

Lecture Notes: Nicholas Copernicus'

On the Revolutions of the Heavenly Spheres

Background, Prefaces and introductions

Circumstances of the book's production. Copernicus (1473-1543) was a Polish church official. His avocation, however, was the study of the heavens. He studied as many previous works of astronomy as he could, and even learned ancient Greek in order to read the parts of Ptolemy that had not yet been translated. In 1514, he had written up a brief outline of the basic ideas that would later become *On the Revolutions of the Heavenly Spheres* (a.k.a. *De Revolutionibus...*), and he showed these notes to friends and other people interested in astronomy, but did not publish this material. These notes already contained the fundamental ideas that (i) the Earth rotates on its axis once every 24 hours, and (ii) the sun was at rest in (nearly) the center of the universe, and all the planets -- *including the Earth* -- revolved around the sun. Copernicus continued to develop the outline into a long book over the next three decades, but remained hesitant to publish. He finally agreed to publish it after his friend and supporter Rheticus published a short summary of the Copernican system in 1541. Copernicus was old by this time, and entrusted the publication procedures to Rheticus. However, when professional duties forced Rheticus to relocate to Leipzig, he had to pass on responsibility for overseeing publication to the clergyman Andreas Osiander, who saw it to completion.

Osiander's preface. Question: What is the aim of science? of astronomy in particular? Osiander's answer:

The astronomer "cannot in any way attain to the true causes," so "he will adopt whatever suppositions enable the motions [of the celestial bodies] to be computed correctly from the principles of geometry for the future as well as the past." Furthermore, "these hypotheses [= 'suppositions'] need not be true or even probable. On the contrary, if they provide a calculus consistent with the observations, that is enough."

Osiander's answer is a version of **instrumentalism** about astronomy. The aim of astronomy is simply to predict (and retrodict) the observed positions of the sun, moon, and stars; astronomy does not aim to give us the *true causes* of the celestial bodies' motions.

Instrumentalism is contrasted with **realism**: the realist claims that the aim of science is not merely to , but also that science aims to discover the *true causes* of events. (Instrumentalism's name comes from the notion that instruments or tools, such as hammers and spoons, are not really the kinds of things that aim at the truth.)

Why is Osiander an instrumentalist about astronomy?

1. If epicycles are the true causes of Venus's retrograde motion, then the apparent size of Venus in the night sky should be changing a great deal -- but it does not.

2. "Different hypotheses are sometimes offered for one and the same motion": that is, two different combinations of epicycles and eccentrics can both capture all the observations. The astronomer simply chooses the one that is "easiest to grasp." But just because some claim is easiest for us to understand, that doesn't make that claim *true*, or even any more likely to be true.
3. The only certain knowledge we humans have is what has been divinely revealed.

Copernicus and the church authorities. It seems that Copernicus (and those around him) expected *De Rev.* to create some trouble with the Catholic Church.

~ Perhaps another reason Oslander forwards an instrumentalist account of astronomy is to ward off possible negative reactions from the church authorities. Copernicus's model of a moving Earth and static Sun will appear to contradict certain biblical texts, in which God makes the Sun stop moving and stand still. However, if the aim of astronomical hypotheses is only to be an instrument that correctly predicts where Mars will be in the night sky, and not to capture the truth about the motions of the celestial bodies, then there is no conflict with holy scripture. [Note: Many astronomically-inclined people, including Rheticus, strongly disapproved of Oslander's Forward, claiming that it distorts the true nature of Copernicus's views. However, *De Rev.* did manage to escape Church persecution for the first few decades of its existence, perhaps in part due to Oslander's preface (which was unsigned, and therefore presumed by most to be written by Copernicus himself.)]

~ A letter of praise from Cardinal Schoenberg is also part of the prefatory material.

~ Copernicus dedicates the whole work to the Pope at the time, Paul III.

Copernicus's Preface to Pope Paul III. Copernicus tells us (and the Pope) that he did not publish his work for almost 30 years because his basic idea is so contrary to conventional wisdom and common sense.

So why *did* Copernicus publish?

- Two friends (a Cardinal and a Bishop) encouraged him to publish.
- There are many disagreements within traditional astronomy, such as:
 1. Astronomers cannot agree on the exact length of the tropical year [= how long it takes the sun to return to exactly the same point that it rose from a year earlier]
 2. Different hypotheses are used to model the same observed motion [just as Oslander pointed out]
 3. The hypothesis of eccentric circles fails to capture "the structure of the universe and the symmetry of its parts."
- The ancients also hypothesized that the Earth moves (Hicetus, Philolaus, Heraclides, Aristarchus).
- Copernicus's model of the cosmos not only saves the phenomena (like Ptolemy's model), but it also (unlike the Ptolemaic system) establishes "the order and size of all the planets and spheres" (see Cohen p.41).
- A better astronomical theory would help in creating better calendars.

***De Revolutionibus*: Book I**

Introduction. Why study the celestial bodies? Copernicus's answer is basically that of *Plato* that we saw earlier in the term. The planets and stars are the most beautiful, most perfect, and most divine of visible things. Studying them pulls our minds "away from vices and toward better things," and creates in a person an "admiration for the Maker of everything."

Ch. 1: The Universe is Spherical. Why? Copernicus offers the following reasons:

- ~ The sphere is the most perfect shape
- ~ The sphere is the shape with the largest 'capacity' [GF-A: volume to surface area ratio?], and the universe is the biggest thing, so it must be a sphere.
- ~ The sun, moon, and planets are spherical
- ~ 'Wholes strive to be spherical': Water drops naturally arrange themselves into a spherical shape

Ch. 2: The Earth is Spherical. Copernicus simply repeats Ptolemy's arguments for this claim.

Ch.4: The Motion of Celestial Bodies is Uniform, Eternal, and (compounded of) Circular Motions Why?

- ~ Copernicus says "the motion appropriate to a sphere is rotation in a circle." [GF-A: Says who? The motion 'appropriate to a racketball' is towards the center of the Earth.]
- ~ Retrograde motion of the planets could make us think the planets do not move in a circles. However, Copernicus replies, these are still composed of circular motions, "because these non-uniformities [=the retrograde motions] occur regularly according to a constant law. This could not happen unless the motions were circular, since only the circle can bring back the past." All processes that repeat regularly are some combination of circular motions.
- ~ Copernicus infers that there must be several distinct motions here,

"because a simple heavenly body cannot be moved by a single sphere non-uniformly. For this nonuniformity would have to be caused either by an inconstancy... in the moving force or by an alteration in the moving body. From either alternative the intellect shrinks. It is improper to conceive any such defect in objects constituted in the best order."

Is impropriety or the shrinking of the intellect a good argument for why the spheres must move uniformly?

Ch. 5: The Earth rotates on its axis once every 24 hours. Even though Copernicus said at the beginning of Ch.4 that rotation is the 'appropriate motion' for a sphere, and Ch.2 showed that the Earth is a sphere, Copernicus does not immediately infer that the Earth must be rotating.

- ~ Copernicus first notes that if all we observe is change of relative position, we cannot infer from that alone what is *really* moving and what is *really* at rest.
- ~ In the case of the change of relative position of the Earth and the fixed stars, Copernicus claims that it makes more sense to attribute motion to one small thing (the Earth) instead of everything else in the gigantic universe (the daily rotation of the stars, sun, moon, and planets).

Ch.6: Ptolemy did not prove that the Earth is at the exact center of the Celestial Sphere.

The classical arguments (from Ptolemy, e.g.) that aim to prove *the Earth is at the center of the universe* do not establish that conclusion. Rather, all they show is that the distance of the Earth from the center of the universe is infinitely small when compared with the distance from the center of the universe to the fixed stars.

Ch.7: Ptolemaic-Aristotelian arguments that the Earth does not move

Ptolemy (you will recall) argued that the Earth does not rotate on its axis, on the grounds that (i) things would fly off the Earth's surface (think of being on a very fast-moving merry-go-round), including parts of the Earth itself and (ii) anything thrown straight up in the air would fall far behind (to the west) of where they were released -- for the Earth's surface would have spun right out from underneath it.

Ch.8: Copernicus's answer to the arguments in Ch.7:

Against (i):

- (a) If the Earth rotates, then its rotational motion is *natural*, and therefore the earth and the things on it won't be thrown violently off its surface.
- (b) If rotational motion sends things flying everywhere, then shouldn't that reasoning apply much more to the fixed stars? They would fly farther and farther away from us.
- (c) Copernicus repeats his claims that because the Earth is spherical, its 'appropriate' motion is rotation, and that (using the examples of sailors on a moving ship) observed change of position does not reveal who is moving and who at rest.

Against (ii):

~ The air etc. somehow shares in the Earth's rotational motion, or is pulled along by it.

Other general responses in favor of a rotating Earth:

- ~ We can revise Aristotle's physics: everything here on Earth has a circular motion in addition to any other motions we detect. So when I drop a ball off the top of a building, that ball is not *really* moving straight down, but rather is moving straight down AND in a circle around the center of the Earth.
- ~ Since being UNchanging is "nobler and more divine" than changing, the stars should be what's NOT moving, since they are nobler than the Earth.

Ch.9: The Earth revolves around the center of the universe

~ The planets appear sometimes closer to us, sometimes farther away. If we assume that all the planets are moving in circular paths, then the earth *cannot* be the center of their circles, and hence cannot be the center of the universe. ~ The planets' non-uniform motion cannot be explained if the Earth is at the center of the universe.

Ch.10: The Order of the Planets

~ The best way to make sense of the fact that Mercury and Venus never appear very far from the Sun is to say that the Sun is nearest to the center of the universe, then Mercury, then Venus, then the Earth.
~ Note the following set of justifications Copernicus gives for placing the Sun at the center of the universe:

"in the middle of everything is the Sun. For in this most beautiful temple, who would place this lamp in another or better position than that from which it can light up the whole thing at the same time? For the Sun is not inappropriately called by some people the lantern of the universe, its mind by others, and its ruler by still others. **[Hermes] the Thrice Greatest [= Trismegistus]** labels it a visible god... Thus indeed, as though seated on a royal throne, the sun governs the family of planets revolving around it." (boldface added)

Question: Is this merely a rhetorical flourish? Or does Copernicus intend this to have 'equal footing' with the other arguments he makes?

~ On this model of the universe, the size of the sphere of revolution is correlated without exception with the period of revolution: Mercury has the smallest sphere, and the shortest time to encircle the Sun (80 Earth days), whereas Saturn has the largest sphere, and the longest time to complete an orbit (30 Earth years).

Arguments against Copernicus.

1. No observed parallax of the fixed stars. How could the distance from the Earth to the Sun be vanishingly small in comparison to the distance to the fixed stars?
2. Copernicus does not have a fully worked out new physical theory. In particular, 'All spheres rotate by nature,' which asserted in order to explain the Earth's daily rotation, seems false: baseballs don't just rotate all on their own. Furthermore, they appear to drop 'naturally' straight down to the center of the Earth -- they rotate usually only when a pitcher throws one... that's a clear case of artificial (=non-natural) motion.
3. Why was the moon circling the Earth? Ptolemy has a natural explanation: all celestial bodies circle the Earth. It seems like Copernicus needs to explain why the moon isn't going around the Sun, if all the bodies in the universe are revolving around the Sun.
4. Copernicus, unfortunately, could not generate an observationally adequate model of the universe using just simple circles revolving around the sun. His final product, in order to get the predictions right, ended up being about as complicated as Ptolemaic models of the universe.
5. (more general) As said above, certain passages from the bible appear to say that the sun moves and the earth stands still. And in a related way, Copernicus's model may give some people the sense that we humans are no longer the center of the universe -- we are not so special as we once thought.