We now return to Europe and look at Copernicus (A.D. 1473–1543). His treatise *De revolutionibus orbium coelestium* [On the revolutions of the heavenly spheres], published in the year of his death, is as substantial as the *Almagest*, but I will not describe it in such detail. What everyone “knows” about Copernicus is that he made the sun stand still: he considered the sun to be fixed at the center of the universe, the planets to be circling round it, and the earth to move just like any other planet. But this is misleading, if not actually false: Copernicus did not place the sun at the center but near the center of the various orbits, and the earth does not move quite like the other planets (it does not have an epicycle (see page 208)).

The preface to *De revolutionibus* was probably written not by Copernicus himself but by the theologian Andreas Osiander, who took a friendly interest in the book. He pointed out that the rôle of an astronomer is to construct a theory from which astronomical movements could be calculated; the theory need not be true, it need only fit the observations, and neither an astronomer nor a philosopher will find certainty unless it is “divinely revealed.” This enabled people who could not stomach a moving earth for theological reasons to teach Copernicus’s system as a mathematically convenient but physically erroneous hypothesis; and indeed the book was not banned until, some sixty years later, Galileo pushed it hard and the church reacted (some would say over-reacted).

*De revolutionibus* is closely modeled on the *Almagest*: a tribute to the authority of that work (well over a thousand years old by 1543). It starts by stating that the universe and the earth are spherical and that heavenly motions are made up of regular circular motions. Then comes the main point in which Copernicus disagreed with Ptolemy. Does the earth rotate? Ptolemy had argued that if the earth rotated everything would be swept toward the west. Copernicus countered this by saying
that anyone who maintains that the earth rotates will postulate that the rotation is "natural." Here he was maintaining Aristotle's distinction between natural motion (which is circular for celestial bodies but rectilinear for earthly bodies) and unnatural motion. He assumed that Ptolemy's reason for thinking that the earth's rotation would have a disastrous effect was that such motion is "violent" (which in the Aristotelian philosophy of motion means simply "unnatural"). Copernicus argued that if Ptolemy was worried by a rotating earth he should have been even more worried by a rotating sky, whose "immensity" would "increase with the increase in movement" and so become infinite. He quoted a supposed axiom of physics that "nothing infinite can be moved" and concluded that the heavens would come to rest. He added that immobility is nobler and more godlike than instability and so should belong to the sky rather than to the earth.

These arguments will strike the modern reader as, to say the least, implausible. The statement, which we read all too often, that Copernicus proved that the earth moves round the sun is simply not true. Nevertheless, sun-at-rest astronomy completely superseded the earth-at-rest astronomies described so far. Why?

In a quite trivial sense, any geostatic theory is equivalent to a heliostatic theory and vice versa. If we make a scale model in a flat box of a geostatic solar system, driven perhaps by an electric motor, place it on a smooth table, and hold the sun still, allowing the box to slide around on the table, we obtain a heliostatic system. But if the geostatic system is Ptolemy's or Aryabhaṭa's, the resulting heliostatic system will not make much sense. If, on the other hand, we start with the geostatic system described on page 175 the resulting heliostatic system does make sense. Such a geostatic system was, in fact, proposed by Tycho Brahe and we might say (details aside) that holding the sun still in Tycho's system gives us Copernicus, while holding the earth still in Copernicus's system gives us Tycho.

Modern astronomy is not heliostatic. Although it is convenient, when dealing with the solar system, to consider motion relative to the sun, not to the earth, the sun is not at rest but moves round the center of our Galaxy. Is the center of the Galaxy at rest? The galaxies are certainly moving relative to each other and the question of which, if any, is "really" at rest is meaningless. All motion is relative. In fact, the difference between geostatic and heliostatic systems is not of great technical astronomical importance. Its importance, if any, is theological and philosophical.

Even Galileo had trouble in finding valid reasons for believing that the earth, not the sun, moved. He was reduced to citing the tides, which he thought were caused by the motion of the earth, like water sloshing round in a tub carried on a moving cart [148a].