

# The Copernican Revolution and the Size of the Universe

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## Abstract

The purpose of this project is to discuss the astronomical development from the heliocentric theory to the geocentric theory. The main goal is to eliminate the common misconception that the Copernican system simply entails a change in the frame of reference from the Ptolemaic system. In particular, we will show how the Copernican system allows us to determine the size of the Universe (in terms of the Sun-Earth distance) and the order of the planets.

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# 1 Introduction

In astronomy, the geocentric system of the universe is the theory that the Earth is at the centre of the universe, and the Sun and other planets revolve around it. Belief in this system was common in ancient Greece and China. It was embraced by both Aristotle and Ptolemy, and most Greek philosophers assumed that the Sun, Moon, stars, and naked eye planets circle the Earth.

Two common observations were believed to support the idea that the Earth is in the centre of the universe. The first is that the stars (including the Sun and planets) appear to revolve around the Earth each day, with the stars circling around the pole and those stars nearer the equator rising and setting each day and circling back to their rising point. The second is the common sense perception that the Earth is solid and stable; it is not moving but is at rest.

Although the geocentric system held sway into the early modern age; from the late 16th century, it was gradually replaced by the heliocentric system of Copernicus, Galileo and Kepler. Heliocentric system is the theory that the Sun is at the centre of the solar system. Although many early cosmologists such as Aristarchus speculated about the motion of the Earth around a stationary Sun, it was not until the 16th century that Copernicus presented a fully predictive mathematical model of a heliocentric system, which was later elaborated by Kepler and defended by Galileo. Although many early cosmologists such as Aristarchus

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In modern times many books claims that the Copernican and the Ptolemaic systems as substantially equivalent. However, we will show in this paper that the Copernican system does not simply entail a change in the frame of reference from the Ptolemaic system. Furthermore, we will show that the chief point of Copernicus was that the heliocentric system allows us to determine the size of the universe and the order of the planets.

## **2 Ptolemaic Involution**

### **2.1 Relativity of Motion**

When people concern the relativity of motion and the concept of inertia, they could completely neglect the chief point of the Copernican system. They think the motions of the universe are the same whether we adopt the Ptolemaic or the Copernican system of view and both views are equally correct. For example, Bertrand Russel mentioned in his book:

In the modern theory the question between Copernicus and earlier astronomers is merely of convenience; all motion is relative, and there is no difference between the two statements: “the Earth rotates once a day” and “the heaven revolve about the Earth once a day.” The two mean exactly the same thing, just as it means

the same thing if I say that a certain length is six feet or two yards. Astronomy is easier if we take the Sun as fixed than if we take the Earth, just as accounts are easier in decimal coinage. All motion is relative, and it is mere convention to take one body as at rest. All such conventions are equally legitimate, though not all are equally convenient.

If the debate between the Ptolemaic and the Copernican systems were only concerning whether the Sun is to revolve around the Earth or the Earth is to revolve around the Sun, we could certainly assert their equivalence. However, this statement will reduce the importance of the Copernican idea, and only to facilitate the development of the Newtonian relativity of motion. For example, Fred Hoyle, in a book written in 1973 said that:

Today we cannot say that the Copernican theory is “right” and Ptolemaic theory is “wrong” in any meaningful physical sense. What we can say, however, is that we would hardly have come to recognize that this is so if scientists over four centuries or more had not elected to follow the copernican point of view. The Ptolemaic system would have proved sterile because progress would have proven too difficult.

Even Mach seems to have completely neglect the point of view of the Copernican system, as clearly emerges when he said that:

Relatively, not considering the unknown medium of space, the motions of the universe are the same whether we adopt the Ptolemaic or the Copernican mode

of view. Both views are, indeed, equally correct; only the latter is more simple and more practical.

From the statements in this subsection, we clearly show that many books claim that the Copernican and the Ptolemaic systems are substantially equivalent with the change in the frame of reference. We will test this statement geometrically in the next subsection.

## 2.2 Ptolemaic Involution

The “Ptolemaic Involution” is an operation that start from the Copernican system with circular orbits around the Sun and then relate the motions around the Earth. Thus, it is a test passing from a heliocentric system to a geocentric system, which is a reversed Copernican revolution.

Using this change of reference, the motion of the inferior planets (i.e. Mercury and Venus) is described as a circular orbit around the Sun, while it turns around the Earth in a deferent-epicycle device (Fig. 1). Hence, it shows clearly that the deferent of the inferior planets coincide with the orbit of the Sun, with the same size as the Earth’s orbit.

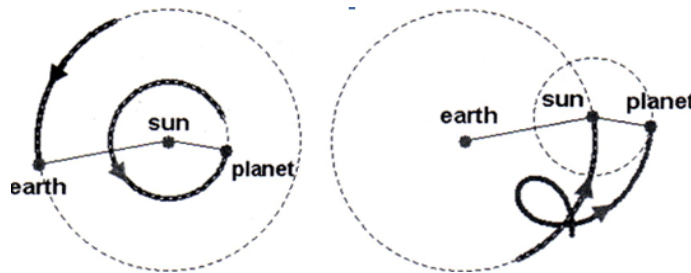


Figure 1. The motion of an inferior planet turns into a deferent-epicycle with the deferent equal to the orbit of the Sun.

The problem of the superior planets, which was considered in the same way with the inferior planets, could be described as a deferent-epicycle system, but with an epicycle much larger than the deferent. To limit the size of the epicycle, a point C is induced to describe a circle around the Earth (E) with the radius of the planet (P) around the Sun (S) (Fig.2). In this way, we obtain a deferent-epicycle device, whose deferent is the orbit of the planet around the Sun and whose epicycle is the orbit of the Earth around the Sun.

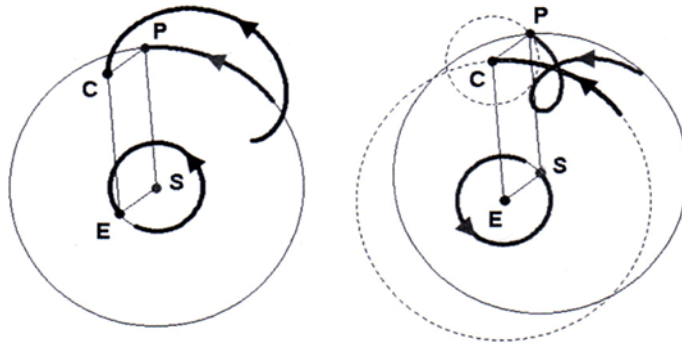


Figure 2. The motion of an superior planet turns into a deferent-epicycle with the deferent equal to the orbit of the Sun.

However, based on the above system transfer, we realize the difference between the Ptolemaic system and the geocentric system obtained by referring the motions of the planets to

the Earth. In the first place, the deferent of the inferior planets in the Ptolemaic system do not coincide with the orbit of the Sun. In addition, the epicycles of the superior planets in the Ptolemaic system do not have the radius equal to the Earth's orbit.

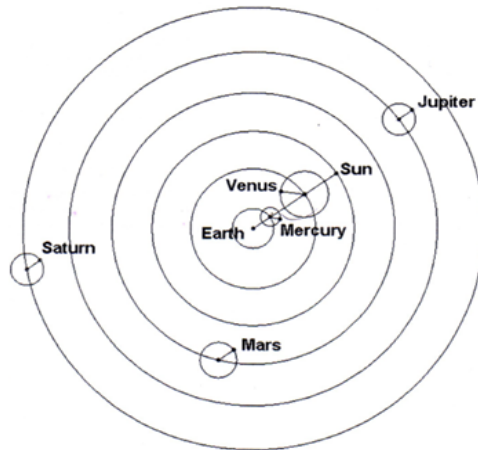


Figure 3. The Ptolemaic system. The deferent of the inferior planets does not coincide with the orbit of the Sun, but the centres of their epicycles remain aligned with the Sun. The epicycle of the superior planets does not have the same size equal to the Sun's orbit, but the line joining the centre of the epicycle to the planet is parallel to the Earth-Sun direction.

If using this Ptolemaic involution (i.e. starting from the Copernican system and referring the motions to the Earth) we do not obtain the Ptolemaic system, it follows that passing from the Ptolemaic system to the Copernican system does not simply entail a change in the frame of reference. To pass from the Ptolemaic system to the Copernican system, a dilatation centred on the Earth to each deferent-epicycle device is needed to apply so that the deferent of the inferior planets and the epicycles of the superior planets come to the same size, that is the Earth's orbit.

## 3 Profound Simplification

### 3.1 80-34 Syndrome

Many simple historical accounts of the Copernican revolution emphasized not the accuracy but the simplicity of the new system, generally in contrast to the horrendous complex scheme of epicycles-upon-epicycles supposedly perpetrated by pre-Copernican astronomers.

This statement reached its most heights in the 1969 Encyclopaedia Britannica, where the article on astronomy states that, 40 to 60 epicycles were required for each planet. More typically, we find what Robert Palter has called the “80-34 syndrome” - the claim that the simpler Copernican system required only 34 circles in contrast to the 80 supposedly needed by Ptolemy.

Also, in Russo’s book *The Forgotten Revolution*, there is a deep connection between Fourier expansion and the possibility of adding more and more epicycles on epicycles to a deferent, but he found that there is no evidence that constructions with many epicycles had ever been used in the Ptolemaic system.

### 3.2 Profound Simplification

Even Copernicus would have had difficulty in establishing an unambiguous final count. A comparison between the Copernican and the Ptolemaic system is more precise if we limit the count of circles to the longitude mechanisms for the Sun (or Earth), Moon, and Planets:

Copernicus requires 18, Ptolemy requires 15. Thus, the Copernican system is slightly more complicated than the original Ptolemaic system. This contrast between the simplicity of the Copernican system and the complexity of the detailed Ptolemaic mechanisms proves to be entirely fictitious.

However, unlike in the Ptolemaic scheme, the relative sizes of the planetary orbits in the Copernican system are fixed with respect to each other and no longer be independently scaled in size. This is certainly one of the most striking unifications brought by the Copernican system: a profound simplification.

In the Preface to Pope Paul III, Copernicus, after having told him of his fears in exhibiting his theory, goes straight on to expound what led him to argue for the motion of the Earth:

Moreover, they have not been able to discover or to infer the chief point of all, i.e. the form of the world and the certain commensurability of its parts. But they are in exactly the same fix as someone taking from different places hands, feet, head, and the other limbs - shaped very beautifully but not with reference to one body and without correspondence to one another - so that such parts made up a monster rather than a man.

What has struck Copernicus is a new cosmological vision, a grand aesthetic view of the structure of the Universe. If this is a response to a crisis, the crisis had existed since A.D. 150. Kuhn has written that the astronomical tradition Copernicus inherited “had finally

created a monster,” but the cosmological monster had been created by Ptolemy himself.

Maybe, like Copernicus says, Ptolemy has been able to invent a geometrical system more accurate than his, but the devices related to each planet can be expanded and shrunk at will and do not even allow them to determine the order of the planets. Contrary to the Ptolemaic system, Copernicus’s heliocentric theory not only explains that phenomena, but, furthermore, determines the order and the sizes of the planetary orbits.

## 4 Conclusion

In the view of the report, there seems to be no particular astronomical reason why the heliocentric cosmology could not have been defended centuries earlier. I believe that it was something outside astronomy in the European intellectual climate in the sixteenth century. The sixteenth century was manifestly an age of change. The new explorations that Columbus set sail across an unknown ocean made Ptolemy’s geography obsolete, even the traditional authority of the Church was to crumble at that period.

To a certain extent, the world was ready for Copernicus’s innovative view of the cosmos. He is among those persons who were able to explain the complications of the visible (the planetary motions) in terms of invisible simplicity. In this report, we try to eliminate some misunderstandings during this process and show that the chief point of Copernicus was that the heliocentric system allows us to determine the size of the Universe and the order of the

planets.

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