work was being printed. She was taught mathematics and astronomy by her mother and father, both accomplished scholars, and by Elias Crätschmair (c.1602-1661),[58] whom she married in 1630.[59] Significantly, she learned to calculate planetary positions using Longomontanus' *Astronomia Danica,* the "Tychonic *Almagest*", which her husband "praised highly"[60] and it was also her husband who asked her to simplify the use of the *Rudolfine Tables* when he became dissatisfied with the accuracy of other tables. But let us pause for a moment to situate the *Astronomia Danica*.

In 1588, when Tycho announced his new system of the world in the *Recentioribus phaenomenis,* that book contained no detailed models for the movements of the Sun, Moon and planets in terms of the new hypothesis. Ten years later, in the 1598 *Astronomiae instauratae mechanica*, he claimed, "With regard to all five planets there remains only one thing to do, namely to construct new and correct tables expressing by numbers all that has been established by 25 years of careful celestial observations … thereby demonstrating the inaccuracy of the usual tables."[61] The theories of the Sun and Moon were sufficiently far advanced that Tycho prepared them for publication in the *Astronomiae instauratae Progymnasmata*, which appeared in 1603 after his untimely death. The *Progymnasmata* presented tables of mean motion for the Sun covering the years 1560 to 1619, and tables for the elements of the Moon's motion covering the years 1560 to 1660 (the latter probably mainly the work of Longomontanus).[62]

As for the "only one thing" that remained to do — extending the application of the new cosmic scheme to the five planets — how much work was really involved can be judged from the time it took to complete. This was, of course, the project that led to the *Rudolphine Tables* published by Kepler nearly a quarter of a century later in 1627, with prominent use of logarithms. But Kepler had abandoned Tycho's cosmic scheme. Five years earlier the first complete set of Tychonic planetary models, and tables, had appeared in Christian Longomontanus's *Astronomia Danica* (Amsterdam, 1622). Unlike Tycho, Longomontanus accepted a rotating earth; unlike Kepler he avoided using logarithms.

In the extended title of her book *Urania Propitia* (*Benevolent Urania*, the same muse celebrated by Tycho in the name of his castle-observatory on Hven) Maria Cunitz promised "...wonderfully easy astronomical tables, comprehending the power of the physical hypotheses brought forth by Kepler, satisfying the phenomena, by a very easy, brief way of calculating, without any mention of logarithms ..."[63] The text is presented first in Latin and then in not-entirely-parallel German. However, despite "the power of the physical hypotheses brought forth by Kepler" when she describes the system of the world, Cunitz follows Tycho:

> Latin: "The orbit of a planet is not a mathematical circle but a kind of natural revolution (*gyrus*) that the planet, the sun and moon describe about the earth, but Saturn, Jupiter, Mars, Venus, and Mercury describe about the sun, by a nonuniform motion and libration in certain and fixed periods in the universe."[64]

This is clearly describing a Tychonic geo-heliocentric system, however the corresponding German is clearer on the shape of the orbit:

> German: "Orbita Planetae, the orbit of a planet (*der umbkrais des Planetens*), is a somewhat elongated circle (*etwas ablänglichter Circkel*), the Sun and Moon around the Earth, the other 5: Saturn, Jupiter, Mars, Venus, Mercury, around the Sun, moving unequally in a certain time, which they describe by approaching and receding unequally in infinite space."[65]

Cunitz is advocating Kepler's result that the orbits of the planets are ellipses with the Sun at one of their foci. She uses the term introduced by Kepler, 'orbit', to refer to their paths. But the Earth is the center of the cosmos. The Sun follows an elliptical path around it, and the other planets follow elliptical paths around the Sun.[66]

It should not be surprising to us that Cunitz is a Tychonist. Her husband and collaborator studied with David Origanus (1558-1628/9), who had been in Breslau, before studying and teaching in Frankfurt. Origanus published two major ephemerides, the first for 1599-1630 and the second for 1609-1655. In the second set, published in 1609, he gave both Tychonic and "Copernican" (i.e. Prutenic), treatments of the Sun and Moon, but only Prutenic treatments for the remaining planets. Recall from above that although Tycho's treatments of the Sun and Moon had appeared in 1603, treatments for all the remaining planets were not available until Longomontanus' work appeared in 1622. In the 1609 introduction Origanus adopted the Tychonic system with a rotating earth. Origanus is mentioned specifically by Longomontanus in the *Astronomia Danica* when he endorses the same arrangement.[67]

Origanus' student, Cunitz' husband Elias Crätschmair, also made almanacs, and followed the preferences of his teacher in cosmic systems. He constructed a perpetual table for finding planetary hours, the *Horologium zodiciale*, published in Breslau in 1626, in which he explicitly acknowledges Origanus and Longomantanus, and he again acknowledges Tycho and Longomontanus in his calendar for 1628.[68] At the end of the calendar he also considers a number of philosophical questions directly relevant to Tychoism, for example whether "whether there are certain and different spheres that move the heavenly bodies around, as is commonly philosophized?"[69] In 1627 he fled, like Cunitz' family, to Liegnitz, where he and Maria married in 1630.

It is also possible that Cunitz's father Heinrich (1580-1629) was a Tychonist. He had studied at Rostock and Frankfurt, which he attended at the right time to also be influenced by Origanus, and he later wrote on astrology and astrological medicine, as well as natural science and mathematics.[70] Taken together this evidence suggests that Cunitz's family were all Tychonists.

5. Conclusion: The Persistence of Tychonism

This paper began as a conference presentation in which I reported on the current state of my research into seventeenth-century Tychonism.[71] Although I have expanded the scope considerably for publication, I should begin this conclusion by emphasizing that this is still an outline. It is clearly incomplete, for example I have barely mentioned Tychonism in the most obvious place, Denmark.[72] And there is much more to say about Jesuit followers of Tycho.[73] However, even in this preliminary state, the project suggests several important conclusions. These are the geographical extent of Tychonism, its surprising historical durability, and the persistent role of religion in the thinking of those who adopted Tycho's cosmic scheme.

In a recent paper Richard Kremer describes the work of Lorenz Eichstadt (1596-1660) who wrote annual prognostications for the city of Stettin, initially the capital of the re-united duchy of Pomerania, and later assimilated by Sweden. According to Kremer, Eichstadt wrote annual prognostications starting in 1630. He also wrote ephemerides for years between 1636 and 1665, which he self-published in Stettin, Danzig and Amsterdam.[74] Initially he took positions for the Sun and Moon from the *Astronomia Danica* and planetary positions from the *Rudolphine Tables* as presented by Jacob Bartsch in 1630. However, he finally gave up the *Rudolphine Tables* completely and based everything on the *Astronomia Danica*, ostensibly because they agreed better with his own observations.[75] Kremer discounts Eichstadt's explicit interest in cosmic schemes, and we should not conclude he adopted the Tychonic scheme from his use of the *Astronomia Danica*, any more than we can infer Maria Cunitz's adoption of heliocentrism from her support for the *Rudolphine Tables.* His actual preference might be determined by examining his *theorica*, published in 1644 or his book on the comet of 1653-4.[76]

Other almanac makers were explicit in their adoption of Tychonism, although, again, the evidence needs to be reevaluated since the work of Schofield. In England, which Schofield otherwise regards as lacking in Tychonists, she claims the almanac makers Arthur Hopton (1587/8-1614) and Walter Strof (active 1619-1652) both endorse the Tychonic system.[77] Hopton made almanacs for the years 1606-1608 and 1610-1614, the year of his death. But although he quotes Tycho's figures for sizes and distances of celestial objects, I have not yet found an explicit endorsement of Tychonism, and in his *Concordancy* from 1612 (reprinted 1615, 1616 and 1635) he gives a standard geocentric account of the planets and still speaks of celestial objects as being 'denser parts of their orbs' which is distinctly non-Tychonic.[78]

On the other hand Strof[79] in 1627 consistently prefers Tycho's values for parameters to those from Reinhold's *Prutenic Tables*,[80] and calls the "observations of Noble Tycho" "infallible", indeed, in choosing parameters: "… I follow him, whose only name is able to shield me both from contempt and contradiction - namely, the thrice noble Tycho Brahe: for from his grounds and observations are they calculated and set down, as they are delivered by him in lib. *Progymnas*. Cap. 7."[81] He goes on to clearly endorse Tycho's world system. In addition to abolishing solid orbs and sublunary comets:

> Many other truths have sprung out of the fruitful seminarie of Uraniburg, which shall ever memorize the founder, as that Venus and Mercury moove about the Sunne, that all other Planets except the Moone, respect the Sunne for their center. That Saturne in opposition to the Sunne is nearer the Earth than Venus in Apogeon. That Mars in opposition is nearer the Earth than the Sunne itselfe.[82]

In addition to Strof in England at the beginning of the seventeenth century, we can also probably count Crätschmair in Germany and definitely count Tammelin in eighteenth-century Finland as Tychonists. Some almanac makers used only the mathematical resources of the *Astronomia Danica* without endorsing its cosmic scheme. But cases like Strof and Tammelin show the spread of Tychonism to a much wider public than either astronomers or natural philosophers. Almanac makers were consumers rather than producers of new knowledge, and these initial results suggest that they adopted Tychonism all over Europe.

As already mentioned, it has been said that the spread of heliocentrism was supported by spreading use of the corresponding tables, that is the *Rudolphine Tables*, including Maria Cunitz's version. But this is much too simple. At the same time that use of the *Rudolphine Tables* was spreading, so too was use of the *Astronomia Danica* with its Tychonic tables. Should we say that use of the *Astronomia Danica* supported the spread of Tychonism? Just the small sample I have described refutes both views. Strof used Tycho's numbers and supported Tycho's cosmic scheme. Hopton used Tycho's figures but did not accept his cosmic scheme. Worst of all Cunitz accepted Kepler's numbers but Tycho's cosmic scheme, not the Copernican system she is often presented as helping to advance.

The durability of Tychonism and the corresponding general interest in astronomical novelties is apparent in Johan Meyer the Younger's print from Zurich in 1707.

Figure 4: '*Astronomia'. A celebration of the art of astronomy, etched and printed by Zurich native Johann Meyer the Younger and published by the Zurich Municipal Library on New Year's Day 1707 "for the benefit of the youth of the city." History of Science Collections, University of Oklahoma Libraries, Norman, Oklahoma.*

Updated versions of Galileo's telescopic discoveries are shown in smaller images around the edge. In the center we see the three main contenders for cosmic schemes, Copernicus, Tycho and Ptolemy, offering shields presenting their ideas to the muse of astronomy. If we look closely at the offering by Tycho, we see that the outer planets after Mars are moving on paths concentric to the fixed stars and the central Earth – in other words this is Riccioli's modification of the original Tychonic system, which has by now become sufficiently widespread that it is worth recording in a print for popular consumption.

Figure 5 (left column, on the next page): *Detail from Johann Meyer the Younger, Astronomia (Zurich: Municipal Library, 1706) showing, left to right, seated figures of Nicholas Copernicus, Tycho Brahe and Claudius Ptolemy with images of their cosmic schemes. History of Science Collections, University of Oklahoma Libraries, Norman, Oklahoma.*

As I have shown here, Tychonism survived well into the eighteenth century. In future work I hope to argue that Tychonism was only abandoned when Newton's physical arguments against it became available. The evidence for this includes the corresponding entries in Chamber's *Cyclopædia, or, An universal dictionary of arts and sciences* (London 1728) in England and the *Encyclopédie, Ou Dictionnaire Raisonné Des Sciences, Des Arts Et Des Métiers* (Neufchatel, 1751-72) in France.[83] However, this argument necessarily requires the consideration of the Cartesian version of heliocentrism as another alternative to Newton's version.

In the present paper I have been more concerned to demonstrate the persistence of Tycho's cosmology than the explain its success, but the following factors are clearly relevant to understanding the reception of Tycho's work. First, Tycho introduced new techniques for making astronomical instruments and observations, and set new standards for precision. In addition to increasing the accuracy of instruments with novel methods for dividing scales, Tycho made a lifelong study of how to improve the accuracy of observational results, for example by correcting for parallax.[84] He also popularized the prosthaphaeresis method for manipulating astronomical data, which used trigonometric identities to simplify calculations (although the key identities may have originated with itinerant mathematician Paul Wittich (c.1546 – 1586 or 1587) and Kassel instrument maker Joost Bürgi (1552-1632)).[85] As we have seen in the cases of Strof in England and several Bartolins in Denmark, the excellence of Tycho's observations was appreciated well into the seventeenth century.[86] But, as I have repeatedly emphasized, accepting observational results or astronomical tables from a particular source does not entail accepting that source's preferred cosmology. If this is not already clear, consider again the *Rudolphine Tables*, prepared from Tycho's data by a Copernican.

Tycho's ongoing fame was clearly a positive factor in the reception of his work, but it is important to see his reputation and public image as something he carefully cultivated, and defended, most notoriously in the persecution of Ursus (Nicholas Reimers, 1551-1600) for plagiarizing his cosmic scheme.[87] However, the Ursus affair is misleading. As John Christianson and Adam Mosley emphasize, Tycho's main aim was to establish collaborative working relationships with other astronomers and scholars, through exchanges of books, letters and visits, turning research from an individual to a community activity. This counts as both another innovation and a strategy for building his own fame and credibility.[88] Even the technical illustrations of his instruments were carefully constructed to further these ends, as Emma Perkins has argued in a study of their iconography.[89]

Astronomical discoveries during the seventeenth century benefitted both Tycho's reputation and his system. One of the most damning pieces of evidence against Ptolemy and Aristotle, the discovery that Venus showed the phases predicted for a Copernican system, could equally be explained in Tycho's cosmos, without the need to move the earth or overturn accepted physics.[90] Telescopic evidence provided two other strong supports for Tychonism. First, the standing objection to a moving Earth that there was no observable stellar parallax had been made more acute by Tycho himself with his unusually large and accurate instruments. It was made even worse by telescopic observations, which pushed the fixed stars further and further away. Copernicans who were prepared to accept this expanded and empty cosmos were further embarrassed by the apparent sizes of stars observed through telescopes. If the cosmos was on the scale that Copernicans needed to make parallax undetectable, then the correlative calculation for the sizes of fixed stars, as understood at the time, made them enormously larger than the Sun or indeed the entire solar system.[91] These problems were reviewed by Riccioli in 1651, who found in favor of Tychonism.

In this paper I have made many critical comments about Christine Schofield's *Tychonic and Semi-Tychonic World Systems*. To balance that, I would like to say here that when Schofield's work appeared it was unprecedented and that it was then and remains now enormously valuable. Schofield's book illuminated much previously unknown history. Read today it also preserves a snapshot of the historiography of science from the time it was written, including the belief that Tychonism was a brief aberrant phase of cosmology and that religion was a negative force in the history of science. In contrast, I have tried to make an initial case for Tychonism's geographical extent and historical durability. Schofield's view of the situation was this:

> Since from this time onwards ["the early decades of the seventeenth century"] many feared not only the uneasiness of their own conscience but also the judgment of their religious leaders, the system of Tycho acquired a band of fearful, half-hearted supporters, who would reject it in favor of the Copernican at the first sign that they might do so with impunity.[92]

Neither the Lisbon Jesuits nor the Turku Lutherans were fearful or half hearted. They believed that their religion and their science should be mutually supportive, and they readily adopted Tychonism along with a host of other astronomical novelties that they were eager to convey to their students. The cases of Turku, Walter Strof in England and Maria Cunitz in Germany show that even Protestants, unfettered by the 1616 condemnation of Copernicanism, still preferred Tychonism. Their reasons were, at least in part, religious. As shown by figures like Kepler, Descartes, and Newton, early modern scientists expected their religious views to interpenetrate, complement and support their scientific work.[93] Similarly, I suggest, astronomers, natural philosophers, almanac makers and lay people in both Northern and Southern Europe saw Tychonism as a cosmic scheme that interpenetrated, complemented and supported their religious views, and we should accept their statements as honest affirmations from an age when science and religion were not yet in conflict.[94]

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Swerdlow, Noel M. 2012 "*Urania Propitia, Tabulae Rudophinae faciles redditae a Maria Cunitia. Beneficent Urania,* the Adaptation of the *Rudolphine Tables* by Maria Cunitz*."* In J.Z. Buchwald (ed.), *A Master of Science History*, *Archimedes* 30. New York: Springer Science, 81-121. DOI 10.1007/978-94-007-2627-7_7

Thoren, Victor 1988. "Prosthaphaeresis Revisited." *Historia Mathematica* 15: 32-39.

Thoren,Victor, with contributions from John R. Christianson. 1990. *The Lord of Uraniborg: A Biography of Tycho Brahe*. Cambridge: Cambridge University Press.

Thykier, Claus, Gyldenkerne, Kjeld, and Darnell, Per Barner (eds.) 1990. *Dansk astronomi gennem firehundrede år.* 3 vols. Copenhagen: Rhodos Forlag.

Notes

[1] Here I am using "research tradition" in very much the way Thomas Kuhn used "normal science tradition". Such traditions begin with an achievement, often presented in the form of a book, that "… was suffi-

ciently unprecedented to attract an enduring group of adherents away from competing modes of scientific activity. Simultaneously it was sufficiently open-ended to leave all sorts of problems for the redefined group of practitioners to resolve." Thomas S. Kuhn 1962 [1996]. *The Structure of Scientific Revolutions*. Chicago: University of Chicago Press, 10. While the normal science tradition lasts, problem solving is cumulative but avoids novelty (Kuhn 1962 [1996], 35-42.). For more details, see Peter Barker 2024, "Islamicate Astronomy as Kuhnian Normal Science." *Studia Historiae Scientarum*, in review.

[2] I postpone for another occasion the question of when and how Tychonism declined and died. However, I suggest that the answers to these questions must at least include a consideration of the conflicts between supporters of Descartes and Tycho, and the use of encyclopedias to refute Tychonism by supporters of Newton in Britain and France. See Le Lay and Passeron 2017. The history of Tychonism outside Europe has also not been sufficiently recognized. See Sayili 1958, Arjomand 2011, Brentjes 2014. On Tychonism in China see especially: Chapman 1984, Hashimoto 1987, Standaert 2003, Jimenez 2015 and Chu 2017. I would also like to draw attention to the important ongoing work of Chen Ji, of University of Science and Technology of China, on Tychonism in the Ming and Quing dynasties, some of which was presented at the Séminaire d'histoire des sciences astronomiques at the Observatoire de Paris, on Oct 1, 2024.

[3] Tycho Brahe 1588. *De mundi aetherii recentioribus phaenomena*. Hven: Sumptibus auctoris. Tycho Brahe 1603 *Astronomiae instauratae progymnasmata.* Prague: Typis inchoata Uraniburgi Daniae, absoluta Pragae Bohemiae: [s.n.], 1602; Christian Longomontanus 1609. *Astronomia Danica*. Amsterdam: Ex Officina Typographica Guiljelmi I. Cæsii.

[4] Luís Miguel Carolino**,** 2023**.** *Geo-Heliocentric Controversies: The Jesuits, Tycho Brahe and the Confessionalization of Science in Seventeenth Century Lisbon*. Knowledge Hegemonies in the Early Modern World, 3. Edizioni Ca'Foscari. Maija Kallinen, 1995. *Change and Stability: Natural Philosophy at the Academy of Turku 1640-1731*. Studia Historica 51. Helsinki: Suomen Historiallinen Seura (Finnish Historical Society).

[5] Perhaps the classic study of the history of Tychonism is Christine Schofield, 1984. *Tychonic and Semi-Tychonic World Systems.* New York: Arno Press.

[6] Carolino 2023, 4 n.6.

[7] G. Strano and G. Truffa, 2007. "Tycho Brahe cosmologist: An overview on the genesis, development and fortune of the geo-heliocentric world-system." In M. Bucciantini, M. Camerota, and S. Roux, eds., *Mechanics and cosmology in the medieval and early modern period*, Florence: Olschki, 73-94, at 90.

[8] A. Sayili, 1958. "An Early Seventeenth Century Persian Manuscript on the Tychonic System." Anatolia 3: 84-86; Kamran Amir Arjomand, 2011. "Transfer of knowledge in the Safavid era: A Persian treatise on the explanation of the New Science based on the opinion of Tico Brahe." *[Iranian] Journal for the History of Science* 10: 1-26. In Persian.; Sonja Brentjes, "Pietro della Valle's Persian Summary of Tycho Brahe's Cosmology for the Astronomer Zayn al-Din Lari." Presented at the Workshop der KG IV "Struktur und Wissenswandelt" organized by P. D. Omodeo (Teilprojekt B06), Berlin, August 11-12, 2014. https://www.academia.edu/1689302/Pietro_della_Valles_Persian_summary_of_Tycho_Brahes_cosmology_for_the_astronomer_Zayn_al_Din_Lari ; Strano and Trufa 2007, 90-1.

[9] "Quae cum ita sint, videant Astronomi quo pacto Orbes caelestes constituendi sint ut haec phaenomena salvari possint." C. Clavius, *Opera mathematica. Ab auctore nunc denuo correcta, et plurimis locis aucta ... 3 Complectens Commentarivm in Sphaeram Ioannis de Sacro Bosco, [et] Astrolabivm.* Mainz: A. Hierat, 1611, 75.

[10] Lattis 1994, 2020 & 261n.73, quoting Ugo Baldini, 1992. *Legem impone subactis: studi su filosofia e scienza dei Gesuiti in Italia, 1540-1632.* Rome: Bulzoni, 237-8.

[11] Kraig Bartel, *Orazio Grassi and a 1623* Treatise on the sphere: *Astronomy and physico-mathematics at the Collegio Romano in the early seventeenth century*. M.A. Thesis, University of Oklahoma, USA, 2016. For additional details see his Ph.D. dissertation, "Early modern Jesuit science education at the *Collegio Romano*: Orazio Grassi, Galileo Galilei and the Controversy over the Comets." University of Oklahoma, 2023.

[12] Carolino 2023a, 2, cf. Cysat, J.B. *Mathemata astronomica de loco, motu, magnitudine, et causis cometæ qui sub finem anni 1618. et initium anni 1619. in coelo fulsit: ex assiduis legitimisq́[ue] variorum phænomenorum observationibus derivata.* Ingolstadt: Ex Typographeo Ederiano, Apud Elisabetham Angermariam,1619, p. 56 [mispaginated as '36'].

[13] Giuseppe Biancani, *Sphaera mvndi, sev, Cosmographia demonstratiua ac facili methodo tradita: in qva totivs mvndi fabrica, vna cvm novis Tychonis, Kepleri, Galilaei, aliorum[que] astronomorum adinuentis continetur.* Bologna: H. Tamborini, 1620, Preface [v].

[14] Bianchani 1620, 255.

[15] Bianchani 1620, 275.

[16] Carolino, 2023 (note 4 above).

[17] Carlino 2023, 57-8.

[18] Carlino 2023, 76.

[19] Carlino 2023, 76 and 146.

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[21] Bartel 2016, 2023.

[22] Carlino 2023, 101-24.

[23] Víctor Navarro Brotons, 2003. "Tradition and Scientific Change in Early Modern Spain: The Role of the Jesuits." In M. Feingold (ed.) *Jesuit Science and the Republic of Letters*. Cambridge (MA): MIT Press, 2003, 331-388, at 347; Muñoz and Pérez de Mesa, n. 90, p. 379. Al-Biṭrūjī: Riccioli 1651, vol. 1: 504 col A, numbered para. 9; spiral path image vol. 1: 504 col B.

[24] Christopher M. Graney, 2015. *Setting Aside All Authority: Giovanni Battista Riccioli and the Science Against Copernicus in the Age of Galileo.* Notre Dame, IN: Notre Dame University Press; Trano and Strufa 2007, 92.

[25] "Quinque autem Planetae minores circa Solem, tanquam centrum suarum Excentricitatum, et fontem luminis ab eo recepti, et eo mediante circa Tellurem, tanquam centrum, et terminum luminis, et influxus reflectendi, movetur in Aethere per se immobili, sed permeabili, per Spiras versus Occidentem semper, ea lege de qua supra, descriptas;" Giovanni Battista Riccioli 1665. *Astronomia Reformata*. Bologna: V. Benatius, 8, col. B, numbered para. 9; Strano and Trufa 2007, 92.

[26] Melchior Cornaeus, 1657. *Curriculum philosophiae peripateticae, uti hoc tempore in scholis decurri solet*. Herbipoli: Eliae Michaelis Zinck. On the arrangement of the planets, 525-38, esp. 527 item 7; 528-9 and 538: Ad confirm I; denial of Copernicanism and rotation of earth, 529.

[27] In the case of Kepler, see the prefatory material in the *Astronomia Nova* (1609); for Galileo see, of course, the Letter to the Grand Duchess Christina (composed 1615, published 1636).

[28] Maija Kallinen, 1995 (above note 3). See p.42 and note 3.

[29] Kallinen 1995, 74.

[30] Simon Svenonis Kexlerus, 1649. *Almanach, På thet Åhret efter wår Herres och Frelsares Jesu Christi födelse, 1650.* [Almanac, On the year after the birth of our Lord and Savior Jesus Christ, 1650.] Turku: Peder Wald; Simon Svenonis Kexlerus, 1666. *Cosmographiæ Compendiosa descriptio et Geographiæ introductio, de Globi Terreni mapparum Geograph. meliori intellectu ac usu.* Turku: P. Hanson.

[31] Simon Svenonis Kexlerus, undated. *Astronomia*. Uppsala University Lib. Manuscript A 301. In Swedish; Kallinen 1995, 147-151.

[32] Andreas Thuronius, 1660. *Almanach, til thet året ... 1661.: Til Åbo horizont.* Turku: P. Hansson; Andreas Thuronius, 1663. *Almanach, til thet året ... 1664.* Turku: P. Hansson; Andreas Thuronius, 1664. *Almanach, til thet året ... 1665.* Stockholm: I. Meurer.

[33] Kallinen 1995, 160.

[34] Kallinen 1995, 141 n.97.

[35] Kallinen 1995, 422-3.

[36] Andreas Thuronius A.- J.G. Alanus, 1664. *Dissertatio Philosophica, De Influxu Astrorum in Mundum Sublunarem.* Turku: P. Hanson, esp. theses 2,3,7 and 8; Kalinnen 174-5 n. 218.

[37] Jaako Lounela 1987. "Ensimmäinen routsinkielinen tähtitieteen oppikirja." [The first astronomy textbook in Russian.] *Opusculum* 7: 51-66. Kallinen 1995, 49-50.

[38] Kallinen 1995, 151-152, corresponding to *Astronomia* pp. 17-20.

[39] Simon Svenonis Kexlerus, 1666. *Cosmographiæ Compendiosa descriptio et Geographiæ introductio, de Globi Terreni mapparum Geograph. meliori intellectu ac usu.* 1666. Turku: P. Hanson; Kallinen 1995, 153-156.

[40] Johannes Flachsenius - J. Grimsteen, 1679. *Dissertatio Philosophica De Hypothesibus Astronomicis,* Turku: J. Winter. Kallinen 1995, 416.

[41] Kallinen 1995, 163.

[42] Johannes Gezelius, 1572. *Encyclopaedia synpotica ex optimis & accuratissimis philosophorum scriptis collecta & in tres partes distributa, in usum studiosae juventutis, cui neque pretium prolixiores authores redimendi, neque …* . Turku: Johan Winter. Kallinen 1995, 28-9 & 162.

[43] Kallinen 1995, 25, 415.

[44] Daniel Achrelius, 1682. *Contemplationum mundi libri tres.* Turku: J. L. Wallius . https://www.google.com/books/edition/Danielis_Achrelii_Contemplationum_mundi/YZ1kAAAAcAAJ?hl=en; Kallinen 1995, 29.

[45] Kallinen 1995, 157-9; the picture is a foldout between pages 14 & 15 of Achrelius 1682, reproduced by Kallinen 158.

[46] Right hand margin, corresponding to letter N, "Aquae supercoelestes"; corresponding to letter "O" in four positions surrounding the figure, "Spatium imaginarium quod est nihil." Achrelius 1682, foldout between pages 14 & 15, reproduced by Kallinen 158.
[47] Achrelius 1682, p. 137. "Cur vero [cometa] cuadam semper a[b] Sole aversam teneat, …".
[48] Magnus Steen – Petrus Petreius, 1697. *De hypothesibus astronomicis copernici & ptolemaei, distribe mathematica, qvam ... praeside ... Magnus Steen, respondent: Petrus Petreius* Turku: J. L. Wallius.
[49] Kallinen 1995, 163-165.
[50] Kallinen 1995, 26.
[51] Kallinen 1995, 421, shows almanacs published in Turku for the years 1700 and 1705; WorldCat shows also 1717, 1718, 1719, 1720, 1721, 1722, 1723, 1724, 1725, published in Stockholm.
[52] Kallinen 1995, 165, citing L.G. Tammelin - S. Nidelström, S. 1706. *Dissertatio mathematica de solis et lunae motibus propriis*. Turku: J. Wall. Kalinnen gives the date as 1707 in the text, but 1706 in his bibliography. Cf. p. 165 and p. 421. I have been unable to resolve this inconsistency.
[53] Achrelius 1682, 112-120, esp. 114, corresponding to the marginal heading "Solum igneum esse probat".
[54] Kallinen 1995, 116.
[55] Schofield 1984, 304; repeated, Christine Jones Schofield, 1989. "The Tychonic and semi-Tychonic world systems." In R. Taton and C. Wilson (eds.), *Planetary Astronomy from the Renaissance to the rise of astrophysics.* Part A: *Tycho Brahe to Newton. The General History of Astronomy*, Vol. 2. Cambridge: Cambridge University Press, 33-44, p. 42 col. B.
[56] On these figures see: Miguel A. Granada, 1996. *El debate cosmológico en 1588: Bruno, Brahe, Rothmann, Ursus, Röslin*. Naples: Bibliopolis - Istituto Italiano per gli Studi Filosofici. Nicholas Jardine and Alain-Phillipe Segondes, 2008. *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.
[57] Swerdlow 2012, 83.
[58] Also Kretschmar, later ennobled as Elias von Löwen. His works are indexed under Crätschmair.
[59] Noel M. Swerdlow, 2012. "*Urania Propitia, Tabulae Rudophinae faciles redditae a Maria Cunitia. Beneficent Urania,* the Adaptation of the *Rudolphine Tables* by Maria Cunitz." In J.Z. Buchwald (ed.), *A Master of Science History*, *Archimedes* 30. New York: Springer Science, 81-121, p. 83. DOI 10.1007/978-94-007-2627-7_7
[60] Swerdlow 2012, 84, both quotes.
[61] Richard L. Kremer, 2020. "Longomontanus on Mars: The Last Ptolemaic Mathematical Astronomer Creates a Theory." In *Ptolemy's Science of the Stars in the Middle Ages,* ed. by David Juste, Benno van Dalen, Dag Nikolaus Hasse and Charles Burnett, PALS 1. Turnhout: Brepols, 2020, 407–443, on 411, n. 14.
[62] Kremer 2020, 42, n. 17; Dreyer 1915, 2:46-56 (sun) and 2:103-16 (moon).
[63] Maria Cunitz, 1650. *Urania Propitia* sive *Tabulae Astronomicae mirè faciles, vim hypothesium physicarum à Kepplero proditarum complexae; facillimo calculandi compendio, sine ulla Logarithmorum mentione, phaenomenis satisfacientes.* Oels, Silesia: Published by the Author, printed by Johann Seyffert.
[64] ORBITA PLANETAE non est circulus Mathematicus; sed quidam gyrus naturalis, quem planeta, [sol] et [luna] quidem circa Terram: [Saturnus] vero [Jove] [Mars] [Venus] et [Mercurius] circa [sol]em, motu et libratione inaequali, certis et statis temporibus, in universo describunt. Cunitz 1650, 7. Cunitz uses what are now called the astrological symbols for the planets, which I have indicated by the written names in square brackets.
[65] "Orbita Planetae, der umbkrais des Planetens / ist ein etwas abländlichter Circkel / den Sonn / und Mond umb die Erde: die andern 5 [Saturn][Jupiter] [Mars] [Venus] [Mercury] umb der Sonn herumb / in gewisser Zeit / ungleich sich bewegende / und durch ungleiche zu näher und entfernung in dem unendlichen raum gleichsam beschreiben." Cunitz 1650, 184, cf. Swerdlow 2012, 88. This transcription and translation by PB, with thanks to KMC for assistance.
[66] Cunitz' adherence to Tychonism has also been noted by Ingrid Guentherodt, 2005. "Augenschein und Finsternisse: zur Sprache von Maria Cunitia (1604?-1664)."*Acta Universitatis Carolinae. Mathematica et Physica*, 46 (Supplement): 15-28 , p. 25.
[67] Longomontanus, 1622, 161; Pietro Daniel Omodeo, 2011. "David Origanus's Planetary System (1599 and 1609).".*Journal for the History of Astronomy*, 42(4): 439-454. Pietro Daniel Omodeo, 2014, *Copernicus in the Cultural Debates of the Renaissance: Reception, Legacy, Transformation.* Leiden: Brill. On Origanus 149, on Longomontanus 155 text to n. 108.
[68] Elias Crätschmair, 1626. *Horologium Zodiacale, Sive Tabulae perpetuae justam & veram singularum horarum planetariarum quantitatem per totum annum complectentes, &c., Das ist: Immerwehrender Magischer- oder Planeten-Stund Zeiger.* Breslau: Publisher: David Mueller, Printer: Georg Bawman. http://digital.slub-dresden.de/id263689395, fol. Aiii verso. On the 1628 calendar see Herbst, Klaus-Dieter 2019 "Crätschmair, Elias" *Biobibliographisches Handbuch der Kalendermacher von 1550 bis 1750* (https://www.presseforschung.uni-bremen.de/dokuwiki/ doku.php? id=craetschmair_elias).
[69] Elias Crätschmair 1628, *Kalendarium*, fol. 7, cited in Herbst 2019. Crätschmair also published calendars with prognostications for 1627 and 1629, all published by David Müller in Breslau and printed by August Gründer in Brieg. Herbst, 2019.
[70] Swerdlow 2012, 83. According to https://de.wikipedia.org/wiki/Heinrich_Cunitz, Heinrich claimed to have studied with Tycho at Uraniborg in 1598-9. If true this would clearly support my case. However, this is chronologically impossible, as Tycho left Uraniborg and Denmark in 1597. More work needs to be done to settle this question.
[71] See n. 93
[72] Briefly, the career of Tychonism in Denmark extends from Longomontanus (d.1647), who returned home and gained first a professorship at the University of Copenhagen and later the patronage of Christian IV. The best source for his life and works is Christianson 2000, 313-319. Support for Tychonism in Denmark continued through several members of the Bartholin family, which Longomontanus married into. Examples are Peter Bartholin (1586 - 1642) who in 1632 published *Apologia pro observationibus, et hypotesibus astronomicis nobilissimi viri Dn. Tychonis Brahedani.* Copenhagen: Joachim Moltken, and Erasmus Bartholin (1625 - 1698), who, assisted by Ole Roemer, edited Brahe's observations for publication between 1664-1670. Tychonism persisted at least through the career of Ole Rømer (d.1710), and perhaps beyond. In general see: Claus Thykier, Kjeld Gyldenkerne, and Per Barner Darnell (eds.) 1990. *Dansk astronomi gennem firehundrede år.* 3 vols. Copenhagen: Rhodos Forlag.
[73] More has already been said by Carolino and Kallinen, of which I have only been able to offer brief summaries. See also, especially Michel-Pierre Lerner's paper "L'entrée de Tycho Brahe chez les jésuites, ou le chante de cygne de Clavius." In *Les jésuites à la Renaissance: Système éducatif et production du savoir, ed. Luce* Giard (Presses Universitaires de France, Bibliothèque d'histoire des sciences, 1995), 145–85, and Christopher M. Graney, 2015. *Setting Aside All Authority: Giovanni Battista Riccioli and the Science against Copernicus in the Age of Galileo*. Notre Dame, IN: Notre Dame Press.
[74] Lorenz Eichstadt, 1634-1636. *Pars prima et secunda Ephemeridum novarum et motuum coelestium quinquennalis [resp. decennalis] ad annos 1636-1650.* Stettin: Laurentius Eichstadius.
Lorenz Eichstadt, 1644. *Ephemeridum novarum et motuum coelestium ab anno 1651 ad annum 1665 pars tertia.* Amsterdam: Laurentius Eichstadius.
Lorenz Eichstadt, 1645. *Ephemeridum novarum et motuum coelestium, ab anno 1651 ad 1665 pars tertia ... a Laurentio Eichstadio*. Gdansk: n.p.
[75] Kremer 2020, 407-9.
[76] Lorenz Eichstadt, 1644. T*abulae harmonicae coelestium motuum: tum primorum tum secundorum seu doctrinae sphaericae et theoriae planetarum.* Stettin (Szczecin): Laurentius Eichstadius; *Idem*, 1653. *Exercitatio astronomica exhibens locum, motum, magnitudinem, causas, effectus & significationes cometæ, qui sub finem anni æ.C.1652 & initium anni æ.C.1653 St. N. illuxit ...* . Gdansk, n.p.
[77] Schofield 1984, on Hopton: 306 and n. 146; Strof: 217 and n. 167.
[78] Arthur Hopton, 1612. *A concordancy of yeares: Containing a new, easie, and most exact computation of time, according to the English account.* [London]: Printed [by Nicholas Okes] for the Company of Stationers. Geocentric planetary system 38-41; stars defined as denser parts of their orbs 49.
[79] The author published the almanac under an anagram of his real name, which is Arthur Frost. I thank Kerr Petbear for pointing this out.
[80] Strof 1627, e.g. B3v-B4r.
[81] Strof 1627, B4v.
[82] Strof 1627, [C4r].
[83] On astronomy in the *Encyclopédie* see Miguel Angel Granada, 2009. "La revolucion, astronomico-cosmologica en la Encyclopédie." In Miguel Angel Granada et al. (éds.), *Filósofos, filosofía y filosofías en la Encyclopédie de Diderot y d'Alembert.* Edicions Universitat, Barcelone, 2009, 77-96; Colette Le Lay and Irène Passeron, 2017. « L'astronomie

dans l'Encyclopédie » Édition numérique collaborative et critique de l'Encyclopédie. HAL Id: hal-02381455, https://hal.science/hal-02381455

[84] Victor Thoren, with contributions from John R. Christianson, 1990. *The Lord of Uraniborg: A Biography of Tycho Brahe*. Cambridge: Cambridge University Press.Christianson 2020, esp. Ch. 5; Ann Blair 1990. "Tycho Brahe's critique of Copernicus and the Copernican system." *Journal for the History of Ideas* 51: 355-377.

[85] Victor Thoren 1988. "Prosthaphaeresis Revisited." *Historia Mathematica* 15: 32-39; Adam Morawiec 2020. "Itinerarium Wittichi Ex Calendarium Sculteti: New Biographical Evidence on the Breslau Mathematician Paul Wittich (ca. 1546–Ca. 1587)." *Centaurus* 62(3): 465-478.

[86] On Strof, see above; on the Bartolins see note 71.

[87] Jardine and Segonds 2008.

[88] Christianson 2020, esp. Ch. 7 and pp. 204-5; Adam Mosley 2007, *Bearing the Heavens: Tycho Brahe and the Astronomical Community of the Late Sixteenth Century.* Cambridge: Cambridge University Press.

[89] Emma Perkins 2018. "Instruments of authority: Tycho Brahe's technological illustrations." *History and Technology* 34(3/4): 259-272.

[90] Roger Ariew 1987. "The phases of Venus before 1610." *Studies in History and Philosophy of Science Part A* 18 (1): 81-92.

[91] Graney 2015, esp. Ch. 9.

[92] Schofield 1984, 264.

[93] On Kepler see Peter Barker, 2000. "The role of religion in the Lutheran response to Copernicus" in M. J. Osler (ed.) *Rethinking the Scientific Revolution*. Cambridge University Press, 59-88, and Peter Barker and Bernard R. Goldstein, 2001, "Theological foundations of Kepler's astronomy," in John Hedley Brooke, Margaret J. Osler, and Jitse van der Meer. (eds.), *Science in Theistic Contexts: Cognitive Dimensions*. *Osiris*, 16, 88-113. On Descartes, note simply the explicit role of God in the *Meditations* and elsewhere. For Newton see e.g. Snobelen, Stephen D. 2003. " "A Time and Times and the Dividing of Time": Isaac Newton, the Apocalypse, and 2060 A.D*" Canadian Journal of History/Annales canadiennnes d'histoire* 38: 537-551, esp. 545-550.

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