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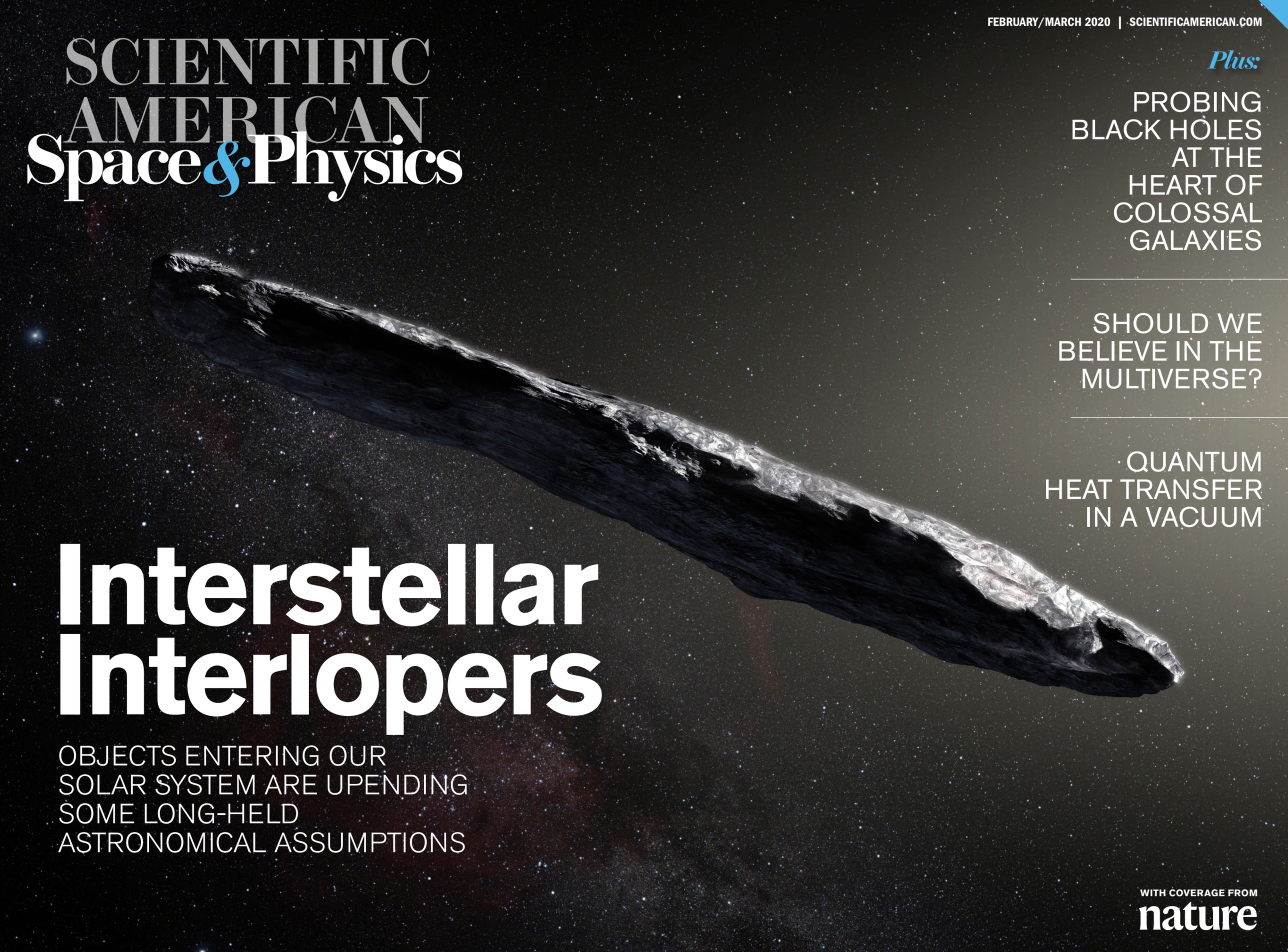


Interstellar Interlopers

OBJECTS ENTERING OUR SOLAR SYSTEM ARE UPENDING SOME LONG-HELD ASTRONOMICAL ASSUMPTIONS

Plus:

PROBING BLACK HOLES AT THE HEART OF COLOSSAL GALAXIES

SHOULD WE BELIEVE IN THE MULTIVERSE?

QUANTUM HEAT TRANSFER IN A VACUUM

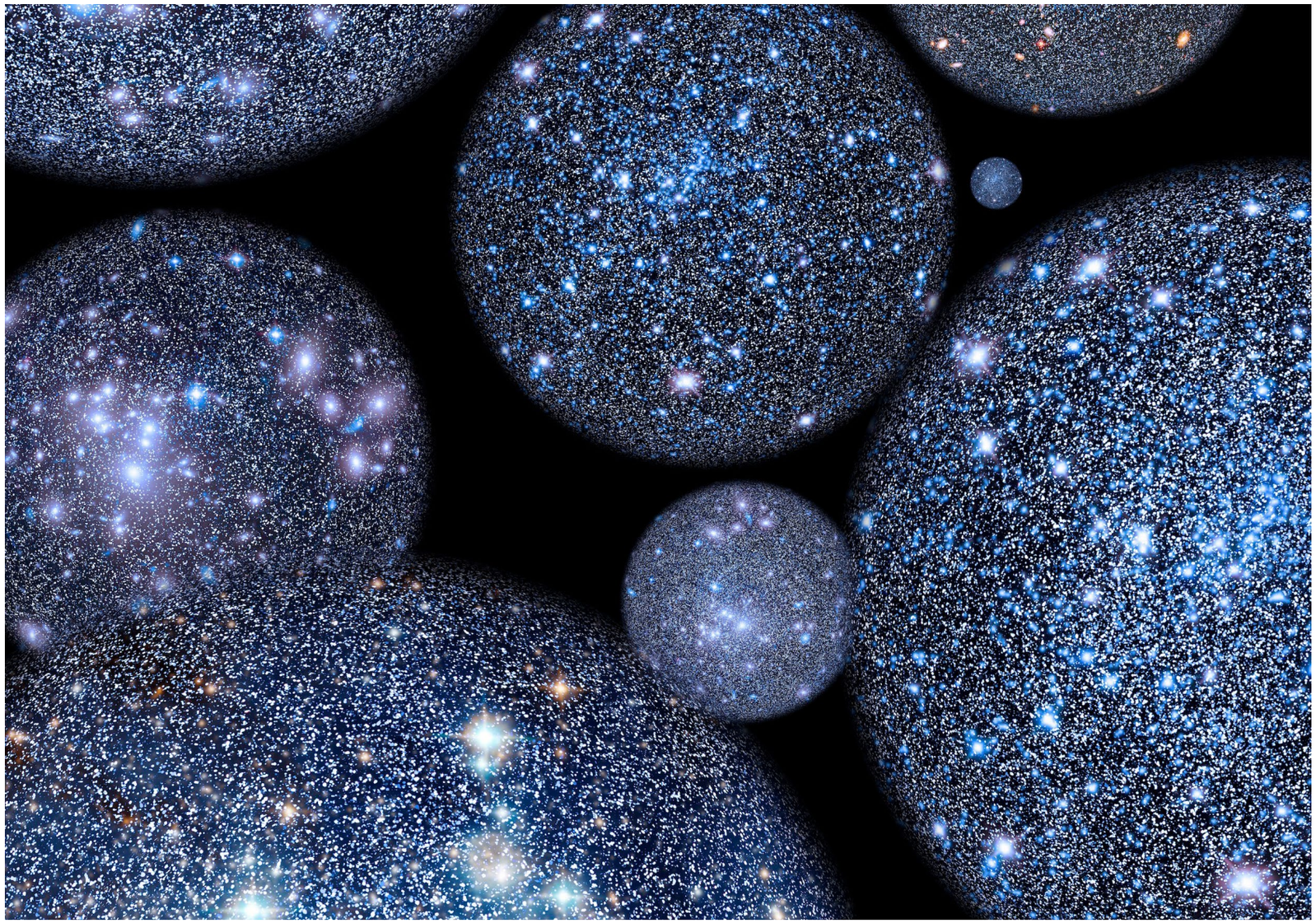
WITH COVERAGE FROM nature

Tom Siegfried is author of *The Number of the Heavens: A History of the Multiverse and the Quest to Understand the Cosmos* (Harvard University Press, 2019).

OBSERVATIONS

Long Live the Multiverse!

The idea that our universe is just part of a much vaster cosmos has a long history—and it's still very much with us



VICTOR DE SCHWANBERG *GETTY IMAGES*

Ernst Mach, the Austrian physicist-philosopher of the late 19th century, famously denied the reality of atoms. "Have you ever seen one?" he mockingly asked of atom advocates. Today many scientists speak with similar derision about the idea that the visible universe is not alone, but rather is only one of many universes—a single bubble in a froth of cosmic carbonation known as the multiverse.

You can't see these other universes, so the idea is not testable, multiverse opponents allege. Besides, invoking a multiplicity of universes to explain reality is a violent violation of Occam's razor, the philosophical principle favoring simple explanations over complicated ones.

But Mach, of course, was wrong about atoms. And throughout history, those arguing against multiple universes have invariably turned out to be wrong as well. In fact, the first proponents of the multiverse were the same ancient Greeks who proposed the existence of atoms. Leucippus and Democritus believed that their atomic theory required an infinity of worlds ("world" being synonymous with "universe"). Their later follower, Epicurus of Samos, also professed the reality of multiple worlds. "There are infinite worlds both like and unlike this world of ours," he averred.

Aristotle, however, argued strongly that logic required one universe only. His view prevailed until 1277, when the bishop of Paris declared that medieval scholars teaching Aristotle's view would be excommunicated—for denying God's

power to create as many universes as he wanted to. Centuries of debate followed. Some argued that God could create more universes but probably didn't; others maintained that reality comprised a "plurality of worlds."

In the 16th century, Copernicus turned the issue on its head. Instead of Aristotle's universe (Earth in the middle, surrounded by planets affixed to rotating spheres), Copernicus placed the sun in the middle, with the planets (including Earth) in orbit. The universe became a solar system, bounded by a sphere of stars. Shortly thereafter Thomas Digges in England redrew the Copernican picture, with stars littered throughout distant space rather than fixed to a single sphere. That raised the possibility of multiple solar system universes scattered throughout the heavens. Giordano Bruno, perhaps influenced by Digges, proclaimed that God is glorified "not in one, but in countless suns; not in a single earth, a single world, but in a thousand thousand, I say in an infinity of worlds."

Bruno's contemporary, the famed astronomer Johannes Kepler, didn't like that idea. He conceived the universe as the solar system. Similar worlds beyond our sight are not scientific. "If they are not seen," Kepler declared, "they for this reason are not pertinent to astronomy." Anything beyond what's visible, he insisted, "is superfluous metaphysics"—a view strikingly similar to the attitude of many toward the multiverse today.

Kepler was wrong, of course. Later telescopes revealed a multitude of stars at great distances, congregating in a lens-like disk, the Milky Way galaxy (of which the sun was one member). Just as Copernicus showed that the Earth is part of a solar system universe, the solar system became just one of many such "universes" in the Milky Way. Once again, the universe was redefined—no longer a set of spheres surrounding the Earth, or a set of planets orbiting the sun, but now a vast disk of stars surrounded by emptiness.

Except in that emptiness appeared fuzzy blobs, called nebulae. Immanuel Kant and others speculated that those blobs were actually galaxies themselves, just very far away—island universes, to use the term coined in the 1840s by the American astronomer Ormsby MacKnight Mitchel. This new vision of a multiverse also met with ridicule. "No competent thinker" believed in island universes, the astronomy writer Agnes Clerke declared at the end of the 19th century. It was an idea that had withdrawn "into the region of discarded and half-forgotten speculations."

But once again, the multiverse prevailed. In 1924 Edwin Hubble reported proof that some of those fuzzy nebulae, such as Andromeda, were indeed island universes as grand as the Milky Way. Hubble pioneered today's current definition of the universe as a vast expanding bubble of spacetime populated by billions and billions of such galaxies.

In the 1980s, a new explanation for how that universe came to be, called inflationary cosmology, revived the multiverse question in a novel way. If the initial big bang launching our universe into existence was followed by a burst of extremely rapid expansion (inflation), that same inflationary event could have recurred in other parts of space. If inflation theory turns out to be correct, our bubble would then be only one of many.

Of course, just because multiverse advocates have been right historically doesn't mean that they will certainly be right again this time. But multiverse opponents are certainly wrong to say that the multiverse idea is not science because it is not testable. The multiverse is not a theory to be tested, but rather a prediction of other theories that can be tested. Inflationary cosmology has, in fact, already passed many tests, although not yet enough to be definitively established.

For that matter, it's not necessarily true that other universes are in principle not observable. If another bubble collided with ours, telltale marks might appear in the cosmic background radiation left over from the big bang. Even without such direct evidence, their presence might be inferred by indirect means, just as Einstein demonstrated the existence of atoms in 1905 by analyzing the random motion of particles suspended in liquid.

Today, atoms actually can be "seen," in images produced by scanning tunneling microscopes. Atoms did not suddenly become real when first imaged, though; they had been legitimate scientific entities for two and a half millennia. Multiple universes have been a topic of philosophical-scientific discussion for just as long.

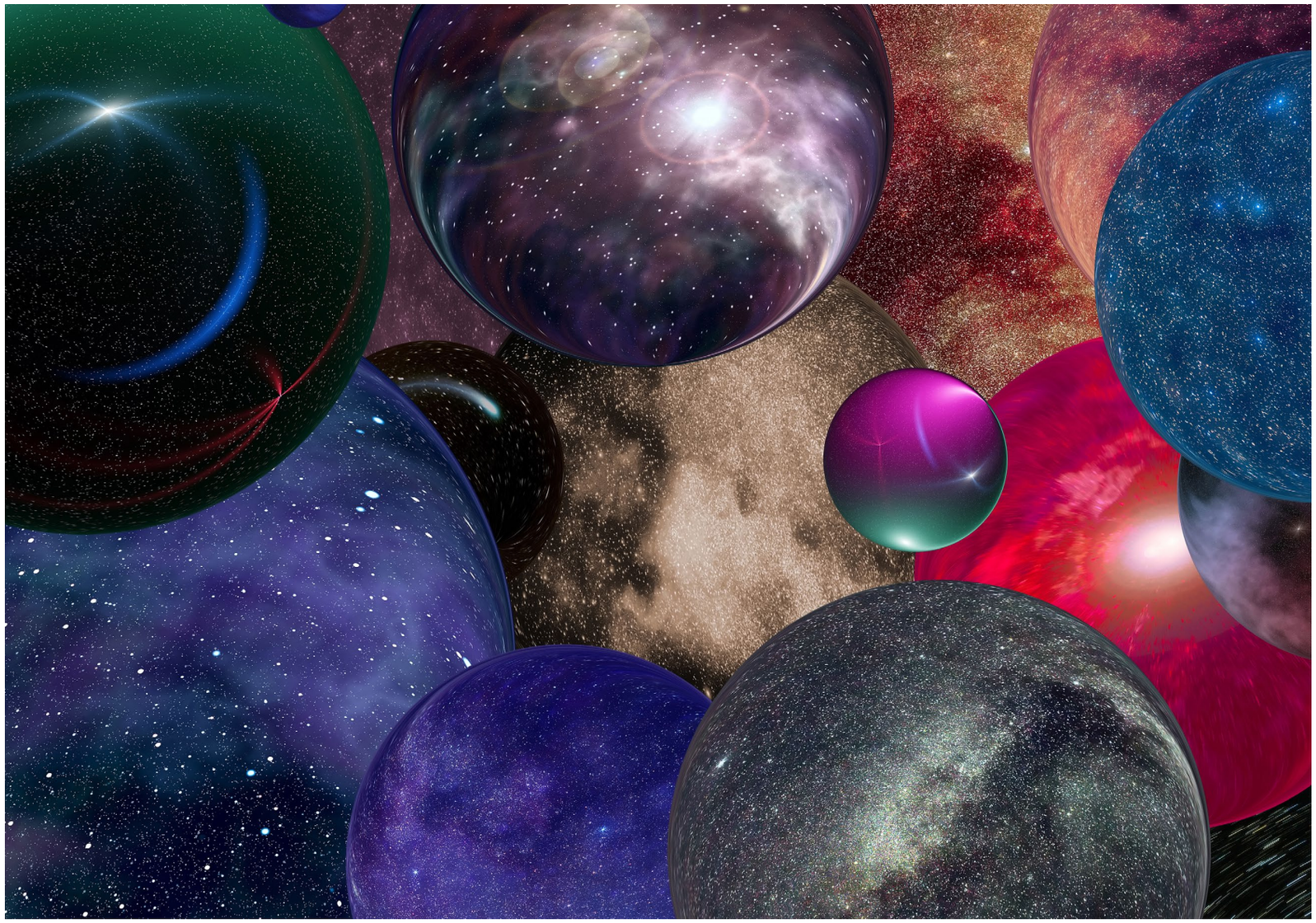
As for Occam's razor, you could check with William of Occam himself, the 14th-century philosopher who articulated that principle. In his day, he was the most enthusiastic of the advocates for a multiplicity of worlds.

John Horgan directs the Center for Science Writings at the Stevens Institute of Technology. His books include *The End of Science*, *The End of War* and *Mind-Body Problems*, available for free at mindbodyproblems.com.

SPACE

Multiverse Theories Are Bad for Science

New books by a physicist and science journalist mount aggressive but ultimately unpersuasive defenses of multiverses



IGOR SOKALSKI *GETTY IMAGES*

In 1990 I wrote a bit of fluff for *Scientific American* about whether our cosmos might be just one in an "infinitude," as several theories of physics implied. I titled my piece "Here a Universe, There a Universe …" and kept the tone light because I didn't want readers to take these cosmic conjectures too seriously. After all, there was no way of proving, or disproving, the existence of other universes.*

Today physicists still lack evidence of other universes or even good ideas for obtaining evidence. Many nonetheless insist our cosmos really is just a mote of dust in a vast "multiverse." One especially eloquent and passionate multiverse theorist is Sean Carroll. His faith in the multiverse stems from his faith in quantum mechanics, which he sees as our best account of reality.

In his book *Something Deeply Hidden*, Carroll asserts that quantum mechanics describes not just very small things but everything, including us. "As far as we currently know," he writes, "quantum mechanics isn't just an approximation to the truth; it is the truth." And however preposterous it might seem, a multiverse, Carroll argues, is an inescapable consequence of quantum mechanics.

To make his case, he takes us deep into the surreal quantum world. Our world! The basic quantum equation, called a wave function, shows a particle—an electron, say—inhabiting many

possible positions, with different probabilities assigned to each one. Aim an instrument at the electron to determine where it is, and you'll find it in just one place. You might reasonably assume that the wave function is just a statistical approximation of the electron's behavior, which can't be more precise, because electrons are tiny and our instruments crude. But you would be wrong, according to Carroll. The electron exists as a kind of probabilistic blur until you observe it, when it "collapses," in physics lingo, into a single position.

Physicists and philosophers have been arguing about this "measurement problem" for almost a century now. Various other explanations have been proposed, but most are either implausible, making human consciousness a necessary component of reality, or kludgy, requiring ad hoc tweaks of the wave function. The only solution that makes sense to Carroll—because it preserves quantum mechanics in its purest form—was proposed in 1957 by a Princeton graduate student, Hugh Everett III. He conjectured that the electron actually inhabits all the positions allowed by the wave function but in different universes.

This hypothesis, which came to be called the many-worlds theory, has been refined over the decades. It no longer entails acts of measurement or consciousness (sorry, New Agers). The universe supposedly splits, or branches, whenever one quantum particle jostles against another, making their wave functions collapse. This process, called "decoherence," happens all the time, everywhere. It is happening to you right now. And now. And now. Yes, zillions of your doppelgangers are out there at this very moment, probably having more fun than you. Asked why we don't feel ourselves splitting, Everett replied, "Do you feel the motion of Earth?"

"As far as we currently know, quantum mechanics isn't just an approximation to the truth; it is the truth."
—Sean Carroll

Carroll addresses the problem of evidence, sort of. He says philosopher Karl Popper, who popularized the notion that scientific theories should be precise enough to be testable, or falsifiable, "had good things to say about" Everett's hypothesis, calling it "a completely objective discussion of quantum mechanics." (Popper, I must add, had doubts about natural selection, so his taste wasn't irreproachable.)

Carroll proposes, furthermore, that because quantum mechanics is falsifiable, the many-worlds hypothesis "is the most falsifiable theory ever invented"—even if we can never directly observe any of those many worlds. The term "many," by the way, is a gross understatement. The number of universes created since the big bang, Carroll estimates, is two to the power of 10 to the power of 112. Like I said, an infinitude.

And that's just the many-worlds multiverse. Physicists have proposed even stranger multiverses, which science writer Tom Siegfried describes in his book *The Number of the Heavens*. String theory, which posits that all the forces of nature stem from stringy thingies wriggling in nine or more dimensions, implies that our cosmos is just a hillock in a sprawling "landscape" of universes, some with radically different laws and dimensions than ours. Chaotic inflation, a supercharged version of the big bang theory, suggests that our universe is a minuscule bubble in a boundless, frothy sea.

In addition to describing these and other multiverses, Siegfried provides a history of the idea of other worlds, which goes back to the ancient Greeks. (Is there anything they didn't think of first?) Acknowledging that "nobody can say for sure" whether other universes exist, Siegfried professes neutrality on their existence. But he goes on to construct an almost comically partisan defense of the multiverse, declaring that "it makes much more sense for a multiverse to exist than not."

Siegfried blames historical resistance to the concept of other worlds on Aristotle, who "argued with Vulcan-like assuredness" that Earth is the only world. Because Aristotle was wrong about that, Siegfried seems to suggest, maybe modern multiverse skeptics are wrong, too. After all, the known universe has expanded enormously since Aristotle's era. We learned only a century ago that the Milky Way is just one of many galaxies.

The logical next step, Siegfried contends, would be for us to discover that our entire cosmos is

one of many. Rebutting skeptics who call multiverse theories "unscientific" because they are untestable, Siegfried retorts that the skeptics are unscientific because they are "presupposing a definition of science that rules out multiverses to begin with." He calls skeptics "deniers"—a term usually linked to doubts about real things, like vaccines, climate change and the Holocaust.

I am not a multiverse denier, any more than I am a God denier. Science cannot resolve the existence of either God or the multiverse, making agnosticism the only sensible position. I see some value in multiverse theories. Particularly when presented by a writer as gifted as Sean Carroll, they goad our imaginations and give us intimations of infinity. They make us feel really, really small—in a good way.

But I'm less entertained by multiverse theories than I once was, for a couple of reasons. First, science is in a slump, for reasons both internal and external. Science is ill served when prominent thinkers tout ideas that can never be tested and hence are, sorry, unscientific. Moreover, at a time when our world, the real world, faces serious problems, dwelling on multiverses strikes me as escapism—akin to billionaires fantasizing about colonizing Mars. Shouldn't scientists do something more productive with their time?

Maybe in another universe Carroll and Siegfried have convinced me to take multiverses seriously, but I doubt it.