How did ancient civilizations make sense of the cosmos, and what did they get right?

March 7 2022, by Susan Bell

An exploded view of the Antikythera mechanism. Credit: Model by UCL Antikythera Research Team, Tony Freeth

In the spring of 1900, a group of Greek sponge divers, blown off course by a storm in the Aegean, stumbled upon the wreck of an ancient Roman ship loaded with treasure that had sunk more than 2,000 years earlier off

the remote Greek island of Antikythera. Returning the following year to retrieve its precious cargo, the divers were forced to end their mission when one died of the bends and two were paralyzed—but not before they succeeded in bringing to the surface a spectacular haul of antiquities.

Among them were bronze and marble statues, fine jewelry and glassware, and—most exciting of all—a startlingly complex cosmological calculator: the Antikythera mechanism.

The world's oldest analog computer and one of the most remarkable scientific objects of antiquity ever found, the mechanical model of the solar system is thought to date to between the third and first centuries B.C. Now fractured into 82 known fragments, there is surviving evidence of 30 bronze gears. However, researchers believe this highly sophisticated device originally included at least 69 intricately engineered meshing gears that enabled the ancient Greeks to track the phases of the moon and the positions of the planets, and even to predict the timing of lunar eclipses decades in advance.

But if the Antikythera mechanism can be considered a stunning embodiment of the ancient Greeks' impressive grasp of astronomy, it drew heavily upon the learning of a much earlier civilization in its use of the 19-year lunisolar cycle.

"The device exemplifies a terrific achievement of synthesis in incorporating complex bodies of observational and theoretical knowledge, much of it deriving ultimately from the Babylonian tradition, and long preceding Greek interests in astronomy," says USC Dornsife's Lucas Herchenroeder, associate professor (teaching) of classics.

Considered the world's first-known astronomers, the ancient Babylonians were avid stargazers. Some 6,000 years ago, they erected watch towers to

scan the night sky, mapped the stars and visible planets and recorded their observations on clay tablets. Their meticulously compiled data provided the foundation to create the first calendars, used to organize the growing and harvesting of crops and the timing of religious ceremonies.

Although their vision of the universe was based on mythological beliefs, the Babylonians' astronomical observations and predictions were astoundingly accurate. They were the first-known people to predict eclipses. They could track and predict the relative movements of the sun, the moon, Mercury and Venus. And—like the ancient Egyptians—they successfully calculated the length of a year.

How did ancient civilizations accomplish these feats of knowledge without the benefit of telescopes, satellites or computer technology? The old-fashioned way: through careful observation, generational record-keeping, pattern recognition and early mathematics. Here we explore what they got right—and wrong—about the cosmos.

The world was their oyster

If the Babylonians' astronomical calculations were remarkably precise by modern standards, their understanding of the cosmos was very far removed from our own. As Arthur Koestler explains in his seminal history of Western cosmology, The Sleepwalkers, the first ancient civilizations—the Babylonians, Egyptians and Hebrews—conceived of their universe as an oyster surrounded by water.

The Babylonian sky was a solid dome through which moisture sometimes seeped as rain, Koestler writes, while the waters below burst to the surface in the form of natural springs, and each day the sun, moon and stars performed a slow, ritual dance across its ceiling, entering from the east and exiting to the west.

As for the ancient Egyptian universe, it was more rectangular and box-like. At first, they conceived of their sky as a cow, one foot planted squarely at each corner of the Earth, or alternatively as a woman resting on her hands and knees. Later, they likened it to a vaulted metal lid. The sun and moon gods, they believed, sailed along a river that flowed upon an elevated gallery around the box's inner walls.

Early Greek cosmology followed similar concepts: Homer's world resembles a floating disk surrounded by Oceanus—the great mythical river, that encircled the world. But as time unfolded, the tremendous advances made by the ancient Greeks in figuring out how the universe is structured propelled them to become the driving force behind the development of Western astronomy and science.

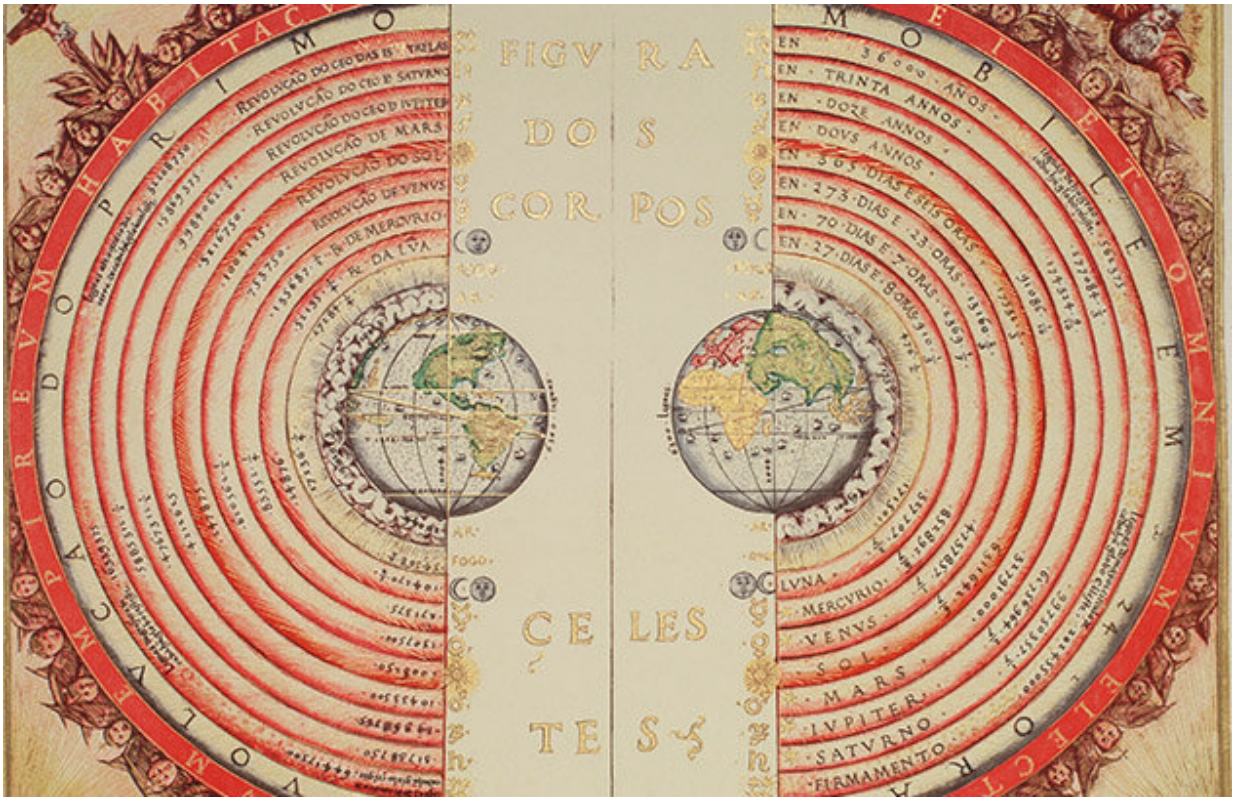


Illustration of the Ptolemaic conception of the universe from Cosmographia, by

Bartolomeu Velho, 1568. Credit: Cosmographia by Bartolomeu Velho

Heliocentric versus geocentric

Considered one of the greatest astronomers of antiquity, Aristarchus of Samos (310 B.C. to 230 B.C.) was responsible for the earliest-known heliocentric theory of the solar system, placing the sun at the center of the known universe, with the Earth revolving around the sun once a year and rotating about its axis once a day. Describing the sun as the "central fire" of the cosmos, he succeeded in correctly mapping all the then-known planets in order of distance around it.

Unfortunately for Aristarchus and the evolution of astronomical knowledge, Aristotle and most of the ancient Greek thinkers rejected his heliocentric theory. Instead, the Earth-centered model of the universe developed by Claudius Ptolemy of Alexandria in A.D. 140 prevailed, dominating Western thinking for nearly 1,400 years until it was finally toppled in the 16th century by Renaissance astronomer and polymath Nicolaus Copernicus.

Apart from its longevity, Ptolemy's geocentric model frankly didn't have much going for it, being not only incorrect but also mind-bogglingly complex. Indeed, it was so convoluted that, after having it explained to him, Alfonso X, the 13th-century King of Castile, was famously reported to have remarked, "If the Lord Almighty had consulted me before embarking upon Creation, I should have recommended something simpler."

Getting it right—sometimes

While Hipparchus of Nicaea (190 B.C. to 120 B.C.) is credited with

discovering and measuring the Earth's precession and the compilation of the first comprehensive star catalog of the Western world, Aristarchus made the earliest-known attempted calculations of the relative sizes of the sun and the moon and their distances from Earth.

He reasoned that the sun, Earth and moon would form a right-angled triangle when the moon is in its first or third quarter. Using the theorem developed a few centuries earlier by Pythagoras—the earliest proponent of the then-radical idea that the Earth was round—Aristarchus calculated (wrongly, it turns out) that the distance from Earth to the sun was between 18 and 20 times the distance to the moon. (The actual ratio is 389:1.) Based on careful timing of lunar eclipses, he also estimated that the size of the moon was approximately one-third that of Earth. There he was surprisingly accurate—the moon's diameter measures 0.27 times that of the Earth.

The Greeks even came close to correctly calculating Earth's circumference, thanks to Eratosthenes (276 B.C. to 195 B.C.), chief librarian at the Great Library of Alexandria in Egypt. Aristarchus had shown that the sun is sufficiently far from Earth that its rays are effectively parallel by the time they reach us. Eratosthenes used varying lengths of shadows, cast by poles stuck vertically into the ground at different latitudes and measured at midday on the summer solstice, to estimate the Earth's circumference as approximately 250,000 stades.

"As the length of stadia varied regionally, the exact length of the unit used by Eratosthenes is uncertain. But his estimate fell within a range of error of roughly 1% to 17% of today's accepted value of 24,901 miles—still an impressive achievement," Herchenroeder says.

Using science to overcome superstition

This deep fascination with the ability to make astronomical calculations

is manifested in the Antikythera mechanism, Herchenroeder notes.

"The mechanism's focus on predicting celestial motion demonstrates awareness of the possibilities of demystifying knowledge of the cosmos many regarded as divine in nature, and hence beyond the normal scope of human understanding," he says. "We have interesting accounts of prediction of lunar eclipses, for example—one of the things this object presumably was able to do."

One such account relates how on the eve of the Battle of Pydna between Rome and Macedon in 168 B.C., both armies were rattled by a lunar eclipse, considering it a bad omen. Cicero recounts how a Roman officer familiar with astronomy explained that an eclipse is a natural event, not a sign of divine disfavor, thus dispelling "empty superstition and fear." The Romans went on to win the battle—a major milestone in their conquest of the Aegean world.

Finding meaning in the stars

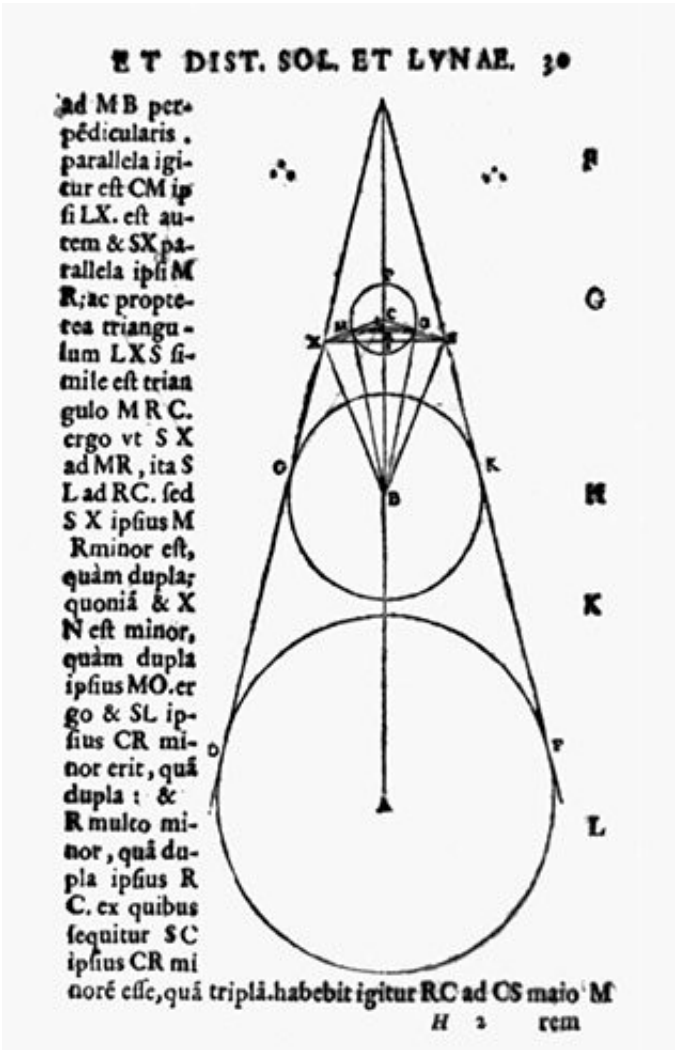


Diagram of the moon, Earth and sun (from top to bottom) in a 1572 edition of Aristarchus' On the Sizes and Distances of the Sun and Moon. Credit: Library of Congress

Many other ancient civilizations also developed sophisticated systems for observing and interpreting the cosmos, using this knowledge to enhance their lives.

Ancient Polynesians learned to use the stars to navigate thousands of miles across the Pacific Ocean, enabling them to colonize distant islands,

including the Hawaiian Islands.

The ancient Egyptians carefully tracked the rising time of the bright star Sirius, whose yearly cycle corresponded with the flooding of the River Nile which they relied upon to sustain their crops.

Ancient European megalithic sites aligned to solstices and equinoxes and going back to

Neolithic societies stretch up the Atlantic Coast. Two of the best known, Stonehenge in England and Newgrange in Ireland, were already ancient when the pyramids were built and were the largest human-made structures anywhere in the world.

Tok Thompson, professor (teaching) of anthropology at USC Dornsife, disagrees with speculation that megalithic sites like Stonehenge were giant observatories, built so that ancient civilizations could figure out the movements and cycles of the planets, the sun and the moon.

"These monuments were ritual enactments, monumentalizing what they already knew," he says.

They also helped societies keep track of time.

"Before there were widespread calendars to connect people, how do you keep a civilization together?" Thompson asks. "Having large festival gatherings at these ritualistically important spots that were anchored in the cosmos, which probably gave them sacred meaning, was one way to do this. It allowed people to memorialize their culture and—most importantly—gave them a place in the cosmos.

"'Why am I here? What happens when I die?" Our focus on the stars has

societal implications, but I think it also has personal implications. It's about giving our lives meaning."

The Venus detectives

Probably the best-known of the classical civilizations of Mesoamerica, the Maya developed a sophisticated calendar based on their astronomical observations.

"Indigenous people all across the Americas were incredible observers of their universe. They had a very astute understanding of natural processes and the world, the movement of time, stars and calendrics," says Eric Heller, lecturer in anthropology at USC Dornsife and an expert on Maya cosmology and ideology.

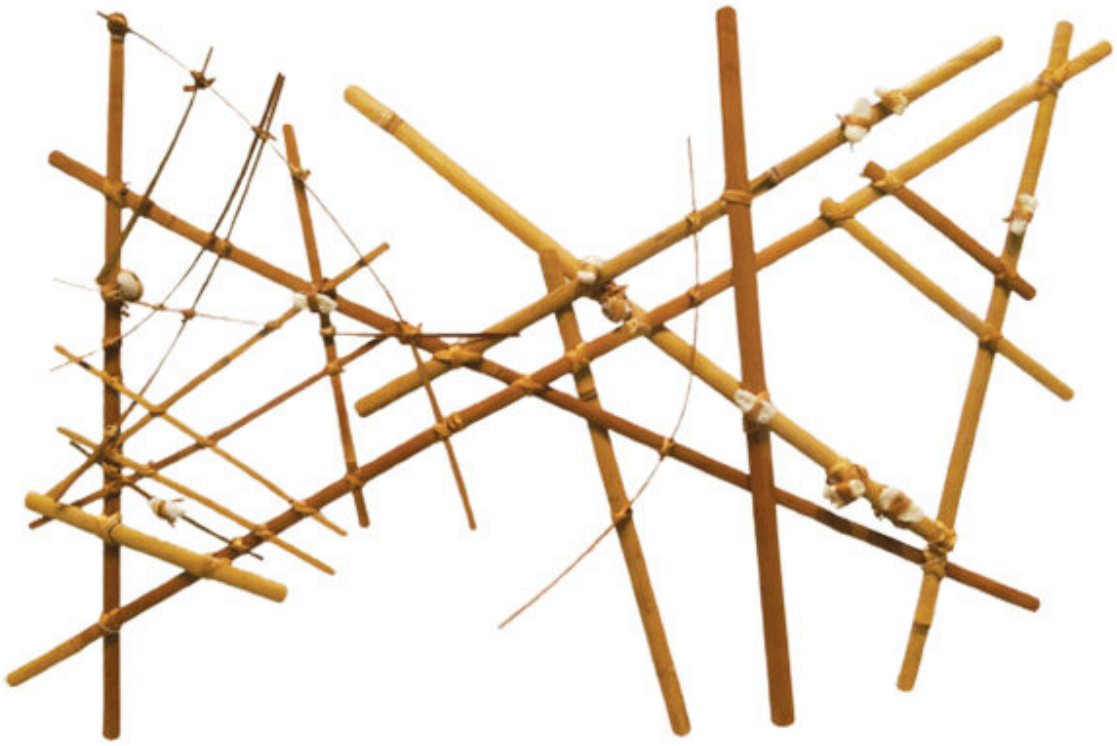
The Maya may have originated on the Pacific Coasts of what are today southern Mexico and Guatemala, as well as the Yucatán, around 2600 B.C. and rose to prominence between 200 B.C. and A.D. 900. The Maya cosmos consisted of three distinct realms, Heller explains.

Beneath their feet lay the underworld, Xibalba, a dark and watery place. Above them were the 13 levels of the upper world, the realm of celestial bodies—gods and deceased ancestors responsible for the operation of the universe.

In between, the terrestrial realm was divided into four corners, roughly corresponding to our cardinal directions and marked by the movement of the sun across the horizon throughout the year, from solstice to equinox and back again.

While the Maya, like many ancient peoples, lived their lives in accordance with the cycles and rhythms of the universe, they also placed tremendous emphasis on the correlation between time and space,

believing that the purpose of humanity was to count the days of creation and maintain the sacred calendars of the cycles of time.



A navigational chart from the Marshall Islands made of wood, sennit fiber and cowrie shells. Credit: Jim Heaphy

The most outstanding evidence for this is the 11th- or 12th-century Dresden Codex. Opening accordion-style to extend 12 feet, its pages are tightly packed with Maya hieroglyphs recording accurate astronomical tables thought to be based on thousands of years of observational knowledge.

"The Maya tracked Venus, which has an incredibly complex motion

across the horizon, over generations so they could predict when it would appear in the sky because they considered it a dangerous omen that could herald war, illness or death," Heller says.

The Codex also contains remarkably accurate tables enabling solar eclipses across Earth to be predicted within a three-day window, and indefinitely into the future. In 1991, two noted Maya scholars, Harvey and Victoria Bricker, used the Dresden Codex to predict a solar eclipse to the day—at least 800 years after the tables were compiled.

An animist view

Most American Indigenous cultures understood their world from the perspective of animism, and the Maya were no exception. Looking up, they saw a world of stars, planets and clouds that lived and moved through the sky and were manifestations of their ancestors, who they believed were playing a major role in the operation of their universe.

"These civilizations felt a connection between stars, the sun and the moon, the clouds in the sky," Heller says. "Everything they saw around them, even the things they touched and used every day, they felt kinship with on some level—something often lost in our modern, post-Enlightenment world."

Heller acknowledges that the Maya's unique way of knowing and representing the world appears strange to us. But in fact, he argues, when we dig deep to unpack and understand these metaphorical representations of natural processes and the cosmos itself, we find a tremendous amount of knowledge.

"It's expressed in radically different ontology but in fact it's the product of deep observational knowledge—the kind of stuff that we might think of as quite scientific in a sense," he says.

One example is the ancient Mesoamerican metaphor for the Earth: a crocodile floating upon a watery underworld whose breath, flowing in and out of cave mouths, brought rain.

"At first glance, I think a lot of people would say, "Well, the Earth's not a crocodile; this doesn't make sense,'" Heller says. "But, in fact, there's a tremendous amount of water beneath Mesoamerica. And the Earth-crocodile's exhalations bringing rain essentially describes changes in barometric pressure and the arrival of rain-bringing weather systems."

Measuring up

So, how does the Maya's knowledge about the universe measure up to our own?

"The Maya got a tremendous amount right about what was around them," Heller says. "They understood how their universe worked, and they had a tremendously effective set of metaphors for expressing the operation of the world processes that dictated in many ways the successes and failures of their lives."

Cavan Concannon, associate professor of religion, agrees, noting that ancient peoples developed ways of navigating their place in the universe with what they had available to them.

"I think in some ways they were also writing themselves into the story of the cosmos. Part of knowing your place is also knowing who you are and why you are in a universe the way it is," Concannon says.

"And so, I'm not certain that it's a question of whether they got it right or wrong. Contemporary science is, itself, a constantly evolving conversation and at some point, everything that we thought we knew about the universe is going to change. The ancients made their way

through the universe in a way that made sense to them and lived their lives in that context. I think we're still doing that."

Provided by University of Southern California

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