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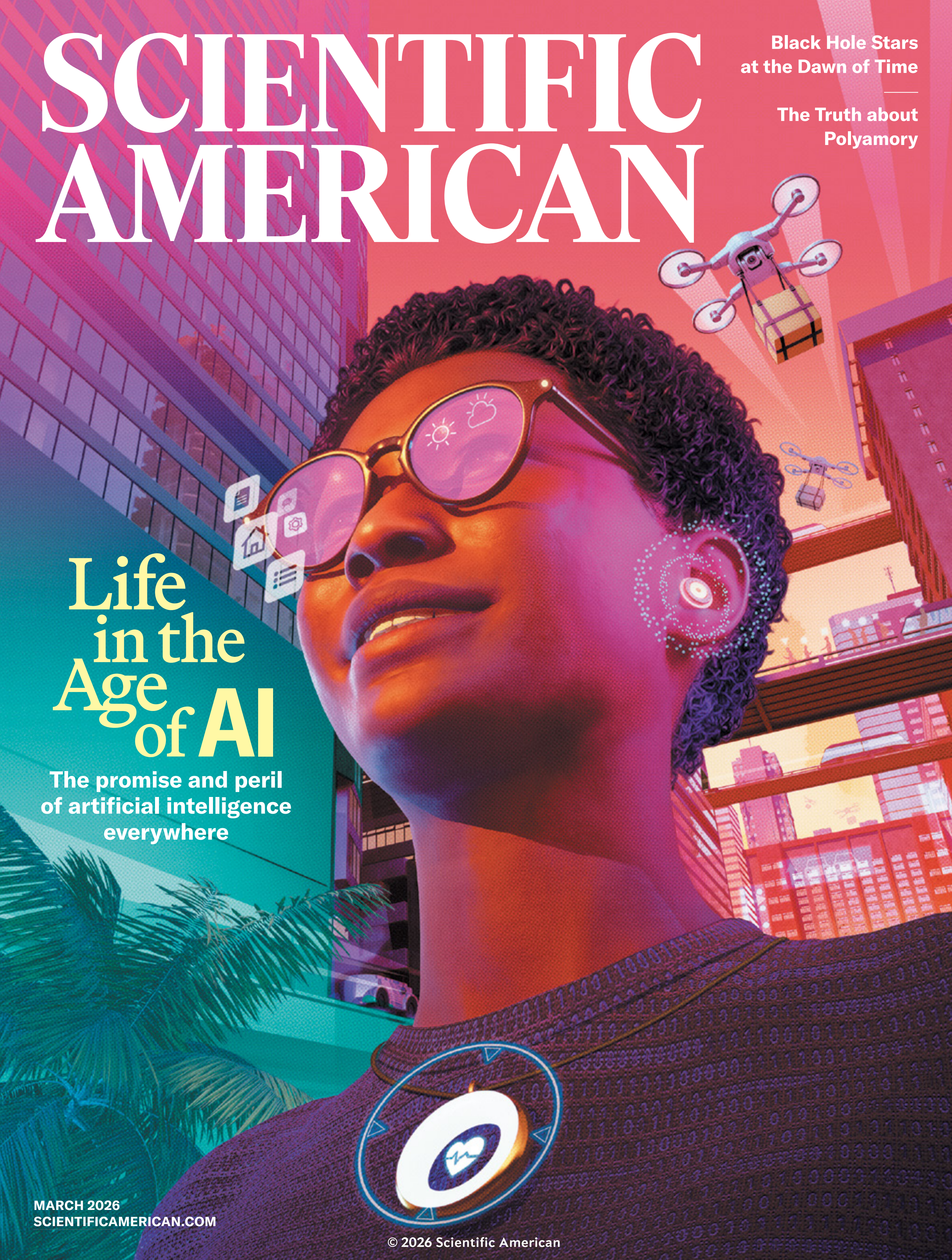
Black Hole Stars at the Dawn of Time

The Truth about Polyamory



Life in the Age of AI

The promise and peril of artificial intelligence everywhere

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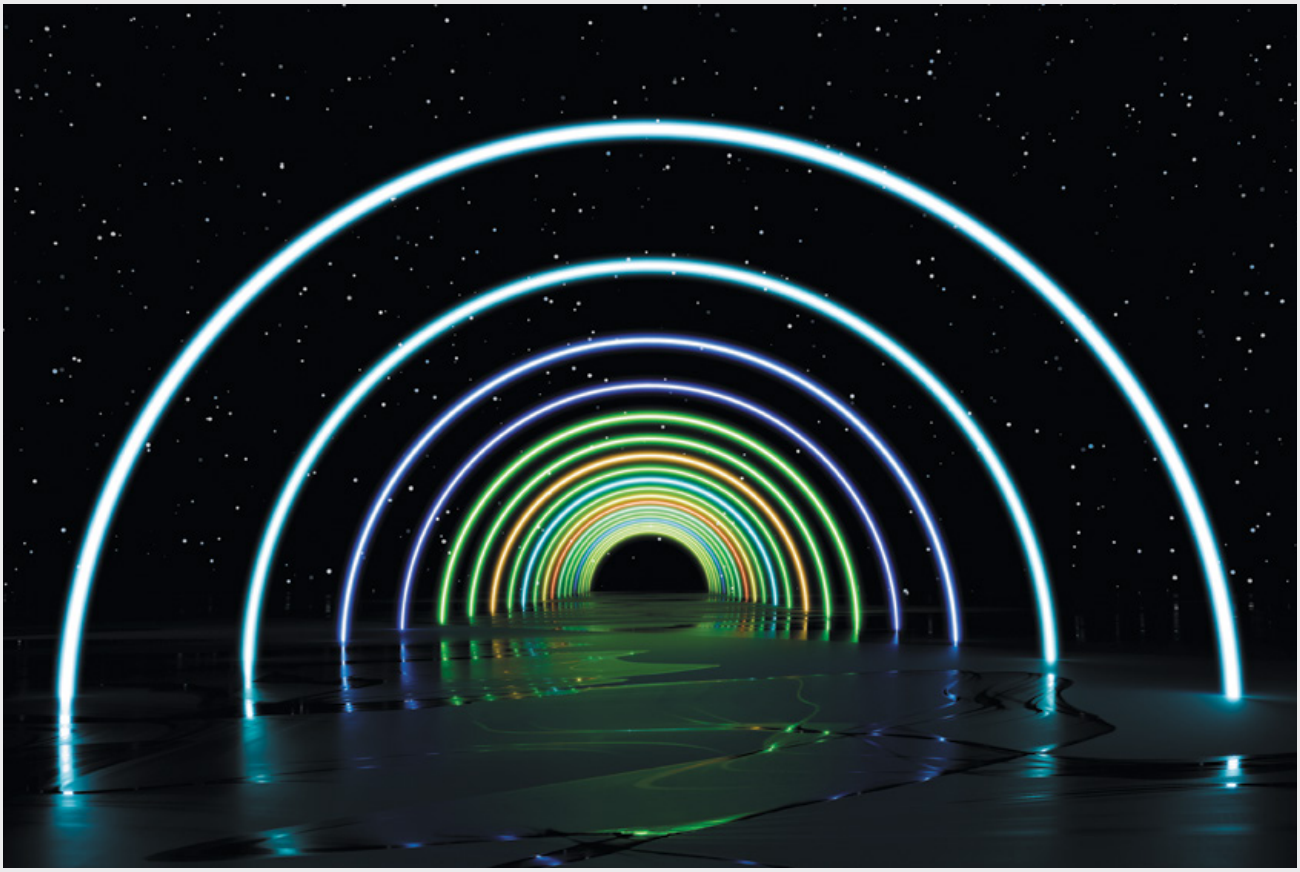

Flavio Coelho/Getty Images

The Universe's Weirdest Optical Illusions

Sometimes the farther away an object is, the bigger it seems to be BY PHIL PLAIT

IT'S ALWAYS AMAZING, and more than a little humbling, when the universe reminds us that our "common sense" is provincial and will fall apart on cosmic scales.

If you're on the surface of Earth—and I'm betting you are—there are many ways to reliably estimate the distance to some object. One thing we do almost subconsciously is compare an object's apparent size with how big we know it to be. For example, you have a good feel for the size of, say, a typical human. So if you see someone looming large in your vision, you can reckon they're nearby, whereas if they appear very small, they must be much farther away.

Of course, some humans are larger or smaller than average, but you can still account for that to get a decent distance estimate. And the overall trend is crystal clear: the farther off an object is, the smaller it appears. The trend is so obvious, in fact, that we can see that the rate of change is linear: Double the distance, and the object will appear to be half its previous size. Look at it from 10 times farther away, and it will seem to be a tenth as big.

This approach works great for familiar objects up to a few kilometers away, but astronomers are notoriously unsatisfied with these relatively tiny scales. We want to know the distances to objects that are trillions of kilometers away—or even billions of times farther than that!

In deep images of the sky from giant telescopes, galaxies abound. Some may be relatively close to us—merely some tens of millions of light-years distant—whereas others may be billions of light-years in the background. Just by looking at the image, how could you tell?

You might assume the galaxies that appear smaller are farther away, in keeping with our earthly intuition, but this tactic won't work; like humans, galaxies come in a range of sizes. When you

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Astronomers put up a Herculean struggle to determine distances.

examine an image, you might be looking at a massive galaxy nearly at the edge of the observable universe or at a tiny dwarf galaxy right in our cosmic backyard. If you're judging by just the image, it's impossible to tell.

There could be some standard physical scale to galaxies, some way to gauge their distance by linking details of their structure to their overall size, but such scenarios are apparently too simple for the universe's true complexity.

It turns out the standard linear scaling we use on Earth would apply at cosmic scales only if our universe were static—unchanging in size over time—but it isn't. Instead the universe is expanding, growing larger every day. This phenomenon brings with it a whole slew of bizarre consequences, but a surprising one is that beyond a certain threshold of separation from us, farther-off galaxies appear to get *bigger* with distance! As so often happens, the cosmos really is a lot odder than you think.

This seemingly paradoxical effect is a consequence of cosmic expansion coupled with the finite speed of light.

When we say a galaxy is, for example, 12 billion light-years away, what we usually mean is that the light from that galaxy took 12 billion years to reach us. But during that light's time in transit, the universe has gotten bigger all the while. That means it was smaller in the past, and the objects in it were much closer together. When the light left that galaxy 12 billion years ago, the galaxy was closer to us, so it appears bigger than expected for that distance once its light arrives here.

This is certainly counterintuitive and, frankly, weird. Still, it's borne out by the equations governing how the universe works. The effect holds for all galaxies but is imperceptibly small for those relatively nearby; their light's travel time is minuscule compared with the age of the universe, so the universe wasn't all that much smaller when they emitted the light we now see. Their apparent size isn't affected enough for us to detect the difference.

But the effect ramps up with distance and begins to dominate for objects with a light-travel time of about 9.5 billion years. Around that point, we're looking so far back in time—so far back in the universe's history of expansion—that the galaxies are effectively magnified, appearing larger than they otherwise would. The exact distance where this effect really kicks in depends on many complicated factors, including how rapidly the universe expands and how much matter it contains. In fact, if we could precisely measure this apparent growth in size, we could then use it to better determine these important cosmological parameters.

Unfortunately, because galaxies don't come in standard sizes, that's quite a difficult task. Worse, this cosmic magnification effect confusingly makes some galaxies look dimmer: if they appear bigger, their light is more spread out, so they become fainter and even more difficult to observe.

As surprising as this effect is, what may be even more astonishing is that we've been able to see far enough to detect it at all from our planetary perch in the backwaters of the Milky Way. Its very existence is one of many reasons astronomers put up a Herculean struggle to determine distances to extremely remote objects. Doing so can reveal information about such objects, of course, but it also tells us about the universe around them and the way it behaved when it was very young. Provided, of course, that we take to heart this hard lesson: once we start talking about distances measured in billions of light-years, our parochial evolution utterly fails us, and we have to be very careful not to extrapolate willy-nilly from our experience on Earth. ●