What can we learn flying through the plumes at Enceladus?

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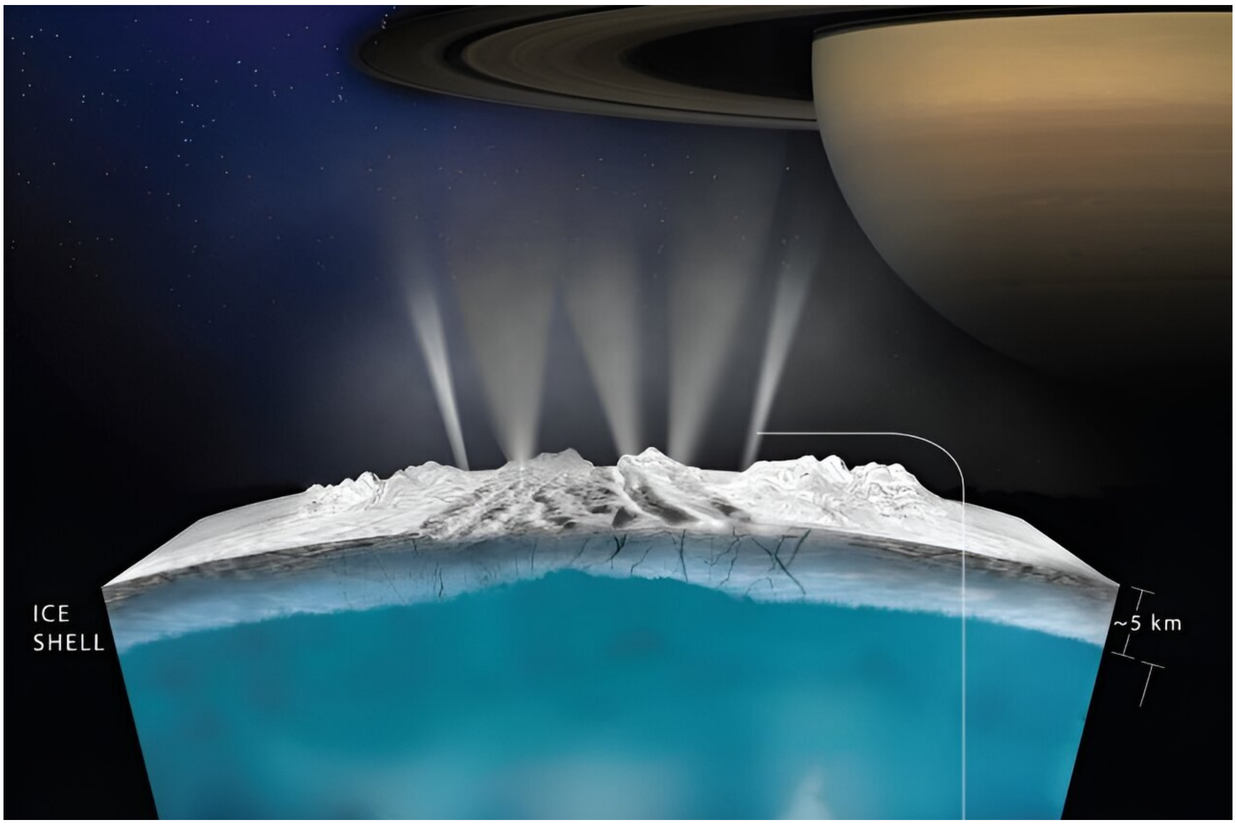

Artist rendering showing an interior cross-section of the crust of Enceladus, which shows how hydrothermal activity may be causing the plumes of water at the moon's surface. Credits: NASA-GSFC/SVS, NASA/JPL-Caltech/SwRI

In the next decade, space agencies will expand the search for extraterrestrial life beyond Mars, where all of our astrobiology efforts are currently focused. This includes the ESA's JUpiter ICy moon's Explorer (JUICE) and NASA's Europa Clipper, which will fly past Europa and Ganymede repeatedly to study their surfaces and interiors.

There's also NASA's proposed Dragonfly mission that will fly to Titan and study its atmosphere, methane lakes, and the rich organic chemistry happening on its surface. But perhaps the most compelling destination is Enceladus and the lovely plumes emanating from its southern polar region.

Since the Cassini mission got a close-up look at these plumes, scientists have been aching to send a robotic mission there to sample them—which appear to have all the ingredients for life in them. This is not as easy as it sounds, and there's no indication flying through plumes will yield intact samples.

In a recent paper published in *Meteoritics & Planetary Science*, researchers from the University of Kent examined how the velocity of a passing spacecraft (and the resulting shock of impact) could significantly affect its ability to sample water and ice within the plumes.

The research was conducted by Prof. Mark Burchell and Dr. Penny Wozniakiewicz (an Emeritus Professor and a Senior Lecturer in Space Science) from the Center for Astrophysics and Planetary Science (CAPS), part of the School of Physics and Astronomy at the University of Kent, U.K.

Their work could have significant implications for missions to Icy Ocean Worlds (IOW), bodies in the outer solar system composed predominantly of frozen water and volatiles with oceans in their interior. These bodies have become of increasing interest to scientists since it is possible some could support life.

The term "Ocean Worlds" has become common in recent years as the number of potential candidates for exploration has increased. Since the Voyager probes passed through the system in 1979, scientists have speculated about the possibility of an interior ocean within Europa based on its surface features. This included patches of "young terrain" sitting next to older, cratered terrain—indicative of regular exchanges between the surface and interior. The Voyager probes noticed similarly youthful terrain on Enceladus when they few past Saturn in 1980 and 1981 (respectively).

However, it was the Cassini-Huygens mission that discovered water vapor and organic molecules venting from the Enceladus' southern polar region in 2004. Over the next 13 years, the Cassini orbiter conducted several more flybys of the moon, yielding additional evidence of an interior ocean and an energy source at the core-mantle boundary.

These findings placed Enceladus among the "Ocean Worlds" that scientists want to examine more closely with future missions. But unlike other IOWs, Enceladus is particularly attractive because of the nature of the plumes around its south pole.

Whereas Europa also experiences plume activity, these are more sporadic and difficult to detect. Due to Europa's higher gravity (~13% vs. 1% of Earth's), water vapor and vented material don't reach nearly as far into space.

As Burchell told Universe Today via email, collecting samples from these plumes seems relatively simple, at least in theory. "Like all IOWs, it has an internal ocean with lots of water. What is in that water is the subject of much speculation and interest," he said. "And Enceladus ejects plumes of water into space, making any space mission that wants to sample the water much easier—you can just fly through the plume."

However, in the realm of practice (as always), things get a little more complicated. Depending on how fast a mission is traveling, the impact it will inflict upon plume material will vary considerably. As Burchell explains, this could jeopardize the very samples a mission was trying to obtain:

"The problem with collecting samples at speed is that a lot of testing has been done with metal and mineral projectile, but less is known about the response of organics to the high-speed impacts. The bonds in the organics will break, but at what speed? And which bonds first? So what you end up with for analysis may not be what came out of Enceladus. But with what biases? What degree of alteration? Understanding this is essential to any successful collection of samples."

According to Burchell, modeling how a spacecraft's velocity would affect its ability to collect samples can be accomplished in one of two ways. On the one hand, there's the computer modeling approach, where teams rely on advanced software to simulate impacts and measure the results. The other is the "kinetic" approach, which consists of firing small grains at targets at the right speeds and then measuring the force of impact. Burchell and his team prefer to do the latter. "In our lab, we like firing things at targets," he said.

Their results clearly showed that the collection speed is critical to sample collection. However, they also found that the results vary from one body to the next. Said Burchell:

"In an orbit at a small body like Enceladus, it is fairly low. But for the larger IOWs, it is greater. And it just gets into the regime where the shock of the impact process in the collection causes increasingly severe alteration to the samples. If you do a flypast of the IOW without orbiting it, you are faster again, and the samples experience a greater shock. It suggests a low-speed orbital collection is best for un-shocked, minimally processed samples. But that needs more spacecraft design and restricts the other science you could do. It is always a tradeoff."

Without the solar system, there are several bodies where water and other volatiles are vented from the interior—a phenomenon known as cryovolcanism. These bodies vary considerably in terms of their size and gravitational pull, ranging from the microgravity (less or slightly more than 1%) of Mimas and Enceladus to the roughly 13%–15% of Europa, Titan, and Ganymede. As a result, these findings could help inform the design of many sample-collection missions destined for IOWs.

More information: M. J. Burchell et al, Icy ocean worlds, plumes, and tasting the water, *Meteoritics & Planetary Science* (2024). DOI: 10.1111/maps.14152

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