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If rogue planets are everywhere, how could we explore them?

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An illustration of an ice-covered rogue planet. Credit: NASA's Goddard Space Flight Center

At one time, astronomers believed that the planets formed in their current orbits, which remained stable over time. But more recent observations, theory, and calculations have shown that planetary systems are subject to shake-ups and change. Periodically, planets are kicked out of their star systems to become "rogue planets," bodies that are no longer gravitationally bound to any star and are adrift in the interstellar medium (ISM). Some of these planets may be gas giants with tightly bound icy moons orbiting them, which they could bring with them into the ISM.

Like Jupiter, Saturn, Uranus, and Neptune, these satellites could have warm water interiors that might support life. Other research has indicated that rocky planets with plenty of water on their surfaces could also support life through a combination of geological activity and the decay of radionuclides. According to a recent paper by an international team of astronomers, there could be hundreds of rogue planets in our cosmic neighborhood. Based on their first-ever feasibility analysis, they also indicate that deep space missions could explore these unbound objects more easily than planets still bound to their stars.

The research was led by Manasvi Lingam, an assistant professor at the Department of Aerospace, Physics, and Space Sciences at the Florida Institute of Technology and the Institute for Fusion Studies at the University of Texas at Austin. Joining him were Andreas M. Heinc, a researcher with the Interdisciplinary Center for Security, Reliability, and Trust (SnT) at the University of Luxembourg and the Initiative for Interstellar Studies (i4is); and T. Marshall Eubanks, the chief scientist at Space Initiatives Inc. Their paper, titled "Chasing nomadic worlds: A new class of deep space missions," was recently published in *Acta Astronautica*.

As Lingam and his colleagues note in their paper, interstellar objects (ISO) are a time-honored field of study that was already quite active by the 1970s. However, the detection of 'Oumuamua in 2017, the first recorded encounter with an ISO, followed by the detection of 2I/Borisov in 2019, has brought this field to the forefront of scientific research. Subsequent research has revealed previous instances where smaller interstellar objects and meteors came to Earth, allowing their abundances to be constrained.

One such object (CNEOS 2014-01-08) was found in the meteor catalog of NASA's Center for Near Earth Object Studies (CNEOS) by Harvard astrophysicists Amir Siraj and Professor Avi Loeb (Prof. Lingam's former mentor). According to CNEOS, this interstellar meteor landed in the South Pacific off the coast of Papua New Guinea in 2014. The Galileo Project (led by Prof. Loeb) mounted a sample retrieval campaign last year, which retrieved hundreds of metallic spherules from the meteor's remains on the ocean floor (360 and counting).

However, Lingam and his colleagues investigate the possibility of studying much larger objects. Research from the 1990s predicted that gravitational microlensing experiments could enable the detection of extrasolar planets, including those unbound to any stars. This has since been confirmed by surveys that have gauged the distribution of rogue planets, indicating that they are likely prevalent within our galaxy. This includes a pair of studies led by David Bennett, a Senior Research Scientist with the Science Mission Directorate (SMD) at NASA Goddard.

The study papers, which are scheduled to appear in the *Astronomical Journal*, suggest that there could be trillions of rogue planets wandering the Milky Way. As Prof. Lingam told Universe Today via email, the prolific nature of rogue objects and their potential to support life presents tremendous opportunities for future exploration:

"It is estimated that there might be as many as 1,000 moon-sized and larger nomadic worlds per star. Hence, even if a small fraction of them possess conditions amenable to life, they would be among the most common abodes for life. This is why they may represent a promising target for astrobiology."

The subject of rogue planets, satellites, and smaller objects' potential for habitability was explored extensively in Prof. Lingam's 2021 book "Life in the Cosmos: From Biosignatures to Technosignatures" (co-authored by Prof. Loeb). For the sake of this study, Prof. Lingam and his colleagues focused on objects significantly larger than meteorites or "Oumuamua and 2I/Borisov—which measured between 100 and 1,000 meters (~330 to 3,300 ft) in diameter. They also cast a wide net that extended for two orders of magnitude, ranging from bodies comparable to Main Belt Asteroids to planets with radii between Earth and Mars.

"We focused on objects in the radius range of 100 to 10,000 km. These worlds can be rocky/icy and may potentially support liquid water in the (sub)surface for up to 100 Myr or more. The number of these objects depends on their size; as many as 1,000 moon-sized and larger nomadic worlds may exist per star."

In addition, they determined that smaller objects are likely to be far more numerous than larger rocky bodies and that they are statistically more likely to be found closer to the inner solar system. Their results also suggest that tens of thousands of planet-sized nomadic worlds could be within a spherical volume centered on Earth and extending to the nearest star system (Proxima Centauri). Whereas Proxima Centauri has three confirmed exoplanets, one of them rocky and located within the star's habitable zone (Proxima b), these rogue planets constitute the nearest exoplanets beyond our solar system.

In the near future, multiple organizations and non-profits want to mount the first interstellar missions to the nearest stars to investigate their planetary systems. Examples include Breakthrough Starshot, a proposed mission architecture combining gram-scale watercraft and directed-energy propulsion (DEP) to achieve interstellar missions in our lifetimes. However, as Lingam and his team noted, these missions would save time and money by directing their efforts to explore potentially-habitable rogue planets nearer to the solar system.

To this end, they investigated several proposed propulsion methods that are currently being investigated for interstellar mission architectures. Specifically, they sought concepts that could accomplish missions to study Earth-sized planets with a 50-year flight timescale.

Said Lingam, "We considered many propulsion systems such as electric and magnetic sails, solar and laser sails, nuclear fusion, laser and nuclear electric propulsion, and chemical propulsion. Among the various candidates, we determined that laser sails (spacecraft propelled by laser arrays) are the most promising for reaching nomadic worlds in a reasonable time frame."

These findings present opportunities for existing and next-generation space telescopes. In the coming years, astronomers hope to expand the search for rogue planets and further constrain the number of unbound objects that are out there right now. In 2027, NASA will launch the next-generation Nancy Grace Roman Space Telescope, the true successor of Hubble and named after NASA's first chief astronomer who played a foundational role in the telescope's creation (hence her nickname, "The Mother of Hubble").

According to the same papers led by NASA Goddard's David Bennett, Roman could find as many as 400 Earth-like rogue planets during its primary mission. The technique key to this process is known as Gravitational Microlensing, typically used for hunting exoplanets bound to stars. This technique combines elements of the Transit Method and Gravitational Lensing, relying on the gravitational force of massive objects to bend and focus light coming from a distant star. As a planet passes in front of this star relative to the observer (aka. transits), there is a measurable dip in brightness that can be used to infer the presence of a planet.

According to Lingam, microlensing surveys performed by Nancy Grace

Roman will help confirm their results and determine the locations of rogue planets in our stellar neighborhood, all of which could be targets for future exploration missions.

"Through the technique of gravitational microlensing, missions like the Nancy Grace Roman Space Telescope and Euclid are expected to empirically constrain the abundances of nomadic worlds, because these telescopes may detect worlds smaller than the Earth (e.g., moon-sized)," Lingam stated.

By exploring rogue objects kicked from their systems, scientists can conduct lucrative astrobiology missions without having to travel to distant stars. These efforts are likely to happen in parallel with missions to the outer solar system, where robotic explorers will travel to icy moons like Europa, Ganymede, Titan, Callisto, etc., and either collect samples from the surface or drill/melt through the surface ice to look for evidence of biosignatures. Even in instances where biosignatures are not evident, the study of rogue bodies will provide considerable insight into the formation and evolution of other planetary systems.

Any way you slice it, studying rogue planets and objects will tell us things about star systems that could only be learned by going there. Given the time, energy, and expense of mounting interstellar voyages, this option is faster, cheaper, and ultimately preferable. Moreover, exploring rogue objects could serve as "pathfinder missions," providing scientists with a taste of what we are likely to find out there in the galaxy and pointing the way toward the most promising locations.

More information: Manasvi Lingam et al, Chasing nomadic worlds: A new class of deep space missions, *Acta Astronautica* (2023). DOI: 10.1016/j.actaastro.2023.07.030. On *arXiv*: arxiv.org/abs/2307.12411

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