STUDYING TYCHO'S STARS: A VIEW OF THE HEAVENS FROM THE PERSPECTIVE OF TYCHO BRAHE

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Abstract:

During his life time, the famed 16th century astronomer Tycho Brahe made a convincing case for what came to be known as the Tychonic System. It was a picture of the heavens as he saw it from his observational complex Uraniborg. Yet despite the scientific prowess that marked everything Brahe did, the design of his system was powerfully influenced by a beliefs that had been in place since Ancient Greece.

One of Copernicus' most capable opponents was born at the time of his death. Having revolutionized observational astronomy at his base, Tycho Brahe was established as the leading astronomer of his day. At his island observatory, Uraniborg, Danish astronomer Tycho Brahe assembled an astounding arsenal of observational data of the night skies. The accuracy of Brahe's instruments, and the sheer abundance of his thirty years' worth of observations were unparalleled in the age before the telescope. Whatever theories came out of Urianiborg were justified by the superiority of his laboratory: other astronomers floundered for data in comparison to the excess at Brahe's fingertips. The Tychonic System that came out of Brahe's work, which had a stationary earth encircled by a sun that was orbited by everything else, was the best and brightest of planetary theories by the turn of the 17th century. And yet, Brahe's main objections to the Copernican system, which he approved of in many respects, was based on a sensibility extraneous to his astronomical data. Although the premise of his star size argument is empirical, careful excavation of the reasoning behind his conclusions reveal a theory motivated by conceptual tradition rather than observational astronomy.

In order to unravel the convictions behind these theories, it is necessary to establish a 17th Century understanding of what astronomers thought they saw when they looked up at the stars. When Brahe was collecting data on the heavens, he measured the width of "stellar discs."[1] These discs, as Christopher Ganey describes, were understood to be "measureable bodies" whose distance from the earth could be calculated by a ratio to the sun's diameter.[2] The smaller the measurements obtained for the star's disc, the greater

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[1] Christopher Ganey, "The Telescope Against Copernicus: Star Observations by Riccioli Supporting a Geocentric Universe," *Journal for the History of Astronomy* 41, no. 4 (2010): 453.
[2] Ganey, "The Telescope Against Copernicus," 453.

its actual distance and physical size from earth. A star that measured two arc minutes in diameter had a "radius at least the distance from the sun to the earth."[3] In Tycho's day, and for many years afterwards, astronomers did not understand that the stellar discs were an illusion, that the measurable glow made from a star was due to a "diffraction of light waves" and did not, in fact, represent the physical size of that star.[4] Thus, when the apparent star diameters Brahe had measured were applied to the Copernican theory, they were inflated to unbelievable proportions.

Tycho Brahe viewed the Copernican theory with mixed feelings at the beginning of his astronomical career. The physical absurdity of a moving earth spoiled an otherwise harmonious planetary system.[5] Having found the parameters of the Copernican cosmos "wanting," he determined that there must be some other way to arrange the universe, different from both Ptolemy's and Copernicus' models.[6] According to Christopher Ganey, Brahe's most "potent argument" against the Copernican hypothesis came in the form of stellar parallax.[7] Brahe reasoned that, if the earth orbited the sun, then the annual position of the stars should appear to change as the earth went from one side of its orbit to the other, much like someone who stands on either side of a pole will see that pole appear to change positions (even though it is *they* are who changing).

Drawing from his impressive repertoire of observations, Brahe measured the apparent diameters of planets and stars. The different sizes of the Tychonic and Copernican cosmos are demonstrated by Ganey's table of results. To take a comparison,

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[3] Ibid., 453.
[4] Ibid., 455.
[5] Ann Blair, "Tycho Brahe's Critique of Copernicus and the Copernican System," *Journal of the History of Ideas* 51, no. 3 (1990): 355.
[6] Ibid., 358.
[7] Ganey, *Setting Aside All Authority*, 32.

the star Sirius in Brahe's measurements was 0.61 earth diameters in size and 14 000 earth radii in distance, while Copernicus had Sirius at 4170 earth diameters in size and 47 439 800 earth radii in distance.[8] Approaching the Copernican theory like any good astronomer, Tycho Brahe hypothesized, experimented, and concluded that the earth could not be in motion. Armies of data were arranged and compared, and theories finalized, through a detailed analysis of star positions and apparent diameters. Because of the lack of observable annual parallax, Brahe was moved to develop his own rendition of the night skies that united the successes of the Copernican theory and retained the "obvious truth" of an unmoving earth.[9] Hence the necessity to create his own scheme that allowed for the benefits of his predecessor and at the same time removed the drawbacks.

In Brahe's own system, the Tychonic System, the problem of parallax disappeared, since the earth did not move. His stars were thus allowed to be much smaller and much closer. In fact, based on the measurements produced by Tycho, his universe shrunk to two-thirds the size of the Ptolemaic cosmos.[10] Because of Brahe's reputation as a juggernaut of observational astronomy, it is difficult to a see a man who mixed data with myth and empirical experience with faith. Renowned throughout Europe, Brahe's systemization of observations was unprecedented. The patronage required to sustain Brahe's project is evidence enough of his renown. The budget for his observational complex on the island of Hven was "proportionally comparable to the budget of NASA."[11] An astronomer before the advent of the telescope, the genius of Brahe was in

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[8] Ganey, "The Telescope Against Copernicus," 460.
[9] David Wilson, "Galileo's Religion *Versus* the Church's Science? Rethinking the History of Science and Religion," *Physics in Perspective* 1, no 1 (1999): 69.
[10] Albert Van Helden, *Measuring the Universe: Cosmic Dimensions from Aristarchus to Halley* (Chicago, 1985), 50.
[11] Ganey, *Setting Aside All Authority*, 26.

the precision and sheer volume of his observations. While astronomers Galilei and Kepler conducted a one-man operation, Brahe had at his fingertips the facilities of the first major European observatory and teams of observers to go with it.[12] Johannes Kepler was even able to discover the elliptical shape of planetary orbits, undermining the circular perfection of the Aristotelian heavens, thanks to the abundance and precision of astronomical positions Brahe recorded.[13] Yet Despite all of this, one must not be blinded by appearances. While Brahe's rejection of the sun-centered Copernican system was predicated on empirical proofs, his reasoning is layered. A closer look reveals how sensibility fed into science, and science into sensibility.

Like the astronomer who argued against him, Copernicus acknowledged that the gap between Saturn (the outermost planet) and that of the nearest stars would have to be "immense" in order to reduce the earth's orbit to a nearly negligible movement through the heavens.[14] To be so far away that the movement of the earth was not reflected in the changing heavens meant stars would have to be enormous to be seen at such distances, If star discs represented the physical size of the star. Thus, if the positions of the stars could not be observed to change, there were two conclusions to be drawn: either the stars were too far away for observable movement, or the earth didn't move. While Copernicus went ahead with his massive cosmos, Tycho Brahe did not. *Why* Brahe and Copernicus came to such different conclusions is telling about their respective views of the cosmos.

In his article *Seeds of a Tychonic Revolution*, Christopher Ganey argues that observations of the heavens substantiated the Tychonic system. Since astronomers of this

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[12] Ibid., 26.
[13] Ibid., 26.
[14] Christopher Ganey, *Setting Aside All Authority: Giovanni Battista Riccioli and the Science Against Copernicus in the Age of Galileo*. (Notre Dame, IN: University of Notre Dame Press, 2015), 32.

time understood stellar discs to be representative of actual star size, astronomical evidence (lack of stellar parallax) was in favor of the Tychonic system. Ganey writes that Tycho's logic was "based on…observation, measurement and geometry."[15] But this is overlooking an important leap in which the mind goes from the mythical to empirical. Brahe's task of discerning earth's orbit through the test of stellar parallax, while empirical in process, distracts from the arbitrary nature of his conclusion. Ganey's statement is credible only if one stops at the stellar parallax test. Beyond this experiment, however, is a state of mind which dictated the meaning of the experiment's outcome. A comparison of Copernicus and Brahe's findings and subsequent conclusions provides a clear example of this process. Copernicus adjusts his understanding of the universe to accommodate a parallax that "[vanished] from [his] eyes."[16] He allows the heavens to become a universe "with no apparent bounds."[17] Copernicus, like Brahe, did not detect any parallax. He, like Brahe, could have discarded the mobility of the earth because of this. But he did not. Instead, he decided to stick with his inflated heavens in order to maintain the integrity of the system he had created. Thus, basing the decision to reject the earth's movement solely on absent stella parallax does not fully explain Brahe's refusal.

For Tycho Brahe, the nature of Copernicus' cosmological monster was not mathematical but conceptual. In many aspects, Brahe believed his rival's work was something to be congratulated. Early in his career, Brahe expressed a deep admiration for Copernicus's "ingenuity and mathematical talent."[18] Although he never accepted the Copernican hypothesis in its entirety, he commandeered the order of planets established

[15] Ibid., 37.
[16] Ganey, *Setting Aside All authority,* 32.
[17] Van Helden, *Measuring the Universe*, 48.
[18] Blair, "Tycho's Critique of Copernicus and the Copernican System," 356.

by Copernicus and made all but one – the earth – orbit the sun. However, the progression of his objection from beginning to end reveals a peculiar lapse in empirical process.

Tycho Brahe did not approve of a sun-centered universe even before he began a serious exploration of the parameters for Copernicus' cosmic sizes.[19] It was only later in his career that Brahe discovered his star-size argument and unleashed it against the Copernican hypothesis. This progression demonstrates that Brahe carried notions developed separately from astronomical study into his development of astronomical theory. At the beginning of his star size research, Brahe wrote a letter to a Copernican by the name of Rothman, expressing his disbelief at the distance the sphere of the stars must be removed to explain an undetectable parallax. Rothman dabbles in theological justification to refute Tycho's desire to restrict the universe to a particular size.[20] Surprisingly, the cause of the astronomers' dispute is rooted in opposing worldviews, not data. According to Albert Van Helden, Brahe's rejection sprang from an arbitrary "notion of cosmic sizes" that originated from a "collective consciousness."[21] It was these notions which lent so much thrust to the further development of his star size argument. The exactitude and observational prowess of this endeavor, in turn, retroactively satisfied his own sensibilities. In his response to Brahe, Rothman appealed to a "higher authority" to "balance the weight of tradition" that was so evident in Tycho Brahe's cosmological theories.[22] In this exchange, one begins to understand why Brahe gave so much time to the study of star sizes and parallax: it was an empirical proof for his conceptual reality. He was not fighting with numbers or calculations, but the very image of what he thought

[19] Ibid., 364.
[20] Van Helden, *Measuring the Universe,* 52.
[21] Ibid., 52.
[22] Ibid., 52.

the universe should be. Where did this image come from? Behind the dissatisfaction with enormous star sizes is an acquired understanding about the dimensions of the cosmos, based on tradition and biblical interpretations.

Brahe sought smaller dimensions in the heavens during the creation of the Tychonic system, because these dimensions corresponded to a common perception in 16th century Europe. While Brahe's anti-Copernican arguments were buttressed by observational data later in his life, they did not form the foundation of his conviction. David Wilson argues that Brahe rejected a heliocentric cosmos for biblical reasons, in addition to his own experiments, as the bible "presented earth as stationary" in several passages.[23] This theological inspiration is clear in an excerpt from his *Progymnasmata:*

> *It is necessary to preserve in this matters some decent proportion, lest things reach out to infinity and the just symmetry of creatures and visible things concerning size and distance be abandoned: it is necessary to preserve this symmetry because God, the creator of the Universe, loves appropriate order, not confusion and disorder.* [24]

Here, Brahe establishes religiosity as the foundation of his convictions. The cosmos could not be enormous for any other reason than the maintenance of an ideal. Symmetry and order was created by God, and to suggest a universe the size Copernicus suggested was, in Brahe's eyes, sacrilege. Digging deeper, it is evident that Tycho's reasoning agrees with traditional views of which biblical literalism is only a part.

The long-standing authority of Ptolemy's cosmology is another foundational facet of the worldview Brahe subscribed to. Brahe may have sent the other planets around the

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[23] Wilson, "Galileo's Religion *Versus* the Church's Science? Rethinking the History of Science and Religion," 68.
[24] Blair, "Tycho's Critique of Copernicus and the Copernican System," 364.

sun instead of the earth, but the Ptolemaic model was still maintained by his immovable earth. Due to this choice, the size of the cosmos and star sizes of Brahe's and Ptolemy's cosmos were guaranteed to be similar. And that similarity was far more appealing than the "conceptual strain" of the Copernican universe.[25] Since the Tychonic system varied only a little from the dimensions given by Ptolemy, he mended the faults of the Copernican system and welded its successes into his own theory. In this way, Brahe's theories capitalized on an older understanding of the cosmos.

In the *Discarded Image,* C.S Lewis argues that the concept of an unending space, as modern society thinks of it, first appeared with Giordano Bruno, a convinced Copernican, in the second half of the 16th century. This is contemporaneous with Brahe's lifetime. Later, In 1667, Lewis suggests Miltion as the first English poet to envision a universe without end in his *Paradise Lost.*[26] Evidently, the far-reaching cosmos that Copernicus adopted by necessity of a moving earth was relatively unheard of, let alone accepted. In the medieval world, the heavens had an absolute size.[27] While the title of C.S Lewis' book suggests that this picture of the heavens was lost in the following centuries, the sensibility of a finite cosmos appears to have persisted well into the 16th century.

It is tempting to summarize the failure of the Copernican system as simply a lack of stellar parallax; Brahe saw in the Copernican theory an empirical weakness, and he effectively exploited it. Yet while it is possible to credit his theories, in some part, to his observational accuracy and arsenal of data, this is not the extent of it. Driving Brahe's experiments was an abstract understanding of the design of the cosmos, an understanding that Tycho ultimately held intact within his own planetary system. When it came to the

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[25] Van Helden, *Measuring the Universe*, 53.
[26] C.S Lewis, *The Discarded Image* (London, UK: Cambridge University Press, 1964), 100.
[27] Ibid., 98.

size of the universe, the Tychonic theory made “no one uncomfortable,” least of all Brahe himself.[28] Thus, as Copernicans floundered for support in the 17th century, the popularity of the Tychonic system was buttressed by its agreement with European notions of cosmic size. Before and after the dawn of the telescope, these traditional images proved a powerful ally to anyone who managed to create a cosmos within their limits.

[28] Van Helden, *Measuring the Universe,* 53.

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