Europa clipper could help discover if Jupiter's moon is habitable

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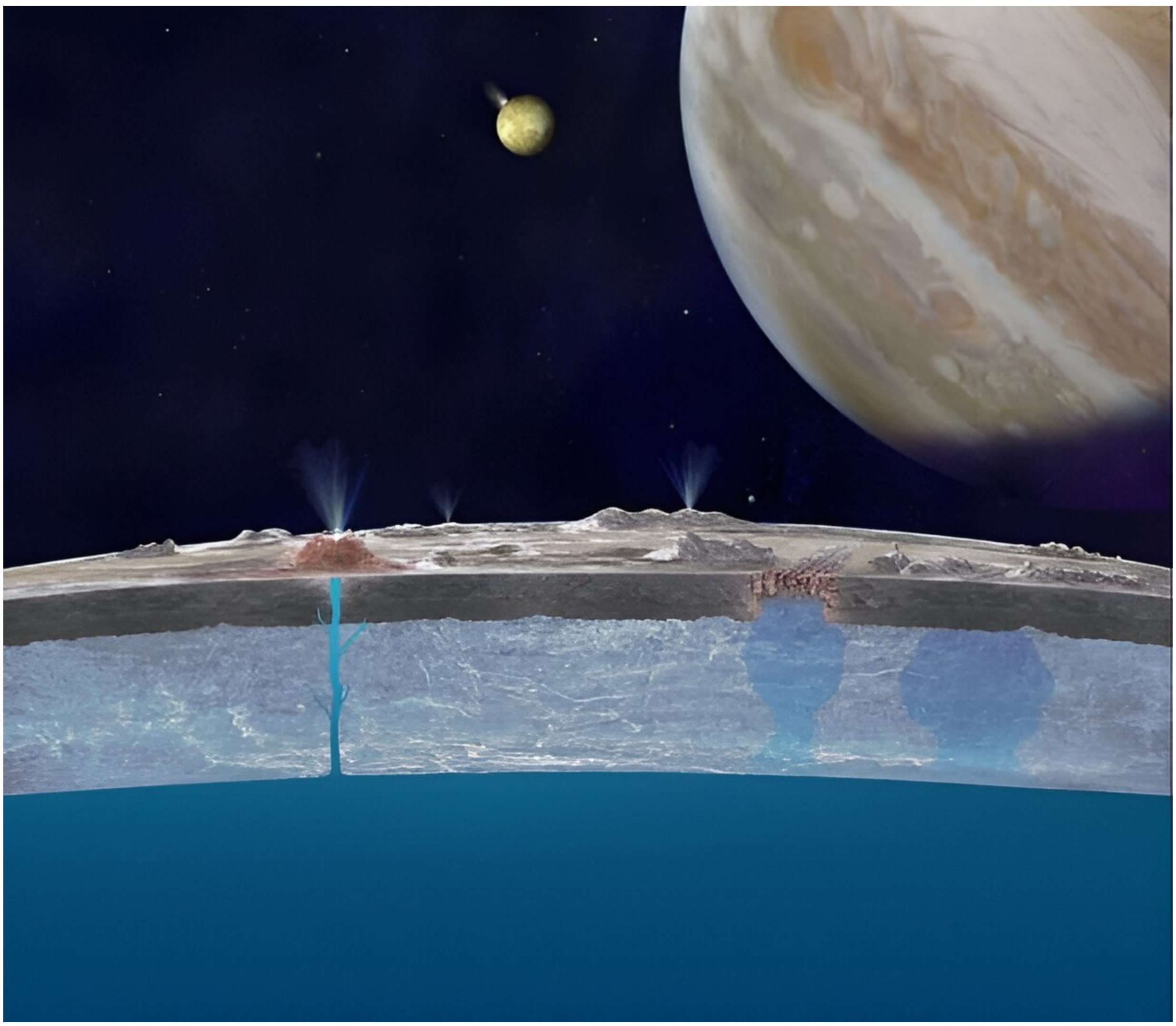

Could shallow lakes be locked away in Europa’s crust? Europa Clipper will find out. Credit: NASA

Since 1979, when the Voyager probes flew past Jupiter and its system of moons, scientists have speculated about the possibility of life within Europa. Based on planetary modeling, Europa is believed to be differentiated between a rocky and metallic core, an icy crust and mantle, and a liquid-water ocean that could be 100 to 200 km (62 to 124 mi) deep. Scientists theorize that this ocean is maintained by tidal flexing, where interaction with Jupiter's powerful gravitational field leads to geological activity in Europa's core and hydrothermal vents at the core-mantle boundary.

Investigating the potential habitability of Europa is the main purpose of NASA's Europa Clipper mission, which will launch on October 10th, 2024, and arrive around Jupiter in April 2030. However, this presents a challenge for astrobiologists since the habitability of Europa is dependent on many interrelated parameters that require collaborative investigation. In a recent paper, a team of NASA-led researchers reviewed the objectives of the Europa Clipper mission and anticipated what it could reveal regarding the moon's interior, composition, and geology.

The team consisted of researchers from the Johns Hopkins University Applied Physics Laboratory (JHUAPL), the Beyond Center at Arizona State University, the Woods Hole Oceanographic Institution (WHOI), Honeybee Robotics, the Southwest Research Institute (SwRI), the Planetary Science Institute (PSI), the Lunar and Planetary Laboratory (LPL), NASA's Goddard Space Flight Center (GSFC) and Jet Propulsion Laboratory (JPL), and multiple universities. Their paper, "Investigating Europa's Habitability with the Europa Clipper," was recently published in *Space Science Reviews*.

What is 'habitability?'

When it comes to the search for life beyond Earth (aka astrobiology), all of humanity's efforts are currently focused on Mars. This will change in the coming years as missions destined for the outer solar system conduct detailed studies of "ocean worlds"—icy bodies with interior oceans. This includes Europa, Ganymede, Titan, Enceladus, Triton, and possibly Pluto and Charon. The Europa Clipper will be the first of these missions to arrive—followed by the ESA's JUpiter ICy moons Explorer (JUICE) in 2031. It will spend the next four years orbiting Jupiter and making close flybys of Europa, studying its surface and interior with its advanced suite of instruments. As the Europa Study Team summarized in their 2012 report:

"Jupiter's moon Europa is one the most promising candidates for hosting life today among ocean worlds in the solar system. In its investigation of Europa's habitability, the Europa Clipper mission seeks to understand the provenance of water, essential chemical elements and compounds, and energy, and how they might combine to make this moon's environments suitable to support life."

As the NASA-led team indicated in their study, the purpose of the Europa Clipper mission is not to detect life itself but to assess Europa's ability to support life as we know it. This will consist of confirming (or refuting) the existence of Europa's interior ocean and determining if it possesses the necessary chemical and energy sources for life to thrive. However, one of the main challenges in investigating the moon's habitability is the nature of the concept itself. Nevertheless, the relevant parameters include hospitable temperatures, pressure, pH, salinity, and the presence of a solvent (such as water).

Steven D. Vance, the Deputy Section Manager for the Planetary Interiors and Geophysics Group at NASA's Jet Propulsion Laboratory (JPL), was also the paper's lead author. As he explained to Universe Today via email:

"Habitability is the potential for supporting life, but not necessarily the presence of life. Some environments are more habitable than others. For example, a lush rainforest provides plenty of water, clement conditions, and nutrients for life. By contrast, in regions of the Atacama desert there are the essential ingredients for life—water, materials (composition), and energy—but hardly any life can be supported because the conditions are cold, dry, and otherwise inhospitable. Understanding a setting's habitability is necessary to interpret any possible detection of life."

Establishing limits

For instance, scientists have long speculated that life inside Europa may resemble the kinds of life observed around hydrothermal vents in Earth's oceans. This includes extremophiles, organisms that can thrive in extreme environments and are not dependent on sunlight for energy. Examples include barophiles, which can exist under extreme pressure, and thermophiles, which live in extreme heat. These organisms establish the upper limits on conditions under which life can survive and offer constraints on whether life is possible on Europa. Said Vance:

"The Europa Clipper mission will synthesize studies of Europa's geology, composition, and interior to understand the detailed properties of its ocean. Among the main things it will do is to figure out how thick the ocean is and where the tidal heat is concentrated in the ice, ocean, and rocky interior. To achieve our goal of understanding Europa's habitability, we will need to synthesize the measurements from the entire suite of 10 instruments."

To investigate Europa's habitability, the Europa Clipper mission has three primary science objectives. These include characterizing the ice shell and any subsurface water, their composition, the ocean's properties, and the nature of exchanges between the surface ice and ocean; identifying the composition of any non-ice materials on the surface and in the atmosphere, including any carbon-containing compounds; and characterizing geological surface features and high-science-interest localities. Because habitability comes down to many interdependent physical and chemical parameters and processes, multiple measurements will be synthesized by the following instruments.

In terms of cameras, the Clipper will rely on the Europa Imaging System (EIS), which consists of a wide-angle and a narrow-angle camera—each with an eight-megapixel sensor—that will produce high-resolution images of Europa, study geologic activity, measure surface elevations, and provide context for other instruments. There's also the Europa THermal EMission Imaging System (E-THEMIS) that will identify regions on Europa where warm liquid water may be near the surface (or might have erupted) and measure surface texture to understand the small-scale properties of the surface.

For spectroscopic investigations, Clipper will carry the Europa UltraViolet Spectrograph (Europa-UVS): to help determine the composition of Europa's atmospheric gases and surface materials and search near Europa for signs of plume activity. The MAss Spectrometer for Planetary EXploration (MASPEX) will analyze gases in Europa's faint atmosphere and possible plumes and study the chemistry of the moon's suspected subsurface ocean, how ocean and surface exchange material, and how radiation alters compounds on the moon's surface.

To characterize the plasma and magnetic environment around Europa, Clipper will use the Europa Clipper Magnetometer (ECM) to confirm that Europa's ocean exists, measure its depth and salinity, measure the moon's ice shell thickness, and study how Europa's ionized atmosphere interacts with Jupiter's ionized atmosphere. The Plasma Instrument for Magnetic Sounding (PIMS) will measure Europa's ionosphere and plasma trapped in Jupiter's magnetic field. It will also attempt to distinguish between Jupiter's magnetic field and Europa's induced magnetic field, which carries information about Europa's ocean.

The Gravity and Radio Science (G/RS) instrument will measure Europa's gravity at various points to show how Europa flexes and help reveal its internal structure. At the same time, the Radar for Europa Assessment and Sounding: Ocean to Near-surface (REASON) will probe Europa's icy shell for the moon's suspected ocean and study the ice's structure and thickness. It will also study the moon's surface elevations, composition, and roughness and search its atmosphere for plumes.

Lastly, chemical analysis will be carried out by the Mapping Imaging Spectrometer for Europa (MISE), which will map the distribution of ices, salts, organics, and the warmest hotspots on Europa. The SUrface Dust Analyzer (SUDA) will search for bits of ejecta launched from Europa's surface due to impacts and evidence of plumes. It will further identify that material's chemistry and area of origin and offer clues to Europa's ocean salinity.

A long history of exploration

As noted, scientists became fascinated with Europa ever since the Voyager probes passed through the system in 1979. These missions demonstrated that Europa is geologically active, as indicated by intersecting linear features that resembled ice flows on Earth. The discovery of volcanoes on Io (the result of tidal flexing) led to speculation that Europa might also experience volcanic activity in its interior. This coincided with the discovery of hydrothermal vents on Earth) just two years prior, which showed that life could be supported by internal energy (rather than sunshine).

The Galileo probe was the first mission to study Jupiter and its moons exclusively, which arrived in 1989. The data acquired by this mission during the more than seven years it orbited Jupiter provided additional evidence of Europa's potential habitability. This included magnetic data that suggested there was a liquid-saltwater layer underneath the icy surface and the detection of clay-like minerals (often associated with organic materials) on the surface. From these missions, scientists developed a "best fit" model for Europa, where an ocean tens to hundreds of km deep resides beneath 3–50 km (1.8 to 31 mi) of ice.

In the past decade, the Hubble Space Telescope acquired multiple images that showed evidence of water vapor and plume activity emanating from Europa's surface. Most recently, the James Webb Space Telescope detected carbon dioxide on the surface, which may have been transferred from the interior through resurfacing. If confirmed, this would mean that the subsurface ocean has carbon, an essential ingredient for life and a building block for organics. Once it reaches Jupiter, the Europa Clipper mission will build upon this impressive foundation and help resolve the mystery of this "ocean world."

The results of this mission will help inform future missions bound for the outer solar system. These include the proposed Europa Lander, which will touch down on the surface to investigate the moon's icy surface and plumes more closely. As Vance concluded:

"Everything we learn about Europa from Europa Clipper will enable the best designs for future missions. For example, high-resolution mapping of the surface will allow us to pinpoint the most scientifically interesting and safest places to land. Knowing the ice thickness and composition will make it possible to design drills tailored to penetrate the ice, possibly all the way to the ocean below."

More information: Steven D. Vance et al, Investigating Europa's Habitability with the Europa Clipper, *Space Science Reviews* (2023). DOI: 10.1007/s11214-023-01025-2

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