New Scientist

WEEKLY October 29 - November 4, 2022

ARE ARTIFICIAL SWEETENERS BAD FOR US?

STUNNING NEW JWST IMAGE

UNCOVERING THE GENETICS OF DYSLEXIA

SUPER-ACCURATE QUANTUM STOPWATCH

CLIMATE ACTION: A PROGRESS REPORT

Ahead of the COP27 summit, what hope do we have of hitting the crucial targets?

OCEAN WORLDS

The search for exoplanets covered in water

PLUS CHATTY REPTILES / WHO IS THE MOST AVERAGE PERSON? / STRETCHY PROTONS / **HOW TO SWEETEN YOUR SWEET POTATOES**

Science and technology news **www.newscientist.com**

No3410 US$6.99 CAN$9.99

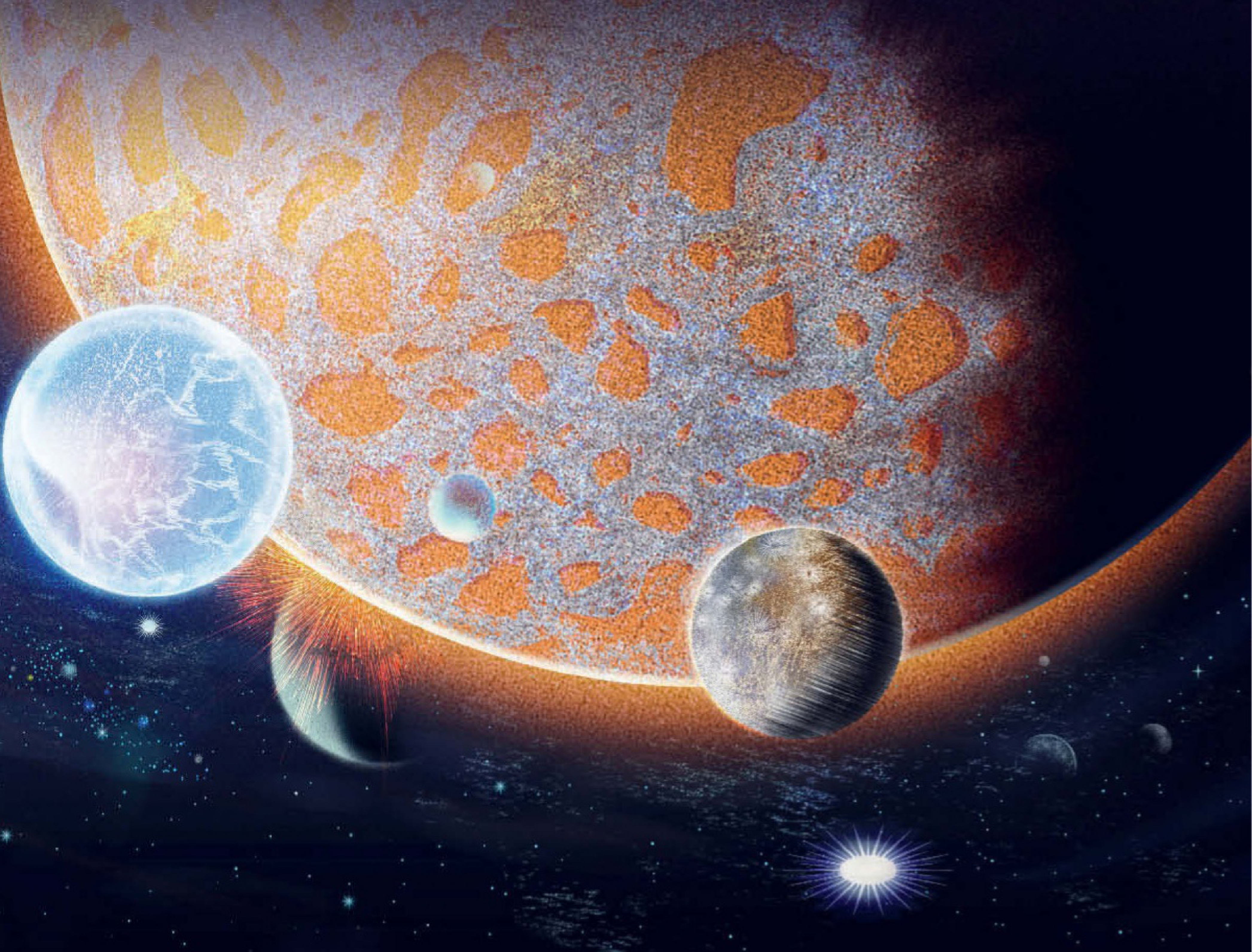
Water, water everywhere

Ocean worlds, planets flush with water and potential homes to alien life, look like they could be common in the galaxy. The race is on to find one, finds **Conor Feehly**

IT LOOKS like there is nothing below the thick, hot clouds we are falling through. But descend a little further and the vista opens up to show an ocean as far as the eye can see. Its surface is steaming, feeding water vapour into the sky. Plunging into the waves, it is hot at first, but cools as we travel further into the darkness, the pressure becoming immense. We dive down hundreds of thousands of metres until we reach the bottom where, instead of rock, the sea floor is made of ice. We have landed on a water world.

When astronomers began discovering planets outside our solar system in the 1990s, they realised that alien worlds come in an array of orbits, masses, sizes and compositions. These exoplanets couldn't be placed in simple rocky or gassy groups like those in our solar system. Some, it has even been suggested, could be 50 per cent rock and a whopping 50 per cent water. Send a spacecraft to a planet like this and the scene it would encounter may be similar to our imagined journey: a thick water vapour atmosphere shielding a vast ocean hundreds of kilometres deep, with an icy mantle below.

LUONGDOO



It was long thought these water planets would be rare, if they existed at all. But fresh insights have led many astronomers to think they may, in fact, be relatively common – and could be promising places to search for alien life. The race is now on to find one.

Life – as we know it, at least – is inextricably tied to liquid water. Our best guesses about the conditions from which life emerged on Earth involve either nutrient-rich pools of water on our planet's rocky surface or deep-sea hydrothermal vents. Either way, it had to be wet. To this day, all life on Earth uses water at some point in its life cycle. So close is the relationship between water and life that our search for extraterrestrial organisms has been largely determined by the presence of that one simple molecule: H_2O.

The idea of exoplanets that not only contain water, but are covered in the stuff, first burst onto the scene in 2004, when Alain Léger, then at the Paris-Sud University in France, and a group of international researchers introduced a new family of planets. These hypothetical worlds initially resembled the ice giants of our own solar system, Uranus and Neptune, which possess vast reservoirs of ice. But instead of remaining in the outer regions of their solar systems like our ice giants, the theoretical ocean worlds migrated during the early phases of planetary formation, when everything was a little chaotic. This movement took them closer to their suns, into the habitable zone, the region around a star in which liquid water can exist on a planet's surface. In this scenario, Léger and his colleagues argued, a planet's reservoirs of ice could melt, leaving a surface ocean of liquid water potentially more than 100 kilometres deep. With so much water, such a world could be booming with life. But critics found one big problem with the idea: if an ice giant did migrate to an orbit closer to its home star, it was likely to lose its atmosphere and any ocean on the surface would eventually evaporate away due to the heat of the star.

Around the same time, exploration of our solar system was revealing another kind of ocean world. Through NASA's Galileo mission, which spent eight years orbiting Jupiter until 2003, planetary scientists discovered that a few of the Jovian moons, such as Europa and Ganymede, were hiding oceans beneath thick sheets of ice. Then, in 2005, NASA's Cassini spacecraft found evidence for plumes of water erupting from Enceladus, a moon of Saturn.

What distinguishes these moons from the kind of worlds suggested by Léger and his colleagues is that their water isn't at the surface, but buried deep below. For those interested in ocean-rich planets outside our solar system, this solved one problem. "You don't have to worry about the atmosphere being stripped away," says Kathleen Mandt at Johns Hopkins University in Maryland. "The ice protects the water from being lost."

But while an icy surface can preserve a water world's oceans, and hence its habitability, a different type of ice may threaten it. This is to do with size. If an Earth-sized planet were to have a similar buried ocean to those we have seen on smaller moons, the immense gravity and pressures at the depths possible on water worlds would compress some of the water into exotic forms of ice that don't occur naturally on Earth. For years it was thought this kind of ice may prevent some life-friendly elements that are found in a planet's core, such as carbon, iron, phosphorus and silicon, › from mixing with a liquid ocean above.

In recent years, research has suggested these high-pressure ices don't automatically rule out the possibility of life. In fact, they might help it. Assuming heavy elements and organic molecules from the rocky core can reach the liquid regions of water worlds, then it is also important that those ingredients are mixed across different depths in the wider ocean. On Earth, similar upwelling and mixing in the oceans opens up different niches for organisms to occupy, and provides the raw materials for life over vast oceanic distances.

In 2018, simulations suggested high-pressure ices may churn through a process called solid state convection similar to the movement of rock in Earth's mantle, says Sam Howell at NASA's Jet Propulsion Laboratory in California. On top of this, the radioactive decay of heavier elements, such as potassium, thorium and uranium, in the cores of these planets may provide enough heat to drive this movement. "It's possible melt may be generated at the ice-rock boundary," says Howell, "providing a crucial site for the mixing of water and heavy elements."

Consensus was building that water worlds with buried oceans, or those on the surface, if they were to persist, could be a great place for life to thrive. But astronomers were still uncertain about how common they might actually be in the cosmos. This comes down to the way we study exoplanets. By carefully watching the way planets block some light from their host stars as they pass between them and us, we can infer these planets' masses, radiuses or sometimes both. If we know both, we can deduce their density. But a rocky planet with a thick hydrogen atmosphere could have the exact same density as an ocean world, says Owen Lehmer at NASA's Ames Research Center. "How do you know which one is going to be correct when they both might have water in the atmosphere?" he says. "It's a really interesting challenge."

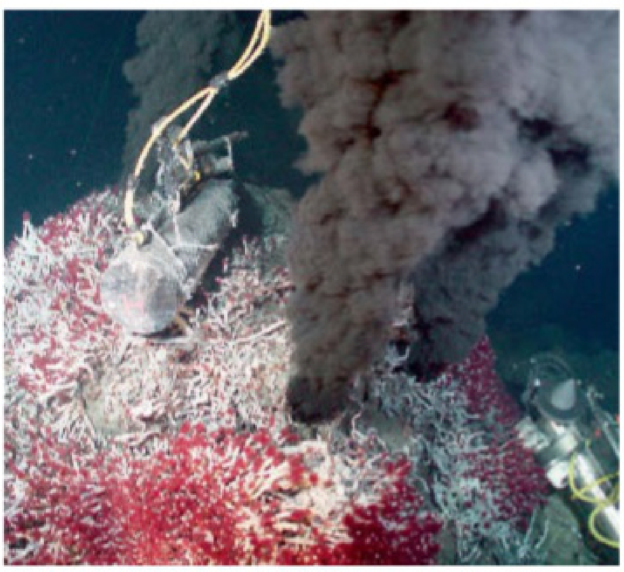
Li Zeng at Harvard University offered a solution to this in 2018. Along with a team of astronomers, Zeng zoned in on a subset of the 4000 or so exoplanets that had been discovered at the time: those between two and four times the size of Earth. When Zeng and his team analysed the radiuses and densities of these exoplanets, two distinct groups emerged: one for small, dense rocky planets, and another for larger, intermediate-sized worlds.

The prevailing idea was that these intermediate planets – 1400 or so of them – were mini-Neptunes, planets with rocky cores surrounded by thick envelopes of hydrogen gas, uninhabitable as far as life on Earth is concerned. But these mini-Neptunes didn't quite fit into a neat category. "They are not dense enough to be rock and iron, but they don't seem to be quite puffy enough to be hydrogen-rich planets," says Lehmer.

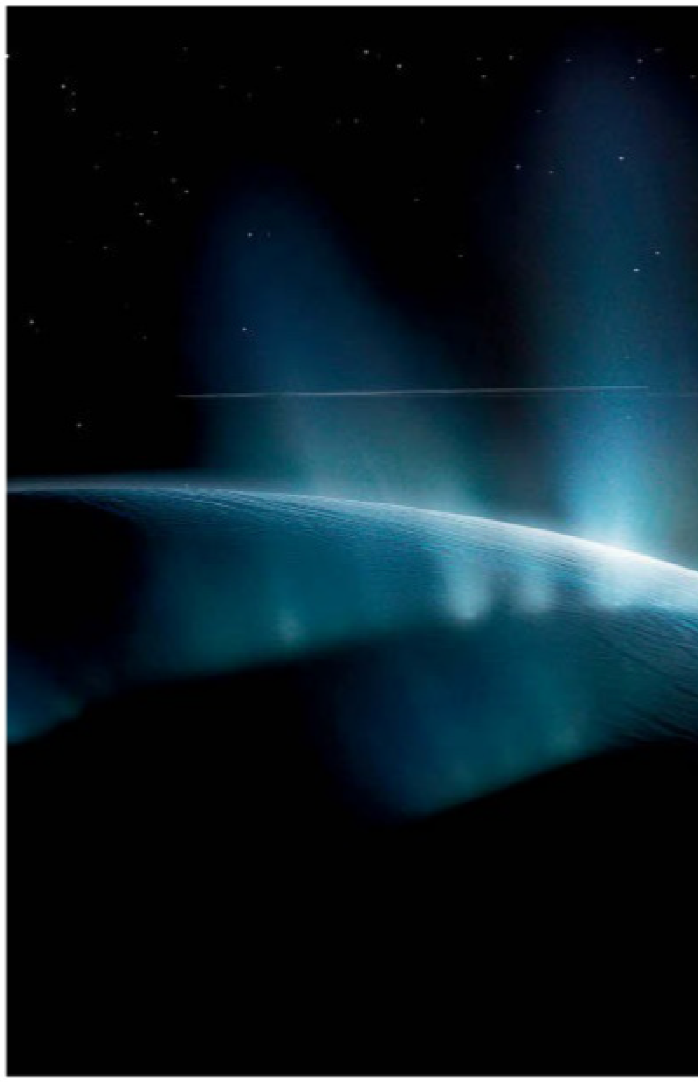
Zeng and his team suggested that, rather than being mini-Neptunes, these planets are water worlds. Planets composed of 50 per cent ice and 50 per cent rock are more likely to represent this second peak in the exoplanet data, they argue. They reasoned that the higher gravity associated with larger gas giants meant they would steal most of the hydrogen gas present in the protoplanetary disc (the materials which coalesce to form a planetary system), leaving the smaller planets with high volumes of commonplace ice.

What's more, when modelling the atmospheres of these proposed water worlds, the team found that, if the planets had the right chemical balance, then methane, ammonia and hydrogen coming from the vast water reservoir could replenish the gradual loss of atmosphere. If the atmosphere remained intact, evaporation from the ocean would be stalled, preserving a possible oasis for life below. On this particular result, Lehmer remains cautious. "Any research on the prevalence of water worlds is still going to be highly uncertain," he says.

Still, the consensus about water worlds was shifting. Together with Zeng's modelling, findings from ancient meteorites that show ice was a common ingredient in the early solar


NOAA

Life might have emerged close to hydrothermal vents, like this one in the Pacific Ocean


MARK GARLICK/SCIENCE PHOTO LIBRARY/ALAMY

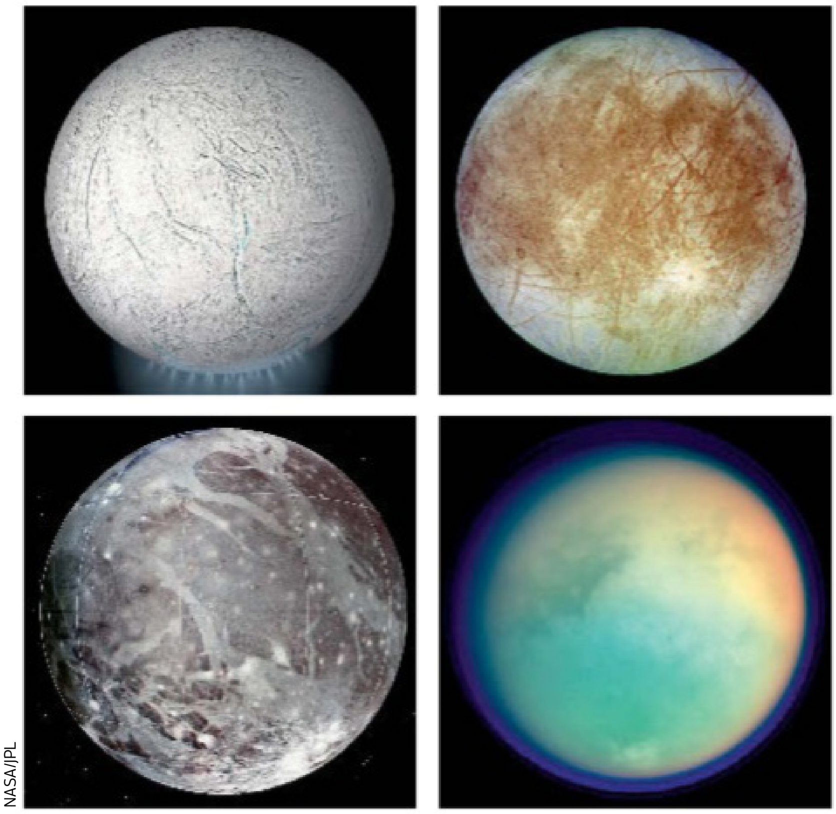
"Life on Earth is unique to Earth. On another world, it might be different"

system and the detection of water in the atmospheres of several exoplanets have persuaded some astronomers that water was a regular ingredient in the formation of planets. Water, after all, is composed of two of the most abundant elements in the universe, hydrogen and oxygen, and was one of the most common molecules when our own solar system formed.

Today, it is generally agreed that there are two kinds of watery exoplanets. The first is a planet that starts further away from its star and contains lots of ice. As it moves closer to its star, the ice melts to form an ocean on the surface, which delays the loss of atmosphere, says Mandt. Or, like Enceladus, there is an icy layer keeping the water in.

The prevalence of water worlds is going to remain a mystery until we can find them outside our solar system. Luckily, the James Webb Space Telescope (JWST) is going to spend a lot of time analysing the atmospheric compositions of potential habitable worlds. And there is a system with a possible water world right on our galactic doorstep.

TRAPPIST-1, with seven known rocky worlds,



We know some moons in our solar system are rich in water: Enceladus (left and top left of the four smaller images) has water shooting out of it. Europa (top right) and Ganymede (bottom left) have buried oceans, as does icy Titan (bottom right)

NASA/JPL

is just 40 light years from Earth. In 2021, Eric Agol at the University of Washington in Seattle and his team estimated that at least four planets in the system could have significant water. The most promising is TRAPPIST-1h, which could be as much as 10 per cent water.

Plans to peer at TRAPPIST-1h in the ultraviolet using JWST might just reveal a Titan-like atmosphere that could be indicative of a vast ocean beneath its surface, says Mandt. "If we find a lot of methane, but not much oxygen or carbon monoxide, that would be an indication of cryovolcanic activity and a Titan-like atmosphere," she says. "In other words, ice volcanoes."

A team led by Mandt has now suggested using Saturn's moon Titan, with its subsurface ocean, as a model for making observations of TRAPPIST-1 h's atmosphere. The two bodies might have a lot in common. Both exist outside of the habitable zone, both probably have liquid oceans beneath a frozen surface and both might have extensive atmospheres. With exoplanets like TRAPPIST-1h, we are limited in the types of observations we can make, whereas with our solar system's icy moons, we are able to look at the surface and make inferences about their compositions directly. This is why using the moons is useful to help us understand exoplanets.

If TRAPPIST-1h doesn't have an atmosphere, it doesn't rule out the possibility of an ocean. It might resemble something more like Europa, which has an ocean beneath a thick sheet of ice. Due to its lack of cryovolcanic activity, Europa doesn't really have an atmosphere, except for the occasional plume of material that comes up from the ice, which is quickly lost to space. Learning anything about the moon's composition by observing its atmosphere is virtually impossible.

Could life survive on such a world? Promising clues come from another moon. In September 2022, jets spewing from Enceladus were found to contain all of the ingredients necessary for life on Earth: carbon, hydrogen, nitrogen, oxygen, phosphorus and sulphur.

Hints from Earth also suggest it is possible. In 2021, James Smith and Paul Anker at the British Antarctic Survey discovered an ecosystem of sponges and barnacles 900 metres below the Antarctic ice shelf – 260 kilometres away from the nearest source of water where photosynthetic organisms can survive. The community may use a form of chemosynthesis, with methane and hydrogen sulphide being potential sources of energy. This is one way life could survive in a sunlight-deprived, icy water world.

Earth can only tell us so much, however. "Life on Earth co-evolved with our planet," says Adrienne Kish, a microbiologist at the National Museum of Natural History in Paris, France. "This means that life on Earth is unique to Earth and life on another world, if it exists, will have undergone a different path with likely a different end product." Some of the basic building blocks, like amino acids, might be similar, as we have spotted these things in interstellar clouds. But on water worlds, any life would have to be equipped to survive high pressures, high salt content and extreme temperatures, as the oceans are likely to be cold away from any hydrothermal vents.

If TRAPPIST-1h doesn't turn up the goods, there is no shortage of other exoplanets to explore. In 2019, observations made with the Hubble Space Telescope confirmed water in the atmosphere of K2-18 b – a planet of around eight Earth masses in the habitable zone of a red dwarf, 124 light years away. Water was also tentatively detected in the atmosphere of planet LHS 1140 b, which is around seven Earth masses and lies within the habitable zone of its star, which is 40 light years away. Modelling estimates have suggested the planet could be around 4 per cent water, which is enough for it to have oceans hundreds of kilometres deep.

But that pales in comparison with TOI-1452 b, discovered in August, whose size and mass suggest it could be 22 per cent water. This planet is 100 light years from our solar system and orbits a pair of red dwarfs. Its 11-day orbit puts TOI-1452 b well within the habitable zone of its two parent stars, and René Doyon at the University of Montreal plans on booking time with JWST to get a more detailed look at it soon. One way or another, observing a distant water world seems like a matter of when, not if. ▮

Conor Feehly is a freelance writer based in Auckland, New Zealand