Study suggests explanation for unusual radar signatures of icy satellites in the outer solar system

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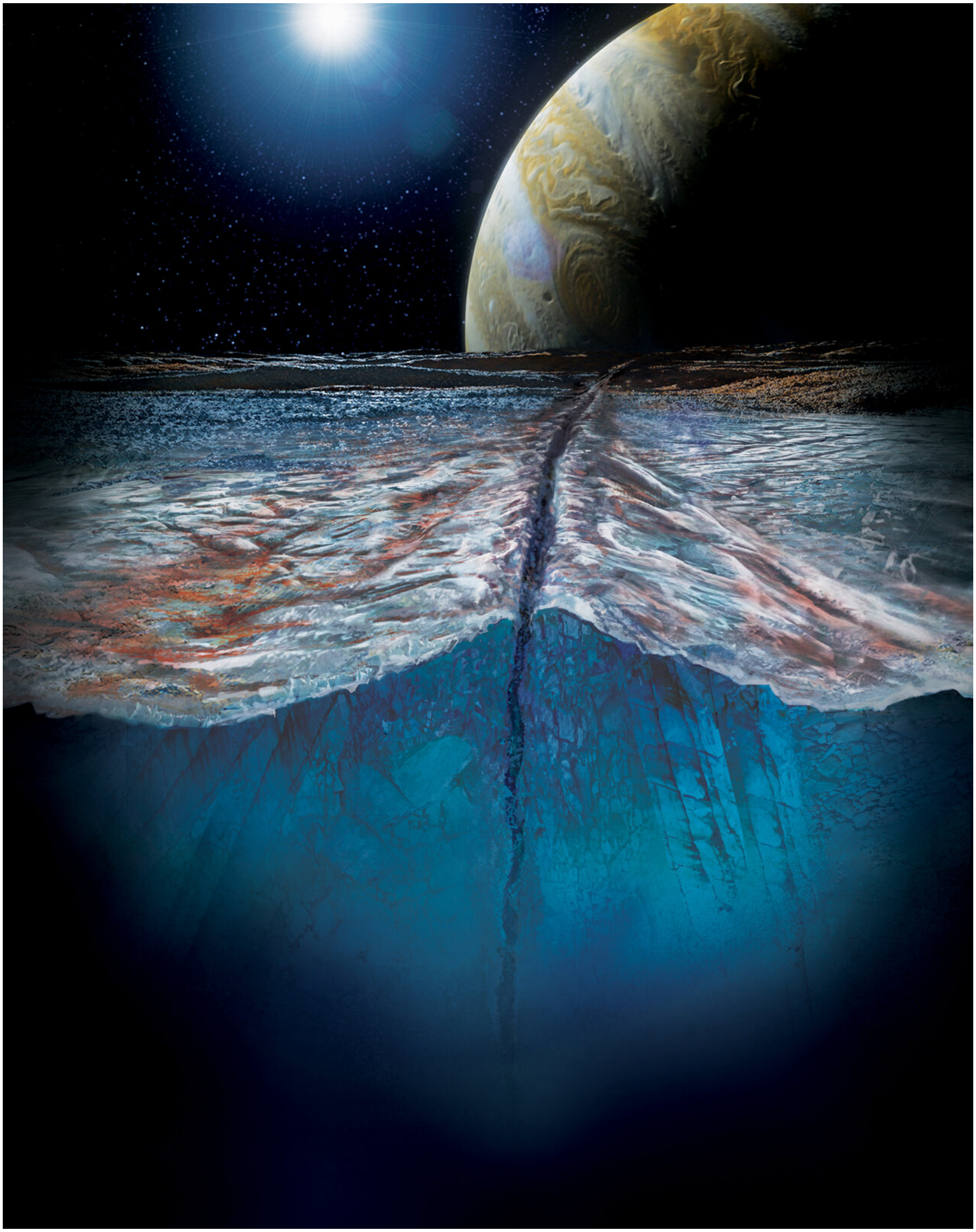

A study co-authored by Southwest Research Institute Senior Research Scientist Dr. Jason Hofgartner explains the unusual radar signatures of icy satellites orbiting Jupiter and Saturn. Their radar signatures, which differ significantly from those of rocky worlds and most ice on Earth, have long been a vexing question for the scientific community. Credit: NASA/JPL-Caltech/SwRI

A study co-authored by Southwest Research Institute Senior Research Scientist Dr. Jason Hofgartner explains the unusual radar signatures of icy satellites orbiting Jupiter and Saturn. Their radar signatures, which differ significantly from those of rocky worlds and most ice on Earth, have long been a vexing question for the scientific community.

"Six different models have been published in an attempt to explain the radar signatures of the icy moons that orbit Jupiter and Saturn," said Hofgartner, first author of the study, which was published this month in *Nature Astronomy.* "The way these objects scatter radar is drastically different than that of the rocky worlds, such as Mars and Earth, as well as smaller bodies such as asteroids and comets."

The objects are also extremely bright, even in areas where they should be darker.

"When we look up at Earth's moon it looks like a circular disk, even though we know it's a sphere. Planets and other moons similarly look like disks through telescopes," Hofgartner said. "While making radar observations, the center of the disk is very bright and the edges much darker. The change from center to edge is very different for these icy satellites than for rocky worlds."

In collaboration with Dr. Kevin Hand of NASA's Jet Propulsion Laboratory, Hofgartner argues that the extraordinary radar properties of these satellites, such as their reflectiveness and polarization (the orientation of light waves as they propagate through space) is very likely to be explained by the coherent backscatter opposition effect (CBOE).

"When you're at opposition, the Sun is positioned directly behind you on the line between you and an object, the surface appears much brighter than it would otherwise," Hofgartner said. "This is known as the opposition effect. In the case of radar, a transmitter stands in for the Sun and a receiver for your eyes."

An icy surface, Hofgartner explained, has an even stronger opposition effect than normal. For every scattering path of light bouncing through the ice, at opposition there is a path in the exact opposite direction. Because the two paths have precisely the same length, they combine coherently, resulting in further brightening.

In the 1990s, studies were published stating that the CBOE was one explanation for the anomalous radar signatures of icy satellites, but other explanations could explain the data equally well. Hofgartner and Hand improved the polarization description of the CBOE model and also showed that their modified CBOE model is the only published model that can explain all of the icy satellite radar properties.

"I think that tells us that the surfaces of these objects and their subsurfaces down to many meters are very tortured," Hofgartner said. "They're not very uniform. Icy rocks dominate the landscape, perhaps looking somewhat like the chaotic mess after a landslide. That would explain why the light is bouncing in so many different directions, giving us these unusual polarization signatures."

The radar observations Hofgartner and Hand used were from the Arecibo Observatory, which was one of only two telescopes making radar observations of icy satellites until it was severely damaged by the collapse of its support structure, antenna and dome assembly and subsequently decommissioned. The researchers hope to make follow-up observations when possible and plan to study additional archival data that may shed even more light on icy satellites and the CBOE, as well as radar studies of ice at the poles of Mercury, the Moon, and Mars.

The paper "An icy-satellite radar-properties continuum that requires the coherent backscatter effect," appears in *Nature Astronomy*.

More information: Jason Hofgartner, A continuum of icy satellites' radar properties explained by the coherent backscatter effect, *Nature Astronomy* (2023). DOI: 10.1038/s41550-023-01920-2. www.nature.com/articles/s41550-023-01920-2

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