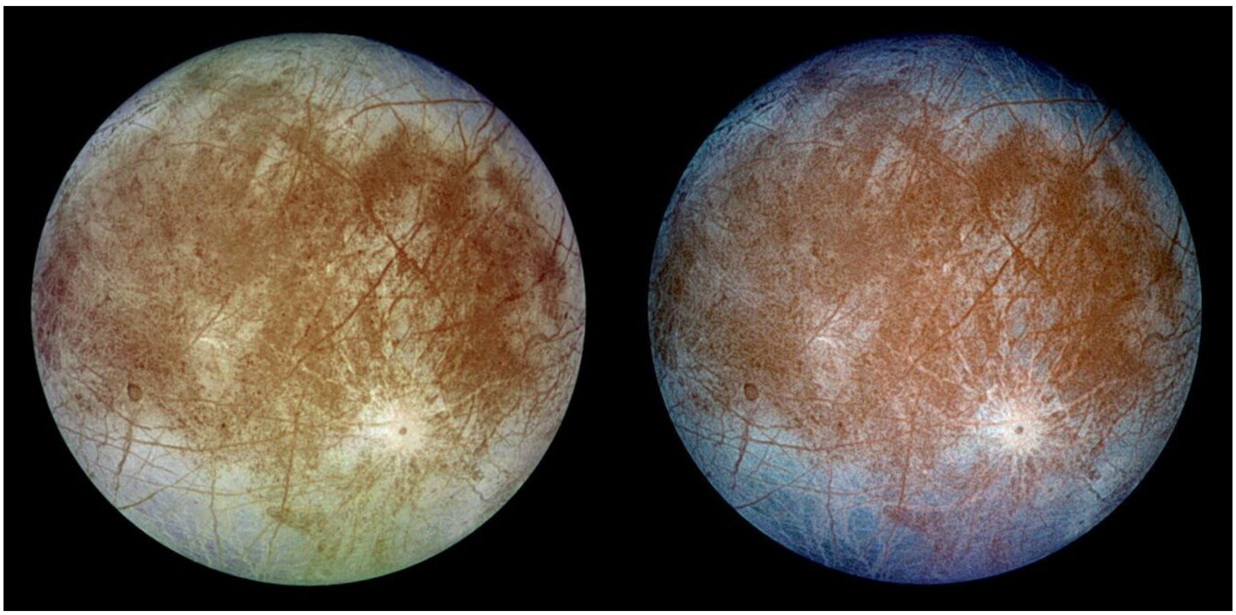
Jupiter's moon Europa produces less oxygen than we thought—it may affect our chances of finding life there

March 9 2024, by Andrew Coates



Europa seen in true colour (left) and false colour (right). Credit: NASA

Jupiter's icy moon Europa has long been thought of as one of the most habitable worlds in the Solar System. Now the Juno mission to Jupiter has directly sampled its atmosphere in detail for the first time. The results, published in *Nature Astronomy*, show that Europa's icy surface produces less oxygen than we thought.

There are plenty of reasons to be excited about the possibility of finding microbial life on Europa. Evidence from the Galileo mission has shown that the moon has an ocean below its icy surface containing about twice the amount of water as Earth's oceans. Also, models derived from Europa data show that its ocean floor is in contact with rock, enabling chemical water-rock interactions that produce energy, making it the prime candidate for life.

Telescope observations, meanwhile, reveal a weak, oxygen-rich atmosphere. It also looks as though plumes of water erupt intermittently from the ocean. And there is some evidence of the presence of basic chemical elements on the surface—including carbon, hydrogen, nitrogen, oxygen, phosphorus and sulphur—used by life on Earth. Some of these could seep down into the water from the atmosphere and surface.

The heating of Europa and its ocean is partly thanks to the moon's orbit around Jupiter, which produces tidal forces to heat an otherwise frigid environment.

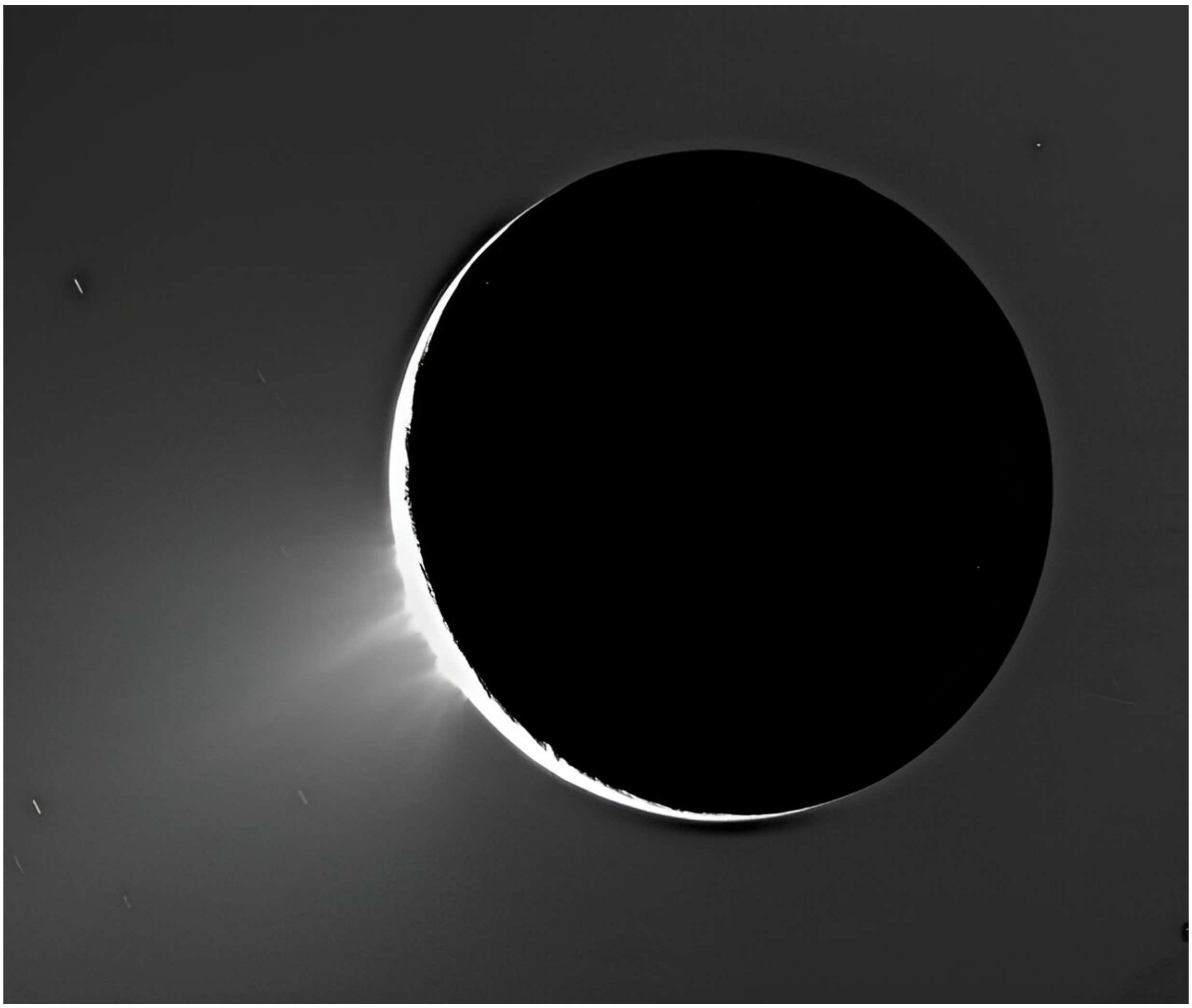
Although Europa boasts three basic ingredients for life—water, the right chemical elements and a source of heat—we don't yet know if there has been enough time for life to develop.

The other prime candidate in our solar system is Mars, the Rosalind Franklin rover's target in 2028. Life might have started on Mars at the same time as it did on Earth, but then probably stopped due to climate change.

A third candidate is Saturn's moon Enceladus where the Cassini-Huygens mission discovered plumes of water from a sub-surface salty ocean, also in contact with rock at the ocean's floor.

Titan is the closest runner up in fourth place, with its thick atmosphere of organic compounds including hydrocarbon and tholins, born in the high atmosphere. These then float down to the surface coating it with ingredients for life.

Losing oxygen



Plumes seen on Europa. Credit: NASA

The Juno mission boasts the best charged particle instruments sent to Jupiter so far. It can measure the energy, direction and composition of charged particles on the surface. Similar instruments at Saturn and Titan found tholins (a type of organic substance) there. But they also measured particles that suggested atmospheres at Saturn's moons Rhea and Dione, in addition to those at Titan and Enceladus.

These particles are known as pickup ions. Planetary atmospheres consist of neutral particles, but the top of an atmosphere becomes "ionised" (meaning it loses electrons) in sunlight and via collisions with other particles, forming ions (charged atoms that have lost electrons) and free electrons.

When a plasma—a charged gas making up the fourth state of matter beyond solid, liquid and gas—flows past an atmosphere with newly formed ions, it disturbs the atmosphere with electric fields which can accelerate the new ions—the first part of an ion pickup process.

These pickup ions then spiral around the planet's magnetic field and are usually lost from the atmosphere, while some hit the surface and are absorbed. The pickup process has rid the Martian atmosphere of particles after the red planet's magnetic field was lost 3.8 billion years ago.

Europa also has a pickup process. The new measurements show the telltale signs of pickup molecular oxygen and hydrogen ions from the surface and atmosphere. Some of these escape from Europa, whereas some hit the icy surface enhancing the amount of oxygen at and under the surface.

This confirms that oxygen and hydrogen are indeed the main constituents of Europa's atmosphere—in agreement with remote observations. However, the measurements imply that the amount of oxygen being produced—released by the surface to the atmosphere—is only about 12kg per second, at the lower end of earlier estimates from about 5kg to 1,100 kg per second.

This would indicate that the surface suffers very little erosion. The measurements indicate that this may amount to only 1.5cm of Europa's surface per million years, which is less than we had thought. So Europa is constantly losing oxygen due to pickup processes, with only a small amount of additional oxygen being released from the surface to replenish it and ending up back on the surface.

So what does that mean for its chances of hosting life? Some of the oxygen trapped in the surface may find its way to the subsurface ocean to nourish any life there. But based on the study's estimate of the overall loss of oxygen, this should be less than the 0.3kg-300kg per second estimated earlier.

It remains to be seen whether this rate, recorded on 29, September 2022, is usual. Perhaps it is not representative of the overall oxygen on the moon. It may be that the eruption of plumes, orbital position and upstream conditions increase and decrease the rate at certain times, respectively.

Nasa's Europa Clipper mission, to be launched later this year, and the Juice mission which will make two flybys of Europa on its way to orbit Ganymede, will be able to follow up these measurements, and provide much more information on Europa's habitability.

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