WHY DID COPERNICUS SET THE EARTH IN MOTION?

Copernicus never tells us why he abandoned the earth-centered universe and instead set the earth in motion. Noel Swerdlow, a leading Copernican scholar, suggested that in his analysis of planetary motion, Copernicus may have come across an anomaly involving the Aristotelian spheres that forced him to choose between the spheres and the earth-centered cosmology (Swerdlow 1972). Swerdlow's proposal is moderately technical, and I hope the attached diagrams will make it clear.

Remember the two problems faced by ancient planetary astronomy: To explain using uniform circular motion (1) the variable speed of the planets, and (2) the retrograde motion. We have already seen how Copernicus (and his Islamic predecessors dealt with the first problem: they replaced the equant with a "minor epicycle." Here we will see what might have led Copernicus to change his approach to the second problem, retrograde motion.

The first diagram (labeled "epicycle'") shows Ptolemy's model for one of the outer planets (Mars, Jupiter, or Saturn). The earth is at C, and the planet is located at a point P on the epicycle. Thus the epicycle center R rotates around the deferent, while the planet P rotates around the center of the epicycle. Remember that a line from C to the Sun S is always parallel to RP. As the planet moves along the "inside" of the epicycle, the part of its path that brings it closest to C, it undergoes retrograde motion.

It turns out that there is a second, equivalent model, shown in the second diagram (labeled "eccentric"). In this model, we draw the same two circles, but *in reverse order*. Thus, we first draw the epicycle (now called an eccentric) centered on C—the smaller circle in the second figure. Then we draw the deferent circle centered on the point D. The planet is at point P, and as before, the sun is somewhere along the line CS.

It is harder to see geometrically how this model leads to retrograde motion. But in fact, both models turn out to be geometrically equivalent. A proof is beyond the scope of the course. But to see how the two models work, just place one figure on top of the other. Make the two points C, and also the two dotted lines CS, coincide. If you have lined up the drawings correctly, you will see a parallelogram CDPR emerge. *Note that both models show the planet P in the same position.*

Ptolemy had known both models, and knew that they were equivalent. But he said very little about the eccentric model. But Regiomontanus in his *Epitome of the Almagest* devoted a lot of attention to it. Copernicus studied the *Epitome* carefully, and Swerdlow has called attention to some of Copernicus's own notes in which he was apparently investigating the eccentric model.

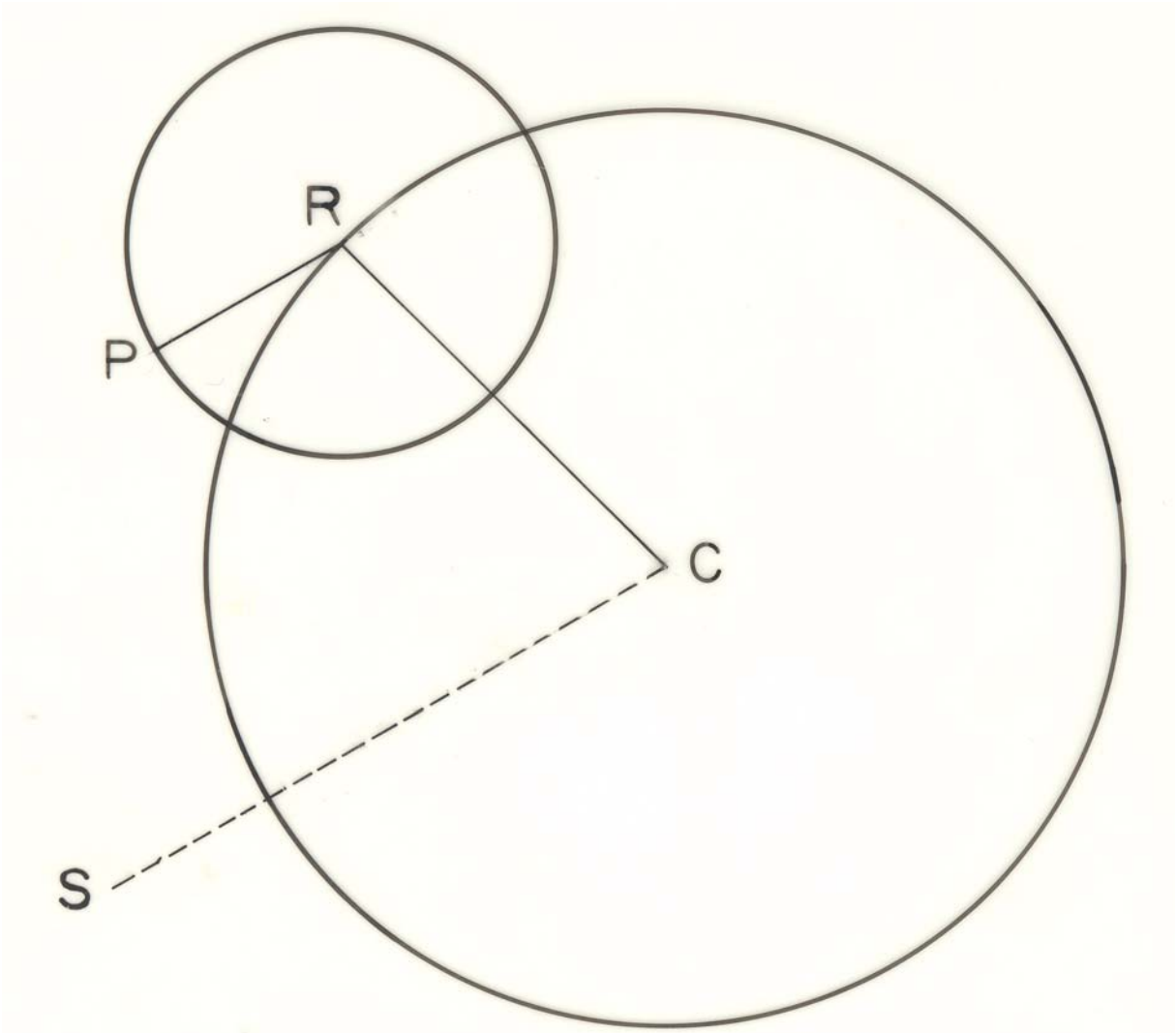
The eccentric model, it turns out, fits in rather nicely with the Aristotelian spheres. The smaller circle, centered on C, represents the sphere of the sun. The larger circle, centered on D, represents the sphere of the planet.

But this interpretation encounters a serious problem for Mars. If one uses observations to calculate the diameters of the two circles, one finds that the sphere of the planet *intersects* the sphere of the sun. Thus for Mars, the radius DP of the larger circle is smaller than shown, so that the larger circle actually cuts into the smaller one. But Copernicus thought of these spheres as real, material objects, just as Aristotle had done. And of course, material spheres cannot intersect—Aristotle's crystalline spheres would shatter!

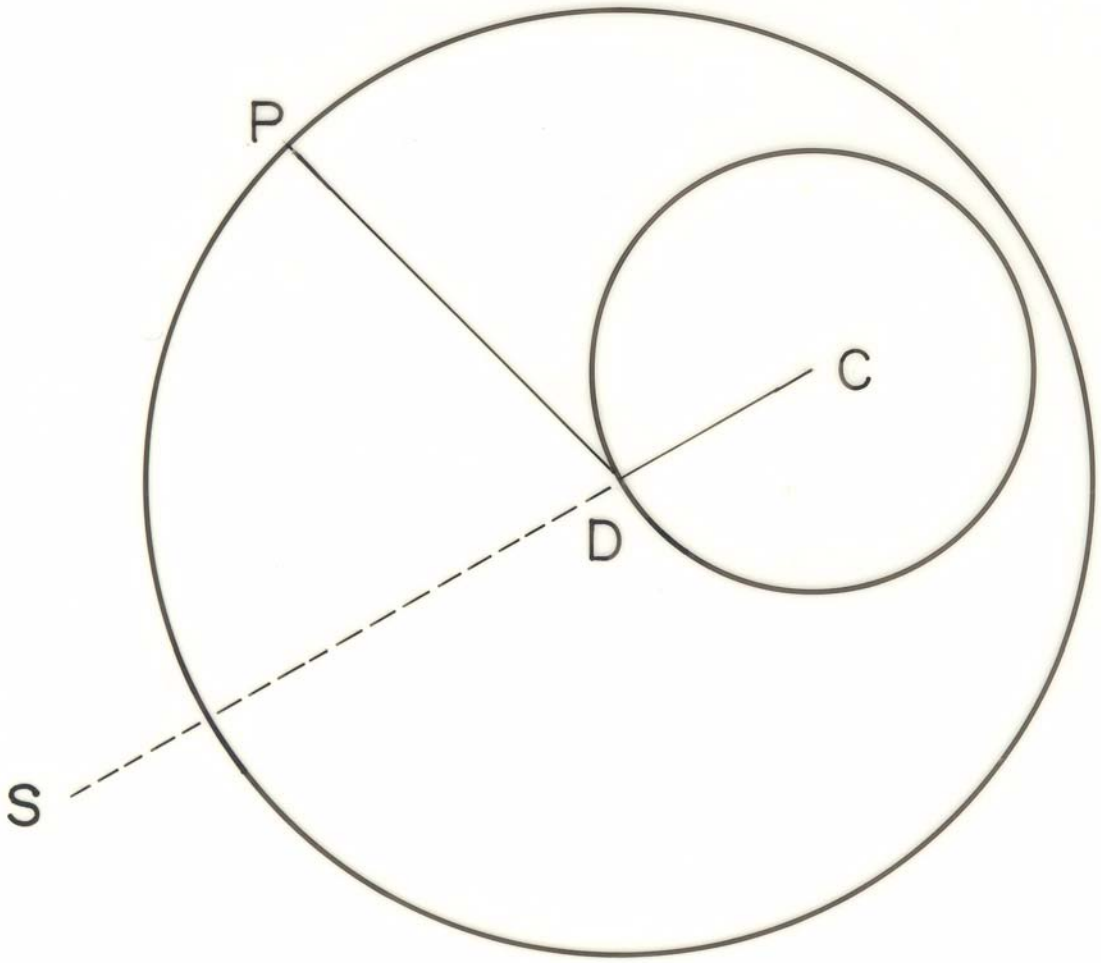
Sverdlow conjectures that Copernicus noticed this dilemma, and felt forced to choose: He could reject the Aristotelian spheres. Or he could keep them by placing the sun at the center, and hence allow all the planets to move on roughly concentric spheres that could not possibly intersect. Swerdlow recognizes that his explanation is no more than a conjecture: Copernicus never tells us what motivated him. But the conjecture is supported by notations Copernicus made in some unpublished manuscripts, in which he seems to be familiar with the eccentric model. If Swerdlow's suggestion is true, it suggests that the innovation of placing the earth in motion was a deeply conservative innovation—it was the only way that Copernicus could retain the material planetary spheres!

REFERENCE

Noel M. Swerdlow, "The Derivation and First Draft of Copernicus's Planetary Theory: A Translation of the *Commentariolus* with Commentary," Proceedings of the American Philosophical Society **117** (1973), 423–512.



EPICYLE



ECCENTRIC