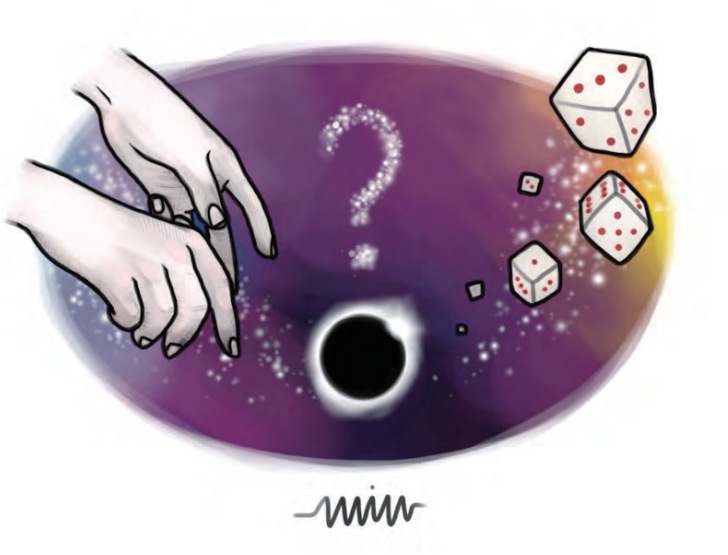
Carbon, the Anthropic Principle, and Multiple Universes (2)

SUNG-CHUL YOON
DEPARTMENT OF PHYSICS AND ASTRONOMY, SEOUL NATIONAL UNIVERSITY



It happened in an instant. A black curtain engulfed its edges. An ominous darkness slowly crept over the sun until finally it was swallowed whole. A cool wind began to blow over the heated earth. Human beings—frail bits of stardust dependent on the sun to survive—trembled in trepidation and anxiety. Clearly, the darkness that engulfed the mother sun, the source of all life, was some beast possessed by evil spirits. "Go away!" they cried with all their might. They could not allow themselves to be vainly abandoned to the darkness. They had to drive the beast off. As their terror mounted, the people's cries grew more desperate: "Away! Away!! Away!!!"

The idea that a total solar eclipse was caused by a beast swallowing the sun was fairly widespread. In Korea, the darkness that engulfed the sun was known as *bulgae* ("fire dog"). In Paraguay and Argentina, people believed it was a jaguar; in ancient Scandinavia, it was thought to be a demon dog sent by the god Loki. The fact that the "beast of darkness" was nothing more than the moon's shadow had been learned long before with the beginnings of agrarian culture. But the special sensations experienced at the sign of the sun being swallowed were not something even a few millennia could easily change.

On August 21, 2017, 190 or so Koreans gathered in the small city of Ontario, Oregon. We were members of a "US total eclipse sightseeing team" assembled by "Science with People" from the much-discussed podcast *Sitting with Science*. The utter exhaustion we felt after traveling by bus for nearly 1,000 miles from Los Angeles through Nevada, Arizona, and Idaho slowly lifted amid our anticipation as the moment drew nearer. The excitement reached a fever pitch at around 10:10 a.m. as the beast's jaws began closing around the sun. But we still could not fathom what we would experience soon afterwards.

Thirty-three seconds past 11:25 a.m. The sun was now completely engulfed, and as its brilliant corona encircled the moon's shadow, we all began to shiver. It was not just the sudden drop in temperature as darkness descended, nor was it the terror and anxiety experienced by the ancients. It was because nature—something we believed to have been secularized and utterly tamed in the modern

day—now seemed utterly unfamiliar. Faced with this great unfamiliarity, we could only shudder in fear. Some members cried out; others fainted or wept. It was a magical minute and 26 seconds—a moment that could not be expressed in human language.

The reason this mere shadow is so awe-inspiring to moderns is because a total eclipse of the sun is an exceedingly rare event, the sort of thing we might only experience once in a lifetime. If the earth's orbit revolution lined up with that of the moon—rather than being tilted by about five degrees as they are now—total eclipses of the sun would be a regular occurrence that we might witness anywhere on earth once a month. They would not inspire any feelings beyond the romance we experience when we behold a full moon.

Total eclipses of the sun are also special for another reason. Although the moon is 400 times smaller than the sun, the two appear to be the same size to our eyes. That's because the moon is 400 times closer to us than the sun. Right now, the moon is receding from the earth at a rate of 38 millimeters per year. The occurrence of tides between the moon and the earth arises because the earth's angular momentum is reduced a bit at a time and transfer to the moon's orbital angular momentum. If the current trend holds, the moon will be much farther away 560 million years from now, and total eclipses of the sun will no longer occur. The fact that human civilization arose at a moment in time when the sizes of the moon and sun appeared outwardly identical is not destiny, but a mere historical accident.

It's an accident that has made crucial contributions to the development of modern science. Perhaps the best example is the discovery of helium, one of the universe's major component substances along with hydrogen. Since the temperature at the surface of the sun is a relatively low 6,000°C, no helium absorption lines or emission lines can occur, but helium emission lines are produced in the hot corona on the sun's exterior. Normally, you can' t see them because the sunlight is too strong. But when the sun has been obscured in a total eclipse, the corona can be clearly seen with the naked eye. It was by observing the corona's spectrum during an 1868 total eclipse in Guntur, India, that the French astronomer Jules Janssen (1824–1907) was able to discover helium emission lines.

An even more dramatic moment came with a total eclipse in 1919, thanks to the activities of a British observation team led by Arthur Eddington. The group observed starlight from behind the sun being bent by the effects of gravity. The amount of bending was twice as large as Newtonian mechanics had predicted, but conformed to the predictions of Einstein's general relativity theory. The paradigm of gravitational theory was altered as a result, while Einstein became a science icon.

To the general public, Eddington's total eclipse observation is seen as a typical example of what science is: a genius like Einstein declares a general principle that applies throughout the universe, and then an observer or experimenter like Eddington demonstrates a phenomenon inevitably predicted by that general principle. There would not seem to be any chance for chance to play a role.

People often see scientific rationality within necessity and religious sentiments within chance. But can chance actually be excluded from science? With the new administration's appointment of certain figures in the scientific community, the pseudoscience of "creation science" has recently become a hot topic in Korea. I've seen one related article where the journalist quoted a science historian to explain creation science. "The reason so many scientists are believers in creation science," the quote said, "is because they are so familiar with finding 'final' results and rational answers that they do not acknowledge the tedious process and contingency in evolution." Sure enough, one of the replies underneath asked, "Is chance science?" Believing chance and science to be unrelated is one of the biggest misunderstandings when it comes to science.

All phenomena that occur in nature are fair game for scientific research, be they chance or necessity. What we call "chance" is merely the manifestation of innumerable possibilities that occur within the regularity of nature. Accidents, in other words, are fragments of the inevitable. This misguided dichotomy between rational necessity and irrational chance is what has spawned the pseudoscience of creation science.

History is a continuum of contingent events, and the earth's history is no exception. While we were passing through Arizona on our way to Oregon, the members of the total eclipse sightseeing group stopped at the Barringer Meteorite Crater. Measuring 200 meters deep and 1.2 kilometers across, this enormous crater was left behind when a 300,000-ton meteorite collided with the earth around 50,000 years ago. All animals within a radius of

several kilometers are believed to have been killed instantly by the impact. But while meteorites crashing into the earth may bring about catastrophes out of Armageddon, they also ironically played an important role in the emergence of life on earth. The meteorites that frequently struck the early earth contained rich stores of water molecules and various organic molecules. Most of the water molecules present on earth today were introduced from outside in this way, as were some of the organic molecules that served as the seeds of life. An "accidental" impact by an asteroid is believed to have played a pivotal role in the extinction of the dinosaurs and emergence of mammals around 65,000,000 years ago. Of all the impacts, however, the most dramatic happened about 4.5 billion years ago when the earth collided with another planet, which scientists have dubbed "Theia." The most likely hypothesis is that the earth's core merged with Theia's in the collision, while matter on the earth's outer surface was swept away to form the moon. The hypothesis offers an excellent explanation for why the moon has the same percentages of isotopes for oxygen and various other substances as the earth despite being less dense.

Created by happenstance, the moon "happens" to be quite large. With the exception of Pluto's moon, no other satellite in the solar system is fully one-quarter the size of the planet it orbits. Since it has a mass 1/81 as large as the earth's and is located relatively nearby, it exerts a major influence in the form of tidal forces, as exemplified by the rising and ebbing tides. The moon also plays a major role in changes in the earth's axis of rotation (often referred to as "precession"). If it weren't for the moon, changes in the earth's axis of rotation would be larger than they are now, resulting in more severe changes in weather. In other words, the emergence of advanced human civilization like ours today might not have been possible without the moon.

According to the law of gravity, an apple released from a person's hand will inevitably fall to the ground in the absence of any external interference. The size of the moon is not determined by some unique method beyond those principles. It is merely the result of various possibilities that could have arisen depending on the conditions of the earth's collision with Theia. Similarly, the reason we humans exist on earth today is not because the laws of physics necessarily dictated it, but because the countless environments on earth happened to create suitable conditions for the emergence of human beings.

When applied to the universe as a whole, this idea leads to what is known as the anthropic principle. It is a simple, self-evident proposition holding that the form of the universe must be consistent with the presence of human life. This is often called the "weak anthropic principle," since it is quite self-evident and does not argue strongly for anything new. For example, we might experience the same sense of wonder when we consider the existence of the 7.63MeV resonance energy level that was so central to the origins of carbon that we do when we behold a total eclipse of the sun. Imagine that—an energy level in carbon that appears to have been precisely fine-tuned for human existence! But the anthropic principle is not a matter of using different theories based on the laws of physics to prove the inevitability of the existence of some fine-tuned energy level. It merely states the obvious, result-based proposition that an environment where humans could emerge was made possible by the existence of that energy level, for whatever reason.

To be sure, many people are not content with this result-focused proposition. After all, the anthropic principle seems to strongly imply that human existence is an accident. As we saw with the case of creation science, chance makes a lot of people uncomfortable. Quite a few still believe that the emergence of intelligent beings is an inevitability inherent to the universe, rather than the chance outcome of certain properties of the universe necessary for their emergence. A representative example is the belief some intelligent designer—such as God—furnished this fine-tuned environment ahead of time for human beings. This argument is sometimes called the "strong anthropic principle," in contrast with the aforementioned weak anthropic principles.

The strong anthropic principle has a teleological element to it and does not appear all that convincing scientifically. But would it not be a form of intellectual laziness for us to content ourselves with something as obvious as the weak anthropic principle? What might we stand to learn from testing the anthropic principle?

Sung-Chul Yoon is a professor at the Department of Physics and Astronomy of Seoul National University. He received his BA and MA degrees in astronomy from Seoul National University and his Ph.D. from Utrecht University. His research interests include massive stars, binary stars, supernovae and their progenitors, and the first stars.