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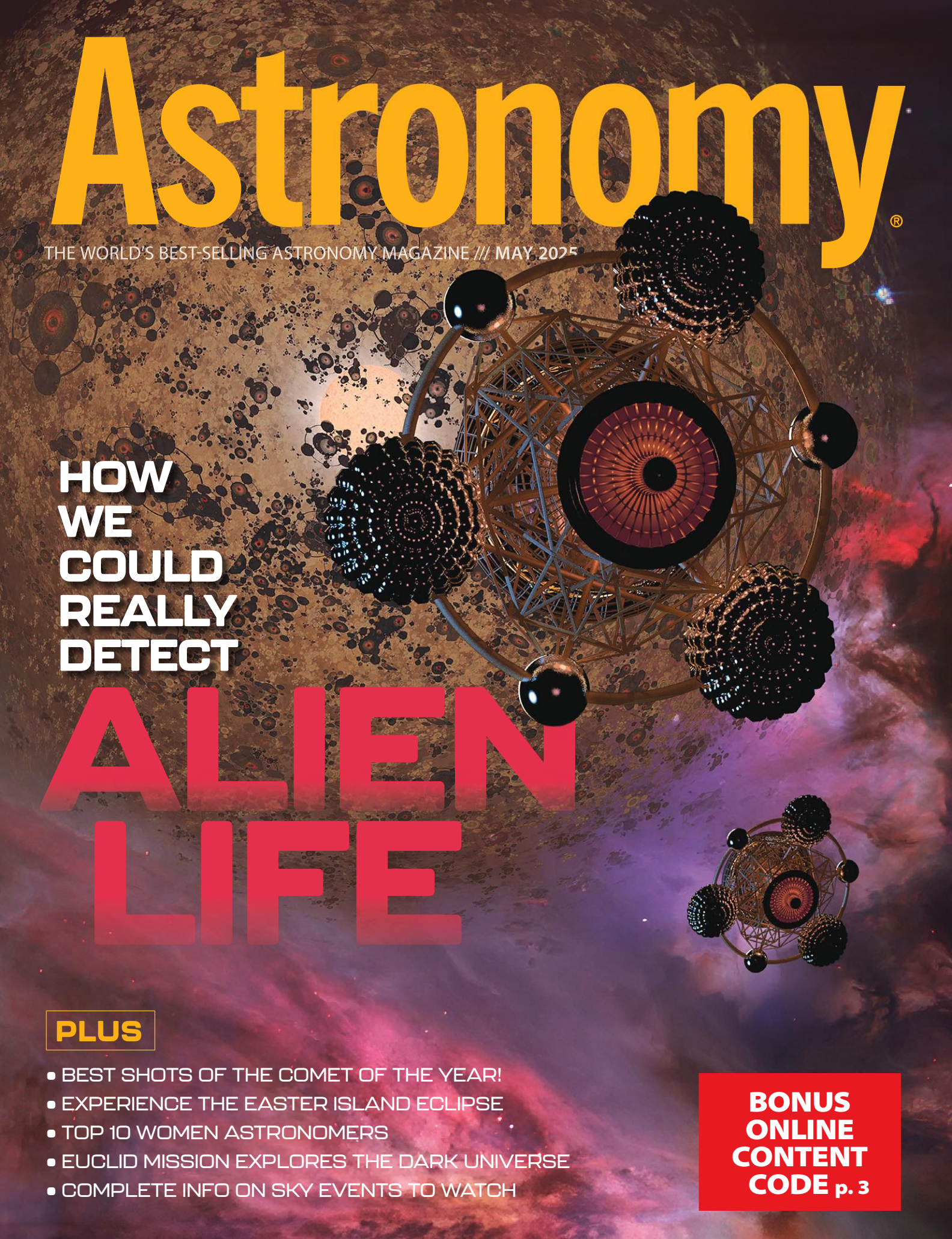

HOW WE COULD REALLY DETECT ALIEN LIFE

PLUS

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CAN WE DETECT ALIEN AR

SETI's senior astronomer explains how colossal artifacts could be the key to finding ET.

BY SETH SHOSTAK

THERE ARE TENS OF BILLIONS of Sun-like stars in the Milky Way, an immense tally that encourages the possibility that extraterrestrial life peppers the universe. Finding evidence for aliens — even microscopic ones — would confirm the widespread belief that life is not an unlikely event, constrained to a small number of planets and moons. It could be commonplace, a ubiquitous cosmic infection.

This idea is not new. Since the time of the classical Greeks, many scholars have assumed that life was everywhere, even though they lacked the technical means to find it. By the 19th century, European novelists were writing stories about sophisticated inhabitants of our Moon, and a century later both scientists and the public were convinced that Mars was teeming with clever beings who had built massive irrigation structures visible from earthly telescopes.

Even though the idea of lunar life is now considered foolish and the belief in canals on Mars has evaporated, the hope for discovering life beyond Earth has intensified. Much of this contemporary interest is powered by our successful discovery of more than nearly 6,000 planets around other stars, and that is surely just a small sample of what's out there. With all that opportunity for life, the idea of hunting for aliens by looking for their infrastructure — artifacts, in SETI parlance — whether irrigation or power systems, surely deserves another look.

NEARBY NEIGHBORS?

Exoplanets, it turns out, are as common as garden ants. However, it might not be necessary to search even that far afield to find some cosmic company. In our solar system, astronomers recognize at least seven worlds that could have reservoirs of liquid water — places where alien microbes could exist. And in a shift of thinking that would have surprised those Victorian-era scientists so focused on arid Mars, we now consider some of the moons of the outer solar system to be our best bets for finding life within rocket range. To 19th-century astronomers, these moons appeared only as luminous dots. But we now know these modest points of light are swathed in water and ice, and may be where we'll first find life beyond our own planet.

Our searches also are less direct now than they were when the Victorians turned

A swarm of satellites — collectively called a Dyson sphere — surrounds a red dwarf sun in this artist's concept. Each satellite is envisioned with solar sails to assist with orbital maneuvers. DON DIXON


TIFACTS?

their telescopes on the Red Planet. Instead, we try to find secondary clues to the presence of biology, such as using spectroscopy to search for atmospheric gases that are the byproduct of metabolism. This approach can work for moons and planets both near and far, for teeming ecosystems or scant microbiology.

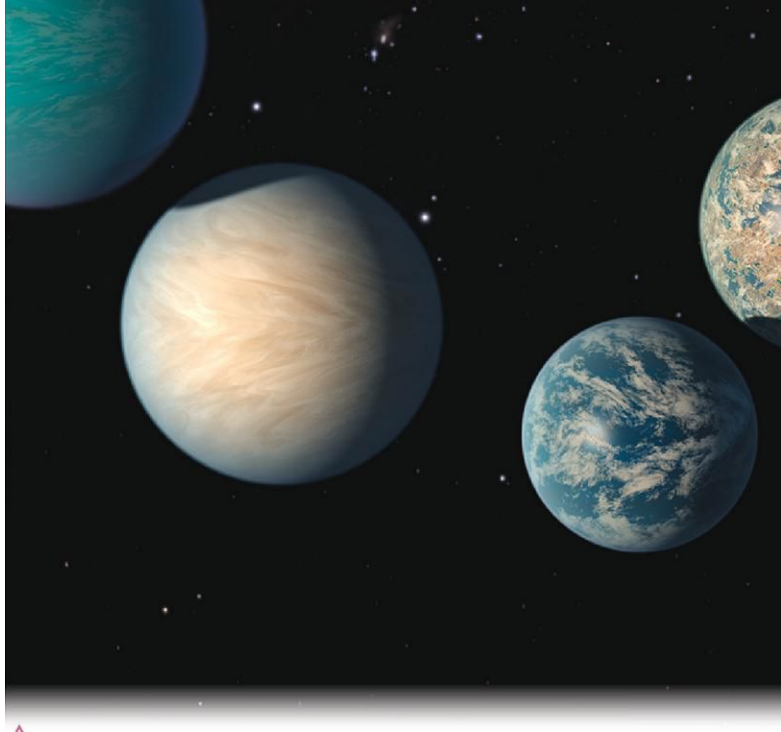
There's little doubt that finding any extraterrestrial life would be a stunning achievement. But the most interesting discovery would be to find intelligent life, which is to say organisms that can rival humans in their cognitive abilities, beings that are like the aliens in our movies and TV shows. Detecting thinking organisms would surely be one of the biggest news stories of all time, if not *the* biggest.

HOW'S IT GOING?

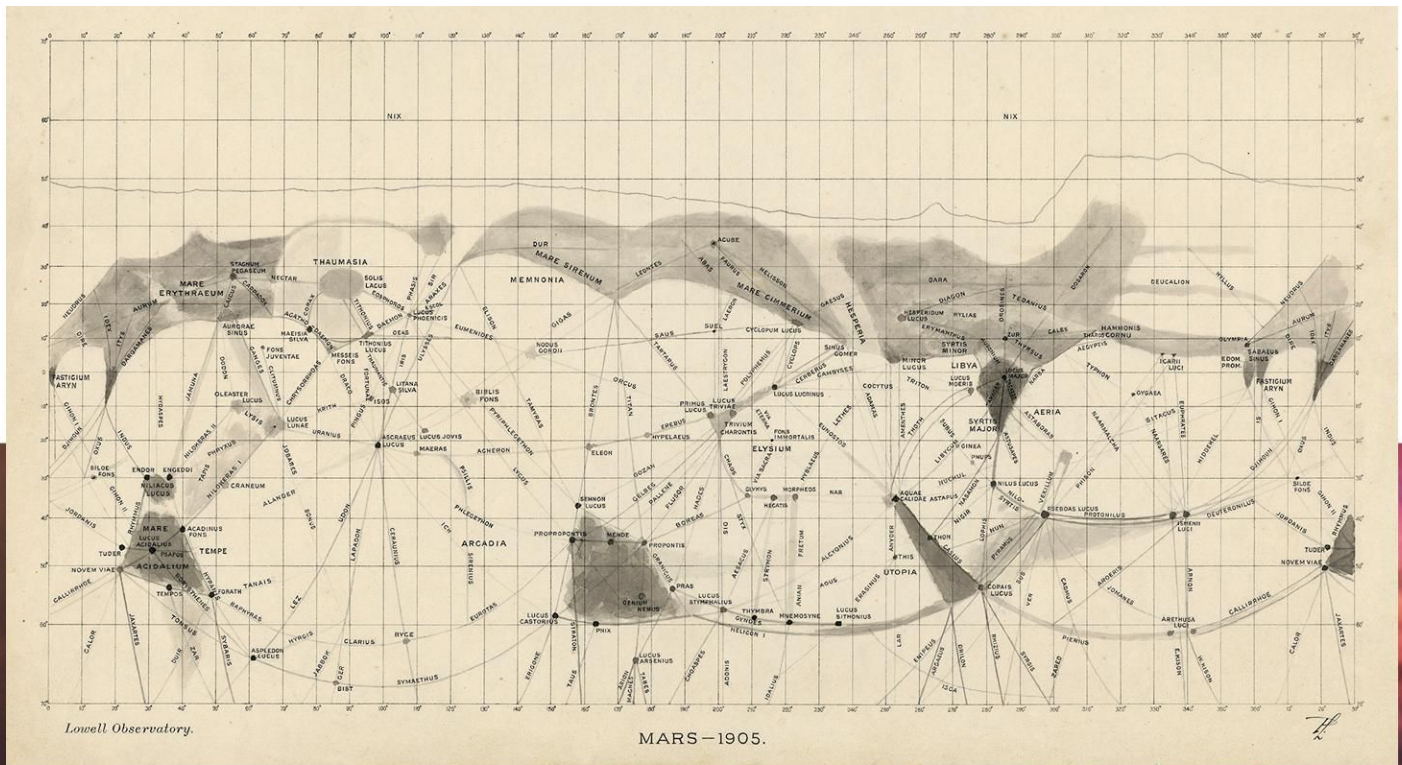
In the absence of direct contact, of course, we are limited to looking for other clues. By the time of World War II, most scientists had discounted the century-long claims of engineering projects — specifically, canals — built by thinking beings on Mars, ascribing them to optical illusions. As the Space Age got underway, flybys of the Red Planet not only failed to find such features, but revealed a desolate and seemingly sterile world.

Astronomers, undaunted, swung their instruments to more distant targets. In 1960, Frank Drake made the first modern attempt to pick up deliberate radio signals from extrasolar societies. He sequentially pointed an 85-foot-diameter (26 meters) radio telescope in West Virginia toward two nearby star systems in an endeavor known as SETI, the Search for Extraterrestrial Intelligence. He whimsically dubbed his two-week effort Project Ozma in a nod to Frank Baum's *Wizard of Oz* book series.

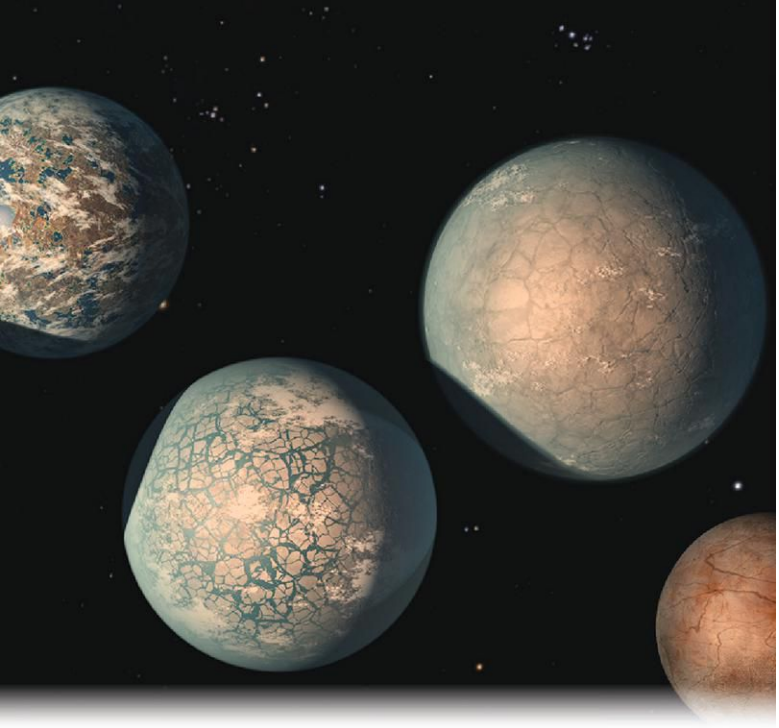
Drake didn't detect any extraterrestrial transmissions. Nonetheless, more than six decades later, radio searches remain the go-to method for trying to prove that someone is out there. Contemporary experiments are similar to Drake's and continue to use



Today, astronomers have confirmed more than 5,000 worlds of all kinds circling other stars, including the seven worlds imagined here, all of which orbit the star TRAPPIST-1. And the list just keeps growing. With so many possibilities in our galaxy alone, what might alien civilizations have left behind for us to find? NASA'S GODDARD SPACE FLIGHT CENTER



Percival Lowell's hand-drawn map of Mars, made in the opening years of the 20th century, shows the Red Planet crisscrossed with linear features he believed were canals built by an intelligent civilization. LOWELL OBSERVATORY ARCHIVES



the highly sensitive equipment of radio astronomy to search for the kind of narrowband signal that only an artificial transmitter could make.

We've still not found aliens, even though a majority of the scientific community, as well as the general public, believe they exist. Mind you, radio waves from the cosmos are commonplace, sustaining a substantial cohort of radio astronomers who study these emissions to learn about the universe. But while we've cataloged several thousand pulsars (spinning neutron stars) and more than a million quasars (feeding supermassive black holes), no signal picked up by our radio telescopes has yet had the characteristics of a deliberate broadcast.

Radio is only one technology communicating aliens might use, however. There are others: for example, flashing signals into space with lasers. Lasers can send many more bits of information per second than a radio transmitter, and consequently some advanced aliens might be using them for interstellar communication. To that end, the LaserSETI network, currently operated from roughly a dozen observatories worldwide, is designed to continually search the entire night sky for flashes of optical laser light originating beyond our solar system.

A CLASSIC IDEA

Signals are not the only kind of evidence for aliens we might find. In particular, we could look for massive artifacts, constructions large enough — or bright enough — to be detectable by our telescopes.

This is hardly a new idea; it goes back at least a half-millennium, when polymath and bishop Nicholas of Cusa suggested that all heavenly bodies were populated by plants and animals. During the Victorian era, several reputable astronomers claimed to have seen signs of intelligent beings in our own solar system. Italian astronomer Giovanni Schiaparelli and American astronomer Percival Lowell both claimed to espy straight-line markings on Mars. Lowell explained these as irrigation ditches constructed to support martian agriculture. The astronomers weren't seeing the martians themselves, of course — just their civil engineering efforts. The so-called martian canals eventually became a trope, if not a fact.

Astronomer Frank Drake utilized the 85-foot (26 m) Howard E. Tatel telescope in Green Bank, West Virginia, pictured here, for his two-week observing campaign in 1960 aimed at searching for signs of extraterrestrial intelligence. NRAO/AUI/NSF

SCALE IT UP

In 1964, Soviet astrophysicist Nikolai Kardashev published a paper in which he classified hypothetical alien civilizations by the amount of power they were capable of harnessing. His framework was later called the Kardashev Scale. Within it, Level I civilizations would be capable of utilizing a planet's worth of power, which he claimed Earth was close to already. (A 2023 *Nature* paper estimates we're at Kardashev Level 0.73 out of 3.)

Level II civilizations would be able to harness the power of their star, which both he and later researchers took to mean use of a Dyson sphere or similar technology.

Aliens with a Level III civilization would have access to power on a galactic scale, a feat that seems unimaginable until you consider that once aliens spread beyond a single planet or system, the metaphorical seal is broken. Indeed, it becomes difficult to imagine how to wipe out a fully established multiplanet species. And while we don't know what their infrastructure or communications might look like, many astronomers think it would be hard for such a civilization not to leave some kind of observable mark on the universe. *—Korey Haynes*

Public works and monuments, such as the famous pyramids of Giza in Cairo, Egypt, can far outlast their civilizations, leaving behind traces for future explorers to find. MIKHAIL KOKHANCHIKOV/DREAMSTIME.COM

Alien signals will certainly be novel and exciting, but not every signal from space is alien in origin. The regular radio blips we see from pulsars — fast-spinning neutron stars emitting beams of radiation from their poles, as imagined here — were once thought to be communications from aliens, but now have a natural explanation. NASA'S GODDARD SPACE FLIGHT CENTER

In 1960, physicist Freeman Dyson suggested another approach. He noted that technically sophisticated aliens might surround their home stars with a constellation of satellites outfitted with solar panels. This phalanx of orbiting light collectors, now termed a Dyson sphere, could capture a large fraction of the star's radiative output. This energy would then be beamed back to the aliens' home planet, powering their high-tech lifestyles with a scheme that offered an endless supply of energy and had no environmental impact. Crucially, scientists understand that these satellites would inevitably become warm, and consequently radiate a weak infrared glow that would make them visible to our telescopes.

The idea of Dyson spheres marking the location of sophisticated societies was not only ingenious, but also made a prediction that could be experimentally verified. The prediction in this case was that the satellites would produce infrared radiation. This meant that astronomers could find a Dyson sphere by noting any unexpected infrared emission from a star system.

For several decades, researchers have tried to do exactly that. Most recently, astronomers at Sweden's Uppsala Observatory surveyed 5 million stars, looking for the telltale glow of a Dyson sphere. They report finding 60 candidates that have more-than-expected infrared radiation, and are following up with additional observations.

THE ADVANTAGE OF ARTIFACTS

Searching for artifacts offers a straightforward advantage over the way SETI has historically been pursued. The traditional approach pioneered by Drake assumes that our telescopes are pointed in the aliens' direction at the same time their signal arrives at Earth.

This synchronicity requirement clearly reduces the chances of successfully eavesdropping on ET. By how much? Alas, we can't say without knowing how many societies are out there. We also need to have an idea of their typical lifetimes — how long do they signal for before they either die or are snuffed out? We don't know either of these things.

But if we hunt for artifacts instead of signals, we can largely avoid such uncertainties. Artifacts can be found at any time subsequent to their construction. The Egyptian pyramids and the American interstate highway system are

WHERE ARE ALL THE ALIENS?

Scientists in large part agree that the prospects are rich for life in the universe. Perhaps less intuitively, they've noted that given the billions of years the universe has existed, even the slowest space-faring society could still spread galaxy-wide in a few million years — the cosmic blink of an eye. So why aren't they visiting us on the regular?

This line of questioning is called Fermi's Paradox, named for Enrico Fermi, a Nobel laureate and architect of the atomic bomb who also pondered the existence of alien life along exactly these lines. While many a thought has been given to possible answers, whether while stargazing, writing a scientific paper, or staring at one's ceiling too late at night, a few theories commonly recur:

The Great Filter. While the prospects for life may be empirically good, some think that life (or perhaps multicellular life, or civilized life) actually developing is exceedingly rare. Perhaps we are a special case, though that's rarely been true any other time we've thought so throughout history.

Self-destruction. For those who look at humanity's tendency

Following in the footsteps of Frank Drake, our most current SETI efforts focus on detecting radio signals from space. The Commensal Open Source Multimode Interferometer Cluster (COSMIC) system uses the Very Large Array in Socorro, New Mexico, shown here, to search for signals while astronomers are using the array for unrelated scientific investigations. ALEX SAVELLO/NRAO

testaments to human existence that could plausibly outlive humans themselves. Even after we are long gone, these engineering projects will tell anyone who finds them that we were once here. And, as a further advantage, a hunt for artifacts doesn't depend on guessing the aliens' choice of frequency or transmitter power.

What sort of artifacts might we expect? While Dyson spheres are certainly one possibility, we can't confidently describe how an alien construction would appear any more than the first humans could accurately anticipate the appearance of a 21st-century cityscape. A fundamental challenge to any artifact hunt is that we can't be sure what we're looking for.

But it's not necessarily an insurmountable problem. We might still find these artifacts simply because they would be novel, and not already members of the known cosmic bestiary. For example, consider the aforementioned quasars. No one predicted the existence of these objects, let alone what they would look like. Indeed, both quasars and pulsars were initially suspected of being alien handiwork. We now have natural explanations for both, but they were discovered because they were different from other objects we knew about at the time.

ONLY THE BEST

Despite the fact that we can't say much about the appearance of alien artifacts, there's little doubt that any we find will be subject to selection effects. The easily detectable ones will surely be the biggest and brightest. This is akin to searching for dogs by listening for barks. You won't find all the dogs, and not necessarily the most interesting ones. Just the ones that make a lot of noise.

Similarly, the hunt for alien engineering efforts — if it turns up anything — will only show us the societies that build things easily visible from light-years away. Such constructions may not be typical, nor even of recent vintage. But no matter how singular such artifacts might be, their discovery would answer a long-standing question: Is anyone out there?

For nearly two centuries, we've searched for clever company in our cosmic neighborhood. Once, that search meant examining our solar system for artifacts, until we later switched strategies, hoping to pick up radio signals or other transmissions as the indication of another technological civilization. The latter is an approach that we've followed for a long time now.

Maybe we should revive the strategy of looking for artifacts. Space is vast, and it's conceivable that we'll never meet the aliens themselves. But we might uncover some of their public works.

Seth Shostak *directs the search for extraterrestrials as the senior astronomer and director of the SETI Institute in Mountain View, California.*

to wage war, pollute Earth, and generally hurt ourselves, a theory that resonates is that intelligent life destroys itself or its planet before it can ever establish a permanent space presence. How hopeful do you feel about our species' next hundred years or so?

Space is hard. While science-fiction dreams of roaming the stars abound, it might be difficult to put into practice, even given millions of years of opportunity. Maybe interstellar travel never proves economically or technologically practical or justifiable, even for advanced civilizations.

Sorry, didn't see you there. It's possible that alien life is so different from that on Earth that we simply can't recognize it, even when looking right at it. Along similar lines, maybe the life-forms are familiar, but their technology is so different that we don't know how to look or listen for them.

Radio silence. Stephen Hawking advised that humanity should limit our signals to outer space, in case the aliens are hostile. Maybe aliens think the same thing, either in general, or about us in particular.

Among us. Or, of course, they could already be here. While this doesn't usually hold much weight among scientists, many UFO aficionados regard it as a given.

The answers are endless. What's your explanation? —*K.H.*