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Hubble helps discover a new type of planet largely composed of water

A whole new world: you may have heard of rocky planets, gas giants and ice giants, but what about water worlds? Learn about the discovery of an entirely new planet type.

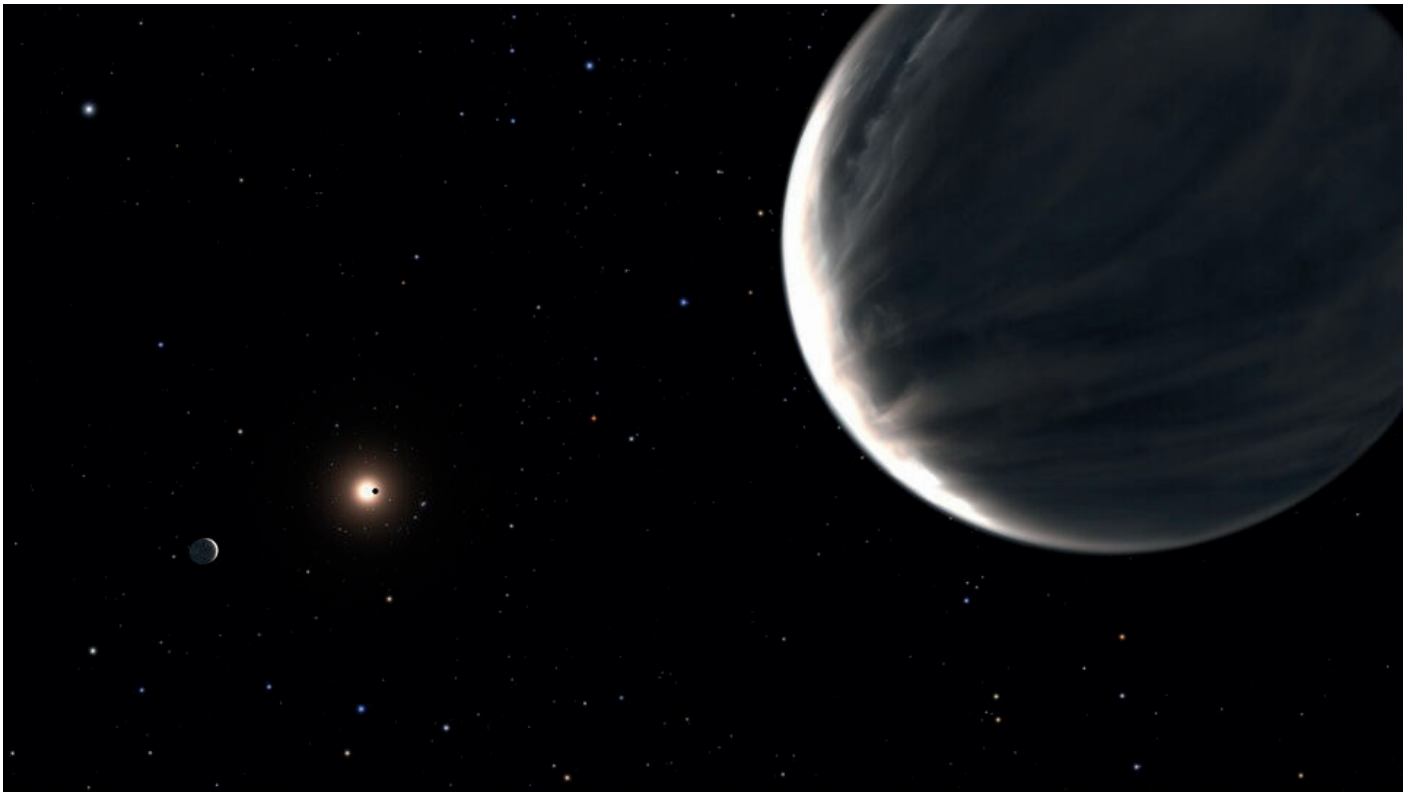
Researchers have found evidence for the existence of a new type of planet they have called a 'water world', where water makes up a large fraction of the entire planet. These worlds, discovered in a planetary system 218 light-years away, are unlike any planets in our Solar System.

The team, led by Caroline Piaulet of the Institute for Research on Exoplanets (iREx) at the University of Montreal, published a detailed study of a planetary system known as Kepler-138 in the journal Nature Astronomy on 15 December.

Piaulet, who is a member of Björn Benneke's research team at the University of Montreal, observed the exoplanets Kepler-138 c and Kepler-138 d with both the NASA/ESA Hubble Space Telescope and NASA's Spitzer Space Telescope. She found that the planets could be composed largely of water.

Water wasn't directly detected, but by comparing the sizes and masses of the planets to models, they conclude that a significant fraction of their volume — up to half of it — should be made of materials that are lighter than rock but heavier than hydrogen or helium (which constitute the bulk of gas-giant planets like Jupiter). The most common candidate material is water.

Illustration of the NASA/ESA Hubble Space Telescope in its high orbit 600 kilometres above Earth



Artist's illustration of Kepler 138 planetary system
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"We previously thought that planets that were a bit larger than Earth were big balls of metal and rock, like scaled-up versions of Earth, and that's why we called them super-Earths," explained Benneke. "However, we have now shown that these two planets, Kepler-138 c and d, are quite different in nature and that a large fraction of their entire volume is likely composed of water. It is the best evidence yet for water worlds, a type of planet that was theorized by astronomers to exist for a long time."

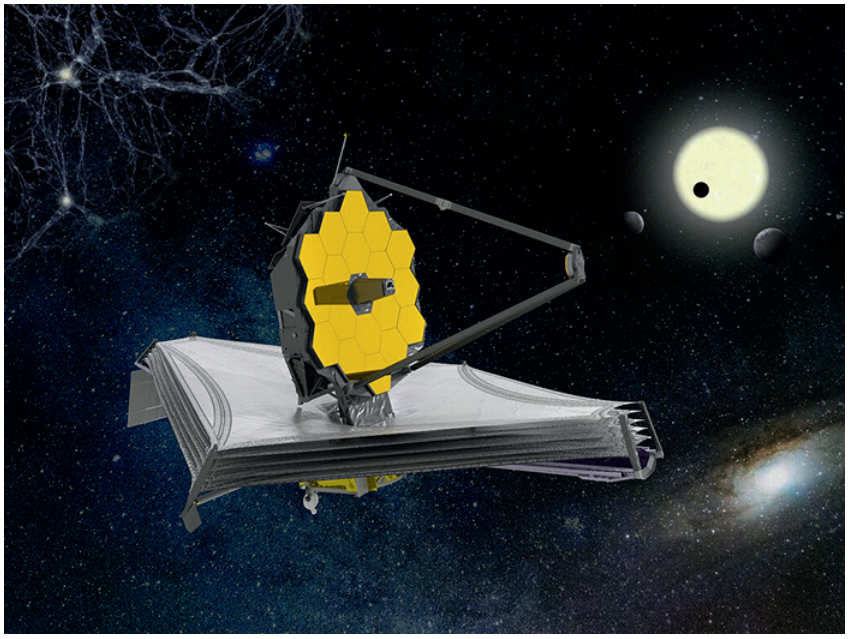
With volumes more than three times that of Earth and masses twice as big, planets c and d have much lower densities than Earth. This is surprising because most of the planets just slightly bigger than Earth that have been studied in detail so far all seemed to be rocky worlds like ours. The closest comparison, say researchers, would be some of the icy moons in the outer Solar System that are also largely composed of water surrounding a rocky core.

"Imagine larger versions of Europa or Enceladus, the water-rich moons orbiting Jupiter and Saturn, but brought much closer to their star," explained Piaulet. "Instead of an icy surface, they would harbour large water-vapour envelopes."

"The secure identification of an object with the density of the icy moons of the Solar System, but significantly larger and more massive, clearly demonstrates the great diversity of exoplanets," added team member Jose-Manuel Almenara of Grenoble Alpes University in France. "This is expected to be the outcome of a variety of formation and evolution processes."

Researchers caution that the planets may not have oceans like those on Earth directly at the planet's surface. "The temperature in Kepler-138 d's atmosphere is likely above the boiling point of water, and we expect a thick dense atmosphere made of steam on this planet. Only under that steam atmosphere could there potentially be liquid water at high pressure, or even water in another phase that occurs at high pressures, called a supercritical fluid," Piaulet said.

The NASA/ESA/CSA James Webb Space Telescope will also facilitate valuable follow-up research. *"Now that we have securely identified the 'water-world' Kepler-138 d, the James Webb Space Telescope is the key to unveiling the atmospheric composition of such an exotic object,"* shared team member Daria Kubyshkina of the Austrian Academy of Sciences. "It will give us critical information enabling us to compare the composition of the icy moons of the solar system with that of their larger and heavier extrasolar counterparts.



Artist's impression of the James Webb Space Telescope
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Recently, another team at the University of Montreal found a planet called TOI-1452b that could potentially be covered with a liquid-water ocean, but Webb will be needed to also confirm this.

In 2014 data from the NASA Kepler Space Telescope allowed astronomers to announce the detection of three planets orbiting Kepler-138, a red dwarf star in the constellation Lyra. This was based on a measurable dip in starlight as each planet momentarily passed in front of the star.

Benneke and his colleague Diana Dragomir, from the University of New Mexico, came up with the idea of re-observing the planetary system with the Hubble and Spitzer space telescopes between 2014 and 2016 to catch more transits of Kepler-138 d, the third planet in the system, in order to study its atmosphere.

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A new exoplanet in the system

While the earlier Kepler space telescope observations only showed transits of three small planets around Kepler-138, Piaulet and her team were surprised to find that the Hubble and Spitzer observations required the presence of a fourth planet in the system, Kepler-138 e.
This newly found planet is small and farther from its star than the three others, taking 38 days to complete an orbit. The planet is in the habitable zone of its star, a temperate region where it receives just the right amount of heat from its cool star to be neither too hot nor too cold to allow the presence of liquid water.
The nature of this additional, newly found planet, however, remains an open question because it does not seem to transit its host star. Observing the exoplanet's transit would have allowed astronomers to determine its size.

With Kepler-138 e now in the picture, the masses of the previously known planets were measured again via the transit timing-variation method, which involves tracking small variations in the precise moments of the planets' transits in front of their star caused by the gravitational pull of other nearby planets. The researchers had another surprise: they found that the two water worlds Kepler-138 c and d are 'twin' planets, with virtually the same size and mass, while they were previously thought to be drastically different. The closer-in planet, Kepler-138 b, on the other hand, is confirmed to be a small Mars-mass planet, and one of the smallest exoplanets known to date.

"As our instruments and techniques become sensitive enough to find and study planets that are farther from their stars, we might start finding a lot more of these water worlds," Benneke concluded. «

Acknowledgements

This article was adapted from an ESA News.

References

[1] Piaulet C et al. (2022) Evidence for the volatile-rich composition of a 1.5-Earth-radius planet. *Nature Astronomy*. doi: 10.1038/s41550-022-01835-4

Resources

- The Hubble Space Telescope is a project of international cooperation between ESA and NASA.
- Have your students join a hackathon to analyse data from ESA's Cheops mission with the Hack an exoplanet activity.
- Find more teaching activities in ESA's Teach with Exoplanets series.
- Read about a planet where it rains iron: (2021) ESO telescope observes exoplanet where it rains iron. *Science in School* **51**.
- Read about the search for alien life: Tatalović M (2020) Alien life and where to find it. *Science in School* **50**.
- Find out how new technology is helping us discover exoplanets: Vieser W (2020) Hunting for exoplanets. *Science in School* **49**: 8–12.
- Turn a webcam into an infrared camera and see the world in infrared light: ESA Education (2022) Infrared webcam hack – using infrared light to observe the world in a new way. *Science in School* **56**.
- Land egg-naut safely and learn about classical mechanics along the way: ESA (2021) Landing on the Moon – planning and designing a lunar lander. *Science in School* **51**.
- Devise a plan for growing plants on the Moon with your classroom: Hardie K, Cardoso C (2020) Astrofarmer: how to grow plants in space. *Science in School* **49**: 33–37.
- Measure distances to the stars like real astronomers with this classroom activity: Pössel M (2017) Finding the scale of space. *Science in School* **40**: 40–45.