Research reveals more about TRAPPIST-1 planets, and the possibility of life

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This artist's impression shows the view just above the surface of one of the middle planets in the TRAPPIST-1 system, with the glare of the host star illuminating the rocky surface. At least seven planets orbit this ultracool dwarf star 40 light-years from Earth and they are all roughly the same size as the Earth. They are at the right distances from their star for liquid water to exist on the surfaces of several of them. This artist's impression is based on the known physical parameters for the planets and stars seen, and uses a vast database of objects in the Universe. Credit: ESO/N. Bartmann

A series of four studies have shed new light on the properties of the TRAPPIST-1 planetary system, currently our most optimal hope for evidence of biological life beyond the Solar system.

Since the extent of the TRAPPIST-1 planetary system was revealed in February 2017, it has captured the imagination of people the world over.

The new studies, including papers published today in *Nature Astronomy* and *Astronomy and Astrophysics*, are the result of researchers working to better characterise the planets and collect more information about them.

The international team first refined the properties of the star at the centre of the system, and secondly improved the measurements of the planets' radii. A third study offers better estimates than ever for the planets' masses while in the fourth study the team performed reconnaissance observations of the planets' atmospheres.

The four international studies were produced in collaboration with University of Birmingham astronomer Dr Amaury Triaud. He explains, "After discovering this incredible planetary system our team was extremely eager to know more about TRAPPIST-1. A year on, we are reporting our results. Thanks to our efforts the TRAPPIST-1 planets are becoming the best studied worlds outside the Solar system."

The team found that all seven planets are mostly made of rock, with up to 5 percent of their mass in water - a significant amount. By comparison, our Earth's oceans account for only 0.02 percent of our planet's mass.

In addition, five of the planets appear devoid of an atmosphere made of Hydrogen and Helium, like for Neptune or Uranus. This new information reinforces the notion that the seven planets of TRAPPIST-1 are similar to the rocky worlds of the Solar system in many ways.

The form that water takes on TRAPPIST-1 planets would depend on the amount of heat they receive from their star, which is a mere 9 percent as heavy as our Sun.

The seven planets are considered temperate, meaning that under certain geological and atmospheric conditions, all could possess conditions allowing water to remain liquid. Work, including the team's series of results, is now proceeding to pinpoint which of these temperate planets are most likely to be habitable.

Of the seven, TRAPPIST-1e, the fourth from the star, is currently the most akin to Earth although much remains to be known, notably the conditions at the surface, and whether it holds an atmosphere.

Dr Triaud continues, "When we combine our new masses with our improved radii measurements, and our improve knowledge of the star, we obtain precise densities for each of the seven worlds, and reach information on their internal composition. All seven planets remarkably resemble Mercury, Venus, our Earth, its Moon, and Mars."

Professor Brice-Olivier Demory, co-author at the University of Bern, added, "Densities, while important clues to the planets' compositions, do not say anything about habitability. However, our study is an important step forward as we continue to explore whether these planets could support life."

As part of this series of work, the team used the Hubble Space Telescope while the planets passed in front of their star, attempting to catch minute signals while starlight interacts with the planets' atmospheres.

Their careful measurements found no evidence for hydrogen-dominated atmospheres on planets TRAPPIST-1d, e and f (b and c were done last year) although the hydrogen-dominated atmosphere cannot be ruled out for g. So far, the collected data is still consistent with, but cannot confirm whether the planets have atmospheres similar to Venus, or Earth. This identification will be carried out by new observations.

"Hubble is doing the preliminary reconnaissance work so that astronomers using Webb know where to start," said Nikole Lewis of the Space Telescope Science Institute (STScI) in Baltimore, Maryland, co-leader of the Hubble study. "Eliminating one possible scenario for the makeup of these atmospheres allows the Webb telescope astronomers to plan their observation programs to look for other possible scenarios for the composition of these atmospheres."

What is TRAPPIST-1?

TRAPPIST-1 is named for the Transiting Planets and Planetesimals Small Telescope (TRAPPIST) in Chile, which discovered two of the seven planets we know of today—announced in 2016. NASA's Spitzer Space Telescope, in collaboration with ground-based telescopes, confirmed these planets and uncovered the other five in the system. Since then, NASA's Kepler space telescope also observed the TRAPPIST-1 system, and Spitzer collected additional data. This new body of data helped the team paint a clearer picture of the system than ever before—although there is still much more to learn about TRAPPIST-1.

The TRAPPIST-1 planets huddle so close to one another that a person standing on the surface of one of these worlds would have a spectacular view of the neighbouring planets in the sky, which would sometimes appear larger than the Moon looks to an observer on Earth. They may also be tidally locked, meaning the same side of the planet is always facing the star, and each side is in perpetual day or night. Although the planets are all closer to their star than Mercury is to the Sun, TRAPPIST-1 is such a cool star that its planets are temperate.

What might these planets be like?

It is impossible to know exactly how each planet looks, because they are so far away. In our own solar system, the Moon and Mars have nearly the same density, yet their surfaces appear entirely different.

Based on available data, here are scientists' best guesses about the appearances of the planets:

TRAPPIST-1b, the innermost planet, is likely to have a rocky core, surrounded by an atmosphere much thicker than Earth's. TRAPPIST-1c also likely has a rocky interior, but with a thinner atmosphere than planet b. TRAPPIST-1d, meanwhile, is the lightest of the planets—about 30 percent the mass of Earth. Scientists are uncertain whether it has a large atmosphere, an ocean or an ice layer—all three of these would give the planet an "envelope" of volatile substances that would make sense for a planet of its density.

Scientists were surprised that TRAPPIST-1e is the only planet in the system slightly denser than Earth, suggesting it may have a denser iron core than our home planet. Like TRAPPIST-1c, it does not necessarily have a thick atmosphere, ocean or ice layer—making these two planets distinct in the system. It is mysterious why TRAPPIST-1e is so much rockier in its composition than the rest of the planets. In terms of size, density and the amount of radiation it receives from its star, this is the most similar planet to Earth.

TRAPPIST-1f, g and h are far enough from the host star that water could be frozen as ice across these surfaces. If they have thin atmospheres, they would be unlikely to contain the heavy molecules of Earth such as carbon dioxide.

How do we know?

Scientists are able to calculate the densities of the planets because they happen to be lined up such that when they pass in front of their star, our Earth and space-based telescopes detect a dimming of its light. This is called a transit. The amount by which the starlight dims is related to the radius of the planet.

To get the density, scientists take advantage of what is called "transit timing variations."

If there were no other gravitational forces on a transiting planet, it would always cross in front of its host star in the same amount of time—for example, Earth orbits the Sun every 365 days, which is how we define one year. But because the TRAPPIST-1 planets are packed so close together, they change the timing of each other's "years" ever so slightly. Those variations in orbital timing are used to estimate the planets' masses. Then, mass and radius are used to calculate density.

Next Steps

The next step in exploring TRAPPIST-1 will be NASA's James Webb Space Telescope, which will be able to delve into the question of whether these planets have atmospheres and, if so, what those atmospheres are like, and whether they allow adequate surface conditions to permit liquid water.

More information: Julien de Wit et al, Atmospheric reconnaissance of the habitable-zone Earth-sized planets orbiting TRAPPIST-1, *Nature*

Astronomy (2018). DOI: 10.1038/s41550-017-0374-z

The nature of the TRAPPIST-1 exoplanets: www.eso.org/public/archives/re … eso1805/eso1805a.pdf

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