Discovery Expands Search for Earth-like Planets

Newly spotted frozen world orbits in a binary star system

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COLUMBUS, Ohio—A newly discovered planet in a binary star system located 3,000 light-years from Earth is expanding astronomers' notions of where Earth-like—and even potentially habitable—planets can form and how to find them.

At twice the mass of Earth, the planet orbits one of the stars in the binary system at almost exactly the same distance from which Earth orbits the sun. However, because the planet's host star is much dimmer than the sun, the planet is much colder than the Earth—a little colder, in fact, than Jupiter's icy moon Europa.

Four international research teams, led by professor Andrew Gould of The Ohio State University, published their discovery in the July 4 issue of the journal *Science*.

The study provides the first evidence that terrestrial planets can form in orbits similar to Earth's, even in a binary star system where the stars are not very far apart. Although this planet itself is too cold to be habitable, the same planet orbiting a sun-like star in such a binary system would be in the so-called "habitable zone" —the region where conditions might be right for life.

"This greatly expands the potential locations to discover habitable planets in the future," said Scott Gaudi, professor of astronomy at Ohio State. "Half the stars in the galaxy are in binary systems. We had no idea if Earth-like planets in Earth-like orbits could even form in these systems. "

Very rarely, the gravity of a star focuses the light from a more distant star and magnifies it like a lens. Even more rarely, the signature of a planet appears within that magnified light signal. The technique astronomers use to find such planets is called gravitational microlensing, and computer modeling of these events is complicated enough when only one star and its planet are acting as the lens, much less two stars.

Searching for planets within binary systems is tricky for most techniques, because the light from the second star complicates the interpretation of the data. "But in gravitational microlensing," Gould explained, "we don't even look at the light from the star-planet system. We just observe how its gravity affects light from a more distant, unrelated, star. This gives us a new tool to search for planets in binary star systems."

But when the astronomers succeeded in detecting this new planet, they were able to document that it produced two separate signatures—the primary one, which they typically use to detect planets, and a secondary one that had previously been only hypothesized to exist.

The first is a brief dimming of light, as the planet's gravity disrupts one of the magnified images of the source star. But the second effect is an overall distortion of the light signal.

"Even if we hadn't seen the initial signature of the planet, we could still have detected it from the distortion alone," Gould said, pointing to a graph of the light signal. ""The effect is not obvious. You can't see it by eye, but the signal is unmistakable in the computer modeling."

Gaudi explained the implications.

"Now we know that with gravitational microlensing, it's actually possible to infer the existence of a planet—and to know its mass, and its distance from a star—without directly detecting the dimming due to the planet," he said. "We thought we could do that in principle, but now that we have empirical evidence, we can use this method to find planets in the future."

The nature of these distortions is still somewhat of a mystery, he admitted.

"We don't have an intuitive understanding of why it works. We have some idea, but at this point, I think it would be fair to say that it's at the frontier of our theoretical work."

The planet, called OGLE-2013-BLG-0341LBb, first appeared as a "dip" in the line tracing the brightness data taken by the OGLE (Optical Gravitational Lensing Experiment) telescope on April 11, 2013. The planet briefly disrupted one of the images formed by the star it orbits as the system crossed in front of a much more distant star 20,000 light-years away in the constellation Sagittarius.

"Before the dip, this was just another microlensing event," Gould said. It was one of approximately 2,000 discovered every year by OGLE, with its new large-format camera that monitors 100 million stars many times per night searching for such events.

"It's really the new OGLE-IV survey that made this discovery possible," he added. "They got a half dozen measurements of that dip and really nailed it." From the form of the dip, whose wings were traced out in MOA (Microlensing Observations in Astrophysics) data, they could see that the source was headed directly toward the central star.

Then, for two weeks, astronomers watched the magnified light continue to brighten from telescopes in Chile, New Zealand, Israel and Australia. The teams included OGLE, MOA, MicroFUN (the Microlensing Follow Up Network), and the Wise Observatory.

Even then, they still didn't know that the planet's host star had another companion—a second star locked into orbit with it. But because they were already paying close attention to the signal, the astronomers noticed when the binary companion unexpectedly caused a huge eruption of light called a caustic crossing.

By the time they realized that the lens was not one star, but two, they had captured a considerable amount of data—and made a surprising discovery: the distortion.

Weeks after all signs of the planet had faded, the light from the binary-lens caustic crossing became distorted, as if there were a kind of echo of the original planet signal.

Intensive computer analysis by professor Cheongho Han at Chungbuk National University in Korea revealed that the distortion contained information about the planet—its mass, separation from its star, and orientation—and that information matched perfectly with what astronomers saw during their direct observation of the dip due to the planet. So the same information can be captured from the distortion alone.

This detailed analysis showed that the planet is twice the mass of Earth, and orbits its star from an Earth-like distance, around 90 million miles. But its star is 400 times dimmer than our sun, so the planet is very cold—around 60 Kelvin (-352 degrees Fahrenheit or -213 Celsius), which makes it a little colder than Jupiter's moon Europa. The second star in the star system is only as far from the first star as Saturn is from our sun. But this binary companion, too, is very dim.

Still, binary star systems composed of dim stars like these are the most common type of star system in our galaxy, the astronomers said. So this discovery suggests that there may be many more terrestrial planets out there—some possibly warmer, and possibly harboring life.

Four other terrestrial planets have been discovered in binary systems that have similar separations using different techniques. This is the first one close to Earth-like size that follows an Earth-like orbit, and its discovery within a binary system was by chance.

"Normally, once we see that we have a binary, we stop observing. The only reason we took such intensive observations of this binary is that we already knew there was a planet," Gould said. "In the future we'll change our strategy."

In particular, Gould singled out the work of amateur astronomer and frequent collaborator Ian Porritt of Palmerston North, New Zealand, who watched for gaps in the clouds on the night of April 24 to get the first few critical measurements of the jump in the light signal that revealed that the planet was in a binary system. Six other amateurs from New Zealand and Australia contributed as well.

Other project collaborators hailed from Ohio State, Warsaw University Observatory, Chungbuk National University, Harvard-Smithsonian Center for Astrophysics, University of Cambridge, Universidad de Concepción, Auckland Observatory, Auckland University of Technology, University of Canterbury, Texas A&M University, Korea Astronomy and Space Science Institute, Solar-Terrestrial Environment Laboratory, University of Notre Dame, Massey University, University of Auckland, National Astronomical Observatory of Japan, Osaka University, Nagano National College of Technology, Tokyo Metropolitan College of Aeronautics, Victoria University, Mt. John University Observatory, Kyoto Sangyo University, Tel-Aviv University and the University of British Columbia.

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