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THE ESSENTIAL GUIDE TO ASTRONOMY

FEBRUARY 2020

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Kepler's Dream, Today's

The great astronomer Johannes Kepler played a central role in the evolution of spaceflight.

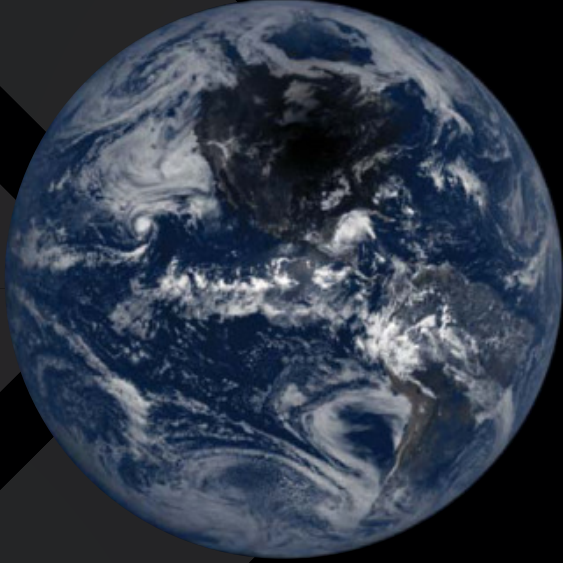
We live in a world made of our ancestor's dreams, where extraordinary feats have become commonplace. Most people alive today have never witnessed a time when we did not capture exquisite images of planets, stars, and galaxies; when we did not regularly shuttle members of our species to a residence orbiting 250 miles above Earth; when we did not plunge spacecraft into the depths of the cosmos, scattering them throughout the solar system and beyond. In the ages before these feats, launching anything into space was mere fantasy, a collaboration of the mind and the pen. Firmly earthbound, we looked up, told stories about far-off worlds, and imagined what it might be like to visit them.

The pathbreaking 17th-century astronomer Johannes Kepler (*S&T*: Aug. 2019, p. 58) authored such a story — a travelogue, an amalgam of science and fiction, detailing a voyage

from Earth to the Moon. His work relates what a journey of this kind entails as people traverse the expanse of space between the two worlds and the discoveries that await them on the other side. It's titled *Somnium (The Dream)*.

The origins of *Somnium* trace back to Kepler's early life. As a student in 1593, he composed a dissertation in which he speculated about the appearance of Earth from the vantage of the Moon. An advocate of the controversial Sun-centered universe, Kepler intended to support one of the theory's assertions: a rotating Earth. Those who opposed heliocentrism maintained that such dramatic movements would be felt or otherwise obvious to the senses. Kepler hypothesized that the apparent motionlessness of Earth is an illusion; the planet spins unbeknown to terrestrial observers because they partake in the rotation. Meanwhile, those same observers witness the Moon traversing the nighttime sky. Kepler

KEPLER'S ECLIPSE DIAGRAM: LIBRARY OF CONGRESS;
ECLIPSE FROM ORBIT: NASA EPIC TEAM; BACKGROUND
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Reality

▲ *Left:* Johannes Kepler was the first scientist to explore in detail how the universe would appear to an observer on the Moon. In this diagram, he shows how a total solar eclipse on Earth would appear from outer space. *Right:* On August 21, 2017, NOAA's Deep Space Climate Observatory fulfilled Kepler's prophecy by photographing a total solar eclipse crossing North America.

► This posthumous portrait of Johannes Kepler was engraved by the 19th-century British illustrator Frederick Mackenzie.



Kepler's Antecedents

Johannes Kepler was one of the most original scientific thinkers of all time. It seems likely that he invented the idea of stationing an observer on the Moon all on his own. But he later encountered some similar ideas in the Greco-Roman authors Plutarch and Lucian, which he ended up referencing extensively in *Somnium*.

Plutarch is best known as a biographer, but he also wrote an influential treatise titled *On the Face Which Appears in the Orb of the Moon*. It dissented from the mainstream Greco-Roman theory that the Moon is a perfect sphere — a theory that struggled mightily to explain the Moon's familiar dark splotches. Instead, Plutarch suggested that the Moon is a complex, irregular world much like Earth and is very likely inhabited.

Two or three generations later, the satirist Lucian of Samosata wrote two works describing journeys to the Moon. His *True History* is a sequence of ever-more-whopping tall tales culminating with the hero's ship being swept up by a whirlwind to the Moon, where he joins the lunar army in a war with the Sun for the right to colonize Venus. In Lucian's *Icaromenippus*, the hero flies to the Moon by strapping bird wings to his arms. There he encounters the goddess Selene, who is indignant with all the scientists who claim that she is a spherical body orbiting high above Earth and shining by the reflected light of the Sun. The hero then proceeds on to Heaven, where he is stripped of his wings and escorted back to Earth by the messenger-god Mercury.

Lucian created delightful farces by juxtaposing contemporary science with traditional religion and mocking both. He didn't really care about exploring the cosmos; his genius was for exploring human foibles. But *Icaromenippus* does have one strikingly modern scene in which the hero looks down from the Moon onto Earth and sees how petty we all are in the grand scheme of the universe.

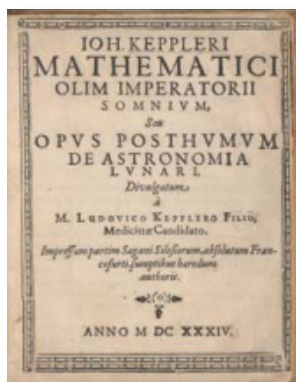
—TONY FLANDERS

imagined what someone would experience if uprooted from our planet and planted on the lunar surface: The motions of the Moon go undetected, while those of Earth are revealed.

Kepler's dissertation challenged the prevailing Earth-centered model of the universe, and unfortunately for him, the professor in charge of dissertations was deeply entrenched in the geocentric worldview. Typically, a dissertation would have been the subject of public debate, but Kepler's writing was denied an audience. Wary of protesting this ruling, Kepler fell silent on the matter. He shelved the work, awaiting a time when circumstances would swing in his favor.

When Kepler returned to the dissertation 16 years later, he decided to reframe it as a dream. He believed that in this context, geocentrists could dismiss objectionable material as inventions of his imagination. Thus, if portrayed as fiction, his thoughts on astronomy might evade censorship.

During this period of revision, Kepler also introduced a passage that addresses lunar flight itself. In telling this stage of the journey, he harks back to the ancient Greeks, with whom literary voyages beyond Earth originated. The stories of antiquity were facetious in their treatment of space travel, recounting humans being lofted into the heavens by whirlwinds or transported across space by gods (see the boxed text on the previous page). Kepler follows this precedent; his explorers require the services of a spirit to convey them between worlds. However, amidst this homage to the ancients, Kepler breaks new ground with an earnest discussion of the practical problems of spaceflight.



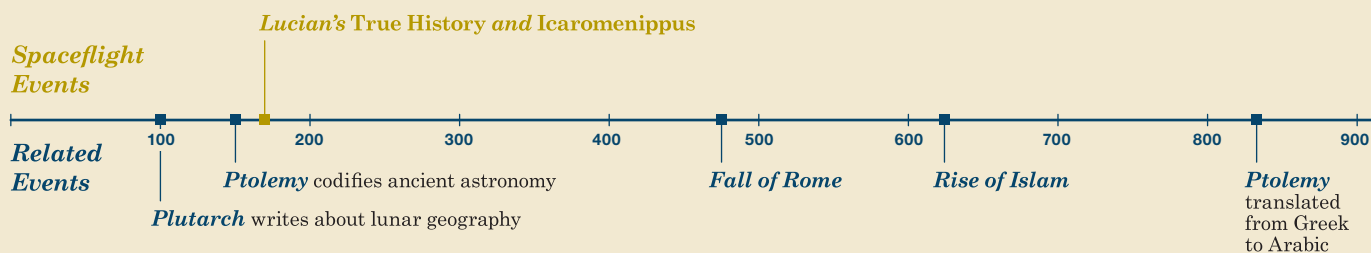
◀ The title page of *Somnium* reads as follows: “By Joh. Kepler, formerly Imperial Mathematician, *Somnium*, or *Posthumous Work on Lunar Astronomy*,” followed by publication information.

Kepler speculated that space is permeated with a deadly barrage of solar radiation. Therefore, Moon flights must be scheduled for a lunar eclipse, when Earth is situated between the Sun and Moon, generating a shroud of darkness in which the voyagers find safe passage.

The rigors of launch are compared to the detonation of explosives. The ascent so jars the explorer that he requires sedation. His body must be fastened and protected, lest his limbs be horrifically torn away. But at the end of this torturous episode, the explorer coasts peacefully to the Moon without any further application of force.

A close inspection of the Moon reveals perilous terrain. Here, Kepler indulges in what he called lunar geography. In *Somnium*, he describes the Moon's features as dwarfing those of Earth. Mountains tower above all earthly peaks, and chasms plummet to depths far below the greatest terrestrial trenches. The climate is no more tame. Each day and night on the Moon causes huge swings in temperature, blistering heat giving way to severe cold.

In time, Kepler proved correct in his assessment of the climate; however, he was wrong about the size of lunar mountains and many other matters, including the presence of life. Kepler populated the lunar landscape with a diverse community of bizarre creatures. He even included a detailed description of how intelligent beings might have built the



The First Spaceflight Manifesto

While Johannes Kepler was working on the first version of *Somnium*, his great contemporary Galileo Galilei heard of a new device that made distant objects appear bigger. Galileo built his own telescope (as we now call it), turned it to the night sky, and in one year he discovered that the Milky Way comprises innumerable faint stars, confirmed Petrarch's theory of complex lunar topography as shown in the sketches on the facing page, discovered Jupiter's four bright moons, and observed their changing patterns. That was a severe blow to the geocentric theory, because

it proved that at least four objects orbit something other than Earth! He published these results in 1610 in a short pamphlet entitled *Sidereus nuncius* (*Starry Message* or *Messenger*) that electrified the scientific community.

Kepler was thrilled by the pamphlet. He wrote an open letter to Galileo titled *Conversation with the Starry Messenger* that discusses the new revelations in detail. Toward the end, he mentions the possibility that both the Moon and Jupiter are inhabited and proceeds to say, “But as soon as somebody demonstrates the art of flying,

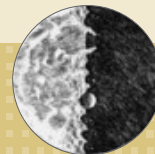
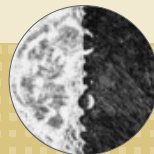
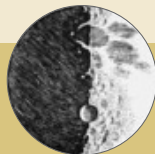
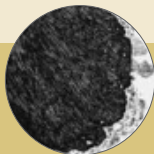
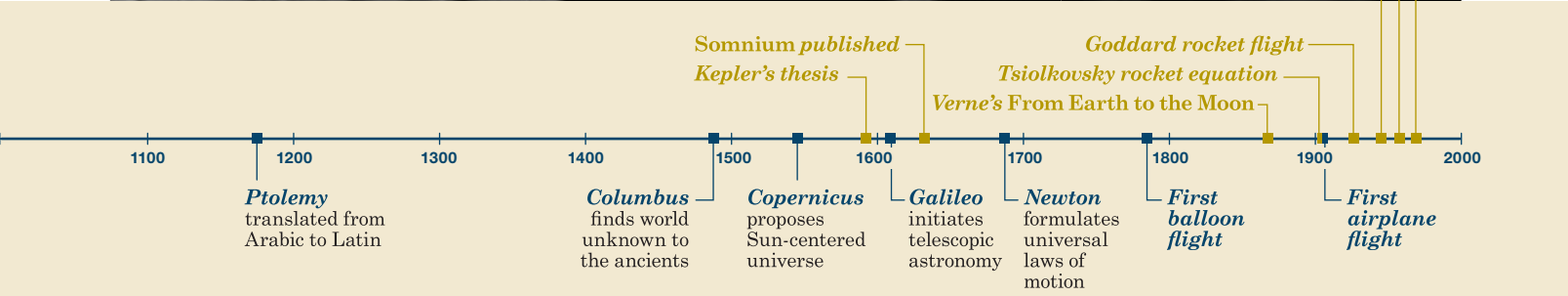
Kepler correctly stated that the most beautiful sight on the Moon's nearside is Earth, which rotates, waxes, and wanes, but always stands in the same spot in the sky. In this photograph, NASA's Lunar Reconnaissance Orbiter captured Earth appearing around the curve of the Moon's surface.



1969
1957
1929
1903
1869
1838
1803
1687
1609
1543
1492
1271

Bootprints on moon
 Sputnik in orbit
 V2 rocket reaches space

EARTHRISE FROM LRO: NASA / GODDARD / ARIZONA STATE UNIVERSITY;
 GALILEO MOON SKETCHES: WIKIMEDIA COMMONS; BOOTPRINT ICON:
 SMALLLIKE / THE NOUN PROJECT



settlers from our species of man will not be lacking.” And then he proposes that he and Galileo prepare the charts to be used by these explorers.

This appears to be the very first time that anyone wrote about colonizing other worlds not as a fantasy or satire, not even as an interesting possibility, but rather as something that is destined to happen.

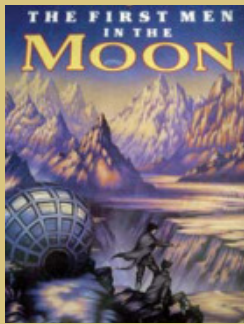
Many people wrote about spaceflight and alien life after *Sidereus nuncius*, drawing parallels with the New World discovered 118 years earlier by Christopher Columbus. It's a testament to Kepler's unique genius that he was thinking about visiting alien worlds when he was a student, 14 years before the telescope was invented.

—TONY FLANDERS

Kepler's Legacy

Like almost all scholarly works of the 17th century, Kepler's *Somnium* was written in Latin, making it inaccessible to the general public. But the small community of scientists interested in alien life and spaceflight took note of the book from the moment that Kepler first circulated his manuscript among his colleagues.

John Wilkins's 1638 book *The Discovery of a World in the Moone* is sprinkled with references to Kepler, including a short discussion of spaceflight at the end. Internal evidence suggests that he



heard about *Somnium* secondhand rather than reading one of the rare copies that had been published just four years earlier.

In 1640 Wilkins expanded his brief note about spaceflight into a discussion of its problems and possible solutions, far more detailed and sophisticated than anything Kepler attempted. It ends with a clarion call to fly to the stars "despite those who choose to crawl on their bellies like reptiles." Written in nontechnical terms for a lay audience, *The Discovery of a World in the Moone* provoked a brief and wildly premature burst of spaceflight enthusiasm.

Jules Verne and H. G. Wells, the fathers of modern science fiction, both mention Kepler's theory of an inhabited Moon. And an offhand reference to "Kepler's sub-volvani" in Wells's 1901 book *The First Men in the Moon* makes it clear that Wells took the idea of selenites sheltering from extremes of heat and cold in a honeycombed Moon directly from *Somnium*, though he channeled Kepler's vision into a much deeper and more disturbing narrative.

All the early rocket pioneers cited Verne or Wells as having inspired them to investigate spaceflight, so the causal chain linking Kepler to real-life space rockets is surprisingly short. And through Verne and Wells, Kepler's influence on popular culture is incalculably huge.

—TONY FLANDERS

lunar craters which, he thought, were too perfectly circular to have been formed by nature. He was unaware of the rocky debris bombarding the Moon, excavating the circles.

He speculated that the inhabitants shelter in caves to protect themselves from extremes of heat and cold, especially on the Moon's farside, where the long lunar night is unrelieved by Earth's glow.

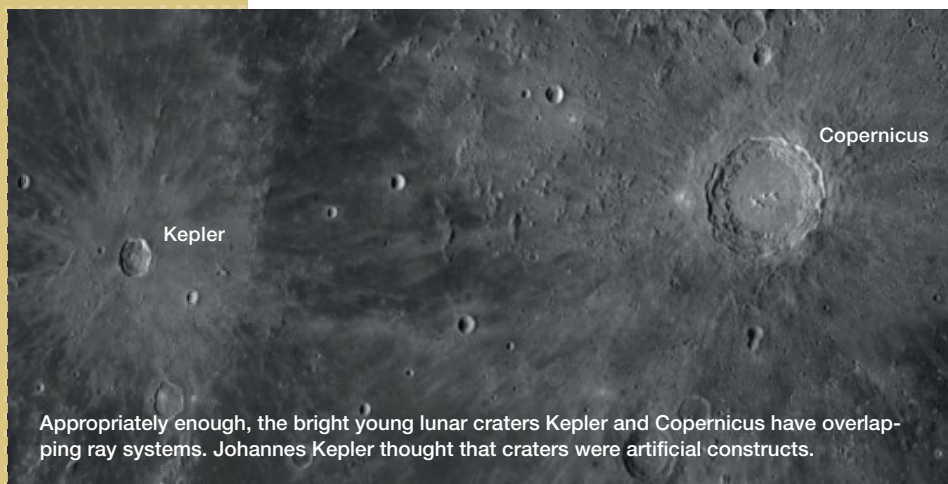
Recalling the hostility that he encountered in his youth, Kepler entrusted the manuscript of *Somnium* to various colleagues for review. He sought to understand how his writing would be received. This decision, he believed, prompted the hardships that soon visited his family.

Kepler's mother, Katharina, was argumentative and temperamental. She quarreled with neighbors and local authorities. Elderly, alone, and the object of public contempt, Katharina was susceptible to the storms of superstition that raged in 17th-century Europe (and America). She was arrested on charges of witchcraft — taken in the night and whisked away in a linen chest.

Kepler came to his mother's defense, entangling himself in a grueling campaign to prove her innocence. He worked diligently to reveal the natural forces underlying the supposed evidence of witchcraft. After six long years, Katharina was acquitted and exiled, warded off by the promise that her return would mean her death.

A grief-stricken Kepler reflected on his mother's arrest and the ordeal that followed. He imagined that a copy of *Somnium* had escaped his colleagues and had been read by one of his mother's enemies. Parts of the text are blatantly autobiographical; for instance, the explorer, like Kepler, was apprenticed to the Danish astronomer Tycho Brahe. Kepler suspected that his mother was, correspondingly, likened to the explorer's mother — a mysterious vendor of drugs and a friend to spirits. So, Kepler feared, it was *Somnium* that had aroused suspicions of sorcery and cries of witchcraft.

The case for Kepler's culpability is tenuous. It seems much more likely that Katharina was just another innocent victim of the paranoia and fear that were rampant in her time. However, Kepler blamed himself, convinced that he had penned



Appropriately enough, the bright young lunar craters Kepler and Copernicus have overlapping ray systems. Johannes Kepler thought that craters were artificial constructs.

► The Kepler spacecraft, shown here launching in 2009, discovered more than 2,600 exoplanets in its nine-year lifespan. Carl Sagan, among others, insisted on naming it after the great 17th-century advocate for exploring alien worlds.

the very evidence that locked her away. He assumed a responsibility that was never his and was plagued by guilt for the rest of his life.

When Kepler returned to *Somnium*, he set out to dispel the misrepresentation of his work and mischaracterization of his mother. Accordingly, he supplemented the manuscript with footnotes containing elucidations of lunar geography, discussions of telescopic observations, and rebukes of those who (he believed) had weaponized his words against an innocent woman. The remarks — 223 in all — are many times longer than the main text, and required a decade to complete.

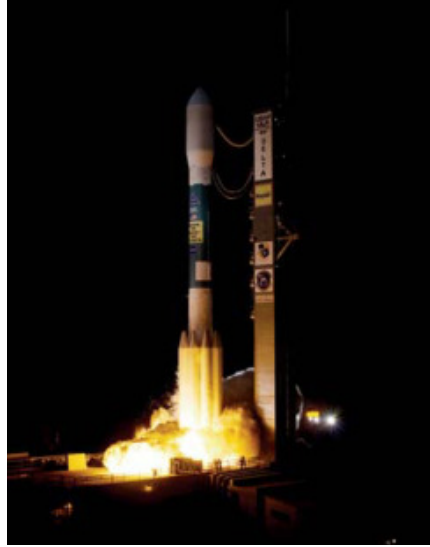
Kepler's *Somnium* was a lifelong exercise in scientific investigation, imagination, and patience. But illness struck Kepler down before the manuscript made it to print. His son Ludwig took charge of the manuscript, which was finally published in 1634, four years after Kepler's death.

Combining a mystical framework, a weak narrative, and a profound but rambling scientific treatise, *Somnium* is not an easy read. While the book had a deep effect on some of Kepler's contemporaries (see the discussion on the facing page), others were confused, and most were probably unaware of its existence. Not until the mid-20th century was *Somnium* studied in earnest. We now recognize it as the first modern contemplation on lunar geography and spaceflight.

A far cry from the doctoral dissertation from which it sprang, the completed *Somnium* is more than an effort to promote and popularize the Sun-centered universe. It's a prophecy about the potential of science and the promise of our species. Kepler believed that space travel was indeed possible, that someday humanity would construct ships suited to the cosmic seas and sail for uncharted worlds.

More than three centuries elapsed after Kepler's death before humans attained spaceflight — before they propelled themselves into the heavens, braving that dangerous expanse, destined for the Moon. Then, far from home, those voyagers beheld Earth from aloft — its lands adorned by vibrant hues, its oceans peeking through wispy clouds — and darkness stretching in every direction. But marooned in a time long past, Kepler was never to know of humanity's rendezvous with the Moon and the bootprints impressed in its surface.

While our capabilities and technologies far surpass those of Kepler's time, our fundamental situation remains the same. We reckon with the blank regions on our maps — all that lies outside our line of sight and beyond our reach. We stare out at the universe through a pinhole, fated to know hardly any of it — just our little corner, perhaps, and a few remote fragments, here and there. We try mightily to force



a retreat of the boundary separating knowledge and ignorance. Yet when we cross one frontier, we discover a new one. So we do what we can, in the time we have, to light up the darkness in which we live, and bequeath a universe a little less unknown.

Each generation that follows us will gaze up with wide eyes and see the universe for the first time. Our successors will access perspectives yet unseen, behold wonders yet unimagined, and reveal the cosmos as it has never been known to us nor any human before. And

we, islanded in our own time, reach into theirs, helping to create a future that we cannot live to experience directly.

Space travel is an endeavor owed to the labor of multitudes — to the generations past who developed the technology and garnered the scientific know-how to propel us into the universe. Now, the time is ours to carry on this remarkable undertaking. Today, it is we, the most recent iteration of humankind, who make the unthinkable plausible and the extraordinary commonplace. We are the next chapter in a story far greater than ourselves — a story spanning from the distant past to distant worlds. With every voyage beyond Earth, we fulfill the dreams of our ancestors and set the stage for our descendants to venture farther than we ever will.

■ **JAKE ROSENTHAL** is an aerospace engineer at NASA's Goddard Space Flight Center. He was born a quarter-century too late to witness humankind's first "giant leap," but at the right time to take part in the next.

FURTHER READING: The standard English translation of Kepler's *Somnium*, with ample commentary, is by Edward Rosen, Dover Publications, 2003. Marjorie Hope Nicolson's *Voyages to the Moon* (Macmillan Co., 1948), sadly long out of print, is a superb synopsis of spaceflight stories from ancient Greece to the first balloon flight in 1783.



After a gravity assist in 1992, NASA's Galileo probe photographed Earth and the Moon as it sped on to its 1995 rendezvous with Jupiter.