Copernican System

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A module on Nicholas Copernicus and his view of the universe.

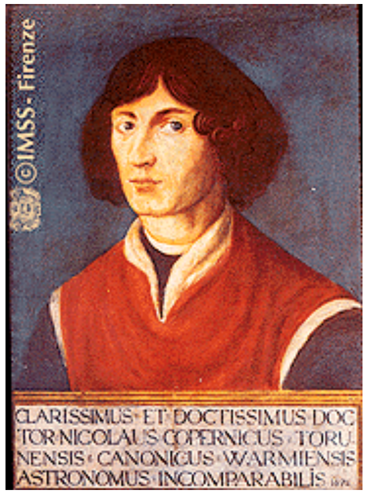

Figure 1: Copernicus

The first speculations about the possibility of the Sun being the center of the cosmos and the Earth being one of the planets going around it go back to the third century BCE. In his *Sand-Reckoner*, Archimedes (d. 212 BCE), discusses how to express very large numbers. As an example he chooses the question as to how many grains of sand there are in the cosmos. And in order to make the problem more difficult, he chooses not the geocentric cosmos generally accepted at the time, but the heliocentric cosmos proposed by Aristarchus of Samos (ca. 310-230 BCE), which would have to be many times larger because of the lack of observable stellar parallax. We know, therefore, that already in Hellenistic times thinkers were at least toying with this notion, and because of its mention in Archimedes's book Aristarchus's speculation was well-known in Europe beginning in the High Middle Ages but not seriously entertained until Copernicus.

European learning was based on the Greek sources that had been passed down, and cosmological and astronomical thought were based on Aristotle and Ptolemy. Aristotle's cosmology of a central Earth surrounded by concentric spherical shells carrying the planets and fixed stars was the basis of European thought from the 12th century CE onward. Technical astronomy, also geocentric, was based on the constructions of excentric circles and epicycles codified in Ptolemy's *Almagest* (2d. century CE).

In the fifteenth century, the reform of European astronomy was begun by the astronomer/humanist Georg Peurbach (1423-1461) and his student Johannes Regiomontanus (1436-1476). Their efforts (like those of their colleagues in other fields) were concentrated on ridding astronomical texts, especially Ptolemy's, from errors by going back to the original Greek texts and providing deeper insight into the thoughts of the original authors. With their new textbook and a guide to the*Almagest*, Peurbach and Regiomontanus raised the level of theoretical astronomy in Europe.

Figure 2: Copernicus

Several problems were facing astronomers at the beginning of the sixteenth century. First, the tables (by means of which to predict astronomical events such as eclipses and conjunctions) were deemed not to be sufficiently accurate. Second, Portuguese and Spanish expeditions to the Far East and America sailed out of sight of land for weeks on end, and only astronomical methods could help them in finding their locations on the high seas. Third, the calendar, instituted by Julius Caesar in 44 BCE was no longer accurate. The equinox, which at the time of the Council of Nicea (325 CE) had fallen on the 21st, had now slipped to the 11th. Since the date of Easter (the celebration of the defining event in Christianity) was determined with reference to the equinox, and since most of the other religious holidays through the year were counted forward or backward from Easter, the slippage of the calendar with regard to celestial events was a very serious problem. For the solution to all three problems, Europeans looked to the astronomers.

Nicholas Copernicus (1473-1543) learned the works of Peurbach and Regiomontanus in the undergraduate curriculum at the university of Cracow and then spent a decade studying in Italy. Upon his return to Poland, he spent the rest of his life as a physician, lawyer, and church administrator. During his spare time he continued his research in astronomy. The result was *De Revolutionibus Orbium Coelestium* ("On the Revolutions of the Celestial Orbs"), which was published in Nuremberg in 1543, the year of his death. The book was dedicated to Pope Paul III and initially caused litle controversy. An anonymous preface (added by Andreas Osiander, the Protestant reformer of Nuremberg) stated that the theory put forward in this book was only a mathematical hypothesis: the geometrical constructions used by astronomers had traditionally had only hypothetical status; cosmological interpretations were reserved for the philosophers. Indeed, except for the first eleven chapters of Book I, *De Revolutionibus* was a technical mathematical work in the tradition of the *Almagest*.

Figure 3: Diagram of the Copernican system, from De Revolutions

But in the first book, Copernicus stated that the Sun was the center of the universe and that the Earth had a triple motion [1] around this center. His theory gave a simple and elegant explanation of the retrograde motions of the planets (the annual motion of the Earth necessarily projected onto the motions of the planets in geocentric astronomy) and settled the order of the planets (which had been a convention in Ptolemy's work) definitively. He argued that his system was more elegant than the traditional geocentric system. Copernicus still retained the priviledged status of circular motion and therefore had to construct his planetary orbits from circles upon and within circles, just as his predecessors had done. His tables were perhaps only marginally better than existing ones.

The reception of *De Revolutionibus* was mixed. The heliocentric hypothesis was rejected out of hand by virtually all, but the book was the most sophisticated astronomical treatise since the *Almagest*, and for this it was widely admired. Its mathematical constructions were easily transferred into geocentric ones, and many astronomers used them. In 1551 Erasmus Reinhold, no believer in the mobility of the Earth, published a new set of tables, the *Prutenic Tables*, based on Copernicus's parameters. These tables came to be preferred for their accuracy. Further, *De revolutionibus* became the central work in a network of astronomers, who dissected it in great detail. Not until a generation after its appearance, however, can we begin point to a community of practicing astronomers who accepted heliocentric cosmology. Perhaps the most remarkable early follower of Copernicus was Thomas Digges (c. 1545-c.1595), who in *A Perfit Description of the Coelestiall Orbes (1576)* translated a large part of Book I of *De Revolutionibus* into English and illustrated it with a diagram in which the Copernican arrangement of the planets is imbedded in an infinite universe of stars.

Figure 4: Diagram of the universe by Thomas Digges

The reason for this delay was that, on the face of it, the heliocentric cosmology was absurd from a common-sensical and a physical point of view. Thinkers had grown up on the Aristotelian division between the heavens and the earthly region, between perfection and corruption. In Aristotle's physics, bodies moved to their natural places. Stones fell because the natural place of heavy bodies was the center of the universe, and that was why the Earth was there. Accepting Copernicus's system meant abandoning Aristotelian physics. How would birds find their nest again after they had flown from them? Why does a stone thrown up come straight down if the Earth underneath it is rotating rapidly to the east? Since bodies can only have one sort of motion at a time, how can the Earth have several? And if the Earth is a planet, why should it be the only planet with a moon?

For astronomical purposes, astronomers always assumed that the Earth is as a point with respect to the heavens. Only in the case of the Moon could one notice a parallactic displacement (about 1°) with respect to the fixed stars during its (i.e., the Earth's) diurnal motion. In Copernican astronomy one now had to assume that the orbit of the Earth was as a point with respect to the fixed stars, and because the fixed stars did not reflect the Earth's annual motion by showing an annual parallax, the sphere of the fixed stars had to be immense. What was the purpose of such a large space between the region of Saturn and that of the fixed stars?

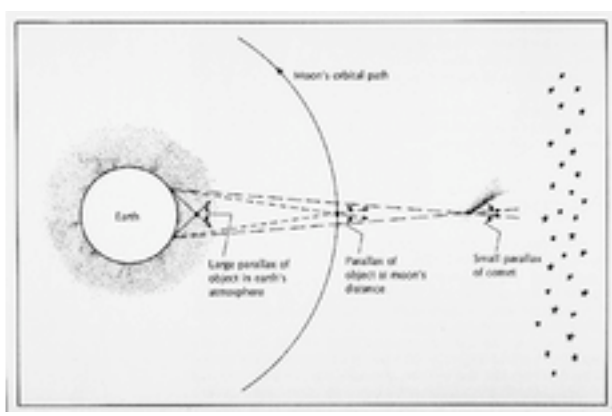

Figure 5: Parallax

These and others were objections that needed answers. The Copernican system simply did not fit into the Aristotelian way of thinking. It took a century and a half for a new physics to be devised to undegird heliocentric astronomy. The works in physics and astronomy of Galileo and Johannes Kepler were crucial steps on this road.

There was another problem. A stationary Sun and moving Earth also clashed with many biblical passages. Protestants and Catholics alike often dismissed heliocentrism on these grounds. Martin Luther did so in one of his "table talks" in 1539, before *De Revolutionibus* had appeared. (Preliminary sketches had circulated in manuscript form.) In the long run, Protestants, who had some freedom to interpret the bible personally, accepted heliocentrism somewhat more quickly. Catholics, especially in Spain and Italy, had to be more cautious in the religious climate of the Counter Reformation, as the case of Galileo clearly demonstrates. Christoph Clavius, the leading Jesuit mathematician from about 1570 to his death in 1612, used biblical arguments against heliocentrism in his astronomical textbook.

The situation was never simple, however. For one thing, late in the sixteenth century Tycho Brahe devised a hybrid geostatic heliocentric system in which the Moon and Sun went around the Earth but the planets went around the Sun. In this system the elegance and harmony of the Copernican system were married to the solidity of a central and stable Earth so that Aristotelian physics could be maintained. Especially after Galileo's telescopic discoveries, many astronomers switched from the traditional to the Tychonic cosmology. For another thing, by 1600 there were still very few astronomers who accepted Copernicus's cosmology. It is not clear whether the execution of Giordano Bruno, a Neoplatonist mystic who knew little about astronomy, had anything to do with his Copernican beliefs. Finally, we must not forget that Copernicus had dedicated *De Revolutionibus* to the Pope. During the sixteenth century the Copernican issue was not considered important by the Church and no official pronouncements were made.

Galileo's discoveries changed all that. Beginning with *Sidereus Nuncius* in 1610, Galileo brought the issue before a wide audience. He continued his efforts, ever more boldly, in his letters on sunspots, and in his letter to the Grand Duchess Christina (circulated in manuscript only) he actually interpreted the problematical biblical passage in the book of Joshua to conform to a heliocentric cosmology. More importantly, he argued that the Bible is written in the language of the common person who is not an expert in astronomy. Scripture, he argued, teaches us how to go to heaven, not how the heavens go. At about the same time, Paolo Antonio Foscarini, a Carmelite theologian in Naples, published a book in which he argued that the Copernican theory did not conflict with Scripture. It was at this point that Church officials took notice of the Copernican theory and placed *De Revolutionibus* on the Index of Forbidden Books until corrected.

Galileo's *Dialogue Concerning the Two Chief World Systems* of 1632 was a watershed in what had shaped up to be the "Great Debate." Galileo's arguments undermined the physics and cosmology of Aristotle for an increasingly receptive audience. His telescopic discoveries, although they did not prove that the Earth moved around the Sun, added greatly to his argument. In the meantime, Johannes Kepler (who had died in 1630) had introduced physical considerations into the heavens and had published his *Rudolphine Tables*, based on his own elliptical theory and Tycho Brahe's accurate observations, and these tables were more accurate by far than any previous ones. The tide now ran in favor of the heliocentric theory, and from the middle of the seventeenth century there were few important astronomers who were not Copernicans.

FOOTNOTES

1. A daily rotation about its center, an annual motion around the Sun, and a conical motion of its axis of rotation. This last motion was made necessary because Copernicus conceptualized the Earth's annual motion as the result of the Earth being embedded in a spherical shell centered on the Sun. Its axis of rotation therefore did not remain parallel to itself with respect to the fixed stars. To keep the axis parallel to itself, Copernicus gave the axis a conical motion with a period just about equal to the year. The very small difference from the annual period accounted for the precesion of the equinoxes, an effect caused by the fact that the Earth's axis (in Newtonian terms) precesses like a top, with a period of about 26,000 years. (Copernicus's ideas about this precession were more cumbersome and based on faulty data.)

GLOSSARY

parallax:

The change in the position of an object in the heavens due to the orbit of the earth. Observable parallax in the fixed stars is a proof of the rotation of the earth around the sun.

Counter Reformation:

As dissenting groups split off from the Catholic Church in what came to be known as the Protestant Reformation, the Church began a series of reform measures of their own. These reform measures aimed to keep Church members from becoming Protestants, and were known as the Counter Reformation.

Carmelite Order:

The Brothers of the Blessed Virgin Mary of Mount Carmel is one of the mendicant orders originating on Mount Carmel in Israel.

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