Where is the ice on Ceres?

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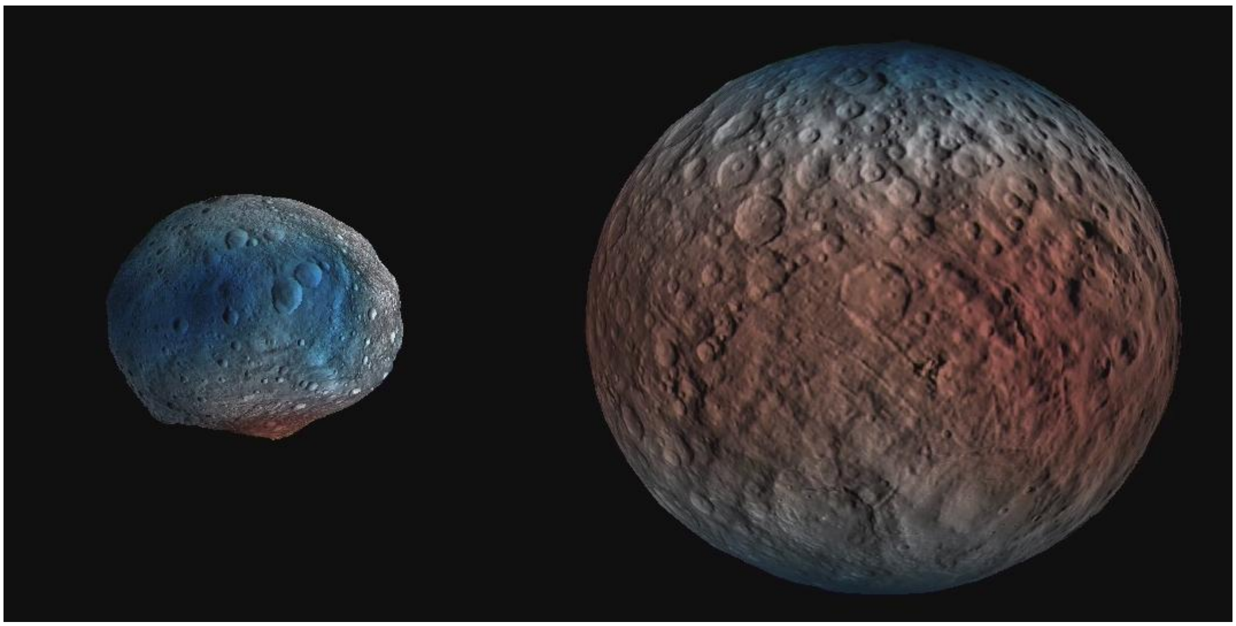


NASA's Dawn spacecraft determined the hydrogen content of the upper yard, or meter, of Ceres' surface. Blue indicates where hydrogen content is higher, near the poles, while red indicates lower content at lower latitudes. Image credit: NASA/JPL-Caltech/UCLA/MPS/DLR/IDA/PSI

At first glance, Ceres, the largest body in the main asteroid belt, may not look icy. Images from NASA's Dawn spacecraft have revealed a dark, heavily cratered world whose brightest area is made of highly reflective salts—not ice. But newly published studies from Dawn scientists show two distinct lines of evidence for ice at or near the surface of the dwarf planet. Researchers are presenting these findings at the 2016 American

Geophysical Union meeting in San Francisco.

"These studies support the idea that ice separated from rock early in Ceres' history, forming an ice-rich crustal layer, and that ice has remained near the surface over the history of the solar system," said Carol Raymond, deputy principal investigator of the Dawn mission, based at NASA's Jet Propulsion Laboratory, Pasadena, California.

Water ice on other planetary bodies is important because it is an essential ingredient for life as we know it. "By finding bodies that were water-rich in the distant past, we can discover clues as to where life may have existed in the early solar system," Raymond said.

Ice is everywhere on Ceres

Ceres' uppermost surface is rich in hydrogen, with higher concentrations at mid-to-high latitudes—consistent with broad expanses of water ice, according to a new study in the journal *Science*.

"On Ceres, ice is not just localized to a few craters. It's everywhere, and nearer to the surface with higher latitudes," said Thomas Prettyman, principal investigator of Dawn's gamma ray and neutron detector (GRaND), based at the Planetary Science Institute, Tucson, Arizona.

Researchers used the GRaND instrument to determine the concentrations of hydrogen, iron and potassium in the uppermost yard (or meter) of Ceres. GRaND measures the number and energy of gamma rays and neutrons emanating from Ceres. Neutrons are produced as galactic cosmic rays interact with Ceres' surface. Some neutrons get absorbed into the surface, while others escape. Since hydrogen slows down neutrons, it is associated with fewer neutrons escaping. On Ceres, hydrogen is likely to be in the form of frozen water (which is made of two hydrogen atoms and one oxygen atom).

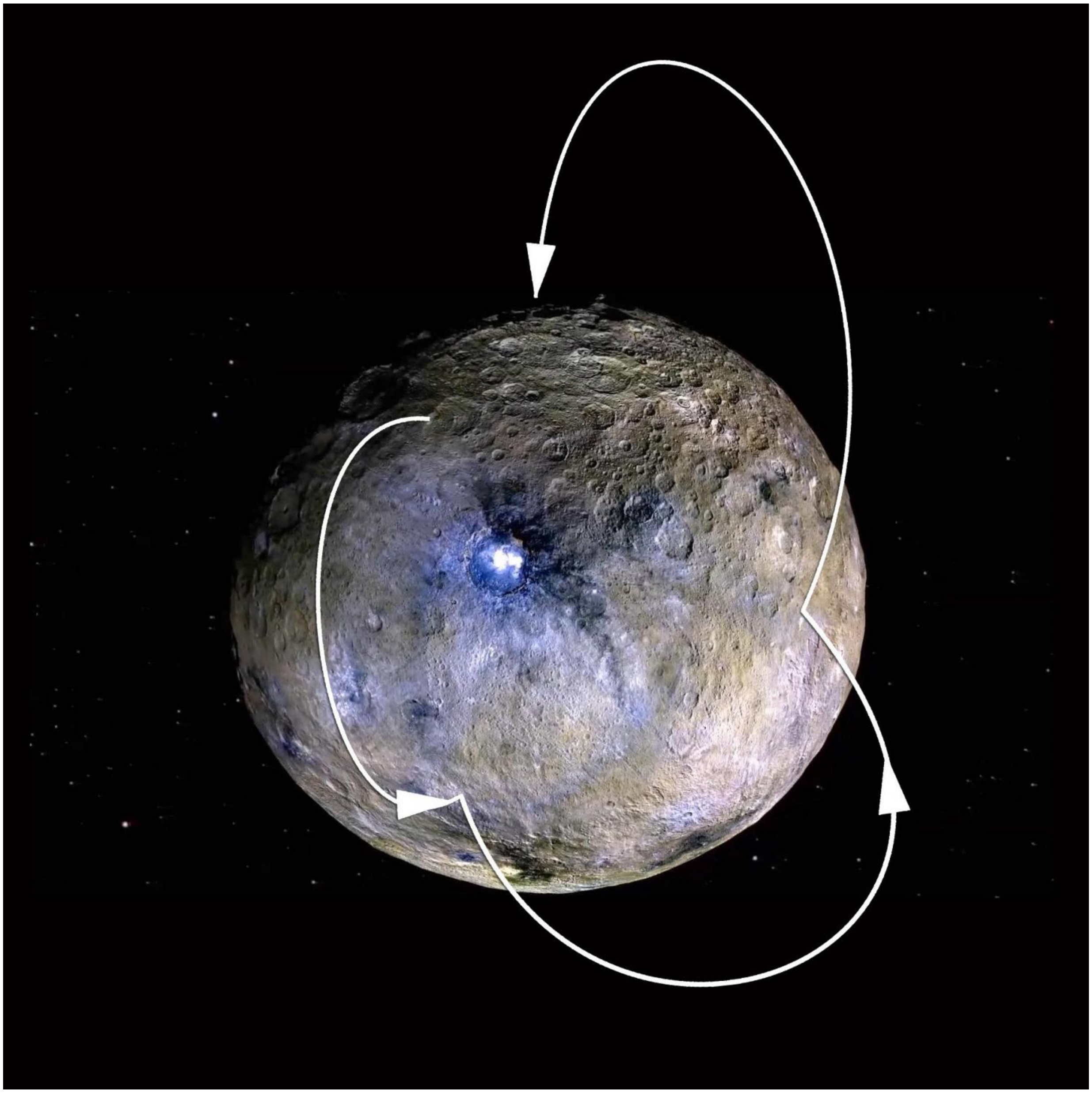
Rather than a solid ice layer, there is likely to be a porous mixture of rocky materials in which ice fills the pores, researchers found. The GRaND data show that the mixture is about 10 percent ice by weight.

"These results confirm predictions made nearly three decades ago that ice can survive for billions of years just beneath the surface of Ceres," Prettyman said. "The evidence strengthens the case for the presence of near-surface water ice on other main belt asteroids."

Clues to Ceres' inner life

Concentrations of iron, hydrogen, potassium and carbon provide further evidence that the top layer of material covering Ceres was altered by liquid water in Ceres' interior. Scientists theorize that the decay of radioactive elements within Ceres produced heat that drove this alteration process, separating Ceres into a rocky interior and icy outer shell. Separation of ice and rock would lead to differences in the chemical composition of Ceres' surface and interior.

Because meteorites called carbonaceous chondrites were also altered by water, scientists are interested in comparing them to Ceres. These meteorites probably come from bodies that were smaller than Ceres, but had limited fluid flow, so they may provide clues to Ceres' interior history. The Science study shows that Ceres has more hydrogen and less iron than these meteorites, perhaps because denser particles sunk while brine-rich materials rose to the surface. Alternatively, Ceres or its components may have formed in a different region of the solar system than the meteorites.



This graphic shows a theoretical path of a water molecule on Ceres. Some water molecules fall into cold, dark craters called "cold traps," where very little of the ice turns into vapor, even over the course of a billion years. Credit: NASA/JPL-Caltech/UCLA/MPS/DLR/IDA

Ice in permanent shadow

A second study, led by Thomas Platz of the Max Planck Institute for Solar System Research, Gottingen, Germany, and published in the journal *Nature Astronomy*, focused on craters that are persistently in shadow in Ceres' northern hemisphere. Scientists closely examined hundreds of cold, dark craters called "cold traps"—at less than minus 260 degrees Fahrenheit (110 Kelvin), they are so chilly that very little of the ice turns into vapor in the course of a billion years. Researchers found deposits of bright material in 10 of these craters. In one crater that is partially sunlit, Dawn's infrared mapping spectrometer confirmed the presence of ice.

This suggests that water ice can be stored in cold, dark craters on Ceres. Ice in cold traps has previously been spotted on Mercury and, in a few cases, on the moon. All of these bodies have small tilts with respect to their axes of rotation, so their poles are extremely cold and peppered with persistently shadowed craters. Scientists believe impacting bodies may have delivered ice to Mercury and the moon. The origins of Ceres' ice in cold traps are more mysterious, however.

"We are interested in how this ice got there and how it managed to last so long," said co-author Norbert Schorghofer of the University of Hawaii. "It could have come from Ceres' ice-rich crust, or it could have been delivered from space."

Regardless of its origin, water molecules on Ceres have the ability to hop around from warmer regions to the poles. A tenuous water atmosphere has been suggested by previous research, including the Herschel Space Observatory's observations of water vapor at Ceres in 2012-13. Water molecules that leave the surface would fall back onto Ceres, and could land in cold traps. With every hop there is a chance the molecule is lost to space, but a fraction of them ends up in the cold traps, where they accumulate.

This movie of images from NASA's Dawn spacecraft shows a crater on Ceres that is partly in shadow all the time. Such craters are called "cold traps." Dawn has shown that water ice could potentially be preserved in such place for very long amounts of time. Credit: NASA/JPL-Caltech/UCLA/MPS/DLR/IDA

'Bright spots' get names

Ceres' brightest area, in the northern-hemisphere crater Occator, does not shine because of ice, but rather because of highly reflective salts. A new video produced by the German Aerospace Center (DLR) in Berlin simulates the experience of flying around this crater and exploring its topography. Occator's central bright region, which includes a dome with fractures, has recently been named Cerealia Facula. The crater's cluster of less reflective spots to the east of center is called Vinalia Faculae.

"The unique interior of Occator may have formed in a combination of processes that we are currently investigating," said Ralf Jaumann, planetary scientist and Dawn co-investigator at DLR. "The impact that created the crater could have triggered the upwelling of liquid from inside Ceres, which left behind the salts."

Dawn's next steps

Dawn began its extended mission phase in July, and is currently flying in an elliptical orbit more than 4,500 miles (7,200 kilometers) from Ceres. During the primary mission, Dawn orbited and accomplished all of its original objectives at Ceres and protoplanet Vesta, which the spacecraft visited from July 2011 to September 2012.

More information: "Extensive water ice within Ceres' aqueously altered regolith: Evidence from nuclear spectroscopy," *Science*, science.sciencemag.org/lookup/ … 1126/science.aah6765

Provided by NASA

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