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Science's Alternative to an Intelligent Creator: the Multiverse Theory

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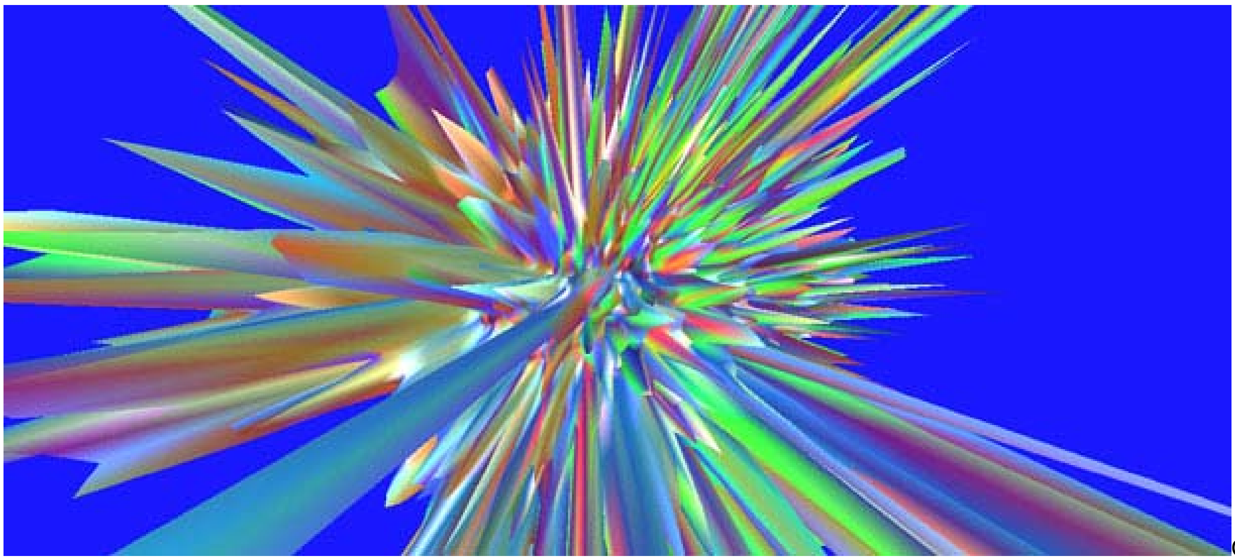
Our universe is perfectly tailored for life. That may be the work of God or the result of our universe being one of many.

by Tim Folger



Computer simulation shows a view of the multiverse, in which each colored ray is another expanding cosmos.

Courtesy Andre Linde

A sublime cosmic mystery unfolds on a mild summer afternoon in Palo Alto, California, where I've come to talk with the visionary physicist Andrei Linde. The day seems ordinary enough. Cyclists maneuver through traffic, and orange poppies bloom on dry brown hills near Linde's office on the Stanford University campus. But everything here, right down to the photons lighting the scene after an eight-minute jaunt from the sun, bears witness to an extraordinary fact about the universe: Its basic properties are uncannily suited for life. Tweak the laws of physics in just about any way and—in this universe, anyway—life as we know it would not exist.

Consider just two possible changes. Atoms consist of protons, neutrons, and electrons. If those protons were just 0.2 percent more massive than they actually are, they would be unstable and would decay into simpler particles. Atoms wouldn't exist; neither would we. If gravity were slightly more powerful, the consequences would be nearly as grave. A beefed-up gravitational force would compress stars more tightly, making them smaller, hotter, and denser. Rather than surviving for billions of years, stars would burn through their fuel in a few million years, sputtering out long before life had a chance to evolve. There are many such examples of the universe's life-friendly properties—so many, in fact, that physicists can't dismiss them all as mere accidents.

"We have a lot of really, really strange coincidences, and all of these coincidences are such that they make life possible," Linde says.

Physicists don't like coincidences. They like even less the notion that life is somehow central to the universe, and yet recent discoveries are forcing them to confront that very idea. Life, it seems, is not an incidental component of the universe, burped up out of a random chemical brew on a lonely planet to endure for a few fleeting ticks of the cosmic clock. In some strange sense, it appears that we are not adapted to the universe; the universe is adapted to us.

Call it a fluke, a mystery, a miracle. Or call it the biggest problem in physics. Short of invoking a benevolent creator, many physicists see only one possible explanation: Our universe may be but one of perhaps infinitely many universes in an inconceivably vast multiverse. Most of those universes are barren, but some, like ours, have conditions suitable for life.

The idea is controversial. Critics say it doesn't even qualify as a scientific theory because the existence of other universes cannot be proved or disproved. Advocates argue that, like it or not, the multiverse may well be the only viable nonreligious explanation for what is often called the "fine-tuning problem"—the baffling observation that the laws of the universe seem custom-tailored to favor the emergence of life.

physical laws clamor for life: the universe knew we were coming.

"For me the reality of many universes is a logical possibility," Linde says. "You might say, 'Maybe this is some mysterious coincidence. Maybe God created the universe for our benefit.' Well, I don't know about God, but the universe itself might reproduce itself eternally in all its possible manifestations."

Taking on Copernicus

Linde is lying in bed, recovering from a bad fall off a bicycle that broke his left wrist. His left hand, bound in a cast, rests on a pillow. Linde is sturdily built, with thick gray hair that flops down over his forehead; you wouldn't necessarily pick him out as a man who spends much of his time lost in thought about the distant universe. Right now he is ignoring his injury, reciting a long list of some of the cosmic coincidences that make life possible.

"And if we double the mass of the electron, life as we know it will disappear. If we change the strength of the interaction between protons and electrons, life will disappear. Why are there three space dimensions and one time dimension? If we had four space dimensions and one time dimension, then planetary systems would be unstable and our version of life would be impossible. If we had two space dimensions and one time dimension, we would not exist," he says.

The idea that the universe was made just for us—known as the anthropic principle—debuted in 1973 when Brandon Carter, then a physicist at Cambridge University, spoke at a conference in Poland honoring Copernicus, the 16th-century astronomer who said that the sun, not Earth, was the hub of the universe. Carter proposed that a purely random assortment of laws would have left the universe dead and dark, and that life limits the values that physical constants can have. By placing life in the cosmic spotlight—at a meeting dedicated to Copernicus, no less—Carter was flying in the face of a scientific worldview that began nearly 500 years ago when the Polish astronomer dislodged Earth and humanity from center stage in the grand scheme of things.

Carter proposed two interpretations of the anthropic principle. The "weak" anthropic principle simply says that we are living in a special time and place in the universe where life is possible. Life couldn't have survived in the very early universe before stars formed, so the universe had to have reached a certain age and stage of evolution before life could arise.

The "strong" anthropic principle makes a much bolder statement. It asserts that the laws of physics themselves are biased toward life. To quote Freeman Dyson, a renowned physicist at the Institute for Advanced Study in Princeton, the strong anthropic principle implies that "the universe knew we were coming."

A Wild Profusion

The anthropic principle languished on the fringes of science for years. Physicists regarded it as an interesting idea, but the real action in the field lay elsewhere. And in the late 1970s, Linde, then a professor at the prestigious Lebedev Physical Institute in Moscow, was in the thick of that action. At the time, he wasn't interested in the anthropic principle at all; he was trying to understand the physics of the Big Bang. Linde and other researchers knew that something was missing from the conventional theory of the Big Bang, because it couldn't explain a key puzzling fact about the universe: its remarkable uniformity.

Strikingly, the temperature of space is everywhere the same, just 2.7 degrees Celsius above absolute zero. How could different regions of the universe, separated by such enormous distances, all have the same temperature?

In the standard version of the Big Bang, they couldn't. The universe as a whole has been cooling ever since it emerged from the fireball of the Big Bang. But there's a problem: For all of it to reach the same temperature, different regions of the universe would have to exchange heat, just as ice cubes and hot tea have to meet to reach the uniform temperature of iced tea?. But as Einstein proved, nothing—including heat—can travel faster than the speed of light. In the conventional theory of the Big Bang, there simply hasn't been enough time since the universe was born for every part of the cosmos to have connected with every other part and cooled to the same temperature.

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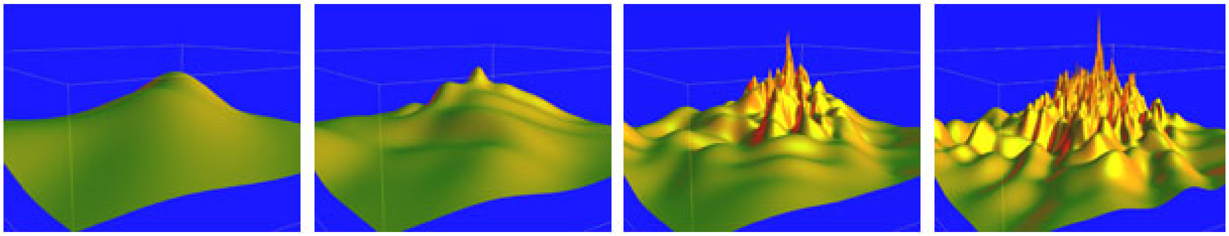

In this computer generated sequence, the universe evolves, inflating and expanding its terrain. The gentle valleys represent quiescent cosmic zones where all is stable. The jutting hills and soaring peaks symbolize the inflationary engine of universe creation, where new cosmic realms embody alternate physics and strange life — or none at all.

Courtesy Andre Linde

MIT physicist Alan Guth found a viable, but flawed, solution to the puzzle in 1981. Linde shored up that work shortly thereafter, making improvements to overcome those flaws. In a nutshell, Guth and Linde proposed that the universe underwent a colossal growth spasm in the first instants of its existence, a phenomenon called inflation. Today widely accepted as the standard version of the Big Bang theory, inflation holds that regions of the universe that are currently separated by many billions of light-years were once close enough to each other that they could exchange heat and reach the same temperature before they were wildly super-sized. Problem solved.

By the mid-1980s Linde and Tufts University physicist Alex Vilenkin had come up with a dramatic new twist that remains nearly as controversial now as it was then. They argued that inflation was not a one-off event but an ongoing process throughout the universe, where even now different regions of the cosmos are budding off, undergoing inflation, and evolving into essentially separate universes. The same process will occur in each of those new universes in turn, a process Linde calls eternal chaotic inflation.

Linde has spent much of the past 20 years refining that idea, showing that each new universe is likely to have laws of physics that are completely different from our own. The latest iteration of his theory provides a natural explanation for the anthropic principle. If there are vast numbers of other universes, all with different properties, by pure odds at least one of them ought to have the right combination of conditions to bring forth stars, planets, and living things.

“In some other universe, people there will see different laws of physics,” Linde says. “They will not see our universe. They will see only theirs. They will look around and say, ‘Here is our universe, and we must construct a theory that uniquely predicts that our universe must be the way we see it, because otherwise it is not a complete physics.’ Well, this would be a wrong track because they are in that universe by chance.”

Most physicists demurred. There wasn’t any good reason to believe in the reality of other universes—at least not until near the beginning of the new millennium, when astronomers made one of the most remarkable discoveries in the history of science.

The Accelerating Universe

In 1998 two teams of researchers observing distant supernovas—exploding stars—found that the expansion of the universe is accelerating. The discovery was baffling. Just about everyone had expected that the cosmic expansion, which started with the Big Bang, must be gradually slowing down, braked by the collective gravitational pull of all the galaxies and other matter out there. But built into the very fabric of space, it seems, is some unknown form of energy—physicists call it simply dark energy—that is pushing everything apart. Many cosmologists were skeptical at first, but follow-up observations with the Hubble Space Telescope, along with independent studies of radiation left over from the time of the Big Bang, have powerfully confirmed the reality of dark energy.

dark energy appears calibrated for stars, galaxies, and us.

The idea that empty space might contain energy was not the part that surprised physicists. Ever since the birth of quantum mechanics in the 1920s, they have known that innumerable “virtual” particles pop into and out of existence all around us, a sort of quantum white noise, always there but forever beneath our notice. What astonished them was the peculiar specificity of the amount: exactly enough to accelerate expansion, yet not so much that the universe would rapidly rip itself apart. The observable amount of dark energy appears to be another one of those strange anthropic properties, calibrated to allow planets, stars, and us.

“If [dark energy] had been any bigger, there would have been enough repulsion from it to overwhelm the gravity that drew the galaxies together, drew the stars together, and drew Earth together,” Stanford physicist Leonard Susskind says. “It’s one of the greatest mysteries in physics. All we know is that if it were much bigger we wouldn’t be here to ask about it.”

Nobel laureate Steven Weinberg, a physicist at the University of Texas, agrees. “This is the one fine-tuning that seems to be extreme, far beyond what you could imagine just having to accept as a mere accident,” he says.

The Multiverse on a String

Dark energy makes it impossible to ignore the multiverse theory.Another branch of physics—string theory—lends support as well. Although experimental evidence for string theory is still lacking, many physicists believe it to be their best candidate for a theory of everything, a comprehensive description of the universe, from quarks to quasars. According to string theory, the ultimate constituents of physical reality are not particles but minuscule vibrating strings whose different oscillations give rise to all the particles and forces in the universe. Although string theory is enormously complex, requiring a total of 11 dimensions to work correctly, it is a mathematically convincing way to knit together all the known laws of physics.

In 2000, however, new theoretical work threatened to unravel string theory. Joe Polchinski at the University of California at Santa Barbara and Raphael Bousso at the University of California at Berkeley calculated that the basic equations of string theory have an astronomical number of different possible solutions, perhaps as many as 101,000. Each solution represents a unique way to describe the universe. This meant that almost any experimental result would be consistent with string theory; the theory could never be proved right or wrong.

Some critics say this realization dooms string theory as a scientific enterprise. Others insist it is yet another clue that the multiverse is real. Susskind, a leading proponent of that interpretation, thinks the various versions of string theory may describe different universes that are all real. He believes the anthropic principle, the multiverse, and string theory are converging to produce a coherent, if exceedingly strange, new view in which our universe is just one of a multitude—one that happened to be born with the right kind of physics for our kind of life.

“Some people would call this the great disaster of string theory, that instead of giving rise to a single theory, it gave rise to something that is so diverse we can never make any sense out of it,” Susskind says. “Others would say, ‘Ah, this is exactly what we need for eternal inflation, for the multiverse, for anthropic thinking, and so forth.’?”

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Prove It

Linde’s recent research has helped solidify the connection between string theory and the multiverse. Some physicists have long embraced the notion that the extra dimensions of string theory play a key role in shaping the properties of new universes spawned during eternal chaotic inflation. When a new universe sprouts from its parent, the concept goes, only three of the dimensions of space predicted by string theory will inflate into large, full-blown, inhabitable spaces. The other dimensions of space will remain essentially invisible—but nonetheless will influence the form the universe takes. Linde and his colleagues figured out how the invisible dimensions stayed compact and went on to propose billions of permutations, each giving rise to a unique universe.

Linde’s ideas may make the notion of a multiverse more plausible, but they do not prove that other universes are really out there. The staggering challenge is to think of a way to confirm the existence of other universes when every conceivable experiment or observation must be confined to our own. Does it make sense to talk about other universes if they can never be detected?

I put that question to Cambridge University astrophysicist Martin Rees, the United Kingdom’s Astronomer Royal. We meet at his residence at Trinity College, in rooms on the west side of a meticulously groomed courtyard, directly across from an office once occupied by Isaac Newton.

Rees, an early supporter of Linde’s ideas, agrees that it may never be possible to observe other universes directly, but he argues that scientists may still be able to make a convincing case for their existence. To do that, he says, physicists will need a theory of the multiverse that makes new but testable predictions about properties of our own universe. If experiments confirmed such a theory’s predictions about the universe we can see, Rees believes, they would also make a strong case for the reality of those we cannot. String theory is still very much a work in progress, but it could form the basis for the sort of theory that Rees has in mind.

“If a theory did gain credibility by explaining previously unexplained features of the physical world, then we should take seriously its further predictions, even if those predictions aren’t directly testable,” he says. “Fifty years ago we all thought of the Big Bang as very speculative. Now the Big Bang from one millisecond onward is as well established as anything about the early history of Earth.”

The credibility of string theory and the multiverse may get a boost within the next year or two, once physicists start analyzing results from the Large Hadron Collider, the new, $8 billion particle accelerator built on the Swiss-French border. If string theory is right, the collider should produce a host of new particles. There is even a small chance that it may find evidence for the mysterious extra dimensions of string theory. “If you measure something which confirms certain elaborations of string theory, then you’ve got indirect evidence for the multiverse,” says Bernard Carr, a cosmologist at Queen Mary University of London.

Support for the multiverse might also come from some upcoming space missions. Susskind says there is a chance that the European Space Agency’s Planck satellite, scheduled for launch early next year, could lend a hand. Some multiverse models predict that our universe must have a specific geometry that would bend the path of light rays in specific ways that might be detectable by Planck, which will analyze radiation left from the Big Bang. If Planck’s observations match the predictions, it would suggest the existence of the multiverse.

When I ask Linde whether physicists will ever be able to prove that the multiverse is real, he has a simple answer. “Nothing else fits the data,” he tells me. “We don’t have any alternative explanation for the dark energy; we don’t have any alternative explanation for the smallness of the mass of the electron; we don’t have any alternative explanation for many properties of particles.

“What I am saying is, look at it with open eyes. These are experimental facts, and these facts fit one theory: the multiverse theory. They do not fit any other theory so far. I’m not saying these properties necessarily imply the multiverse theory is right, but you asked me if there is any experimental evidence, and the answer is yes. It was Arthur Conan Doyle who said, ‘When you have eliminated the impossible, whatever remains, however improbable, must be the truth.’?”

What About God?

For many physicists, the multiverse remains a desperate measure, ruled out by the impossibility of confirmation. Critics see the anthropic principle as a step backward, a return to a human-centered way of looking at the universe that Copernicus discredited five centuries ago. They complain that using the anthropic principle to explain the properties of the universe is like saying that ships were created so that barnacles could stick to them.

“If you allow yourself to hypothesize an almost unlimited portfolio of different worlds, you can explain anything,” says John Polkinghorne, formerly a theoretical particle physicist at Cambridge University and, for the past 26 years, an ordained Anglican priest. If a theory allows anything to be possible, it explains nothing; a theory of anything is not the same as a theory of everything, he adds.

> IF THE PLANCK SATELLITE detects bending light, that would be evidence for the multiverse.

Supporters of the multiverse theory say that critics are on the wrong side of history. “Throughout the history of science, the universe has always gotten bigger,” Carr says. “We’ve gone from geocentric to heliocentric to galactocentric. Then in the 1920s there was this huge shift when we realized that our galaxy wasn’t the universe. I just see this as one more step in the progression. Every time this expansion has occurred, the more conservative scientists have said, ‘This isn’t science.’ This is just the same process repeating itself.”

If the multiverse is the final stage of the Copernican revolution, with our universe but a speck in an infinite megacosmos, where does humanity fit in? If the life-friendly fine-tuning of our universe is just a chance occurrence, something that inevitably arises in an endless array of universes, is there any need for a fine-tuner—for a god?

“I don’t think that the multiverse idea destroys the possibility of an intelligent, benevolent creator,” Weinberg says. “What it does is remove one of the arguments for it, just as Darwin’s theory of evolution made it unnecessary to appeal to a benevolent designer to understand how life developed with such remarkable abilities to survive and breed.”

On the other hand, if there is no multiverse, where does that leave physicists? “If there is only one universe,” Carr says, “you might have to have a fine-tuner. If you don't want God, you'd better have a multiverse."

As for Linde, he is especially interested in the mystery of consciousness and has speculated that consciousness may be a fundamental component of the universe, much like space and time. He wonders whether the physical universe, its laws, and conscious observers might form an integrated whole. A complete description of reality, he says, could require all three of those components, which he posits emerged simultaneously. "Without someone observing the universe," he says, "the universe is actually dead."

Yet for all of his boldness, Linde hesitates when I ask whether he truly believes that the multiverse idea will one day be as well established as Newton's law of gravity and the Big Bang. "I do not want to predict the future," he answers. "I once predicted my own future. I had a very firm prediction. I knew that I was going to die in the hospital at the Academy of Sciences in Moscow near where I worked. I would go there for all my physical examinations. Once, when I had an ulcer, I was lying there in bed, thinking I knew this was the place where I was going to die. Why? Because I knew I would always be living in Russia. Moscow was the only place in Russia where I could do physics. This was the only hospital for the Academy of Sciences, and so on. It was quite completely predictable.

"Then I ended up in the United States. On one of my returns to Moscow, I looked at this hospital at the Academy of Sciences, and it was in ruins. There was a tree growing from the roof. And I looked at it and I thought, What can you predict? What can you know about the future?"

Cosmic Coincidences

If these cosmic traits were just slightly altered, life as we know it would be impossible. A few examples:

• Stars like the sun produce energy by fusing two hydrogen atoms into a single helium atom. During that reaction, 0.007 percent of the mass of the hydrogen atoms is converted into energy, via Einstein's famous e = mc2 equation. But if that percentage were, say, 0.006 or 0.008, the universe would be far more hostile to life. The lower number would result in a universe filled only with hydrogen; the higher number would leave a universe with no hydrogen (and therefore no water) and no stars like the sun.

• The early universe was delicately poised between runaway expansion and terminal collapse. Had the universe contained much more matter, additional gravity would have made it implode. If it contained less, the universe would have expanded too quickly for galaxies to form.

• Had matter in the universe been more evenly distributed, it would not have clumped together to form galaxies. Had matter been clumpier, it would have condensed into black holes.

• Atomic nuclei are bound together by the so-called strong force. If that force were slightly more powerful, all the protons in the early universe would have paired off and there would be no hydrogen, which fuels long-lived stars. Water would not exist, nor would any known form of life.
T. F.