Johannes Kepler, Giordano Bruno, and Scientific Martyrdom

BY CHRISTOPHER GRANEY

How do we cope with today's problem of truth? Our instincts might incline us to cope through gathering with friendly minds to tell familiar stories about what truth is and how we are the ones who recognize it. But what if those stories turn out to illustrate that the problem of truth is longstanding, even when those stories are about objective truth, such as truth revealed by science?

One of the most famous of such stories is that of Giordano Bruno, the supposed martyr to science.[1] Bruno was burned alive in Rome in 1600—scorched, the story goes, for his ideas about the stars being other suns, orbited by other earths. "It was because the philosophical astronomer, Giordano Bruno, asserted these distant suns to be centers of other systems that the Inquisition caused him to be burned alive at Rome before the terrified people." So wrote Camille Flammarion, a prominent science writer of the later 19th century.[2] In his 2015 *The Invention of Science,* David Wootton describes Bruno as having been subject to years of solitary confinement and prolonged torture before finally being burned, as "he had refused to recant his heresies, including his belief in other inhabited worlds." Bruno matters, says Wootton, because of the truth of his ideas:

> because he was, on occasion, *right*.... [W]e now know that the sun is a star, that other stars have planets.... We are not at the center of the universe: rather, the Earth is just another planet. Bruno would find himself more at home in our universe than would Cardinal Bellarmine, the man who played the key role in his trial, as he played the key role in the Catholic Church's condemnation of Copernicanism in 1616. On crucial points Bruno was *right* before anyone else....[3]

Of course, Bruno *was right* about that particular matter of science. The first episode in Neil deGrasse Tyson's 2014 reboot of Carl Sagan's and Ann Druyan's television series *Cosmos* contained within it a short, animated feature on Bruno.[4] The climax was a confrontation between Bruno and a cartoon churchman—Bellarmine, presumably—and the churchman's supporting band of robed uglies who condemn Bruno. Presumably, the story would have been less relevant to a science series such as this had he been burned at the stake for some other offense. In point of fact, Bruno said a number of things that many people of his time found deeply offensive, most of which had nothing to do with science. Note Wootton's reference to "heresies," plural. Whether Bruno's advocacy of other suns and earths actually played any part in his condemnation is a subject that historians have

Giordano Bruno (left) and Johannes Kepler (right). Image credits: Wikimedia Commons.

considered, given his skepticism of the central tenets of Christianity, such as "holding opinions contrary to the Catholic faith" in denying the divinity of Christ, the virginity of Jesus' mother Mary, transubstantiation, and others.

But let us suppose for the moment that Flammarion's assessment is correct, and it was just for his advocacy of the plurality of worlds that Bruno was condemned. As it happens, even under this supposition, Giordano Bruno could never have been a martyr to science. His ideas about other worlds, for which he was supposedly burned, were contrary to science. Indeed, they were contrary to what persons with even a rudimentary understanding of astronomy could see with their own eyes. One person who pointed this out was the astronomer Johannes Kepler.

Kepler argued that Bruno was entirely mistaken about the stars. Like Bruno, Kepler supported Copernicus's idea that the Earth, along with Venus, Mars, Jupiter, etc. orbited the sun. Indeed, Kepler is the genius who worked out the laws of orbital motion for these bodies, laws we still use today. But Kepler rejected the idea that stars were other suns. Why? Not because he was insufficiently bold, or excessively attached to traditional ideas. In developing those laws, he had boldly set aside ideas about celestial objects and perfect circles to which astronomers had been attached for over two millennia. No, the reason Kepler gave for rejecting the idea that stars were other suns was because observations, measurements, and calculations—science, if you will—showed that they could not be suns.

Kepler explained this in an essay he wrote to Galileo in 1610.[5] Noting Galileo's description of the appearance of stars as seen through the telescope, Kepler says that Galileo's observations indicate that "the fixed stars generate their light from within, whereas the planets, being opaque, are illuminated from without; that is, to use Bruno's terms, the former are suns, the latter, moons or earths." Kepler grants to Bruno that stars are like the sun insofar as they generate their own light. But that is all he grants Bruno, for he then continues,

> Nevertheless, let him [Bruno] not lead us on to his belief in infinite worlds, as numerous as the fixed stars and all similar to our own.... You [Galileo] do not hesitate to declare that there are visible [with a telescope] over 10,000 stars.... Suppose that we took only 1000 fixed stars, none of them larger than *1'* (yet the majority in the catalogues are larger).

This measurement of *1'* that Kepler gives is *one minute of arc*, one 30th the apparent diameter of the full moon in the night sky. Kepler continues:

> If these were all merged in a single round surface, they would equal (and even surpass) the diameter of the sun. If the little disks of 10,000 stars are fused into one, how much more will their visible size exceed the apparent disk of the sun? If this is true, and if they are suns having the same nature as our sun, why do not these suns collectively outdistance our sun in brilliance? Why do they all together transmit so dim a light...? When sunlight bursts into a sealed room through a hole made with a tiny pin point, it outshines the fixed stars at once. The difference is practically infinite.... Will my opponent tell me that the stars are very far away from us? This does not help his cause at all. For the greater their distance, the more does every single one of them outstrip the sun in diameter.

Kepler makes three important points about stars here. The first pertains to their apparent sizes. When he refers to how "large" stars appear, he is referring to the fact that, when people with excellent vision look up at the stars, they see dots of light of varying size. People with weaker eyes may see stars as being spiked with flares or looking like fuzzy balls; Kepler writes that, to his own weak eyes, "any of the larger stars, such as Sirius [the most prominent of the naked-eye stars in our night sky]... seems to be only a little smaller than the diameter of the moon." However, to those with clear eyes, Sirius is a bright dot, much smaller than the moon, yet slightly larger than the stars Betelgeuse and Rigel that mark nearby Orion's upper left shoulder and lower right knee; these in turn appear larger than the stars that mark Orion's belt; and the belt stars appear larger than the stars that comprise the Pleiades that Orion faces. When clear-eyed people try to ascertain the size of those dots, they find that the brighter ones appear to have a diameter at least one thirtieth that of the moon—at least *1'*. Astronomers ranging from the ancients right up to Kepler's late boss, Tycho Brahe, had measured the apparent sizes of the stars. They consistently reported that the most prominent stars measured at least *1'*, and thus Kepler's reference to "the majority in the catalogues."

The second point Kepler makes pertains to the light of the stars. He is saying that their light is inherently weaker than the sun's. They cannot be suns that just appear small on account of distance. Distance makes objects appear smaller, but not weaker in light. Imagine standing on a beach, or in a grassy field in a park. A square foot of the ground's surface

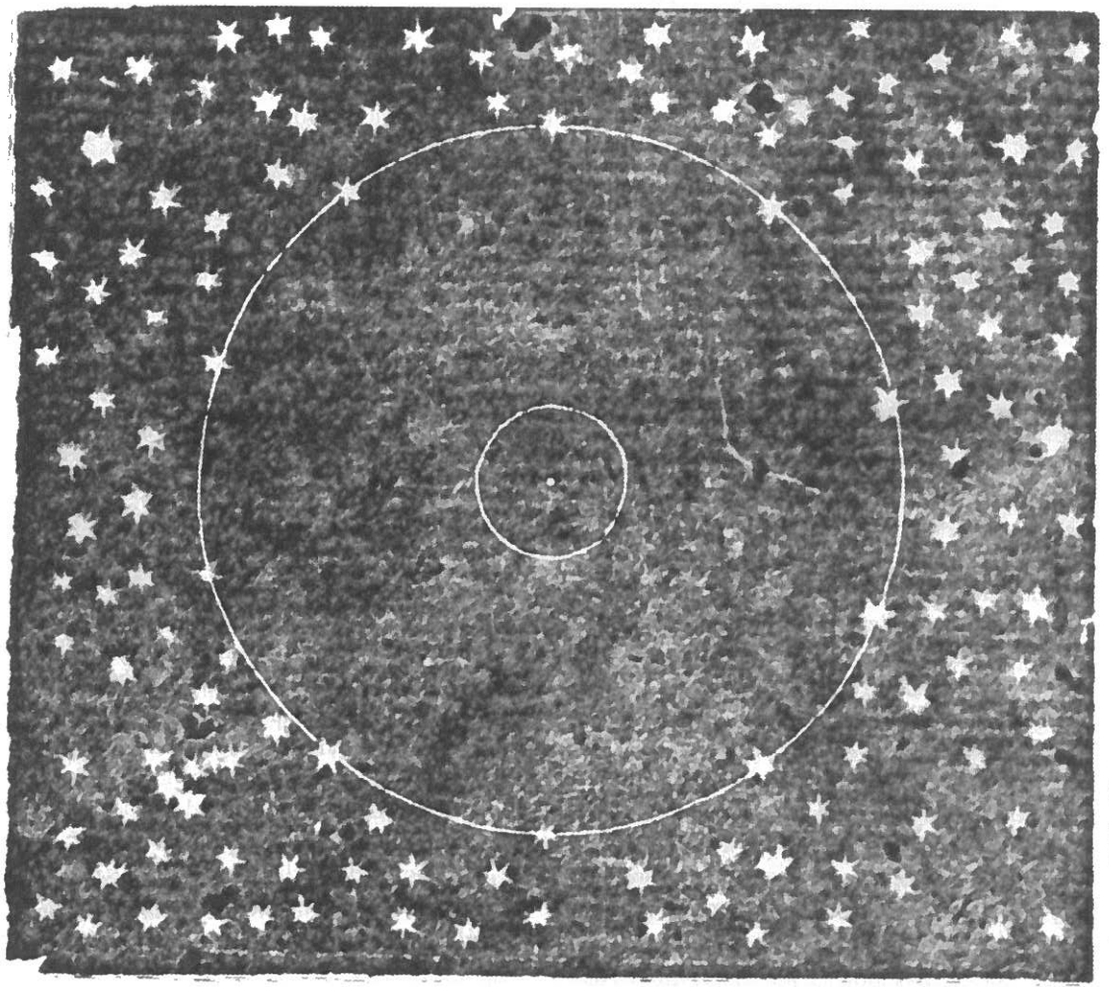


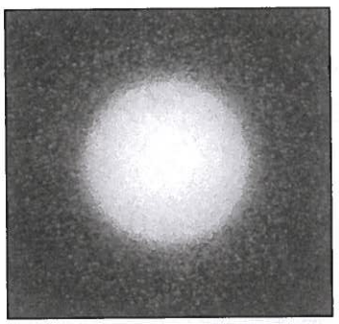
Diagram of the universe of stars from Kepler's *Epitome of Copernican Astronomy,* showing a small sun (the dot at the center) surrounded by large stars. Image credit: ETH-Bibliothek Zürich, Alte und Seltene Drucke.

appears no dimmer to you on account of it being farther away from you. If it did, then the ground would fade to dark as you looked farther and farther out along that beach or field. It does not. The "surface brightness" of the ground does not depend on distance. The ground is illuminated by the sun, but surface brightness is constant with distance for objects illuminated from within, too—light travel and the rules of geometry that govern it do not change based on how the light is produced.

The surface brightness of stars, then, will not depend on distance, and, as Kepler notes, the surface brightness of stars obviously does not match that of the sun. Add up all those starry dots of light, he says, and you have something that rivals the sun in size but is so much weaker in light output that "the difference is practically infinite." And indeed, modern measurements show it would take *ten billion* Siriuses in the night sky to light up the ground the way the sun does. Kepler is showing us that observation, measurement, and calculation reveal that stars are not suns. *Science*, he is saying, reveals Bruno to be wrong.

But Kepler has a third point to make about the stars. The sun and moon appear nearly equal in diameter, as a solar eclipse so dramatically illustrates. Thus, a star that appears one 30th the diameter of the moon also appears one 30th that of the sun. Here lies the further trouble for Bruno. Imagine that the typical star is in fact another sun—identical to the sun in actual physical bulk. That star would then have to be 30 times more distant than the sun to appear the size it does. That is not possible.

It is not possible because in the Copernican system, the Earth circles the sun annually, moving with respect to the stars. Were stars merely thirty times farther away than the sun, then astronomers like Kepler would have easily detected Earth's



A star as seen through a very small aperture telescope, from John F. W. Herschel's *Treatises on Physical Astronomy.* The star appears as a disk of measurable size, but the image is an entirely spurious product of optics and does not reflect the physical size of the star. This is a telescopic view, but observers using naked eye instruments saw and measured similarly spurious stellar disks, and recorded the measurements in catalogs. Image credit: ETH-Bibliothek Zürich, Alte und Seltene Drucke.

motion by observing them. But in fact, astronomers could detect no sign of any annual motion relative to the stars. Copernicus had said that this was because the stars were so far away that by comparison Earth's annual movement was as nothing; they were much farther away than 30 solar distances.

Now note how Kepler says "the greater their distance, the more does every single one of them outstrip the sun in diameter." For stars to be at the distance required by Copernicus, and still be seen from Earth as dots one thirtieth the diameter of the moon, they would have to be enormous. Kepler calculated that Sirius was larger than the entire solar system, meaning that even the smallest stars visible to the eye had to be the size of Earth's orbit—utterly dwarfing the sun.[6] Kepler has already shown us that stars are not suns as regards light. Now he shows that stars are not suns as regards size.

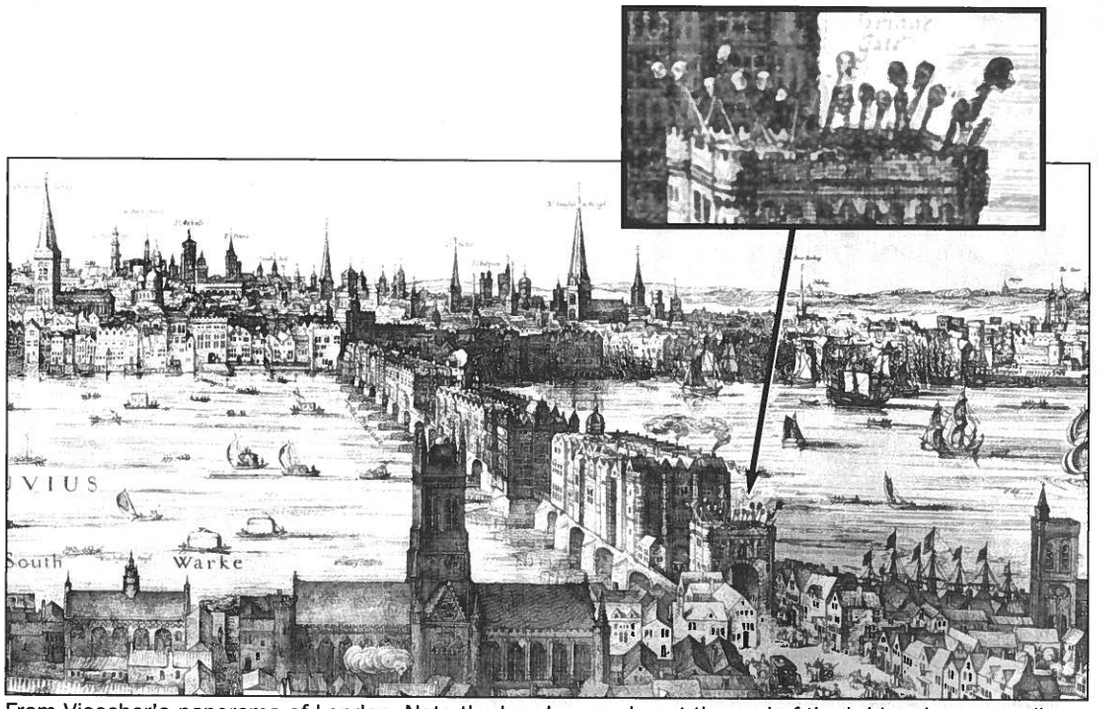
Kepler shows us that the most simple, reproducible observations and measurements, combined with the most basic geometrical calculations, seem to reveal that, contrary to Bruno, stars are not suns. Rather, stars seem to be enormous but dim bodies—utterly dwarfing the sun by size, utterly outclassed by the sun in brilliance. So it follows that while there are many stars in the visible universe, there is only one sun, and thus only one solar system. "It is quite clear," Kepler wrote in his essay to Galileo, "that the body of our sun is brighter beyond measure than all the fixed stars together, and therefore this world of ours does not belong to an undifferentiated swarm of countless others."

Bruno had written of a universe in which "the stars beyond Saturn are…those innumerable suns or fires more or less visible to us around which travel their own neighboring earths."[7] That idea could not stand up to the simplest science. Thus, Bruno could be no martyr to science, even were Flammarion right that Bruno was burned because of what he asserted about other systems of suns and earths.

Bruno was no martyr to science, but rather just one more person caught up in the cruelties of the 17th century, when many people were executed for even relatively petty crimes. Claes Visscher's panorama of London in Kepler's time (following page) illustrates the grimness of that era, showing over a dozen severed heads stuck on poles atop the southern end of London Bridge, there for all to see as they went about their daily business. Theft of a pail of milk could bring the death sentence. A certain 17th-century Welsh milkmaid is said to have escaped such execution only because she could read, and, being sent to America in bondage instead, she would marry an African prince kidnapped into slavery, and eventually teach a future astronomer, her grandson Benjamin Banneker, to read.[8] In such a world, a man burned for refusing to recant heresies that deeply offended his contemporaries would seem sadly unremarkable.

Then how did Giordano Bruno end up being known as a man who was *right* about a matter of *science*? He became *right* because science's history was forgotten. Astronomers in Kepler's time widely debated the nature of stars in a Copernican universe. Even Galileo addressed the issue. The question of enormous star sizes in particular became important. Many astronomers agreed with Kepler that stars in a Copernican universe must be huge; many opposed Copernicanism because they found such stars absurd (if Earth did not move, by contrast, then the stars need be not even 30 solar distances away, and no larger than the sun). Kepler saw no absurdity in enormous stars, by the way: he said that God could create on a huge scale (the stars), yet also shower even the small things in his universe with brilliance (the sun) and life (the Earth) and creativity (human beings). Anti-Copernicans scoffed at such arguments. The debate raged for decades.[9]

But the whole business was moot. The apparent diameters of stars turned out to be spuriously large, an illusion caused by the wave nature of light and other effects; they do not, in fact, reflect the physical sizes of stars at all. It took another century after Kepler before astronomers understood this. By Flammarion's time astronomers, having developed



From Visscher's panorama of London. Note the heads on poles at the end of the bridge. Image credit: Wikimedia Commons.

tools in previous decades to study the nature of light, to measure the distances to stars, and even to determine the compositions of stars and sun both, had powerful scientific evidence saying that stars were suns. The fact that at one time powerful scientific evidence had said that stars were not suns was forgotten. Giordano Bruno ended up being the guy who was *right*, the guy who would find himself at home in our universe. A statue of him was erected in Rome in 1889, with a plaque to that effect. He became a martyr to science, despite his ideas being contrary to what persons of his time possessing even a rudimentary understanding of astronomy could see with their own eyes.

Today, when uncritical and conspiratorial thinking can seem preferred over the methods of science, and truth to belong to whoever can seize the narrative, Giordano Bruno and Johannes Kepler further challenge our ideas of what is true. One of these men was right in his day but is wrong now; the other was the opposite. Science strongly supported one then; it strongly supports the other now. But Bruno and Kepler do illustrate how the process by which we select familiar stories about what truth is can lead us astray; their writings show that their story is not the received narrative, told for the past century and a half by storytellers ranging from Flammarion to *Cosmos*. Bruno and Kepler illustrate that determining what the truth is, even about something objective like science, is a longstanding challenge. S

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