the true death knell of the geocentric model was sounded by Galileo's observation in 1610 of the moons circling the planet Jupiter. Like Copernicus, who avoided exposing his radical ideas to any but a few fellow astronomers until they were published posthumously in his epic *De Revolutionibus*, Galileo had feared opposition by the church until his friend Cardinal Barberini ascended to the papacy as Urban VIII. Regrettably, Galileo's maladroitness in court politics led his enemies to denounce him to Pope Urban, who was then currying favor with Protestant princes. The pope issued an edict requiring that Galileo recant his support of the heliocentric model.

As the popular version has it, opposition to the Copernican heliocentric model, both by religious leaders and by some outspoken academics, was based on several factors. Primarily, though, it was based on opposition to any change in the accepted Aristotelian beliefs and adherence to the status quo that has bedeviled scientific innovation to the present day.

Leonid V. Azaroff
(leeazaroff@comcast.net)
University of Connecticut
Storrs

It is important to get the history right when we are teaching physics. I feel compelled to point out, though, that in attempting to correct physicists' understanding of the history, Mano Singham's article "The Copernican Myths" actually creates a new myth: namely, the idea that physicists distort history when they present the development of the heliocentric solar system.

Singham begins with a "breezy version of the Copernicus story," supposedly the version related in numerous physics textbooks, and then informs us that, "apart from the final sentence, not much" of that version is true. He only gives one reference for the "breezy" version: the introductory text by Paul Fishbane and coauthors.[1] If we check the pages Singham references, however, almost nothing of that version can be found. On page 1, Fishbane and coauthors write, "Blind reverence for authority impedes scientific progress," but they clearly have in mind the issue of scientific, not religious, authority.

Little of Singham's version of the "myth" can be discerned in the other pages of Fishbane and coauthors referred to by Singham (pages 320 and 321). Religious authority is not mentioned at all. Fishbane and his coauthors could be faulted for their apparently derogatory use of the phrase "culturally imposed belief"—couldn't we equally well say that Paul Dirac's theory of the electron was based on a culturally imposed belief in differential equations?—but their history, brief as it is, is essentially correct.

I have checked the other introductory physics texts on my shelf, and I find even less of Singham's "breezy" picture in those books. I can only conclude that Singham's version is a straw man, an invention of Singham's. The "Copernican myths," it seems, are completely mythical.

Historical context can be useful in introductory physics as a way to motivate discussion of a topic and to provide color and promote interest. Teachers and authors should certainly strive to present history correctly. But it is a disservice to textbook authors to ascribe to them errors they did not commit. And there is no point in creating new myths in the attempt to correct the old ones.

Reference

1. P. Fishbane, S. Gasiorowicz, S. Thornton, *Physics for Scientists and Engineers*, 2nd ed., Prentice Hall, Upper Saddle River, NJ (1996).

Robert N. Oerter
(roerter@gmu.edu)
George Mason University
Fairfax, Virginia

The persistence of myths in the history of science is demonstrated by the fact that even Mano Singham's article is not free of them. He mentions Martin Luther's alleged statement against heliocentrism in 1539 as one of the prominent voices of the Protestant opposition to Copernicus's ideas. In the most frequently quoted version of that statement, Luther is alleged to have branded Copernicus as a fool who will turn the whole science of astronomy upside down. However, historian of science Andreas Kleinert from Martin Luther University in Halle, Germany, has shown that "the famous citation from Luther's table talks is next to worthless as an historical source, that Luther never referred to Copernicus or to the heliocentric world system in all his voluminous writings, and that there is no indication that Luther ever suppressed the Copernican viewpoint."[1] Luther was not responsible for the Protestant opposition to Copernicanism, nor did he lead a crusade against it. His opinion about the heliocentric system was indifferent or ignorant but not hostile.

Reference

1. A. Kleinert, *Berichte z. Wissenschaftsgesch.* **26**, 101 (2003).

Michael Schaaf
(michael_schaaf@hotmail.com)
Finnentrop, Germany

At the end of his historical account, Mano Singham observes, "The story of the Copernican revolution shows that the actual history of science often bears little resemblance to the popular capsule versions." In the case of the Copernican revolution, that is particularly true, because the heliocentric model of the solar system, although frequently attributed to Copernicus, is actually from an ancient Greek astronomer, Aristarchus of Samos (circa 310–230 BC).[1]

In view of religious criticisms of Copernicus, it is particularly interesting to note that Aristarchus was criticized by Cleanthes the Stoic, who said that Aristarchus should be charged with impiety, as Plutarch wrote, albeit many years later.[2] So not only did Aristarchus anticipate Copernicus, but Cleanthes the Stoic anticipated the criticism of Martin Luther's lieutenant, Philipp Melanchthon, who, as Thomas Kuhn reports, recommended that severe measures be taken to restrain the impiety of the Copernicans.[3] Most students, before taking a course in astronomy or in the history of science, don't know about Aristarchus, although they have all heard about Copernicus. Even Stephen Hawking, in *A Brief History of Time* (Bantam Books, 1988), makes no mention of Aristarchus of Samos.

About 100 years after Aristarchus, Seleucus the Babylonian, a major astronomer of his time, proclaimed that Aristarchus's heliocentric model was not just hypothetical but true. Seleucus, not unexpectedly, also came in for criticism because he advocated the heliocentric model.

Presentations of the history of astronomy and physics should give more recognition to these pre-Copernican astronomers; otherwise, we are simply perpetuating another myth. It would be more appropriate to emphasize that Copernicus's great and enduring accomplishment was that he got the heliocentric model moving forward again after it had been held back for 1800 years. Properly highlighting Aristarchus's contribution also serves to illustrate that science can undergo retrograde motion in its development, as indicated by the enormous length of time the Ptolemaic model held sway, despite the fact that approximately 300 years before Ptolemy, the physically more insightful model of Aristarchus had been proposed.

References

1 T. Heath, *Aristarchus of Samos, the Ancient Copernicus*, Clarendon Press, Oxford, UK (1913); reprinted by Dover, New York (1981).
2. Plutarch, *On the Face in the Moon's Orb*, cited in ref. 1.
3. T. Kuhn, *The Copernican Revolution: Planetary Astronomy in the Development of Western Thought*, Harvard U. Press, Cambridge, MA (1957).

Frank R. Tangherlini
(frtan96@sbcglobal.net)
San Diego, California

I suggest an additional myth to Mano Singham's delightful account. That is the myth that the heliocentric theory was conceived by Copernicus with no precedent. In the third century BC, Greek astronomer Aristarchus of Samos postulated the theory. He had correctly calculated the size of the Moon and its distance from Earth. He also calculated the Sun's size and its distance from Earth, but his results for the Sun were far wrong because he lacked instruments to correctly obtain an angular measurement. Nevertheless, those calculations apparently led him to the idea that Earth revolves around the Sun. Aristarchus also concluded that the fixed stars were almost infinitely far away, and he thus explained the lack of parallax in our solar circumnavigation. So he essentially had the big picture.

Copernicus mentioned Aristarchus in earlier versions of his text, but he later deleted such mention.

Paul Dickson
(pwdickson@bellsouth.net)
Aiken, South Carolina

The article on Copernican myths was interesting in baring the tendency of physicists to rewrite their histories, but it is clear there are other myths that even Mano Singham perpetuates. In the Ptolemaic system, the planets did not move uniformly in circles about Earth. The motion of a planet was in two circles: an epicycle on which the planet moves, and a main cycle on which the center of the epicycle moves. Although both were circles, neither centered on Earth. The main cycle was centered on a point displaced from Earth, depending on the planet. Furthermore, although the motion on the cycle was uniform, it was only so (equal angles in equal time) around the equant, a point at equal distance on the other side of the center of the circular orbit as the center is from Earth.

As Julian Barbour emphasized in his brilliant book *The Discovery of Dynamics* (Oxford University Press, 2001), these features of the main cycles are just Johannes Kepler's first two laws, to first order in the eccentricity of the ellipse. An ellipse is a circle to first order. Earth and the equant are the two foci of the ellipse, and the uniform rotation about the equant (second focus) is Kepler's second law (equal areas in equal times about the first focus) to first order. That is, the Ptolemaic system was, in many respects, closer to our modern description of the heavens than was the Copernican, which eliminated the equant and off-center circle.

Copernicus explained one great puzzle of the Ptolemaic system. The angle of the Sun around its orbit, the angle of the epicycle center around the major cycle (circular orbit) of the inner planets, and the angle of the outer planets in their epicycle were all the same at all times.

Copernicus recognized that if one scaled all the orbits appropriately, and made the Sun rather than Earth the center, then all those cycles with identical angles disappeared, leaving the planets in much simpler orbits around the Sun. That scenario also created a solar orbit for Earth around the Sun. The collapse of the number of parts of the orbits was the great advance. In achieving it, Copernicus had established a relative scale for the whole solar system.

But with that step forward, Copernicus took at least one large one backward, from our point of view. He got rid of the baggage of the offset orbit center and the equant and thereby destroyed the ellipticity of the Ptolemaic orbits. He thus had to introduce additional epicycles to explain what the Ptolemaic system explained automatically. Had he retained the equants, the Copernican system would have been simpler, with fewer epicycles than the Ptolemaic. It was 60 years before Kepler, in positing his elliptical orbits, restored and improved on the equants.

One could even argue that the centrality of Earth in the Ptolemaic system followed naturally from observation. If Earth moved, one would expect the stars, if they were bodies at different distances from Earth, to exhibit parallax. To the naked-eye accuracy of about one minute of arc, no stellar parallax is visible. Is it more sensible to postulate that the stars are at least a million times farther away than the Sun, or that Earth does not move? The latter, as emphasized by