What does the abundance of water in the solar system mean for life?

April 21 2017, by Jonti Horner

This illustration shows Cassini diving through geyser plumes on Saturn's the ocean world moon of Enceladus. Credit: NASA/JPL-Caltech

There was much excitement when NASA recently revealed new details about the oceans that lurk beneath the surface of Saturn's tiny moon Enceladus and Jupiter's Europa.

Why the excitement? Well, here on Earth, where you have water, energy and nutrients, you have life. So why not life on these other worlds?

Thanks to measurements made by the Cassini spacecraft, we already knew that Enceladus has an ocean buried deep beneath its surface.

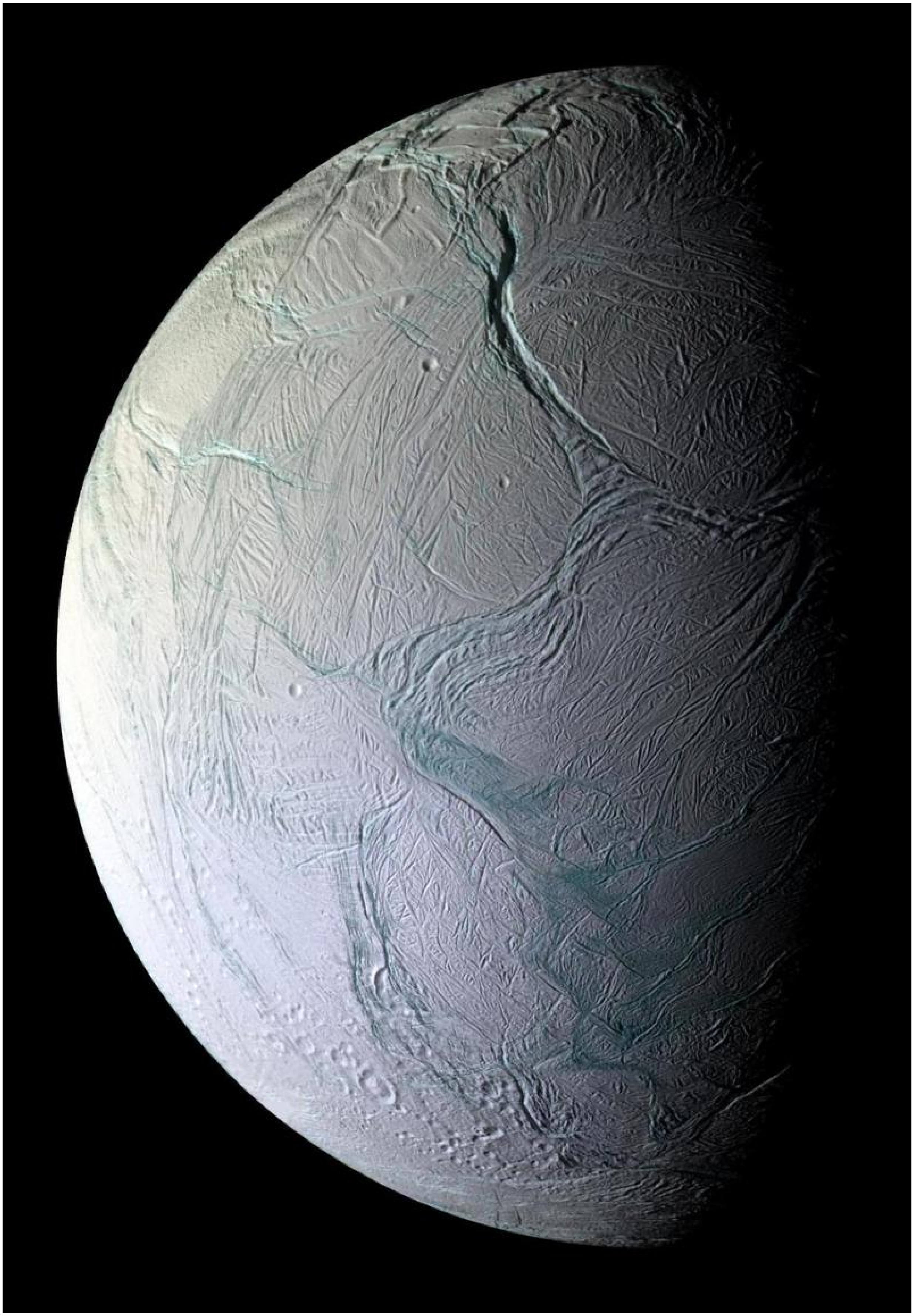
From the new research, published in Science this month, it now seems highly likely that at the base of that ocean, hydrothermal vents are actively spewing nutrients and energy into the dark ocean depths.

The vented material drives chemical reactions, deep in the ocean, releasing molecular hydrogen that is eventually carried away from the moon in the giant geysers we observe.

Jupiter's icy moon Europa has also long been known to host a sub-surface ocean that contains more liquid water than is present on the entire planet Earth.

Like Enceladus, it is thought that the base of Europa's ocean might feature hydrothermal activity, and hence that it might be a suitable place for life to develop and thrive.

This month's results tie Europa and Enceladus more closely together than ever. Observations of Europa with the Hubble Space Telescope revealed two episodes of geyser-like eruptions showed water being ejected to an altitude of 50km above the moon's surface in 2014, and 100km in 2016.



Enceladus, just 500km across, is now known to host a buried ocean of liquid water. Credit: NASA/JPL/Space Science Institute

Water, water everywhere

When we look at other planets we see no oceans, no lakes and no rivers.

In the past we tended to imagine that water was a scarce and precious resource. But as we learn more about our place in the Universe, we are becoming ever more aware that water is everywhere.

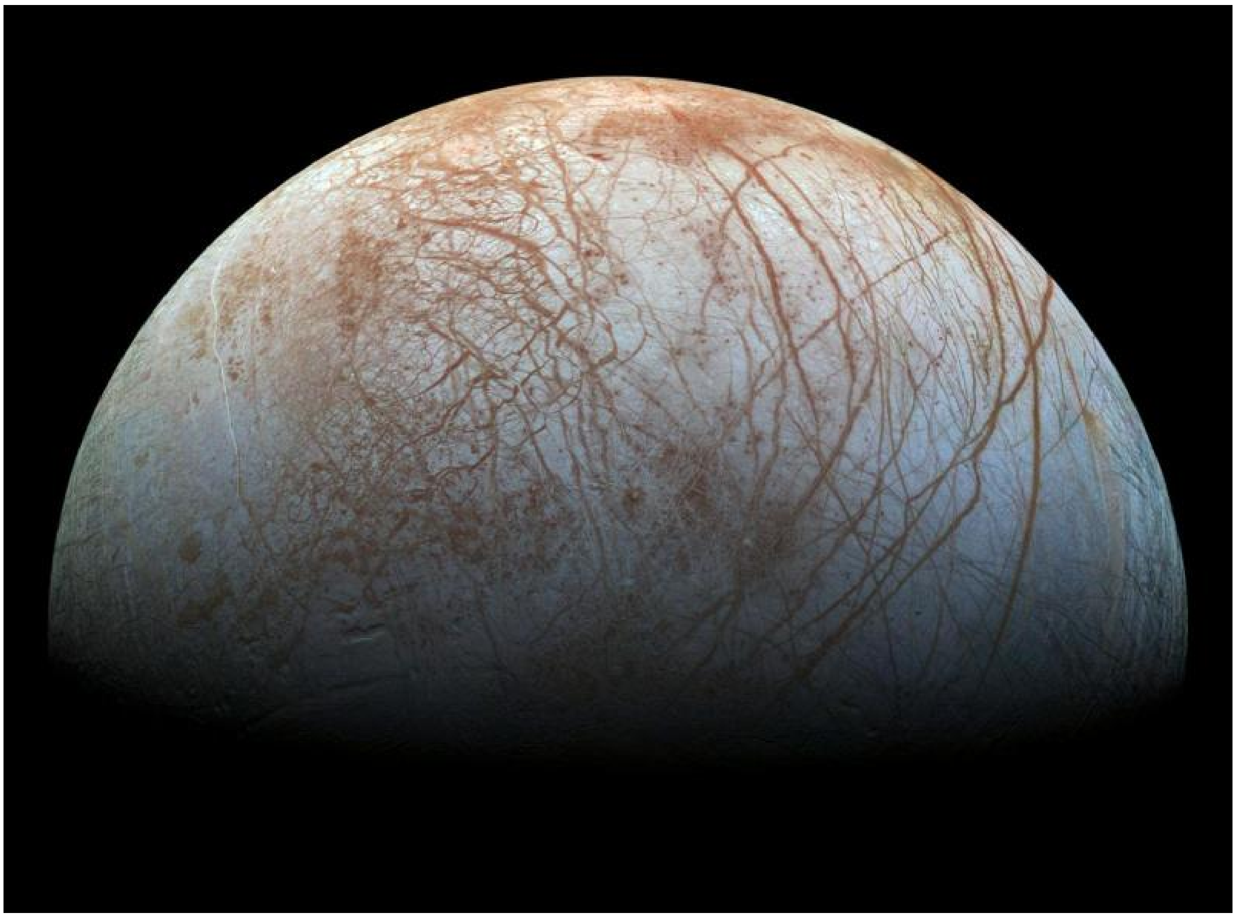
Around 75% of all atoms in our galaxy are hydrogen, and it is the most common element in the Universe. Oxygen is the third most common element in space, albeit making up only about 1% of the total sum of all the atoms that are out there.

Water (H_2O) is made of two hydrogen atoms and one oxygen atom. So it should be no surprise that water is everywhere, nor that it played a key role in the formation and evolution of our planetary system.

Make me a planet

When our Sun was forming, the planets and other debris of the Solar system grew around it from a disk of dust, ice and gas. The material closest to the proto-Sun was so hot that only the most refractory elements and compounds (those with the highest melting and boiling points) were solid.

At greater distances, the temperature was lower and more material could freeze, adding to the mass of solid material floating around in what is known as a protoplanetary disk.



Jupiter's icy moon Europa. Beneath the icy surface lurks a vast ocean, containing more water than can found on our whole planet. Credit: NASA/Jet Propulsion Lab-Caltech/SETI Institute

Eventually, at distances several times farther from the Sun than the Earth, the temperature was cold enough for water to be solid, a point called the "ice line" or "snow line". Beyond this, water ice made up the great bulk of solid material. With more solid material, the distant planets grew far more rapidly than their terrestrial cousins.

At the heart of Saturn, Uranus and Neptune, and probably at Jupiter's core, lie the seeds around which those planets' gaseous atmospheres were gathered. Dust and gas in the disk gradually stuck together, growing to form larger and larger cores.

Eventually, a critical mass was reached, at which point the growing proto-planets' gravity could feed from the gas around them in the disk, swelling them into the giants we see today.

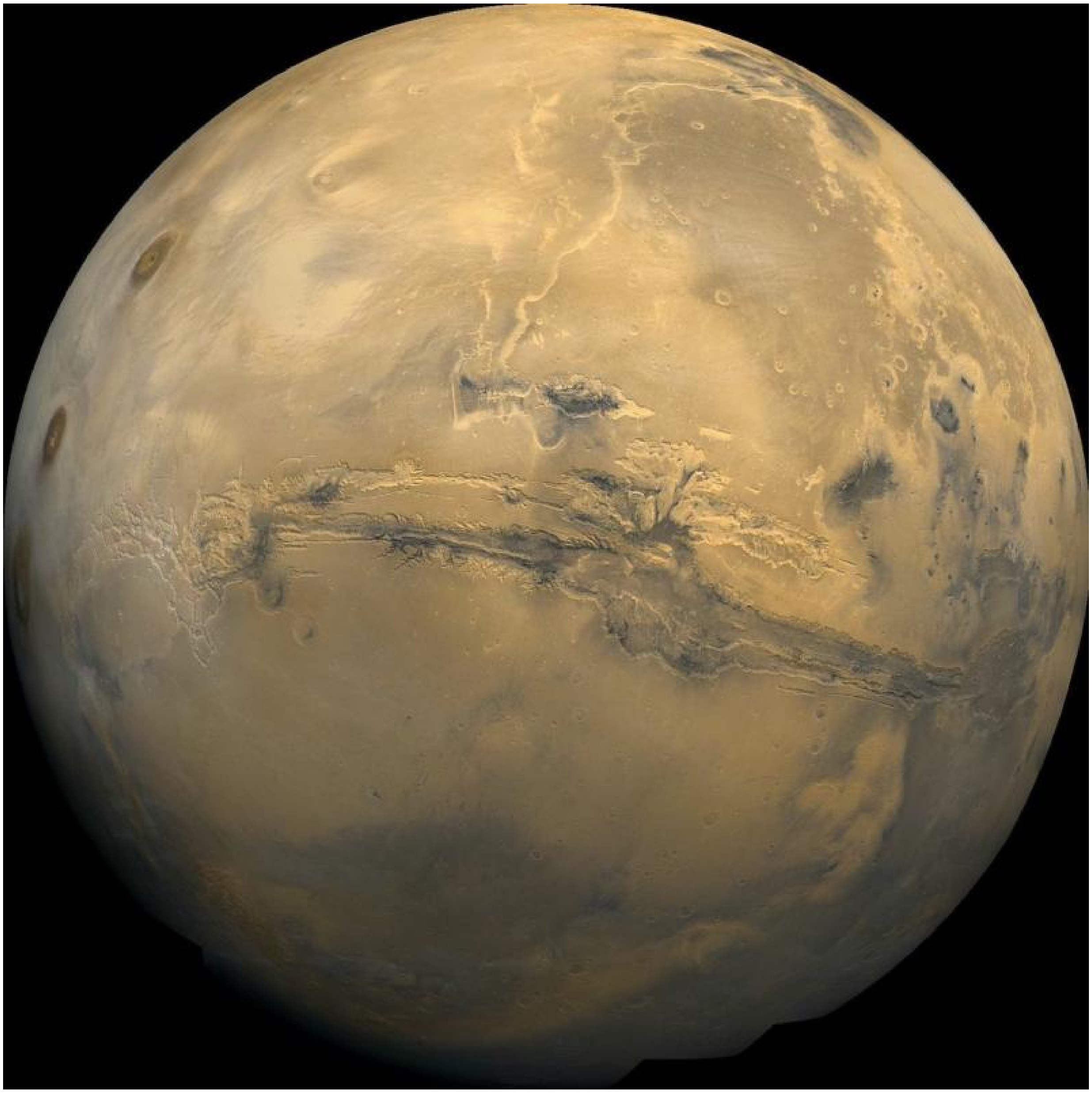
Those cores remain, behemoths of ice and rock ten times the mass of Earth, shrouded in vast atmospheres.

That leads to an interesting possibility. Far beneath the clouds of Uranus and Neptune, it seems likely that temperatures and pressures will have allowed the material of the cores to differentiate, with the heaviest materials (the metals) sinking to the centre, to be surrounded by a mantle of volatile material - primarily water and ammonia.

Just like Earth's mantle, that material is likely molten - not an ocean as we imagine it, but certainly not hard, solid rock.

Icy debris in the Solar system's depths

The vast amounts of ice in the young Solar system was not all devoured by the giant planets. Each of those worlds (Jupiter, Saturn, Uranus and Neptune) is accompanied by a swarm of dozens of satellites, ranging in size from bodies larger than our Moon to objects just metres or a few kilometres across.



Mars, Earth's closest planetary neighbour, is a beautiful planet but is currently far from 'Earth-like'. Credit: NASA/USGS

Most of those moons are more water than anything else.

For many years, it was assumed that the icy moons were just that -

frozen husks, solid to their core. But in recent years that idea has gradually been replaced by a newer, more exciting paradigm. The water at the surface of those moons is solid - as hard as granite in many cases. But deep below, in their interiors, lurk buried oceans.

The first such ocean identified was the one beneath the ice of Jupiter's moon Europa, a world about the size of our Moon. But Europa is not alone.

Results from the Galileo spacecraft, which orbited Jupiter for eight years in the late 1990s and early 2000s, found tantalising hints that two of Jupiter's other large moons, Ganymede and Callisto, may also house deeply buried oceans.

Then came the Cassini mission to Saturn. Saturn's largest moon, Titan, has a thick atmosphere, and Cassini deployed the Huygens lander on its arrival in the system, to parachute through the clouds and see what lurks beneath.

The answer is lakes, rivers and rain. But not liquid water. The ice on frigid Titan's surface is harder than granite. Instead, Titan's surface features liquid methane and ethane and large, slow-falling raindrops of methane.

More recently, Cassini measurements have suggested that the ethane and methane oceans on Titan might not be the only liquid there. Just like Europa, there is evidence of a saltwater ocean buried deep beneath the moon's surface.

Far from liquid water being scarce beyond Earth, it is becoming ever more apparent that it might be common throughout the Solar system.

An artist's impression of a protoplanetary disk around a young star, in which planets are being born. Credit: NASA/JPL-Caltech

It isn't just moons in the outer Solar system that seem to host liquid water. Recent research has suggested that the largest asteroid, Ceres, might have just such an ocean, as might Pluto.

And there are still millions of other icy bodies out there, just waiting to be explored.

Water in the inner Solar system

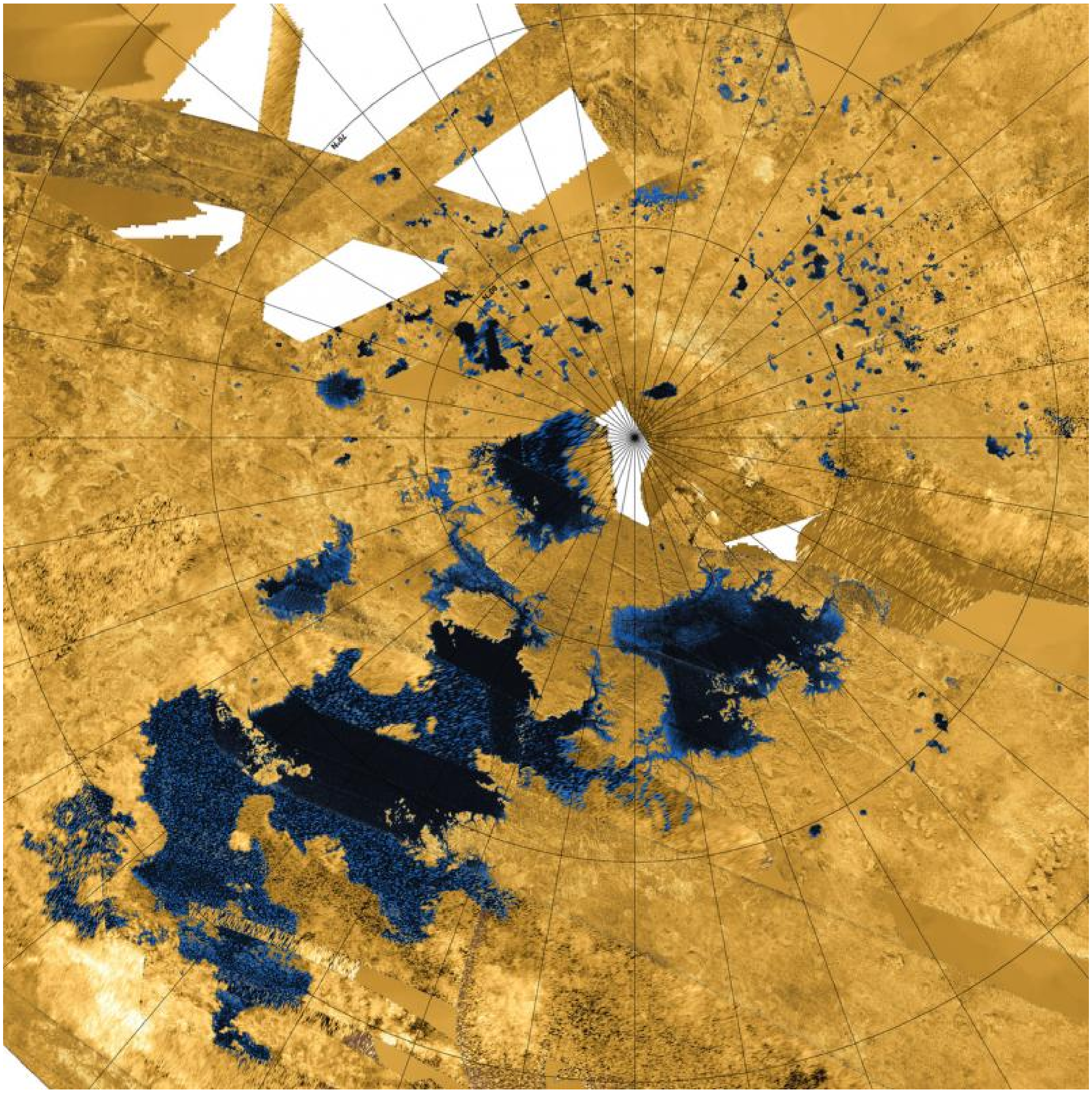
All that brings us closer to home, to the inner Solar system. We know that Earth has water, although it is a far drier world than the objects we have discussed so far.

This isn't actually a surprise. Earth formed in the warm part of the protoplanetary disk, at a location well within the "snow line". In fact, the origin of Earth's water has been a puzzle to astronomers for many years.

It seems most likely that Earth's water was delivered from the colder reaches of the Solar system through impacts, most likely from the outer reaches of the asteroid belt. That delivery through bombardment would also have targeted Mars and Venus.

There is growing evidence that both Mars and Venus once had oceans much like Earth's - until the vagaries of time took their toll.

In the 4.5 billion years since the Solar system's formation, the Sun has grown markedly more luminous. As a result, Venus grew ever warmer until its oceans boiled, hundreds of millions of years ago.



Lakes, seas, and rivers of methane and ethane on the surface of Saturn’s largest moon, Titan. Credit: NASA/JPL-Caltech/Agenzia Spaziale Italiana/USGS

Mars, by contrast, has gradually frozen, losing its atmosphere under the combined influence of chemical weathering at the planet's surface, and the stripping action of the Solar wind and radiation. The water is still there, but no longer in the form of planet-girding oceans.

Habitable worlds

So back to Europa, Titan and Enceladus with their oceans buried beneath tens or hundreds of kilometres of ice.

Could those worlds be habitable? Definitely. With every year that passes, we gather ever more evidence that points in that direction.

Could there be life there? Again, it is possible, but herein lies the catch.

All those locations are right on our doorstep, and yet any life upon them is buried so deeply that we cannot find it. To do so will almost certainly require landers, to drill through the ice to the oceans beneath - an incredibly challenging task.

What does this mean for life elsewhere? Well, if our Solar system tells us anything, it is that our universe is drenched in water. Quite literally, there's water everywhere. Maybe, just maybe, that's a hint that we might not be as alone as we think.

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