An Earth-sized rogue planet discovered in the Milky Way

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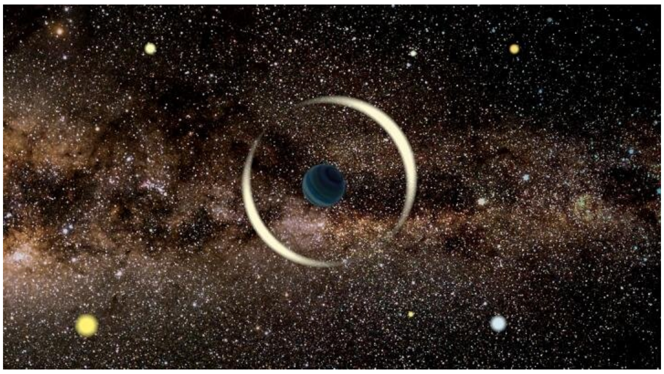

An artist's impression of a gravitational microlensing event by a free-floating planet. Credit: Jan Skowron / Astronomical Observatory, University of Warsaw

Our galaxy may be teeming with rogue planets, gravitationally unbound to any star. An international team of scientists, led by Polish astronomers, has announced the discovery of the smallest Earth-sized free-floating planet found to date.

Over 4,000 extrasolar planets have been discovered to date. Although many of the known exoplanets do not resemble those in our solar system, they have one thing in common—they all orbit a star. However, theories of planet formation and evolution predict the existence of free-floating (rogue) planets, gravitationally unattached to any star. Indeed, a few years ago, Polish astronomers from the OGLE team from the Astronomical Observatory of the University of Warsaw provided the first evidence for the existence of such planets in the Milky Way. Writing in *Astrophysical Journal Letters*, OGLE astronomers announced the discovery of the smallest rogue planet found to date.

Exoplanets can only rarely be directly observed. Usually, astronomers find planets using observations of the light from the planet's host star. For example, if a planet crosses in front of its parent star's disk, then the observed brightness of the star periodically drops by a small amount causing so called transits. Astronomers can also measure the motion of the star caused by the planet.

Free-floating planets emit virtually no radiation and—by definition—they do not orbit any host star, so they cannot be discovered using traditional methods of astrophysical detection. Nevertheless, rogue planets can be spotted using an astronomical phenomenon called gravitational microlensing. Microlensing results from Einstein's theory of general relativity—a massive object (the lens) may bend the light of a bright background object (the source). The lens' gravity acts as a huge magnifying glass which bends and magnifies the light of distant stars.

"If a massive object (a star or a planet) passes between an Earth-based observer and a distant source star, its gravity may deflect and focus light from the source. The observer will measure a short brightening of the source star," explains Dr. Przemek Mroz, a postdoctoral scholar at the California Institute of Technology and a lead author of the study. "Chances of observing microlensing are extremely slim because three objects—source, lens, and observer—must be nearly perfectly aligned. If we observed only one source star, we would have to wait almost a million year to see the source being microlensed," he adds.

This is why modern surveys hunting for gravitational microlensing events are monitoring hundreds of millions of stars in the Milky Way center, where the chances of microlensing are highest. The OGLE survey—led by Warsaw University astronomers—carries out one such experiment. OGLE is one of the largest and longest sky surveys, starting operations over 28 years ago. Currently, OGLE astronomers are using a

1.3-meter Warsaw Telescope located at Las Campanas Observatory, Chile. Each clear night, they point their telescope to the central regions of the galaxy and observe hundreds of millions of stars, searching for those which change their brightness.

Gravitational microlensing does not depend on the lens' brightness, so it enables the study of faint or dark objects such as planets. Duration of microlensing events depends on the mass of the lensing object—the less massive the lens, the shorter the microlensing event. Most of the observed events, which typically last several days, are caused by stars. Microlensing events attributed to free-floating planets have timescales of barely a few hours. By measuring the duration of a microlensing event (and shape of its light curve) we can estimate the mass of the lensing object.

The scientists announced the discovery of the shortest-timescale microlensing event ever found, called OGLE-2016-BLG-1928, which has the timescale of just 42 minutes. "When we first spotted this event, it was clear that it must have been caused by an extremely tiny object," says Dr. Radoslaw Poleski from the Astronomical Observatory of the University of Warsaw, a co-author of the study.

Indeed, models of the event indicate that the lens must have been less massive than Earth, it was probably a Mars-mass object. Moreover, the lens is likely a rogue planet. "If the lens were orbiting a star, we would detect its presence in the light curve of the event," adds Dr. Poleski. "We can rule out the planet having a star within about 8 astronomical units (the astronomical unit is the distance between the Earth and the sun)."

OGLE astronomers provided the first evidence for a large population of rogue planets in the Milky Way a few years ago. However, the newly-detected planet is the smallest rogue world ever found. "Our discovery demonstrates that low-mass free-floating planets can be detected and characterized using ground-based telescopes," says Prof. Andrzej Udalski, the PI of the OGLE project.

Astronomers suspect that free-floating planets actually formed in protoplanetary disks around stars (as "ordinary" planets) and they have been ejected from their parent planetary systems after gravitational interactions with other bodies, for example, with other planets in the system. Theories of planet formation predict that the ejected planets should be typically smaller than Earth. Thus, studying free-floating planets enables us to understand the turbulent past of young planetary systems, such as the solar system.

The search for free-floating planets is one of the science drivers of the Nancy Grace Roman Space Telescope, which is currently being constructed by NASA. The observatory is scheduled to start operations in the mid-2020s.

Because of the brevity of the event, additional observations collected by the Korea Microlensing Telescope Network (KMTNet) were needed to characterize the event. KMTNet operates a network of three telescopes—in Chile, Australia, and South Africa.

More information: Przemek Mróz et al. A Terrestrial-mass Rogue Planet Candidate Detected in the Shortest-timescale Microlensing Event, *The Astrophysical Journal* (2020). DOI: 10.3847/2041-8213/abbfad

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