poles that correlate to where the sphere meets the axis of rotation.

HERDSMAN: Exactly. Now, if that axis of rotation lines up with some relatively fixed star in the sky . . . then?

BOY: The North Star!

HERDSMAN: And, where would it be if you stood at the top of the sphere and you wanted to look at the North Star?

BOY: Directly overhead, at the zenith point in the sky?

HERDSMAN: Then, where would it be if you stood at the half-way point between the poles on the surface of the sphere?

BOY: I suppose it would be straight out at the horizon.

HERDSMAN: And, if you walked a little more than half-way up between the middle and the top, say 50 degrees up from the middle?

BOY: I think I need to draw it out in the dirt.

HERDSMAN: Nonsense! You are a Greek: you need to be able to do geometry in your head. Just think about it and you will get it.

BOY: Okay, I will. But, do you think that I am ready to learn about something that I heard some of the older shepherds talking about, called "the retrogradations of the wandering stars"?

HERDSMAN: Are you familiar with the Pythagorean student of Archytas by the name of Eudoxus?

BOY: Indeed, he is the mathematician from Cnidos who attends all of Platon's lectures at the Academy at Athens.

HERDSMAN: Well, you do seem to be familiar with him. But one thing you may not know is, that he is now studying astronomy in Egypt with the priests of Heliopolis, and just before he left he had discussions on this very subject with one of the oldest herdsman I know.

BOY: And you were present when these dialogues took place?

HERDSMAN: Not exactly, but I do from time to time run into that old herdsman, and he has been more than happy to repeat for me the discussions in their entirety.

BOY: Could you?

HERDSMAN: Could I what?

BOY: Could you repeat those conversations, so that I might be enlightened?

HERDSMAN: I could and would, so long as I can remember them, that is. For as of this very moment, I am not entirely certain that I will be able to fully recall them.

BOY: Well, by Zeus, I hope you can remember.

HERDSMAN: For your sake, my son, and mine too, I hope I can as well.

Kepler and Tycho Brahe

TYCHO: On this instrument, a small quadrant of gilded brass, where there would otherwise be a blank surface, I had an artist paint a young man, wreathed in laurel, sitting on a square stone near a tree that is green and leafy on one side. In one hand he holds a celestial globe, and in the other a book, all the while stretching his feet out upon the green grass and herbs that cover the root of the tree.

KEPLER: Yes, it all looks very beautiful—and expensive.

TYCHO: I must admit, Johannes, that over the past few months you have done a most excellent job in assisting

Mathematical

In *The New Astronomy,* Johannes Kepler demonstrated that Ptolemy's, Copernicus's, and Tycho Brahe's planetary systems gave exactly the same computational results, so there was no way to tell which one was true. Despite the fact that all three were radically different, there was a common error that pervaded them. All three were mathematical models for the purpose of predicting the motions of the planets, while making no attempt to discover the physical causes. Consequently, all three imposed the mathematics of perfect circles and uniform motion onto the planetary

me in calculating my observations of the stars.

KEPLER: M'lord Tycho, sir, you were there as well.

TYCHO: When you submitted your book *Mysterium Cosmographicum* to me, some time back—I believe it was about four years ago, in 1596 or 1597—I said to myself, "What a mind on this young lad! But he needs the help and experience of a nobleman." I still can't believe that teacher of yours tried to hide you from me. My good friend . . . what's his name?

KEPLER: Michael . . . Michael Maestlin.

TYCHO: Right. When I was still doing observations in Hven, if you recall, on my pretty little island, in the palace which I called Uraniborg, where I had many more people on my staff.

KEPLER: Yes, I remember. Lord Christian IV, after the death of his father, Frederick II, sought to harm your comfort of place. Lord Christian, unlike his father, held you in low esteem, took the gold that fed your mistress Uraniborg, and soon you had to close down, all because you refused to repair the chapel of the Magi at Rokilde.

TYCHO: That ungrateful child, all the things I did for that court he refused to recollect. Let him lose the best thing he ever had! *Me!*

KEPLER: You do speak of yourself quite often, and well.

TYCHO: Yes, I do. Have I mentioned that, because I am an artist, I make instruments, and map that which is logically perfect: the heavens? These works of art

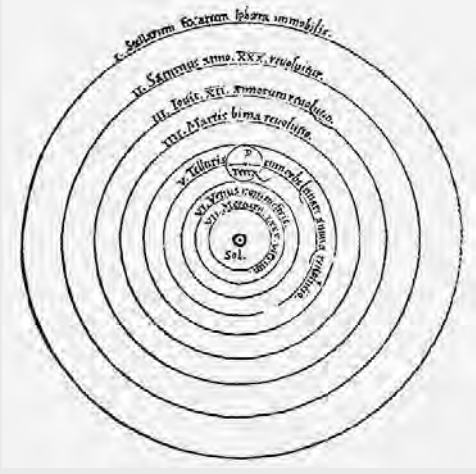
Models vs. Truth

orbits, when the physical observations showed otherwise. Kepler's investigation of physical causality—the "intention" of the Creator—led him to the discovery that the planetary orbits were elliptical.

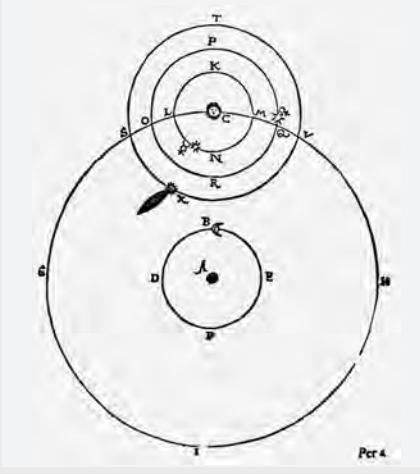
(a) The Ptolemaic system, with the Earth at the center and all the planets and the sun moving around it in perfect circles. (b) The Copernican system, with the sun at the center, and all the planets, including the Earth, moving around it in perfect circles. (c) The system of Tycho Brahe, in which the Earth is at the center, and all the planets move about the sun in perfect circles, while the sun moves about the Earth in a perfect circle.

—Bruce Director

(a) Ptolemaic system: Earth-centered.



(b) Copernican system: sun-centered.



(c) System of Tycho Brahe: mixed Earth- and sun-centered.