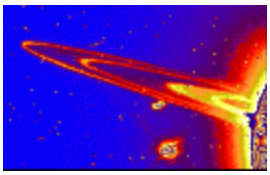
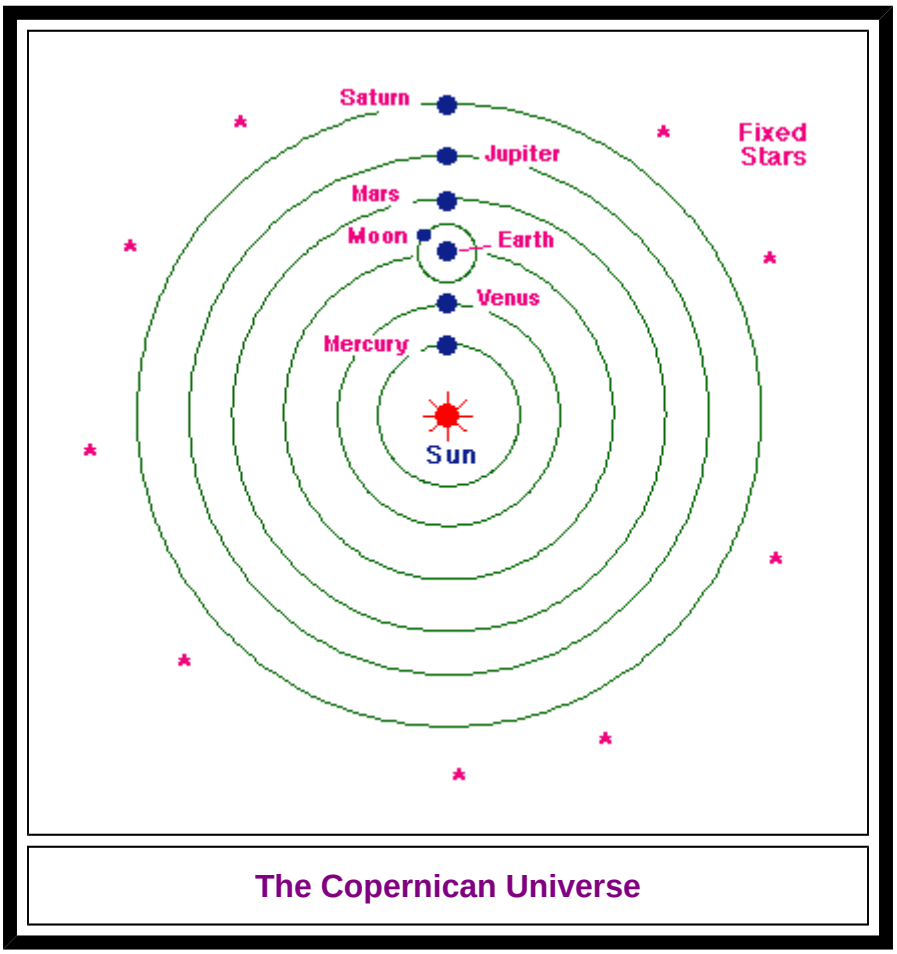


The Copernican Model: A Sun-Centered Solar System

The Earth-centered Universe of Aristotle and Ptolemy held sway on Western thinking for almost 2000 years. Then, in the 16th century a new idea was proposed by the Polish astronomer Nicolai Copernicus (1473-1543).

The Heliocentric System

In a book called *On the Revolutions of the Heavenly Bodies* (that was published as Copernicus lay on his deathbed), Copernicus proposed that the Sun, not the Earth, was the center of the Solar System. Such a model is called a *heliocentric system*. The ordering of the planets known to Copernicus in this new system is illustrated in the following figure, which we recognize as the modern ordering of those planets.



The Copernican Universe

In this new ordering the Earth is just another planet (the third outward from the Sun), and the Moon is in orbit around the Earth, not the Sun. The stars are distant objects that do not revolve

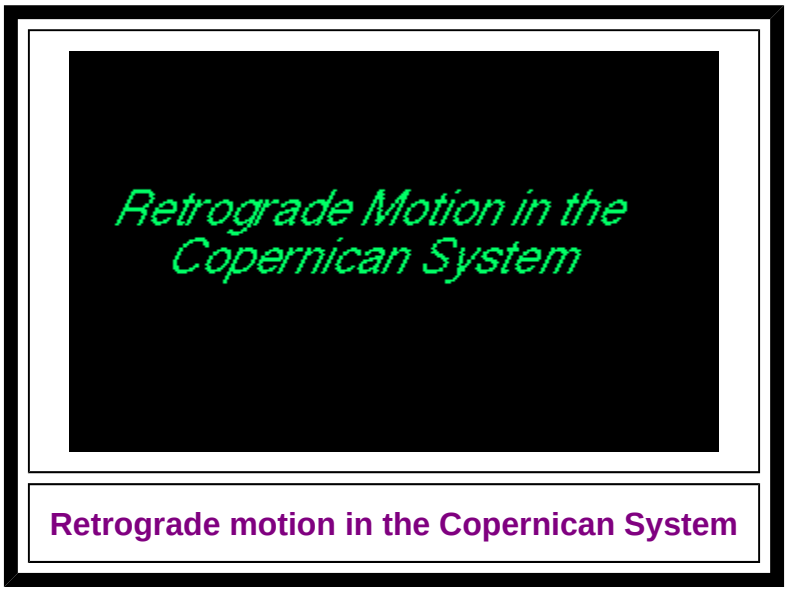
around the Sun. Instead, the Earth is assumed to rotate once in 24 hours, causing the stars to appear to revolve around the Earth in the opposite direction.

Retrograde Motion and Varying Brightness of the Planets

The Copernican system by banishing the idea that the Earth was the center of the Solar System, immediately led to a simple explanation of both the varying brightness of the planets and retrograde motion:

1. **The planets in such a system naturally vary in brightness because they are not always the same distance from the Earth.**

2. **The retrograde motion could be explained in terms of geometry and a faster motion for planets with smaller orbits, as illustrated in the following animation.**



Retrograde motion in the Copernican System

A similar construction can be made to illustrate retrograde motion for a planet inside the orbit of the Earth.

Copernicus and the Need for Epicycles

There is a common misconception that the Copernican model did away with the need for epicycles. This is not true, because Copernicus was able to rid himself of the long-held notion that the Earth was the center of the Solar system, but he did not question the assumption of uniform circular motion. Thus, in the Copernican model the Sun was at the center, but the planets still executed uniform circular motion about it. As we shall see later, the orbits of the planets are not circles, they are actually ellipses. As a consequence, the Copernican model, with it assumption of uniform circular motion, still could not explain all the details of planetary motion on the celestial sphere without epicycles. The difference was that the Copernican system required many *fewer epicycles* than the Ptolemaic system because it moved the Sun to the center.

The Copernican Revolution

We noted earlier that 3 incorrect ideas held back the development of modern astronomy from the time of Aristotle until the 16th and 17th centuries: (1) the assumption that the Earth was the center of the Universe, (2) the assumption of uniform circular motion in the heavens, and (3) the assumption that objects in the heavens were made from a perfect, unchanging substance not found on the Earth.

Copernicus challenged assumption 1, but not assumption 2. We may also note that the Copernican model implicitly questions the third tenet that the objects in the sky were made of special unchanging stuff. Since the Earth is just another planet, there will eventually be a natural progression to the idea that the planets are made from the same stuff that we find on the Earth.

Copernicus was an unlikely revolutionary. It is believed by many that his book was only published at the end of his life because he feared ridicule and disfavor: by his peers and by the Church, which had elevated the ideas of Aristotle to the level of religious dogma. However, this reluctant revolutionary set in motion a chain of events that would eventually (long after his lifetime) produce the greatest revolution in thinking that Western civilization has seen. His ideas remained rather obscure for about 100 years after his death. But, in the 17th century the work of Kepler, Galileo, and Newton would build on the heliocentric Universe of Copernicus and produce the revolution that would sweep away completely the ideas of Aristotle and replace them with the modern view of astronomy and natural science. This sequence is commonly called the *Copernican Revolution*.

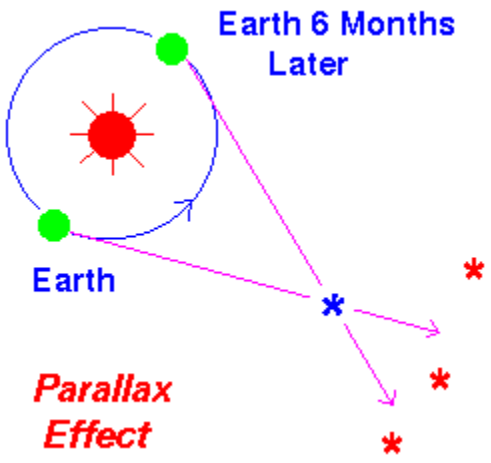
Been There, Done That: Aristarchus of Samos

The idea of Copernicus was not really new! A sun-centered Solar System had been proposed as early as about 200 B.C. by Aristarchus of Samos (Samos is an island off the coast of what is now Turkey). However, it did not survive long under the weight of Aristotle's influence and "common sense":

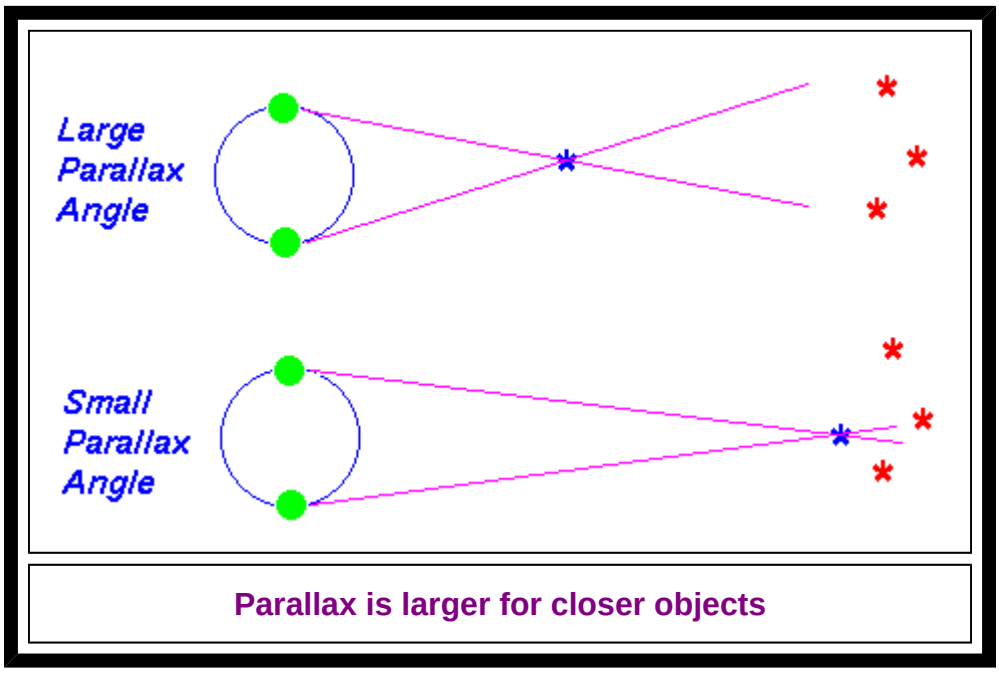
1. **If the Earth actually spun on an axis (as required in a heliocentric system to explain the diurnal motion of the sky), why didn't objects fly off the spinning Earth?**

2. **If the Earth was in motion around the sun, why didn't it leave behind the birds flying in the air?**

3. **If the Earth were actually on an orbit around the sun, why wasn't a parallax effect observed? That is, as illustrated in the adjacent figure, stars should appear to change their position with the respect to the other background stars as the Earth moved about its orbit, because of viewing them from a different perspective (just as viewing an object first with one eye, and then the other, causes the apparent position of the object to change with respect to the background).**



The first two objections were not valid because they represent an inadequate understanding of the physics of motion that would only be corrected in the 17th century. The third objection is valid, but failed to account for what we now know to be the enormous distances to the stars. As illustrated in the following figure, the amount of parallax decreases with distance.



Parallax is larger for closer objects

The parallax effect is there, but it is very small because the stars are so far away that their parallax can only be observed with very precise instruments. Indeed, the parallax of stars was not measured conclusively until the year 1838. Thus, the heliocentric idea of Aristarchus was quickly forgotten and Western thought stagnated for almost 2000 years as it waited for Copernicus to revive the heliocentric theory.

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