THE NEW
ATLANTIS
A Journal of Technology & Society

Human Uniqueness in the Cosmos II

Meaning in a Silent Universe

Marcelo Gleiser

Copernicus could not have anticipated the damage his sun-centered cosmos would ultimately do to his fellow Christians' sense of place in the world. Dislodging the Earth from the center of the cosmos turned out to be much more than an act of original scientific thinking; in effect, it redefined the order of things, including the unique position of humankind in creation. Martin Luther was an early and vociferous critic, even before Copernicus's great work *On the Revolutions of the Heavenly Spheres* was published in 1543, and is said to have called the Polish canon a fool for daring "to turn the whole art of astronomy upside-down." About a century later, the French mathematician and Christian philosopher Blaise Pascal wrote that "The eternal silence of these infinite spaces terrifies me." And in another one of his reflections he said:

> When I consider the short span of my life absorbed into the preceding and subsequent eternity,...the small space which I fill and even can see, swallowed up in the infinite immensity of spaces of which I know nothing and which knows nothing of me, I am terrified, and surprised to find myself here rather than there, for there is no reason why it should be here rather than there, why now rather than then. Who put me here? On whose orders and on whose decision have this place and this time been allotted to me?

Who are we, but wanderers of the heavens, amid an abundance of other worlds? What role is there for us in the vast emptiness of space? These questions are central to our post-Copernican age. They provoke what could be called the "Copernican angst": How are we to find purpose in a seemingly purposeless universe?

Pascal found his answer in the Christian faith, wagering that, given the stakes of the choice—the possibility of eternal bliss or eternal punishment—it is rational to believe in God as the benevolent creator

***Marcelo Gleiser** is the Appleton professor of natural philosophy and a professor of physics and astronomy at Dartmouth College. He is the author, most recently, of* The Island of Knowledge: The Limits of Science and the Search for Meaning *(Basic Books, 2014).*

who made man in his image. Three hundred and fifty years later, Pascal's choice may seem untenable to many. Yet, despite all that we have learned about the cosmos and ourselves, Pascal's questions still haunt us. The passage of time, the pain of loss, and the awareness of our mortality—these remain essential to our humanity, and so does the question of our place in the universe. While present-day science may not restore our position at the center of the cosmos, nor reveal the design of a benevolent creator, it can aid us in our search for meaning in the universe. By establishing our uniqueness—not to say our centrality—within the vast expanse of the heavens, modern science can help alleviate the Copernican angst.

Determined or Free?

By the early seventeenth century, the Copernican model had become part of a major transformation in the sciences throughout Europe. Independently of one another, Galileo and Kepler began to develop the modern concepts of inertia, force, and the planetary laws that explain the celestial movements described by Copernicus. This new science rejected ancient notions about the "perfect" circular motions of heavenly bodies and about the "natural" place of objects on Earth, around the same time that Francis Bacon devised a program for replacing the old natural philosophy with a new scientific method that would provide a systematic way to reveal the workings of the natural world. Later in the same century and into the next, Isaac Newton completed the architecture of this new science, deriving universal, mathematical laws for physics and astronomy.

But if the old science was left behind, divine purpose was not: for Newton, to decode nature was to decipher the blueprint of God's creation. Despite popular misconceptions about Newton's universe being like "clockwork"—leaving God absent—Newton envisioned a participatory God, fully enmeshed in the details of cosmic mechanics. However, to an extent that would surely surprise Newton, the success of his science in accurately predicting motion in the skies made many of his assumptions about divine participation appear superfluous to later generations. Through the writings of eighteenth-century Enlightenment thinkers, such as Voltaire, Diderot, and d'Alembert, a new, more rationalistic approach blossomed. As theism transformed into deism, God became progressively more distant, a sovereign mind responsible for engendering the cosmos and its laws, but nothing else. In this way of thinking, God no longer interfered in the affairs of men nor offered direct spiritual guidance.

The new science had inspired a new worldview, one that left little room for the supernatural. In the early nineteenth century, when Napoleon asked the French physicist and mathematician Pierre Simon de Laplace why his *Treatise of Celestial Mechanics* made no mention of a divine creator, Laplace reportedly replied: "I had no need of such an hypothesis." The cosmos was now a clockwork, precise and autonomous in its functioning. And all aspects of nature were accessible through scientific reason, which had uncovered laws determining the behaviors of all material entities, from invisible atoms to the heavenly bodies.

Where do humans fit in this new scientific worldview? In a now-classic formulation of scientific determinism, Laplace proposed in his book *A Philosophical Essay on Probabilities* that to an "intelligence sufficiently vast," capable of knowing the positions and velocities of all particles in the cosmos—often called "Laplace's demon" or "Laplace's superman"—the future would be perfectly predictable. It is a short step to imagine that the behavior of all beings in the universe—animate and inanimate alike—is predetermined. If humans are composed of material particles, each following a given trajectory in space and time, then, in a purely mechanistic universe, human behavior should in principle be perfectly predictable too. There would be no real freedom of choice, no free will. Neither the fact that you are reading this essay nor the fact that I chose to write it using these particular words is due to our free choices but is the outcome of how the thousands of trillion trillions of atoms in each of our bodies move about space and time according to physical laws. In effect, we are deluded automata, erroneously believing that we are the free causes of our behavior.

But if we are simply pre-programmed machines, what happens to doubt, to love, to guilt, or to compassion? Is there no room for mystery in this ultra-deterministic universe? One cannot blame the Romantics for their outrage; the mechanistic science seemed to rob us of our humanity.

How seriously are we to take this worldview? Many may find repulsive the proposition that our freedom is illusory. After all, we feel that our choices define us to a very large extent and set the directions we take in our lives. Should I marry my college sweetheart or become a Buddhist monk in Nepal? If our choices are predetermined, we seem to lose our individuality. No one denies that many of our choices are influenced by context: where, when, and how we grow up, our family histories, the people that cross our paths, and countless other factors. Still, we like to believe that we have some freedom in choosing between the options presented to us throughout our lives, and that with enough willpower we are even able to radically change direction in life.

Fortunately, modern physics suggests that Laplace's demon is impossible—that is, given the laws of physics, it is impossible for us, or for the most powerful computer imaginable, ever to predict the behavior of all particles and thereby to know the future and to erase our sense of freedom. Already in classical physics, there are at least three challenges to the idea. First, since information cannot travel faster than the speed of light, this intelligence could not gather in a single instant the positions and the velocities of all particles that exist, and even the slightest delay would mean the data are already inaccurate by the time they have been collected. So unless this hypothetical intelligence were somehow to operate beyond the laws of nature as we now understand them, it could never collect the initial data needed to run its predictions. Second, even assuming such data gathering to be possible, the sheer number of particles in existence would require computing power of absurd proportions: just to store the positions and velocities of all atoms in the universe would presumably require a memory device so large it would have to be composed of a vast amount of the atoms in the universe. Even if we confined the computation to our planetary sphere of influence, the numbers would still be staggering. Third, since any measurement of a physical quantity, such as position, velocity, distance, or mass, comes with a degree of imprecision, the initial data fed into the computation will not be perfectly accurate. Chaos theory tells us that in complex systems—those made of many mutually interacting parts, such as the brain or the weather—such initial discrepancies, even if extremely small, lead to enormously different outcomes, which only increase as time goes by. Hence slightly different initial data sets would predict radically different future outcomes. Within the framework of only classical physics, we can safely conclude that any such intelligence cannot exist within the laws of nature, which means that no amount of scientific advance can refute the fact that the future will always be, in part, unknowable.

Add quantum physics to the mix and things only get worse for this vast intelligence. Quantum physics tells us that at very small distances matter behaves in profoundly counterintuitive ways. Central to this behavior is Heisenberg's uncertainty principle, which states that we cannot measure both the position and velocity (or more accurately, what physicists call the "momentum") of a particle to arbitrary precision: there is always a residual error that increases if we try to improve the accuracy in the measurement of one of the two variables. (By "particle" I mean any object that obeys quantum rules, such as a small molecule, atom, or elementary particle.) Try to pin down a particle's position and the error in its velocity increases, and vice versa. Nothing sits still in the realm of the quantum; there is an inherent agitation, a jitteriness that never goes away. This uncertainty makes it impossible in principle for any intelligence following the laws of physics to know determinately both the position and velocity of every particle in the universe at the same time, which means it cannot predict with precision how the particles will behave—and therefore what will happen in the future. At best, it could make probabilistic predictions about possible future outcomes, without knowing which would prevail. Both classical and quantum physics save us from the chains that a deterministic knowledge of the future would put on us. But does it go far enough in rescuing our humanity from the clutches of a mechanistic worldview? Is it enough to stave off the Copernican angst?

Incompletely Knowable Reality

In a famous passage from Book VII of *The Republic*, Plato presents his allegory of the cave. A group of prisoners is chained inside a large cave, unable since birth to look in any direction but forward. Their world—what they would call their reality—is whatever they see projected onto the wall in front of them. They cannot see that there is a fire behind them, and that what they see on the wall are shadows of statues and various other shapes. In effect, the prisoners are being tricked into taking mere images for reality. Plato uses this allegory to illustrate how our senses acquaint us with how things appear, rather than with how they truly are.

Plato is of course right that our senses offer only a very limited, and often even misleading, view of reality. But we can augment our senses using the tools and experimental instruments of modern science—our "reality amplifiers." Thus, we "see" microscopic bacteria, submicroscopic particles, and stars and galaxies millions of light years away. Nevertheless, even with this remarkable amplification, our perception is always limited; there is much that lies beyond the grasp of our instruments and so escapes our reach. As Bernard Le Bovier de Fontenelle wrote in a popular 1686 science book, "All philosophy…is founded upon two things, either that we are too short-sighted, or that we are too curious." We want to see more—everything—but can only ever see a fraction of reality. It is as if we lived not in a single cave but in a succession of them, lodged inside one another like layers of an onion. We move to larger caves only to find another wall surrounding us.

This results in a seeming paradox: new knowledge prompts new ignorance. Since our vision of physical reality is necessarily incomplete, we can never know reality in full. Indeed, the way science constructs knowledge of physical reality—what I have elsewhere called "natural constructivism" (see my books *A Tear at the Edge of Creation* and *The Island of Knowledge*)—precludes full knowledge, even though we continue to learn more and more about the world. New knowledge, often acquired through new tools, brings new questions that we were not equipped to ask before. Consider biology before and after the invention of the modern microscope, or astronomy before and after the invention of the modern telescope. Albert Einstein captured this limitation to our knowledge well when he wrote: "what I see in Nature is a magnificent structure that we can comprehend only very imperfectly, and that must fill a thinking person with a feeling of 'humility.'"

This brings us back to the issue of free will and determinism. It is possible that nature is at bottom completely deterministic—that, as Einstein famously put it, "God does not play dice"—but that our inherently limited view of nature precludes us from ever fully uncovering the underlying deterministic reality. We may indeed be puppets but can never learn how our strings are being controlled.

There are thus two possibilities. First, our free will is just an illusion, albeit one that cannot be shaken since it results from our limited grasp of the nature of physical reality. Everything in the universe (as we don't know it, so to speak) is in fact predetermined, but our narrow view ensures the *appearance* of free will, even if it is not really there. Perhaps the evolution of the cosmos is locked into the blueprint of the underlying, all-encompassing mechanism driving physical reality, while remaining forever beyond our grasp. Our limitations in describing physical reality call for humility, and if there is a grand design for the cosmos, we can never know it.

The second possibility, which I find more compelling, is that there are no hidden mechanistic gears churning everything that happens in the universe. Rather, there is randomness inherent in the smaller scales of physical reality, expressed by the probabilistic laws of quantum physics. This randomness ensures that there are no deterministic causes operating at the bottom of things we perceive. Energy flows through all scales of reality, manifest as radiation and matter arranged into organized structures that satisfy certain basic physical principles. We can uncover these principles only partially: as we probe reality and identify patterns and regularities, some indeterminacies will always remain, which we can never fully eliminate. This view, perhaps surprisingly, will help us see our place in the cosmos as nevertheless significant.

The Just-Right Universe

If the universe appears to lack any ultimate design and we are just a coalescence of matter, temporarily assembled by contingency and soon to dissolve into nothingness, how are we to find meaning? We are back to the Copernican angst. In the almost five hundred years since Copernicus published his landmark treatise on the heavenly spheres, we have learned much about the universe and about our seemingly insignificant place within it. We live on a small planet around a small star, in an average-sized galaxy among hundreds of billions of other galaxies, in an expanding universe made mostly of dark matter and dark energy—mysterious ingredients of yet unknown composition. The stuff that we are made of—electrons, protons, and neutrons—comprises a small fraction of what fills the universe. On the face of it, science appears to decree our insignificance; the more we learn about the universe, the more insignificant we seem.

However, this way of looking at things is misleading. Our significance should not be measured by our size relative to the rest of the cosmos, but rather by how different we are from everything else in it. As with precious gems and metals, it is our rarity that makes us special, and one way to express what is rare about us is that we have enough self-awareness to ask questions about our origins and place in the cosmos. The emergence of higher intelligence necessary to ask such questions entails that the universe has changed in profound ways over the course of its existence. Stars had to burn for a long time in order to fuse hydrogen into carbon, nitrogen, oxygen, and other heavier chemical elements; planets and moons had to have relatively stable orbits, and other geophysical conditions were needed to support the complex biochemistry of life's metabolic and reproductive functions. And it took time for intelligent, self-aware creatures to develop through the workings of evolution. The emergence of life requires an old universe—one that is at least a few billion years old; intelligent life requires even more.

As scientists in various fields have argued, life as we know it cannot emerge in just any kind of universe; very specific conditions are needed. (The question of why this may be so is what physicist Paul Davies terms the "Goldilocks Enigma.") The idea is that only a particular universe has the properties necessary for life to emerge. Such properties include the masses and charges of the elementary particles (for example, the masses of the electron and the proton, and the intensity of the electric attraction between the two), the amount of matter in the universe, and the fact that it is expanding at a certain rate. This set of conditions is what some have in mind when they appeal to the "anthropic principle"—a term proposed by astrophysicist Brandon Carter in the 1970s. Because the physical processes leading to the formation and burning of stars in an expanding universe are highly specific, there is not much leeway in the values of physical parameters consistent with such phenomena. We—and life in general—could only exist in a universe where the constants of nature have values very close to what we in fact measure.

The anthropic principle has gained renewed attention with recent multiverse theories, which hypothesize that our universe is one of many universes. This has raised the question yet again of why our universe, including life and even intelligent life, exists. Interestingly, the development of contemporary multiverse theories has much to do with one of the most prominent efforts to understand better why the physical properties of our own universe are the way they are: superstring theory. As conjectured, superstring theory offers a way to unify into a single framework the four known forces of nature—gravity, electromagnetic force, and the strong and weak nuclear forces. The theory is compellingly elegant mathematically, but it involves a number of difficulties, including that its equations admit of many possible solutions—more than 10^{500}, according to some estimates.

This is where the connection between superstring theory and the idea of the multiverse comes from. The multiverse comprises the set of possible solutions to the equations of superstring theory, what is known as the "landscape." While the original motivation for superstring theory, going back decades, was to provide a unique solution for *our* universe, the theory has led to the suggestion that our universe is but one of a vast multitude of possible universes, each with different sets of constants and physical properties. So if superstring theory is right, we have no satisfying answer to the question "Why *this* universe?" Instead, we must simply accept that our existence in this universe is the result of a statistical fluke within the plethora of possible universes.

Of these universes, only a very small subset has the Goldilocks recipe needed for life. Here is where anthropic reasoning comes in: it helps scientists to compute for each physical parameter in our universe the range acceptable for life. Too fast a cosmic expansion, and galaxies and stars could not form; too slow a cosmic expansion, and the universe would collapse before stars could form. (This subject—sometimes called the "fine-tuning" of the universe for life—is discussed in depth in the next article in this issue.)

Critics maintain that the anthropic principle does not really teach us anything new about the universe, but instead offers only a range of possible values for what we already know. In other words, anthropic reasoning just narrows the range of possible choices for certain physical parameters—such as the rate of cosmic expansion—based on the properties of the known universe, but it fails to offer a way to explain why the universe has this particular set of parameters and not a different set. But even if we were to take seriously the idea of a multiverse, and therefore also the idea that our universe is just one of many others, the fact that our universe happens to be among the small subset of universes that has the Goldilocks recipe would strengthen the point that it is rare. We should consider our existence not as an irrelevant accident because many other universes are possible but as a rare gem in an unlikely universe.

Human Meaning and Uniqueness

To fill out this picture of the universe we have developed thus far—which is not geocentric but "humancentric," in the sense that it emphasizes how special human life is—we can organize cosmic history into four different ages, from Big Bang to intelligent life. (A more detailed discussion of this idea can be found in my 2012 article "From cosmos to intelligent life: the four ages of astrobiology," published in the *International Journal of Astrobiology*.) First is the *physical age*, when our universe came into being roughly 14 billion years ago. The universe expands, matter coalesces into the atomic nuclei of the lightest chemical elements (hydrogen, helium, and their isotopes), atoms form, then stars and galaxies. The universe is at this point roughly one billion years old. The *chemical age* begins as heavy stars begin to die, fusing hydrogen into the elements of the periodic table and forging the key ingredients for life. These ingredients are then sprinkled onto the nascent planets and moons orbiting stars in the hundreds of billions of galaxies scattered across space. Eventually, prebiotic biomolecules emerge in some region (or regions) of the universe, laying down the conditions needed for primitive life. Here the universe enters the *biological age*, and Darwinian evolution begins. Then, finally, complex organisms emerge. And of those possible worlds that support simple unicellular life, an even smaller subset harbors creatures possessing self-awareness and the capacity to develop advanced technologies through the manipulation of energy and materials. This is the *cognitive age*; the one in which we now live.

When we consider this process from the beginning of the universe to human life, we cannot help but wonder whether we are the first or only beings in the universe to have reached the cognitive age. Could there be other intelligent beings spread across the universe? Of course, there very well could be—even in our own galaxy—although we currently have no evidence one way or the other. At the very least, from a biological and geophysical perspective, we know that there could not be very many such creatures "out there." The steps from simple life to complex, multicellular life and then to intelligent life are exceedingly difficult to accomplish and may well not occur anywhere else in the same way. Any world in which life exists must have a very specific geophysical story, and that story determines, to a large extent, what kind of life can exist there; the history of life on a planet mirrors the planet's life history. Furthermore, life evolves through random mutations and has no discernible plan—certainly no plan to reach intelligence at some allotted time. Biological life is about adaptability, not teleology. Intelligence may help a species to survive, but it is not the inevitable endpoint of evolution.

We can now combine the arguments in support of "humancentrism" to illustrate how modern science can restore our sense of uniqueness, even within our vast and purposeless universe—that is, how modern science can help alleviate the Copernican angst. A universe governed by laws but filled with randomness instead of pre-programmed purpose is not necessarily a meaningless one. On the contrary, the fact that our cosmos produced *us* implies that it will never be meaningless for us. Our existence in a purposeless universe might even be more meaningful than an existence predetermined by some mysterious cosmic plan. Why? Because we are unique and uniquely in control of our own destiny—uniquely responsible for our choices—rather than puppets controlled by unknown mechanisms.

From among all the possible universes in the multiverse, ours stands out as a rare one in which life is possible. Even if we disregard the multiverse as a theoretical fancy, in our own universe, our planet still stands out as one that has the rare combination of geophysical and biochemical properties needed for life not only to emerge but to evolve continually for billions of years. It is here, rather than elsewhere, that living molecular assemblies developed the unlikely ability to ponder their origin and their place in the cosmos. If there are other such organisms living in other worlds—and there very well may be—they are far removed from us, as vast interstellar distances preclude easy travel and communication.

We must come to terms with both our cosmic loneliness *and* our cosmic significance. We may be alone in a purposeless universe, but we are for that very reason unique. With our poems and symphonies, scientific theories and stories, we are—as far as we know—the noblest expression of what highly organized, intelligent organic matter is capable of. We create, and the universe creates through us, in a mutual exploration of what is possible, constrained by and enabled by the laws of nature. We ought therefore not only to celebrate and preserve life, which is so special and unlikely, but to preserve the memory of all that we have created and will create, expressions of our search for meaning in a universe that never ceases to amaze us.