All eyes on Proxima Centauri b

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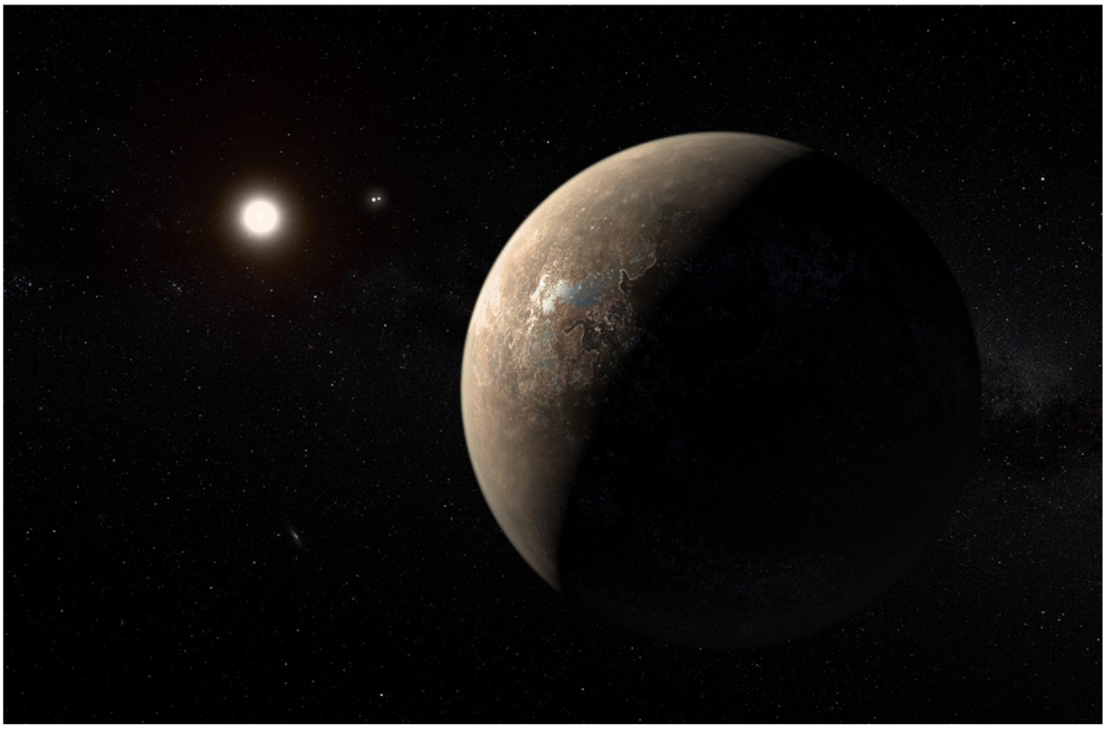
An Earth-sized planet next door: that was the startling announcement last August. Astronomers had found an exoplanet orbiting the sun's closest stellar neighbor, a cool red dwarf star called Proxima Centauri (1). Even better, the nearby world orbited within its parent star's habitable zone, meaning liquid water could exist on the planet's surface, which raised the prospects for its harboring life.

But aside from its mass—at least 1.3 times that of Earth's—and the length of its year—a zippy 11 days—little was known about the new exoplanet, called Proxima Centauri b. Almost immediately, a rush of papers appeared, presenting ways to estimate Proxima b's temperature, atmospheric composition and thickness, and even whether a worldwide ocean spans its surface. The proposed methods are extraordinarily tricky, pushing the boundary of what's possible.

"This planet is so good, so optimum, and so close to us, that using state-of-the-art technology we [can] demonstrate that it's not science fiction to do these observations," says astronomer Christophe Lovis of the University of Geneva in Switzerland. With two recently discovered systems garnering ample headlines—the potentially habitable planets near the star TRAPPIST-1 and a super-Earth orbiting the red dwarf LHS 1140—Proxima b offers a test case for how astronomers might take the first steps toward closer inspection of planets that seem to be prime candidates for life (2, 3).

In the future, enormous ground-based telescopes and specially designed space-based ones will allow astronomers to image exoplanets like Proxima b directly, providing unparalleled information about them. And with the world a mere 4.25 light-years from Earth, a few dreamers are starting to think bigger. A project called Breakthrough Starshot hopes to figure out if it is possible to accelerate a flotilla of extremely small satellites to one-fifth the speed of light and reach the Proxima Centauri system in only a couple of decades.

"You see the stars at night and wonder if we can visit them," says theoretical physicist Abraham Loeb of the



Proxima b, shown here in an artist's conception orbiting the red dwarf star Proxima Centauri, may prove to be a test case for how astronomers conduct initial inspections of potentially habitable planets. Original image courtesy of ESO/M. Kornmesser; retouched version courtesy of Wikimedia Commons/Karl 432.

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Harvard–Smithsonian Center for Astrophysics in Cambridge, Massachusetts. "This could be the next major leap forward; not just visiting a place like Mars or the moon, but doing something that is quite extraordinary."

In Our Sights

Part of a triple star system—along with the larger, yellow, sun-like twins Alpha Centauri A and B—Proxima and its kin have been subject to intensive exoplanet searches ever since astronomers have had the capability to do so. But Proxima Centauri is particularly finicky for these kinds of investigations. As a red dwarf, it is much more active than stars like our sun, throwing off energetic stellar flares that can interfere with astronomers' readings. "You're trying to look for little blips around the star but it's like someone's got ahold of the dimmer switch and they're playing around with it," says astronomer David Kipping of Columbia University in New York.

A team led by astronomer Guillem Anglada-Escudé, of the Queen Mary University of London in England, was able to spot Proxima b by running an algorithm on several years' worth of archival data from the Very Large Telescope (VLT) and the High Accuracy Radial velocity Planet Searcher (HARPS) instrument at the La Silla Observatory, both of which are overseen by the European Southern Observatory in Chile. The analysis yielded compelling clues for a planet, which the researchers then followed up on with a rigorous months-long observational campaign in early 2016. The astronomers spotted a tiny periodic wobble in the light from Proxima Centauri, indicating that a planet was tugging gravitationally on the star. Though some astronomers were initially skeptical, the data were robust enough to win over critics.

"I heard about this potentially habitable planet through the press and said 'Yeah, yeah, sure,'" says astrophysicist Laura Kreidberg of Harvard University in Cambridge, Massachusetts. "And then I saw the paper and said, "Oh wow, this is actually legit."

Soon thereafter, Kreidberg published a paper with Loeb on how to answer one of the first important follow-up questions for Proxima b: whether it has an atmosphere (4). During the first billion or so years of their lives, red dwarf stars shine far brighter in UV and X-ray radiation than they do later on, blasting any orbiting planets. Furthermore, a planet like Proxima b is so close to its parent star that it is likely to be tidally locked, meaning one side is always turned to the burning sun while the other faces the darkness of space. Combined with the excessive flaring problem, this increases the chances that atmospheres of these sorts of rocky worlds can burn off long before life can develop.

Astronomical Answers

The upcoming James Webb Space Telescope (JWST), scheduled to launch next year, could test Proxima b's atmospheric retention abilities. As the exoplanet orbits, viewers on Earth will see different parts of it illuminated, much like the moon changing phases in the night sky. JWST's infrared capabilities will be able to capture the combined thermal emission from both the star and planet, which should vary sinusoidally as the little world goes through phases during its 11-day orbit.

An airless body will show wild temperature swings; the sunlit side of the moon can reach 117 °C, whereas its dark side remains at −179 °C. In contrast, an atmosphere will efficiently move heat around: day–night temperature differences on our planet can be as little as a few degrees. The signal would be a good proxy for atmospheric thickness; a tenuous Mars-like atmosphere wouldn't redistribute heat as well as a denser Earth-like one.

Like any world, Proxima b is reflective. As starlight bounces off its surface, it could pass through a hypothetical atmosphere, imparting information about the gases present. The trouble is that Proxima Centauri is about 10 million times brighter than its planetary companion, so the planet's reflected light is completely washed out in the star's glare. Working with astronomer Ignas Snellen, of the University of Leiden in the Netherlands, Lovis came up with the idea of using a two-part system at the VLT to tease out Proxima b's secrets (5).

First, the researchers will use a sophisticated adaptive optics instrument called Spectro-Polarimetric High-contrast Exoplanet Research (SPHERE), which corrects for the turbulence in Earth's atmosphere that blurs telescopic images, creating a much clearer picture of the star and planet together. "Instead of having a planet that's 10 million times fainter, we will have a planet that's 1,000 times fainter," says Lovis. "Which is still 1,000 times, but it's already much better."

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—David Kipping

The data will then be passed through the Echelle SPectrograph for Rocky Exoplanet and Stable Spectroscopic Observations (ESPRESSO) instrument, which can disentangle the planet's light from the star's using an ingenious trick. When a body emitting radiation moves, the radiation's wavelength will grow longer as it travels away from an observer and shorter as it comes closer, an effect known as a Doppler shift. Although the starlight from Proxima Centauri will remain constant, the reflected light from Proxima b will get ever-so-slightly Doppler-shifted as it travels through its orbit, an effect that ESPRESSO can detect to unravel the two light effects from one another and hence provide astronomers a peek at the planet's molecular make-up. Biosignature molecules, such as oxygen and water vapor, would make for exciting findings.

The technique could also capture small changes in reflectivity as the planet rotates. An ocean on Proxima b would act like a mirror, creating a bright glint that the VLT might potentially observe. Getting SPHERE and ESPRESSO up to such challenges will require upgrades, including a new coronagraph in SPHERE and an optical fiber link between the instruments, but Lovis and Snellen think they should be able to provide the first information about Proxima b's composition and surface features within 3–5 years.

Pioneering Planet

In many ways, Proxima b will be a trailblazer. The exoplanet does not appear to eclipse its parent star, meaning starlight can't filter through any potential atmosphere (6). But the methods described above don't rely on such light, making them applicable to rocky worlds around other nearby red dwarf stars and complementary to techniques used for transiting exoplanets, such as those at TRAPPIST-1 (7). For nearby stars, the odds of finding a transiting Earth-sized exoplanet in the habitable zone is low, "less than 2 percent," says astrophysicist Jayne Birkby, also of the Smithsonian Center for Astrophysics. "So if we really want to understand our local neighborhood of exoplanets, we need all these techniques to work."

The best characterization, though, may be several more years away. In the 2020s, a new generation of ground-based observatories, such as the Thirty Meter Telescope, Giant Magellan Telescope, and European Extremely Large Telescope will begin focusing on nearby exoplanets with their huge mirrors. The Wide Field Infrared Survey Telescope, a space-based observatory scheduled to launch in the mid-2020s, might similarly use an enormous petal-like screen, known as a starshade, to selectively filter out Proxima Centauri's light and see the exoplanet. Beyond that, the astronomical community hopes to select either the Habitable Exoplanet Imager or the Large UV Optical and Infrared telescope to fly in the 2030s, either of which would be direct exoplanet imaging powerhouses.

But perhaps the most audacious scheme devised for Proxima b is Breakthrough Starshot, announced in April 2016, even before the exoplanet was discovered. Based on previously published ideas, the project would shoot centimeter-sized spacecraft with a 50-gigawatt laser, imparting each with the same thrust as the Space Shuttle at launch (6). The laser light would push a solar sail, a highly reflective extremely thin sheet, attached to each nanocraft, accelerating them toward the Proxima Centauri system. The initiative began with $100 million from Russian venture capitalist Yuri Milner. Loeb, who chairs the project's advisory committee, says they hope to use the next 5 years to identify whether such a mission is feasible while also working on developing some of the necessary technology.

"I think if it works and human ingenuity is up to the task, it would be a tremendous return," says Kipping, who is not involved in the initiative. "There's only so much you can do from 4 light-years away."

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