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The Popular Creation Story of Astronomy Is Wrong

The old tale about science versus the church is wide of the mark.

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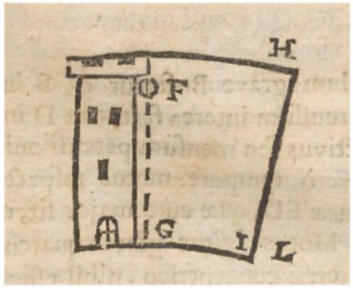
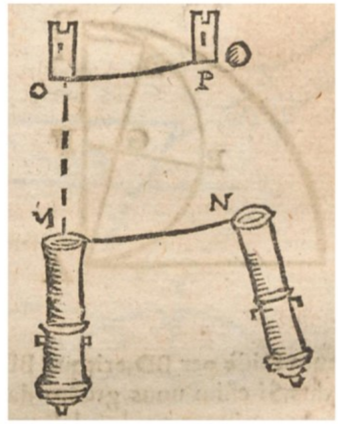
MAY 17, 2018

In the early years of the 17th century, Johannes Kepler argued that the universe contained thousands of mighty bodies, bodies so huge that they could be universes themselves. These giant bodies, said Kepler, testified to the immense power of, as well as the personal tastes of, an omnipotent Creator God. The giant bodies were the stars, and they were arrayed around the sun, the universe's comparatively tiny central body, itself orbited by its retinue of still tinier planets.

This strange view of the universe held by Kepler, the innovative astronomer who set the stage for Isaac Newton and the advent of modern physics by freeing astronomy from the perfect circles of Aristotle and working out the elliptical nature of orbital motion, was held by a number of early supporters of Nicolaus Copernicus and his heliocentric ("sun-centric") theory. Kepler's view was the view that science—repeatable observations of the stars and rigorous mathematical analysis of the data gleaned from those observations—demanded. It was also the Achilles' heel of the Copernican theory. Astronomers who maintained that the Earth sits immobile, at the center of the universe, attacked the giant stars as an absurdity, concocted by Copernicans to make their pet theory fit the data. The story of this "giant stars" view of the universe has been all but forgotten.

SPIN CLASS: These illustrations are manifestations of the Coriolis Effect, a force acting on most anything moving on the surface of a rotating sphere. They were drawn by 17th-century Jesuit, Claude Francis Milliet Dechales, who used them as part of an argument against Earth's motion. The illustration on the left shows a ball (F) being dropped from a tower. If the Earth is not rotating, the ball just drops from F to G. If Earth is rotating, then because the top of the tower is farther from the center of Earth than the bottom, the top will move farther during the ball's fall than will the bottom: the top ends up at H, while the bottom ends up at I. So the ball, which is moving at the speed of the top when released, won't land at I, but at point L. The ball will not fall straight to the bottom of the tower on a rotating Earth. The illustration at right is the same idea, but for a projectile. A cannon fires at a target to the north. If Earth is not rotating, the ball flies straight to hit the point the cannon is aimed at. If the Earth is rotating, then the cannon, being closer to the equator than the target, is moving to the right faster than the target, as is the ball coming out of the cannon. So, the ball does not hit the mark, but goes to the right and misses. In either case, Earth's rotation should be detectable. The argument was that, since deflection was not detectable, then the Earth must not rotate. The anti-Copernicans were dead right. But detecting the effects turned out to be a lot more complicated than it seemed at the time.

That is unfortunate. The story of Kepler and the giant stars illustrates a robust dynamism present in science from its very birth. That dynamism stands in contrast to the usual tales we are told about the birth of science, stories portraying the debates around the Copernican theory as occasions when science was suppressed by powerful, entrenched establishments. Stories of scientific suppression, rather than scientific dynamism, have not served science well. The story of giant stars does.

Johannes Kepler laid out his ideas about giant stars in a book he wrote in 1606 called *De Stella Nova* or *On the New Star*. The book was about a *nova*, a new star that simply appeared for a while in the sky in 1604. According to Kepler, the nova outclassed all the other stars, rivaling even Sirius, the brightest of all the stars that regularly adorn the night sky. In *On the New Star*, Kepler addressed the size of the nova, concluding that its girth substantially exceeded that of the orbit of Saturn (the most distant planet known at the time). Sirius was similarly huge, and even the smallest stars were larger than Earth's orbit.

The stars were in fact the size of universes. Kepler's former boss, Tycho Brahe, had proposed a theory of the universe which borrowed from Copernicus, but which kept Earth fixed in place at the center of the universe. Before his death in 1601, Brahe had been the "Big Science" of his day, with a big observatory, the best instruments, lots of top-notch assistants (such as Kepler), his own publishing operation, and lots of money. The sun, moon, and stars circled the immobile Earth in Brahe's geocentric ("Earth-centric") theory, while the planets circled the sun. The stars were located just beyond Saturn, marking the edge of the observable universe. Kepler's sizes for the nova and Sirius were larger than Brahe's whole universe, while his sizes for lots of other stars were comparable to such a universe.

Why would Kepler say that stars were universe-sized? Because the data said they were, at least if the heliocentric theory was right. In that theory, Earth circles the sun yearly. So, if at one time of the year it is moving toward a certain star, six months later it will be moving away from that same star. We might expect to see some stars growing brighter throughout the spring on account of Earth approaching them, and then growing dimmer throughout the fall. There is a name for this sort of effect: *parallax*. But no one could see any parallax. Copernicus had an explanation for this: The orbit of the Earth must be like a tiny point by comparison to the distance to the stars. Earth's orbit was negligible in size as regards the stars, and Earth's motion was negligible in effect. As Copernicus had put it, "that there are no such [parallax] appearances among the fixed stars argues that they are at an immense height away, which makes the circle of [Earth's] annual movement or its image disappear."

A problem lies in this negligible size and immense distance. People who have good vision and look up at the sky will see the stars as little round dots, with small but measurable apparent sizes. Astronomers dating all the way back to Ptolemy during the second century had determined that the more prominent of those star dots measure somewhere in the range of one-tenth to one-twentieth the diameter that the round moon appears to be. In *On the New Star*, Kepler said bright stars measure one-tenth the moon's diameter, Sirius a bit more. The problem is, a star that appears one-tenth the moon's diameter when seen in the sky would be one-tenth the moon's true physical diameter only if it was the same distance away from us as the moon. But stars are more distant than the moon. Were that star then 10 times more distant than the moon, its true size would be the same as the moon—it would only appear one-tenth the moon's size on account of greater distance. Were that star 100 times more distant, its true diameter would be 100 times that of the moon. Were it 1,000 times farther away than the moon, its true size would be 1,000 times larger.

And what if that star, which appears to be one-tenth the diameter of the moon, were at the distance the Copernican theory required in order for there to be no detectable parallax? That star would be, Kepler said, as big as the orbit of Saturn. And every last star visible in the sky would be at least as big as the orbit of Earth. Even the smallest stars would be orders of magnitude larger than the sun. This may seem strange to us today, because we know now that stars come in many sizes, and while a very few are larger than Earth's orbit (the star Betelgeuse in Orion being a prominent example), the vast majority are "red dwarfs" that are far outclassed by the sun. However, in Kepler's time this was a simple matter of observation, measurement, and math—the ordinary stuff of science. An astronomer of that time who believed Copernicus, believed the measurement data, and believed math, simply had to believe that all the stars were huge. (More on where they went wrong, in a moment).

The case for huge stars was so solid that the details regarding the measurements of them did not matter. Johann Georg Locher and his mentor Christoph Scheiner would neatly summarize the giant stars problem in their 1614 astronomy book *Disquisitiones Mathematicae* or *Mathematical Disquisitions*. They wrote that in the Copernican theory the Earth's orbit is like a point within the universe of stars; but the stars, having measurable sizes, are larger than points; therefore, in a Copernican universe every star must be larger than Earth's orbit, and of course vastly larger than the sun itself.

Because of the giant stars, Locher and Scheiner rejected the Copernican theory, and backed Brahe's theory. That theory was compatible with the latest telescopic discoveries, such as the phases of Venus that showed it to circle the sun. In Brahe's theory, the stars were not so far away—just past Saturn. An astronomer in Kepler's time who believed Brahe, believed the measurement data, and believed math, did not have to believe that the stars were huge. (Brahe had calculated that they ranged in size between the larger planets and the sun.) Locher and Scheiner were not alone—for many astronomers, including Brahe himself who first raised the issue, the giant stars were just too much.

But Kepler had no problem with giant stars. For him, they were part of the overall structure of the universe; and Kepler, who saw ellipses in orbits and Platonic solids in the arrangement of the planets, always had an eye out for structure. He saw the giant stars as an illustration both of God's power and of God's intent in putting the universe together. In discussing the parts of the universe—the stars, the solar system (the system of the "movables," as Kepler calls them), and the Earth—the words of *On the New Star* rise almost to the level of poetry, even in translation.

> *Where magnitude waxes, there perfection wanes, and nobility follows diminution in bulk. The sphere of the fixed stars according to Copernicus is certainly most large; but it is inert, no motion. The universe of the movables is next. Now this—so much smaller, so much more divine—has accepted that so admirable, so well-ordered motion. Nevertheless, that place neither contains animating faculty, nor does it reason, nor does it run about. It goes, provided that it is moved. It has not developed, but it retains that impressed to it from the beginning. What it is not, it will never be. What it is, is not made by it—the same endures, as was built. Then comes this our little ball, the little cottage of us all, which we call the Earth: the womb of the growing, herself fashioned by a certain internal faculty. The architect of marvelous work, she kindles daily so many little living things from herself—plants, fishes, insects—as she easily may scorn the rest of the bulk in view of this her nobility. Lastly behold if you will the little bodies which we call the animals. What smaller than these is able to be imagined in comparison to the universe? But there now behold feeling, and voluntary motions—an infinite architecture of bodies. Behold if you will, among those, these fine bits of dust, which are called Men; to whom the Creator has granted such, that in a certain way they may beget themselves, clothe themselves, arm themselves, teach themselves an infinity of arts, and daily accomplish the good; in whom is the image of God; who are, in a certain way, lords of the whole bulk. And what is it to us, that the body of the universe has for itself a great breadth, while the soul lacks for one? We may learn well therefore the pleasure of the Creator, who is*

author both of the roughness of the large masses, and of the perfection of the smalls. Yet he glories not in bulk, but ennobles those which he has wished to be small.

In the end, through these intervals from Earth to the sun, from sun to Saturn, from Saturn to the fixed stars, we may learn gradually to ascend toward recognizing the immensity of divine power.

Other Copernicans shared Kepler's views. Copernicans like Thomas Digges, Christoph Rothmann, and Philips Lansbergen, spoke of the giant stars in terms of God's power, or God's palace, or the palace of the Angels, or even God's own warriors. And Copernicus himself had invoked the power of God in discussing the immense distances of the stars, noting "how exceedingly fine is the godlike work of the Best and Greatest Artist."

The anti-Copernicans were unpersuaded. Locher and Scheiner noted that Copernicus's "minions" did not deny that stars had to be giant in a Copernican universe. "Instead," the two astronomers wrote, "they go on about how from this everyone may better perceive the majesty of the Creator," an idea they called "laughable." One anti-Copernican astronomer, Giovanni Battista Riccioli, wrote that calling in divine power to support a theory "cannot satisfy the more prudent men." Another, Peter Crüger, regarding the size of stars, commented, "I do not understand how the Pythagorean or Copernican System of the Universe can survive."

The anti-Copernicans were not just the Party of No. Locher and Scheiner reported telescopic discoveries. They urged that astronomers engage in programs of systematic telescopic observations in order to use eclipses of Jupiter's moons to measure the distance to Jupiter, and to use Saturn's "attendants" (not yet understood to be rings) to probe Saturn's motion. They worked out an explanation for how Earth might orbit the sun: by continually falling toward it, just as an iron ball might continually fall toward Earth. (This insight came decades before the birth of Newton, who would give us our modern explanation of an orbit being a kind of fall, and who would explain orbits by means of a cannon ball being fired from atop a mountain.) They also investigated the question of how any rotation of Earth might influence the trajectories of falling bodies and projectiles. In fact, other 17th-century anti-Copernicans like Riccioli would develop this idea further, theorizing about what today we call the "Coriolis Effect" (which bears the name of the scientist who described it in the 19th century) and arguing that the absence of any such effect was another piece of evidence indicating that Earth in fact does not move.

When we learned in school about the Copernican Revolution, we did not hear about arguments involving star sizes and the Coriolis Effect. We heard a much less scientifically dynamic story, in which scientists like Kepler struggled to see scientifically correct ideas triumph over powerful, entrenched, and recalcitrant establishments. Today, despite the advances in technology and knowledge, science faces rejection by those who claim that it is bedeviled by hoaxes, conspiracies, or suppressions of data by powerful establishments.

But the story of the Copernican Revolution shows that science was, from its birth, a dynamic process, with good points and bad points on both sides of the debate. Not until decades after Kepler's *On the New* Star and Locher and Scheiner's *Mathematical Disquisitions* did astronomers begin to come upon evidence suggesting that the star sizes they were measuring, either with the eye or with early telescopes, were a spurious optical effect, and that stars did not need to be so large in a Copernican universe.

When the usual story of the Copernican Revolution features clear discoveries, opposed by powerful establishments, we should not be surprised that some people expect science to produce quick, clear answers and discoveries, and see in scientific murkiness the hand of conspiratorial establishments. We might all have a more realistic expectation of science's workings if we instead learned that the Copernican Revolution featured a dynamic scientific give and take, with intelligent actors on both sides—and with discoveries and progress coming in fits and starts, and sometimes leading to blind alleys such as Kepler's giant stars. When we understand that the simple question of whether the Earth moved posed scientifically challenging problems for a very long time, even in the face of new ideas and new instruments, then we will understand better that scientific questions today may yield complex answers, and those only in due course.

Christopher M. Graney is the author of Mathematical Disquisitions: The Booklet of Theses Immortalized by Galileo*, a translation of Locher and Scheiner's original Latin work. He encourages support for the humanities, because science needs Latinists and historians who can do a better job of translating and analyzing early scientific works than he, a physicist, can do.*