TRAPPIST-1 outer planets likely have water, research suggests

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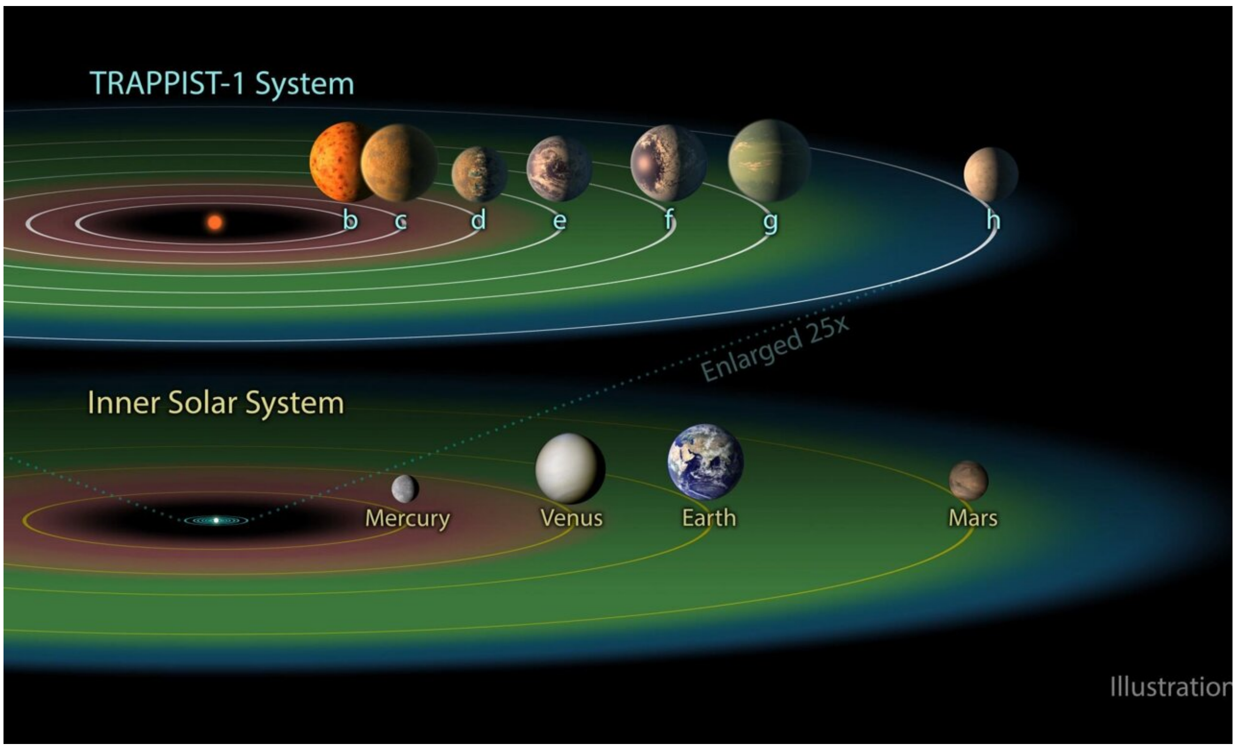


Three of the TRAPPIST-1 planets—TRAPPIST-1e, f and g—dwell in their star's so-called "habitable zone." Credit: NASA/JPL

The TRAPPIST-1 solar system generated a swell of interest when it was observed several years ago. In 2016, astronomers using the Transiting Planets and Planetesimals Small Telescope (TRAPPIST) at La Silla Observatory in Chile detected two rocky planets orbiting the red dwarf star, which took the name TRAPPIST-1. Then, in 2017, a deeper analysis found another five rocky planets.

It was a remarkable discovery, especially because up to four of them could be the right distance from the star to have liquid water.

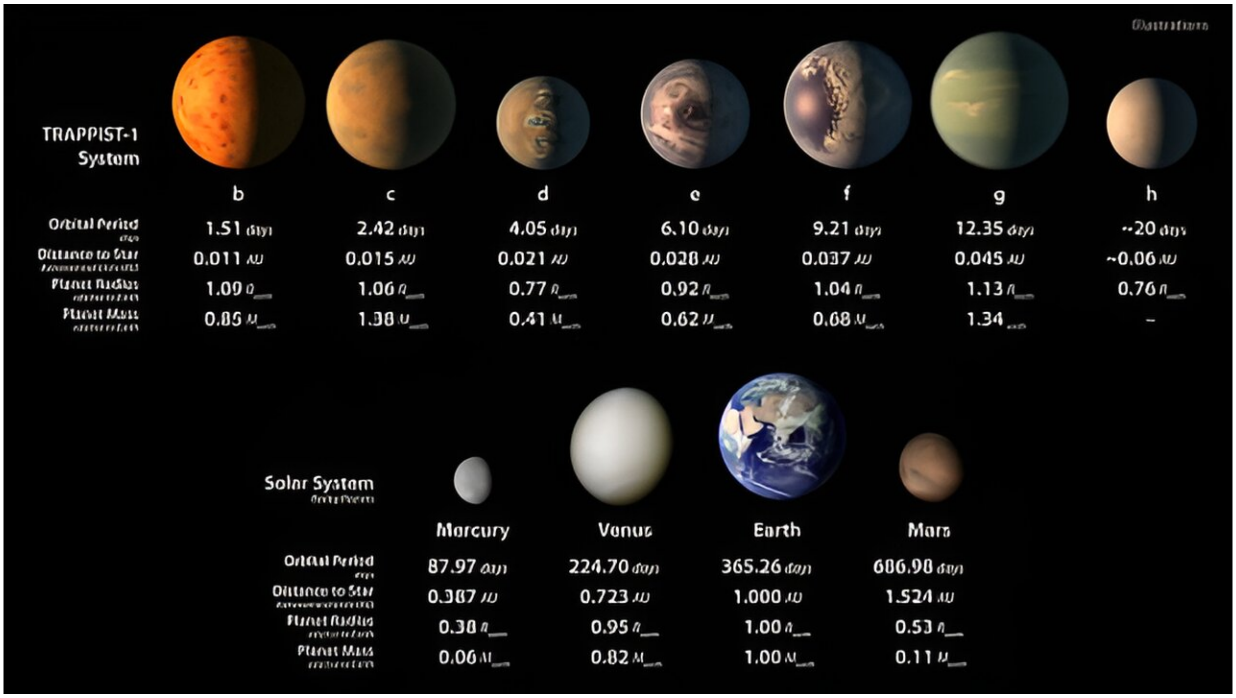
The TRAPPIST-1 system still gets a lot of scientific attention. Potential Earth-like planets in a star's habitable zone are like magnets for planetary scientists.

Finding seven of them in one system is a unique scientific opportunity to examine all kinds of interlinked questions about exoplanet habitability. TRAPPIST-1 is a red dwarf, and one of the most prominent questions about exoplanet habitability concerns red dwarfs (M dwarfs.) Do these stars and their powerful flares drive the atmospheres away from their planets?

New research accepted for publication in the *Planetary Science Journal* and available on the preprint server *arXiv*, examines atmospheric escape on the TRAPPIST-1 planets. Its title is "The Implications of Thermal Hydrodynamic Atmospheric Escape on the TRAPPIST-1 Planets." Megan Gialluca, a graduate student in the Department of Astronomy and Astrobiology Program at the University of Washington, is the lead author.

Most stars in the Milky Way are M dwarfs. As the TRAPPIST-1 makes clear, they can host many terrestrial planets. Large, Jupiter-size planets are comparatively rare around these types of stars.

It's a distinct possibility that most terrestrial planets are in orbit around M dwarfs.



Artist concepts of the seven planets of TRAPPIST-1 with their orbital periods, distances from their star, radii and masses as compared to those of Earth. Credit: NASA/JPL

But M dwarf flaring is a known issue. Though M dwarfs are far less massive than our sun, their flares are way more energetic than anything that comes from the sun. Some M dwarf flares can double the star's brightness in only minutes.

Another problem is tidal locking. Since M dwarfs emit less energy, their habitable zones are much closer than the zones around a main sequence star like our sun. That means potentially habitable planets are much more likely to be tidally locked to their stars.

That creates a whole host of obstacles to habitability. One side of the planet would bear the brunt of the flaring and be warmed, while the other side would be perpetually dark and cold. If there's an atmosphere, there could be extremely powerful winds.

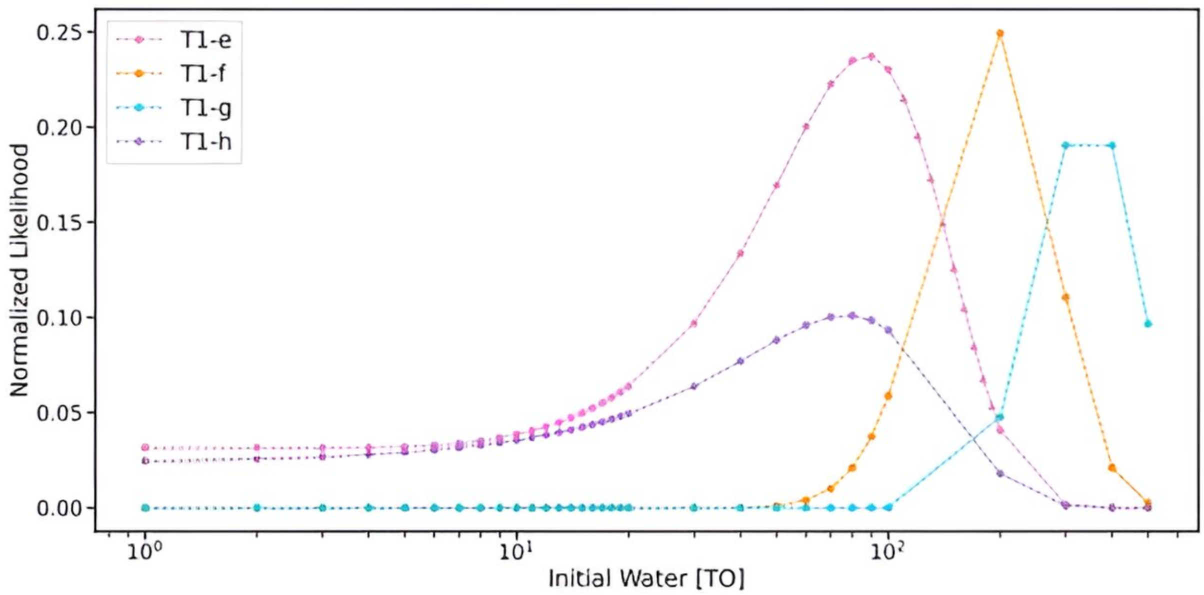
"As M dwarfs are the most common stars in our local stellar neighborhood, whether their planetary systems can harbor life is a key question in astrobiology that may be amenable to observational tests in the near term," the authors write. "Terrestrial planetary targets of interest for atmospheric characterization with M dwarf hosts may be accessible with the JWST," they explain.

They also point out that future large ground-based telescopes like the European Extremely Large Telescope and the Giant Magellan Telescope could help, too, but they're years away from being operational.

Red dwarfs and their planets are easier to observe than other stars and their planets. Red dwarfs are small and dim, meaning their light doesn't drown out planets as much as other main-sequence stars do. But despite their lower luminosity and small size, they present challenges to habitability.

M dwarfs have a longer pre-main-sequence phase than other stars and are at their brightest during this time. Once they're on the main sequence, they have heightened stellar activity compared to stars like our sun. These factors can both drive atmospheres away from nearby planets. Even without flaring, the closest planet to TRAPPIST-1 (T-1 hereafter) receives four times more radiation than Earth.

"In addition to luminosity evolution, heightened stellar activity also increases the stellar XUV of M dwarf stars, which enhances atmospheric loss," the authors write. This can also make it difficult to understand the spectra from planetary atmospheres by creating false positives of biosignatures. Exoplanets around M dwarfs are expected to have thick atmospheres dominated by abiotic oxygen.



In this research, the authors took into account the predicted present-day water content for each of the outer planets and then worked backwards to understand their initial water content. This figure shows "The likelihood of each initial water content (in TO) needed to reproduce the predicted present-day water contents for each of the outer planets," the authors write. The four outer planets would've started out with enormous amounts of water compared to Earth. Credit: Gialluca et al, 2024

Despite the challenges, the T-1 system is a great opportunity to study M dwarfs, atmospheric escape, and rocky planet habitability. "TRAPPIST-1 is a high-priority target for JWST General and Guaranteed Time Observations," the authors write. The JWST has observed parts of the T-1 system, and that data is part of this work.

In this work, the researchers simulated early atmospheres for each of the TRAPPIST-1 (T-1 hereafter) planets, including different initial water amounts expressed in Terrestrial Oceans (TO.) They also modeled different amounts of stellar radiation over time. Their simulations used the most recent data for the T-1 planets and used a variety of different planetary evolution tracks.

The results are not good, especially for the planets closest to the red dwarf.

"We find the interior planets T1-b, c, and d are likely desiccated for all but the largest initial water contents (>60, 50, and 30 TO, respectively) and are at the greatest risk of complete atmospheric loss due to their proximity to the host star," the researchers explain. However, depending on their initial TO, they could retain significant oxygen. That oxygen could be a false positive for biosignatures.

The outer planets fare a little better. They could retain some of their water unless their initial water was low at about 1 TO. "We find T1-e, f, g, and h lose, at most, approximately 8.0, 4.8, 3.4, and 0.8 TO, respectively," they write. These outer planets probably have more oxygen than the inner planets, too. Since T1-e, f, and g are in the star's habitable zone, it's an intriguing result.

T-1c is of particular interest because, in their simulations, it retains the most atmospheric oxygen regardless of whether the initial TO was high or low.

The potential habitability of T-1 planets is an important question in exoplanet science. The type of star, the number of rocky planets, and the ease of observation all place it at the top of the list of observational targets. We'll never really understand exoplanet habitability if we can't understand this system. The only way to understand it better is to observe it more thoroughly.

"These conclusions motivate follow-up observations to search for the presence of water vapor or oxygen on T1-c and future observations of the outer planets in the TRAPPIST-1 system, which may possess substantial water," the authors write in their conclusion.

More information: Megan T. Gialluca et al, The Implications of Thermal Hydrodynamic Atmospheric Escape on the TRAPPIST-1 Planets, *arXiv* (2024). DOI: 10.48550/arxiv.2405.02401

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