

Chapter 8

Copernicus

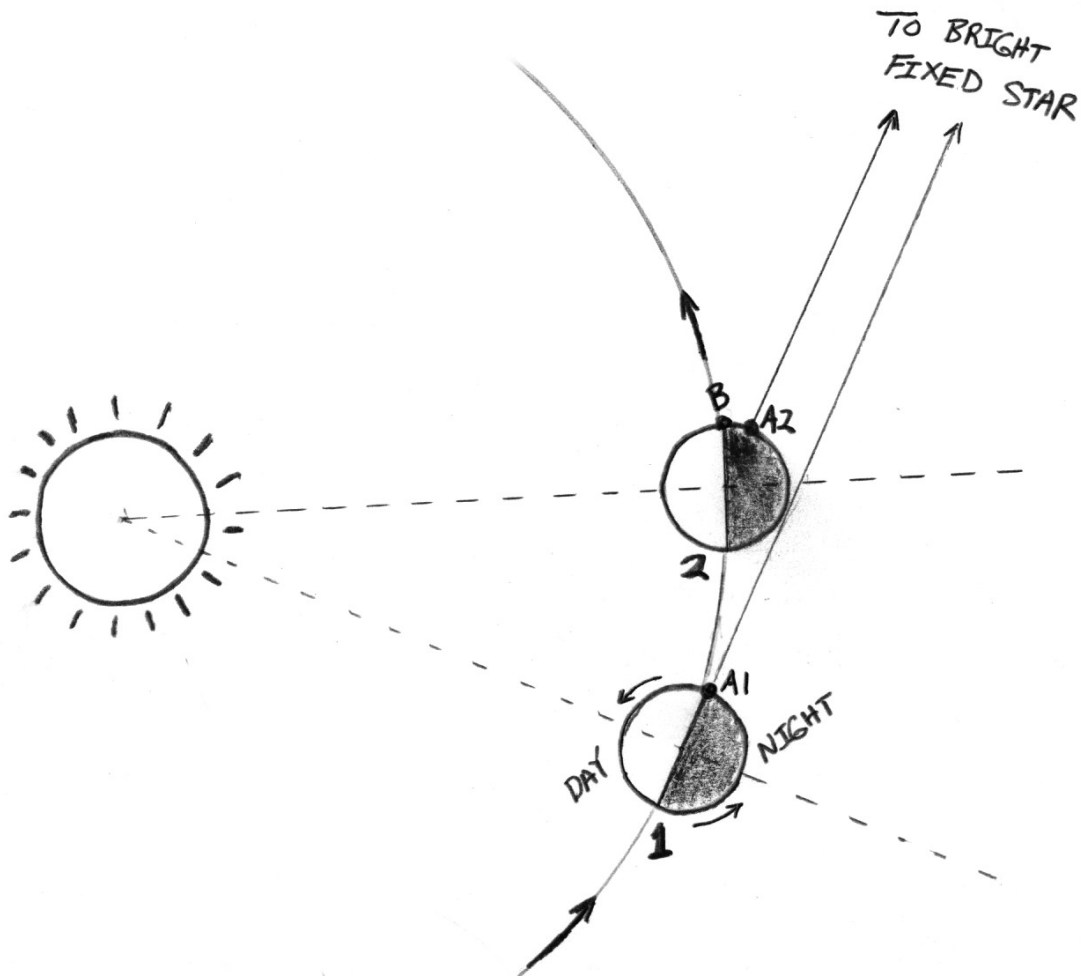
The heliocentric theory of Aristarchus (recall from Chapter 6) was brought back to life by the Polish astronomer Nicolas Copernicus¹ in the 16th century. Copernicus resurrected all the ideas of Aristarchus's theory -- the Earth revolving about the sun; the sun and the fixed stars not moving at all; the fixed stars being a vast distance from the sun; the rising and setting of the sun occurring due to the Earth rotating about itself -- but Copernicus also fleshed out Aristarchus's ideas, adding in the moon and the wandering stars.² Copernicus said the wandering stars circled the sun, just like the Earth did. The moon circled the Earth. Copernicus's heliocentric theory could explain all the cycles of the heavens that we learned about in Chapter 2.

Note that in Copernicus's heliocentric theory the wandering stars and the Earth share something in common -- they all circle the sun. In this way the wandering stars appear to be other Earths, and the Earth appears to be a wandering star. Or, put another way, in the Copernican theory, Mercury, Venus, Earth, Mars, Jupiter, and Saturn are all *planets* in some sense of what a planet is in our modern way of thinking. Also note that, in Copernicus's theory, the fixed stars and the sun share something in common -- they don't move. They might be suns themselves, suns that look small because they are a vast distance away.

The Copernican theory did a fantastic job of explaining the retrograde motions of the wandering stars (planets) -- why the wanderers went into retrograde, why they brightened during retrograde, and why the retrograde motion always occurred during a sun-Earth-wanderer alignment (recall from Chapter 6 that the geocentric epicycle theory could not explain the alignment question). In essence the heliocentric theory said that

1 Copernicus lived from 1473 to 1543.

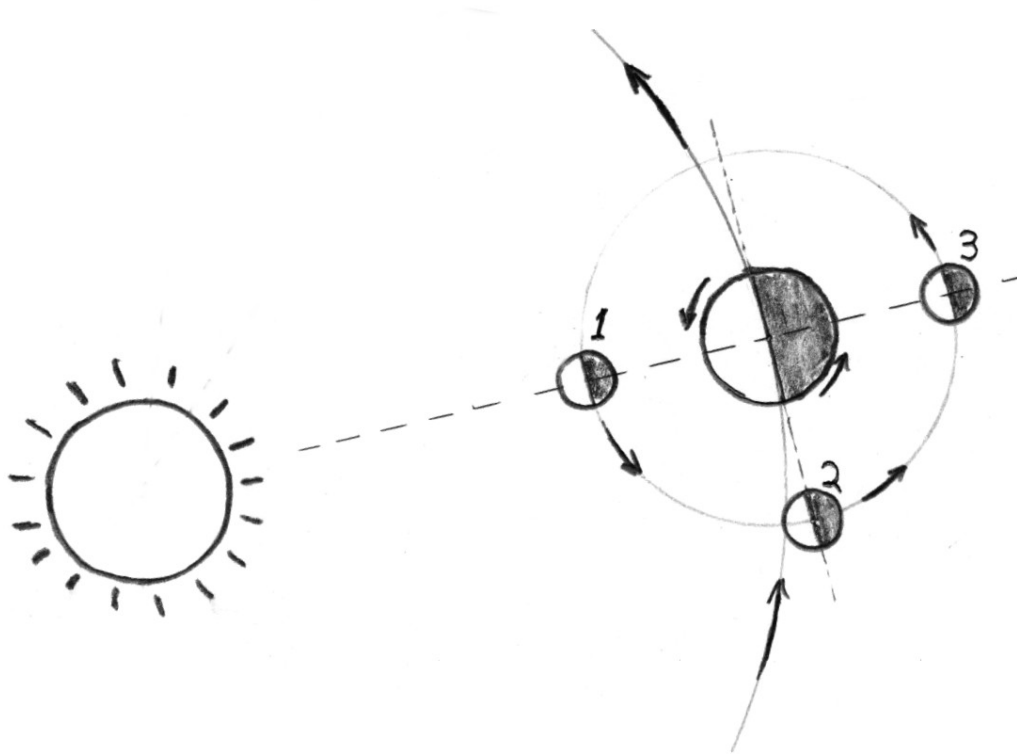
2 We should recall from Chapter 6 that no copy of Aristarchus's work on heliocentrism survived the passage of time -- Aristarchus could have had the heliocentric theory as fully fleshed out as Copernicus did.



How does the heliocentric theory explain the cycles of the sun and stars? This is how:

The Earth is revolving about the sun *and* rotating about itself. When the Earth is at position 1, an observer at A1 sees a bright fixed star (very far away) directly overhead. The observer at A1 also sees the sun rising (the observer is on the line between day and night, moving from night to day). The Earth rotates and progresses along its orbit until the star is again overhead for the observer (Earth at position 2, observer at A2). Because of the motion of the Earth about the sun, the Earth will have to rotate a little more before the observer will see the sun rising – so that the observer is at B. The time for the Earth to rotate from A1 to A2 is 23 hours, 56 minutes; to rotate from A1 to B is 24 hours.

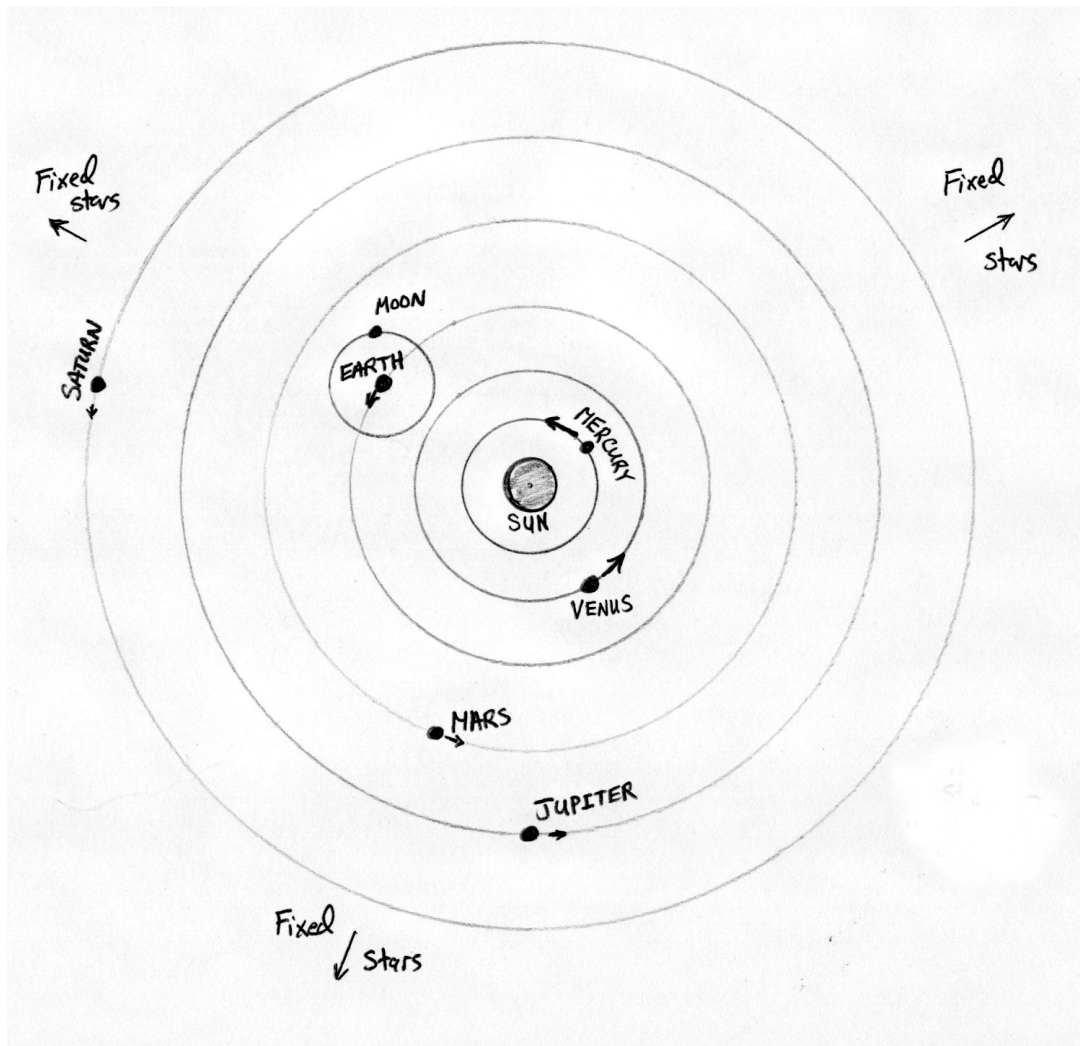
The explanation of the cycles of the sun and stars are more complex in the heliocentric theory than in the geocentric theory. In the geocentric theory the sun simply circles the Earth once every 24 hours, and the stars circle once every 23 hours, 56 minutes.



How does the heliocentric theory explain the cycle of the moon? This is how:

The moon circles the Earth as the Earth circles the sun. When the moon is at 1, lying along a line between the sun and the Earth, only its dark side faces the Earth and the moon is near the sun in the sky – this is New Moon. The moon takes 7.5 days to circle from 1 to 2, where the moon will appear half lit, and another 7.5 days to circle from 2 to 3 (Full Moon), and so forth. The total time for the moon to circle the Earth and return to lying along a line between the sun and the Earth is 30 days.

The explanation of the cycle of the moon is more complex in the geocentric theory than in the heliocentric theory. In the geocentric theory both sun and moon race around the Earth every day, with their differing speeds yielding a 30 day cycle (see Chapter 4).



Copernicus's heliocentric theory. The fixed stars lie in an unmoving sphere a vast distance from the sun and are not shown in this sketch. Mercury circles the sun the most rapidly (once every 88 days), followed by Venus (7½ months), Earth (1 year), Mars (2 years), and Jupiter (12 years), with Saturn circling the sun least rapidly (once every 29 years). The moon circles the Earth once every 30 days.

retrograde motion *did not actually occur* -- a planet (wanderer) never actually reversed direction. Rather, retrograde motion was *an illusion* caused by the relative motions of the Earth and another planet. For example, in the Copernican theory Earth circles the sun more rapidly than does Mars. So, as the two planets race around the sun, Earth will periodically “lap” Mars. When Earth is passing Mars, the act of passing creates the *illusion* that Mars is moving backward. But in fact Mars never reverses direction at all -- it

moves at a constant rate the entire time. Furthermore, when Earth passes Mars the distance between them will be at a minimum, so Mars will appear at its brightest. And lastly, when Earth passes Mars it passes between Mars and the sun, so all three of them fall along a line. Thus the retrograde motion, the brightening, and the alignment are all neatly explained with the Copernican theory. As Copernicus put it:

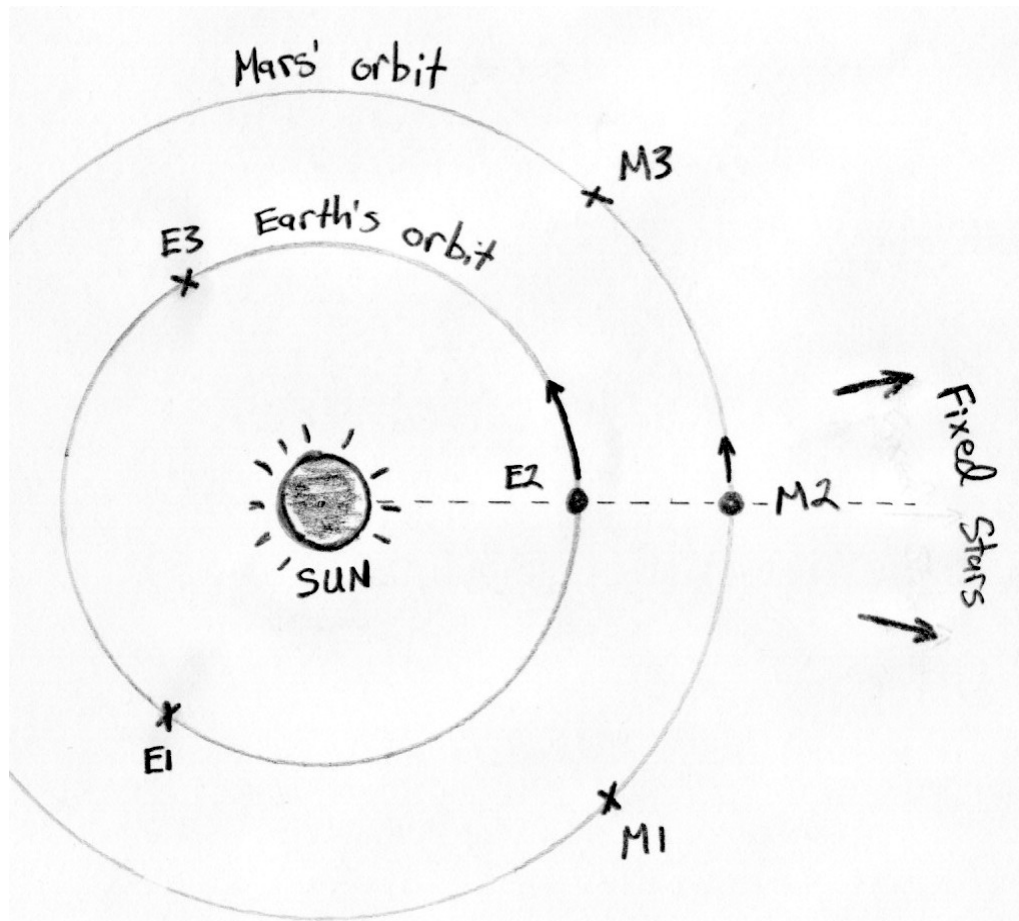
Therefore in this ordering we find that the world has a wonderful commensurability and that there is a sure bond of harmony for the movement and magnitude of the orbital circles such as cannot be found in any other way. For now the careful observer can note why progression and retrogradation appear greater in Jupiter than in Saturn and smaller than in Mars; and in turn greater in Venus than in Mercury. And why these reciprocal events appear more often in Saturn than in Jupiter, and even less often in Mars and Venus than in Mercury. In addition, why when Saturn, Jupiter, and Mars are in opposition³ they are nearer to the Earth than at the time of their occultation⁴ and their reappearance. And especially why at the times when Mars is in opposition to the sun, it seems to equal Jupiter in magnitude and to be distinguished from Jupiter only by a reddish color, but when discovered through careful observation by means of a sextant is found with difficulty among the stars of second⁵ magnitude? All these things proceed from the same cause, which resides in the movement of the Earth.

But that there are no such appearances among the fixed stars argues that they are at an immense height away, which makes the circle of annual movement or its image disappear from before our eyes since every visible thing has a certain distance beyond which it is no longer seen, as is shown in optics. For the brilliance of their lights shows that there is a very great distance between Saturn the highest of the planets and the sphere of the fixed stars. It is by this mark in particular that they are distinguished from the planets, as it is proper to have the greatest

3 *Opposition* is when the sun and the planet are on opposite sides of the Earth.

4 *Occultation* is when the sun lies between a planet and Earth, so that the planet cannot be seen.

5 *Second magnitude*: second-rate stars. The brightest stars are first-rate stars or stars of first magnitude.



Retrograde motion in the Copernican theory. Both Earth and Mars circle the sun counter-clockwise at constant rates; Earth's rate is faster than Mars' rate; Earth moves from E1 to E2 to E3 in the time Mars moves from M1 to M2 to M3. Earth is shown in the act of passing between Mars and the sun (Earth at E2, Mars at M2). Since, when passing Mars, the Earth moves between Mars and the sun, the three bodies must fall along a line at that time. The act of Earth passing Mars creates the *illusion* of Mars moving backwards, but it is only an illusion; in fact Mars' counter-clockwise motion never changes. The Mars-Earth distance at E2 is at a minimum, so Mars is at maximum brightness. Before Earth reached E2 it was behind Mars and gaining on it; the Mars-Earth distance was decreasing so Mars was increasing in brightness. After Earth passes E2 it will be ahead of Mars and leaving Mars behind – the Mars-Earth distance will increase so Mars will decrease in brightness.

*difference between the moved and the unmoved. How exceedingly fine is the godlike work of the Best and Greatest Artist!*⁶

The Copernican theory also eliminated the other troublesome aspects of geocentric theories mentioned in Chapter 6 -- the insanely fast motion of the heavens and the problem of a large sun circling a much smaller Earth. However, the Copernican theory suffered from the three big heliocentric theory problems we discussed in Chapter 6 -- the issue of us on Earth moving at extremely high speeds, and not being able to detect that motion; the issue of what powered the motion of the Earth (and other planets as well); and the issue of annual parallax.

But whereas at the time of Aristarchus the problems with heliocentrism kept it from being widely accepted, in Copernicus's time there were ways around those problems that might make heliocentrism more palatable. Since the time of the ancient Greeks various people had argued that, if everything on Earth's surface were carried along at the same speed, then we would not notice our motion; some of Buridan's successors had updated this *common motion* argument. Buridan's impetus theory provided a way for things to move without a Prime Mover to power them. And of course the question of annual parallax could be dealt with by assuming the fixed stars were a vast distance away, as Copernicus (and Aristarchus) did.

At the same time, the heliocentric theory under Copernicus faced a fourth problem, one that did not exist for Aristarchus. The fourth problem with heliocentrism was that a heliocentric theory seemed contrary to Christian scripture. Scripture spoke of a moving sun and a fixed Earth, not a fixed sun and a moving Earth -- in Joshua:

Then spake Joshua to the Lord in the day when the Lord delivered up the Amorites before the children of Israel, and he said in the sight of Israel, Sun, stand thou still upon Gibeon; and thou, Moon, in the valley of Ajalon. And the sun stood still, and the moon stayed, until the people had avenged themselves upon

6 Nicolaus Copernicus, *On the Revolutions of Heavenly Spheres*, translated from Latin into English by C. G. Wallis (Amherst, New York: Prometheus Books, 1995), pg. 26-27. This translation is from 1995 -- Copernicus's original book was published in 1543.

*their enemies. Is this not written in the book of Jasher? So the sun stood still in the midst of heaven, and hastened not to go down about a whole day.*⁷

-- in the Psalms:

*He has pitched a tent there for the sun, which comes forth like the groom from his bridal chamber and, like a giant, joyfully runs its course. At one end of the heavens it comes forth, and its course is to their other end; nothing escapes its heat.*⁸

*You fixed the Earth upon its foundation, not to be moved forever.*⁹

-- in Ecclesiastes:

*The sun also ariseth, and the sun goeth down, and hasteth to his place where he arose.*¹⁰

It was possible to get around this problem, too. One could always argue that the Bible was speaking to the point of view of people on Earth, who saw the sun rise and set; it was not intending to provide a detailed lesson in astronomy. However, if nothing else, these things ensured that European Christian culture would naturally favor Aristotle's geocentric view. Aristotle's ideas were part of the culture of the time. For example, a popular view was that, just as Aristotle had various circles of heaven (Moon, Mercury, Venus, sun, etc.), so also were there various circles of hell -- where the lower into the Earth you went the more hellish it got, until, at the center of the Earth, and therefore at the very center and lowest point of the universe, was Satan himself -- Satan was as low as you could get!¹¹

Despite the fact that there were ways around the various problems with heliocentrism, Copernicus was worried that his heliocentric theory would not be welcomed.

7 Joshua 10:12-13 (King James Version).

8 Psalm 19:6-7 (New American Bible).

9 Psalm 104:5 (New American Bible).

10 Ecclesiastes 1:5 (King James Version).

11 Dear Reader, we need to emphasize here that the circles of hell and Satan living in the center of the Earth was not a matter of orthodoxy in Christian theology, Catholic or Protestant -- it was only a "popular" view.

Copernicus presented his theory in a book entitled *On the Revolutions of Heavenly Spheres*, which he dedicated to the Pope (Pope Paul III). In his dedication he expressed his worries:

*I can reckon easily enough, Most Holy Father, that as soon as certain people learn that in these books of mine which I have written about the revolutions of the spheres of the world I attribute certain motions to the terrestrial globe, they will immediate shout to have me and my opinion hooted off the stage.*¹²

Copernicus (who was a Catholic cleric who worked at a cathedral) viewed his theory in religious terms --

*Accordingly, when I had meditated upon this lack of certitude in the traditional mathematics concerning the composition of movements of the spheres of the world, I began to be annoyed that the philosophers, who in other respects had made a very careful scrutiny of the least details of the worlds, had discovered no sure scheme for the movements of the machinery of the world, which has been built for us by the Best and Most Orderly Workman of all.*¹³

-- and he pointed out that friends who were Catholic Christian religious leaders (a bishop and a cardinal) as well as learned scholars encouraged his work. But he nevertheless had concern that people would use the Bible to attack his ideas:

*But if perchance there are certain "idle talkers" who take it upon themselves to pronounce judgment, although wholly ignorant of mathematics, and if by shamelessly distorting the sense of some passage in Holy Writ to suit their purpose, they dare to reprehend and to attack my work; they worry me so little that I shall even scorn their judgments as foolhardy.*¹⁴

Nor was this worry limited to Catholic Christians. Andreas Osiander, a Lutheran Christian theologian who helped get Copernicus's book published, wrote an introduction to *On the Revolutions of Heavenly Spheres* which also predicted that certain people would

12 *On the Revolutions of Heavenly Spheres*, pg. 4.

13 *On the Revolutions of Heavenly Spheres*, pg. 6.

14 *On the Revolutions of Heavenly Spheres*, pg. 7.

be gravely offended by the heliocentric theory. Osiander sought to mollify such readers by reminding them that --

*...it is not necessary that these hypotheses should be true, or even probably; but it is enough if they provide a calculus which fits the observations....*¹⁵

Copernicus died just before his book was published in 1543, and so he did not get to see whether his ideas would be “hooted off the stage” or not. They were not; Copernicus remained respected as an astronomer. But they were not accepted either. As we have mentioned in this chapter, yes, Copernicus's heliocentric theory had its strengths and yes, there were ways around its weaknesses. But the geocentric ideas of Aristotle (and Ptolemy) had their strengths as well. Aristotelian geocentrism had already survived the challenge of heliocentrism under Aristarchus of Samos, during the time of the ancient Greeks. Unless something changed, Aristotelian geocentrism was going to survive the challenge of heliocentrism under Nicolaus Copernicus of Poland, during the time of the European Christians -- who had all the same reasons to favor geocentrism over heliocentrism that the ancient Greeks had, plus the reason of Christian scripture as well.

15 *On the Revolutions of Heavenly Spheres*, pg. 3.