

To cite this article: Yeuncheol Jeong (2022). HISTORICAL CONTINGENCIES FOR COSMOLOGY [1] -A CHOICE BETWEEN PTOLEMY'S AND COPERNICAN MODEL, International Journal of Applied Science and Engineering Review (IJASER) 3 (3): 07-12

HISTORICAL CONTINGENCIES FOR COSMOLOGY [1] -A CHOICE BETWEEN PTOLEMY'S AND COPERNICAN MODEL

Yeuncheol Jeong

Department of History, Sejong University, Seoul, Korea

DOI: <http://dx.doi.org/10.52267/IJASER.2022.3302>

ABSTRACT

During the Scientific Revolution, Copernican Sun-centered Universe had replaced Ptolemy's Earth-centered Universe. However, this was not made possible due to scientific rationality and objectivity based on the best available sets of empirical evidence at the time. The transition from Ptolemy's to Copernican model was aesthetic and psychological in nature rather than rational and objective.

KEYWORDS: History and Philosophy of Astronomy, History of Science, Philosophy of Science, Scientific Revolution, Ptolemy, Copernicus, Theory choice

INTRODUCTION

In the sixteenth and seventeenth century, during the Scientific Revolution, Copernican Sun-centered Universe had replaced Ptolemy's Earth-centered Universe. Many believe this progress on cosmology is made possible due to scientific rationality and objectivity based on the best available sets of empirical evidence at the time. This article tries to debunk or clarify some of the main myths surrounding this issue.

Ptolemy's Earth centered Universe

Ptolemy's Earth centered Universe was established around the second century AD in the city of Alexandria, the center of Hellenism culture at that time. This cosmology was based on Aristotle's Earth-centered natural philosophy, together with Aristotle's cosmological arrangement of four elements, namely, Earth, Water, Air, Fire in the ascending order from Earth which is located at the center of the Universe. The main reason behind Ptolemy's acceptance of Aristotle's Earth being at the center is due to the fact that there was no available evidence showing any stellar parallax, i.e.

apparent positional changes of some nearby stars with respect to far away background stars due to Earth's motion around the Sun. For example, several centuries earlier than Ptolemy, Hipparchus already reported of fixed locations of almost all visible stars on the night sky with no apparent positional changes of any stars due to possible Earth's motion around the Sun. This gave Ptolemy confidence that Earth is not moving and thus it is located at the center of the Universe.

Ptolemy's Earth centered Universe is discussed in a book, *Almagest*. This book discusses some of the most important aspects of observational facts in terms of Earth centered Universe. First, the Moon always moves in the eastward direction, delaying its rise above Earth's horizon about an hour every day. This everyday eastward motion of the Moon is called the Moon's prograde motion. Second, Mercury and Venus are always observed within a relatively small angular distance from the Sun. Therefore, they are not visible during bright daylight time. Instead they are only observable either during the time of early dawn just before the sunrise, or during early evening right after the sunset. Furthermore, Third, all the planets, namely, Mercury, Venus, Mars, Saturn, and Jupiter, are not always moves in the eastward direction. They sometimes show some westward motions causing their rising above the horizon faster and faster every day. This occasional westward motion of the planets is called the retrograde motion. Thus, planets show the prograde and the retrograde motion whereas the Moon shows only the prograde one.

Introduction of *Almagest* to Renaissance Europe

In *Almagest*, Ptolemy tries to explain these observational features of the Moon, the Sun and the planets, using one orbital circle for the Moon and the Sun, and a combination of one big and one small circle, a deferent and an epicycle, respectively, for the planets orbital motion around Earth. In this Ptolemy's model, the first celestial body, the Moon is always moving around Earth in one orbital circle of a deferent only in the eastward direction. After the Moon, Mercury, Venus, The Sun, Mars, Saturn and Jupiter are all located in order. While the Sun is also moving around the Earth in one orbital circle of a deferent only in the eastward direction as in the case of the Moon, the planets are moving on a small epicycle while, at the same time, the centers of the planets' epicycle are then moving around Earth in a big circle of a deferent. Thus, the planets are making some sort of spiral motion if viewed from the above. If viewed from Earth, they are then sometimes making the same eastward motion as the Moon, i.e. the prograde motion, or sometimes making the opposite westward motion with respect to the Moon, i.e. the retrograde motion. In particular, since Mercury and Venus are always near to the Sun with a small angular distance, the centers of their epicycles are forced to move together with the Sun behind. In this configuration, Mercury and Venus are only allowed to have small circular motion of epicycles in front of the Sun if observed from Earth. However, the

motion of Mars, Saturn and Jupiter have nothing to do with the location of the Sun. They are freely moving around Earth in a combination of an epicycle and a deferent.

When Almagest was introduced in the Islamic world, a lot of efforts were made toward improving for the motion of Mars by increasing the number of its epicycles. At its climax, Ptolemy's model accommodates more than a half dozen epicycles for Mars with individually different sizes and rotational rates for each epicycle. This certainly will improve the accuracy for the motion of Mars but, at the same time, this system of multiple epicycles for Mars greatly increases an overall complexity of Ptolemy's model, making mathematically harder and harder to understand it. When European had an access to the Islamic version of Almagest, its mathematical difficulty was probably too formidable for them to fully grasp its contents at first. Fortunately, however, the fifteen and sixteen century Renaissance activities put an unexpected emphasis on the ultimate source of light, the Sun, in a new painting technique called "perspective", i.e. developing three dimensional effects on a two dimensional medium. This technique of perspective contrasts of light and shadow to express three dimensional effects. Since the ultimate source of light happens to be the celestial body, the Sun, this unexpected new technical development of perspective during the Renaissance period generated a great interest in the Sun. The Sun could even enjoy the spiritual status of some magical world. This neo-Platonic status of the Sun is essential to understand the cultural drive for Copernican Sun-centered Universe.

Copernican Sun centered Universe

Copernicus was probably one of the very few European mathematicians at the time who were able to grasp the full complicating meaning of the Islamic version of Ptolemy's Universe. Copernicus realized that the complicating nature of Ptolemy's Universe is a direct outcome of its attempted accuracy in explaining the motion of the planets, especially, the motion of Mars. In other words, anyone who tries to simplify Ptolemy's model (i.e. reducing the number of planets' epicycles) necessarily has to decrease its accuracy on the motion of the planets. Thus, as long as the center of the Universe remains to be Earth, Ptolemy's model has to keep both its accuracy and complexity at the same time. Finally, Copernicus saw no other possible way to simplify Ptolemy's model without changing its central body from Earth to the Sun. In addition, the Roman Catholic Church at that time also had an intention to simplify Ptolemy's model to develop a new practical calendar system. This practical need for a new calendar system gave him an additional opportunity leading to his Sun-centered Universe in 1543.

Unfortunately, however, in 1543, Copernicus was not able to finish his book, *On the Revolutions of the Heavenly Spheres*, which was eventually published after his death through the help of his friend,

Osiander, who wrote the author preface part of the book in the name of Copernicus. In the preface, it is claimed that Earth is still at the center of the Universe, but for the sake of mathematical calculation, the simpler Sun-centered Universe is investigated. Because of this preface, the Roman Catholic Church allowed its publication.

In Copernican Earth-centered Universe, a combination of an epicycle and a deferent is still utilized as in the case of Ptolemy's Universe. First of all, Mercury and Venus are located on their epicycles and then each center of their epicycles is orbiting around Earth following its big circle of deferent. After Mercury and Venus, Earth is located on its deferent but does not have its own epicycle. In this configuration, Earth is a third planet from the Sun and the only planet with a deferent and no epicycle. In a sense, Earth gave away its role as the center of the Universe to the Sun. Thus the Sun took over Earth as the new center of the Universe in Copernicus model. In other words, they exchanged their roles as the center between Ptolemy's and Copernican Universe.

Connecting the epicycle centers of Mercury and Venus to the Sun in Ptolemy's Universe to force them near to the Sun is no longer required in Copernican Universe. In Copernican Sun-centered Universe, two inner planets, Mercury and Venus, are orbiting nearer to the Sun than Earth is. So, Mercury and Venus never deviate from the Sun more than a certain degree of angle from Earth's point of view, which greatly simplifies one of the main features of Ptolemy's Universe. Reducing the complexity of Ptolemy's universe is the single most important merit of Copernican model. Furthermore, according to Ockham's razor, the simplest explanation is regarded as the best explanation, which certainly favors the simplicity of the Sun-centered Universe over Earth centered one.

Simplicity vs. Accuracy

However, Copernican model had one big disadvantage. Achieving simplicity demanded a definite cost to Copernicus. He had to sacrifice the accuracy of his model for the simplicity. In this respect, for the sake of simplicity, he had to reduce the number of epicycles for Mars, thus sacrificing the accuracy of Mars motion. During the Medieval period in the Islamic world, Mars had to equip with the multiple number of epicycles. At least half a dozen epicycles are employed to account for a complexity of Mars motion. Reducing the number of epicycles is a sure way of lowering an accuracy level. Nonetheless, Copernicus ended up allowing only one deferent and one epicycle for Mars. He almost had to abandon all the necessary accuracy that had been achieved for Mars in the Islamic world during the Medieval time. In other word, achieving the maximum simplicity means sacrificing all the accuracy achieved for Mars (Kuhn, 1957).

Therefore, as long as accuracy goes, Ptolemy's model has an edge over Copernican one. On the other hand, Copernican model had an edge over Ptolemy's in simplicity. This is not an easy choice. Some prefer simplicity over accuracy while others prefer accuracy over simplicity. So, this kind of model choice between Ptolemy's and Copernican model is an aesthetic and psychological choice, rather than a rational and objective one (Kuhn, 1962). Therefore, this model choice is irrational rather than rational. Here, you should keep that in mind that none of the models had anything to do with the truth because the relevant question involved here was something like "what is the center of the Universe?" Since neither the Sun nor Earth is at the center of the known Universe in a modern sense, none of the models have anything to do with the concept of the truth as in a strict sense of its literal meaning. Both of the models are false and the theory choice between them has something to do with aesthetic and psychological value choice, rather than rational and objective one. Therefore, those experts who prefer simplicity over accuracy may already have developed some sympathy on the special status for the Sun and ended up supporting for the Sun's central role in the Universe. This preference itself is not rational nor objective.

Crucial evidence

However, somebody may claim that Copernican Sun-centered model had an observational evidence while Ptolemy's Earth-centered one does not have any. For example, a full moon phase of Venus is often considered to be the crucial observational evidence for Copernican Sun-centered Universe. That is because, in Ptolemy's Universe, Venus is allowed to make only a small epicycle motion in front of the Sun with Earth being at the center. From Earth's view, Venus never moves behind the Sun, thus generating only a crescent phase at best during a maximum but still small angular separation from the Sun. On the other hand, in Copernican Universe, Venus can move freely behind the Sun from Earth, thus generating a full moon phase during a straight line alignment from Earth to the Sun direction.

Sometimes it has been claimed that a full moon phase of Venus was actually observed through a telescope by Galileo. However, this claim needs to be scrutinize. A straight line alignment of Earth-Sun-Venus cannot make a full moon phase of Venus observable from Earth during a daylight time due to very bright Sun light. The only possible chance to observe a full moon phase of Venus in this configuration is possible only when the Sun is below the horizon while Venus is still slightly above the horizon, i.e. Mars being on the horizon just before the sunrise or right after the sunset. However, unfortunately, any telescopic observation for any celestial body on the horizon is almost impossible due to some substantial scattering by a thick layer of atmosphere in the horizontal direction, compared to a relatively thin layer of atmosphere in the direction toward the zenith, a sky point right above an

observer's head. Since Earth is a big round sphere, the atmospheric thickness greatly varies depending on the direction and its thickness is maximized in the horizontal direction.

Instead, Ptolemy's Universe had its own observation evidence. It is a lack of stellar parallax. If Earth is moving around the Sun, it can be expected that some nearby stars are supposed to have periodic shifts of their location compared to other distant background stars. In fact, it is well known that, since the time of Hipparchus, no stars seemed to show any angular change in their locations, thus implying that Earth is fixed in its location at the center of the Universe. This observational lack of stellar parallax seems to strongly favors Ptolemy's Universe. The stellar parallax was finally discovered as late as in the 1820s with an advent of large telescopes. However, for many centuries, this lack of stellar parallax was the single biggest evidence for Ptolemy's Universe.

CONCLUSION

Both Ptolemy's and Copernican models seem to have some sort of crucial evidence. So it is unfair to claim that Copernicus alone have an observational evidence. It is also unfair to say that Copernican model is true while Ptolemy's model is a myth. The theory choice between these two models are aesthetic and psychological in nature rather than rational and objective.

REFERENCES

- Kuhn, T. S. *The Copernican Revolution: Planetary Astronomy in the Development of Western Thought* Cambridge: Harvard University Press, 1957
- Kuhn, T. S. *The Structure of Scientific Revolutions* Chicago: University of Chicago Press, 1962