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Shaken and Stirred: Lab Studies Ice From Frigid Worlds

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The most exotic frozen cocktails on Earth won't be found in a chic restaurant or trendy bar. Scientists are mixing up these icy concoctions in a rather nondescript laboratory not much bigger than a janitor's closet. The surroundings are spartan, but the recipes they're using are out of this world.

Researchers in JPL's Ice Physical Properties Laboratory are recreating the ices found on the frigid bodies that inhabit the cold, outer reaches of our solar system. The goal is to study up-close the chemical and physical processes that take place on and beneath the surface of Titan, Europa, and other fascinating icy bodies such as Enceladus and Iapetus. The lab has specialized equipment, some of it newly invented, to replicate many of the ices found on these frozen worlds and measure how they respond to different conditions.

This unique facility is helping scientists answer questions about how Jupiter's ice-covered moon Europa might harbor a liquid ocean beneath its surface and how the freezing Enceladus, which circles Saturn, can produce plumes of water ice particles. "We're trying to shed light on processes that have occurred in the evolution of these bodies and understand what is happening on them now," said JPL planetary scientist Julie Castillo.

Saturn's moon Titan, where the surface temperature is about 94 Kelvin (minus 290 degrees Fahrenheit), is of particular interest to the lab's scientists. Its environment is rich in organic chemicals thought to be possible precursors to life. There is evidence that active cryovolcanoes may be spewing super-chilled liquids onto the moon's surface and into its thick atmosphere. While Titan has lakes of liquid methane on its surface, the water on Titan's surface is frozen to rock-like hardness.

Castillo and her colleagues in the ice lab are studying how ice, hydrocarbons and mixtures of water and ammonia interact on this mysterious, haze-shrouded moon. "We are replicating the conditions found at Titan in the lab," Castillo said. "We can produce methane rain like that on Titan and see what happens when it falls on a cold, icy substrate like Titan's surface."

"Recreating and testing ices like those found on Titan and Europa allows us to understand how certain processes work in the extreme conditions of these icy satellites," said the ice lab's principal investigator and manager, JPL physicist Martin Barmatz. Barmatz, together with Castillo, Cassini scientist Karl Mitchell and Fang Zhong of JPL's low-temperature physics group, was instrumental in establishing the lab two years ago. So far a dozen JPL scientists have been involved with the facility.

"We study physical processes on a microscopic scale, but the results give us insight into large processes such as cryovolcanism," said Barmatz. "These findings improve our ability to interpret data from missions like Cassini that study icy bodies."

Lab scientists began their ice research with pure water, to which they added more ingredients, such as ammonia or salts, to mimic the content of the ices found in the outer solar system. Zhong and Joe Young, known as the lab's "cryogenics geniuses," devised new apparatus for testing these exotic ices.

The lab is equipped with an array of devices to test the mechanical properties of different ices, such as how they respond to changes in pressure. There are also facilities for calorimetry and viscometry-making measurements of the effect of heat on ice and the consistency of ice. "Our cryogenic apparatus are world-class," said Barmatz.

One of the early goals for lab scientists was to create and study clathrate hydrates, water ices that form at low temperture and under high pressure and have molecules of different gases locked inside their ice crystals. Postdoctoral researcher and Titan specialist Mathieu Choukroun, who joined the lab last year, has developed a specialized high-pressure system for making many types of these frozen compounds.

Clathrates may be one explanation for the plume activity on Enceladus, Scientists theorize that many of the gases detected in the jets of gas and ice that shoot out from Enceladus' south polar region could have come from clathrates. Understanding ice behavior will help explain how some frozen worlds can become warm enough to have active features like plumes, ice volcanoes or subsurface liquid reservoirs.

"For decades, scientists have been trying to understand tidal heating," said Castillo. Tidal heating is warming caused by friction when a body is flexed by the gravitational pull of a nearby planet. "We've been able to demonstrate in the lab how ice responds to tidal forcing over a period of days. This is the only lab in the world with this capability. We found that the mechanism many computer models use to describe tidal heating isn't correct and are providing new data on how ice deforms when under pressure. The ice actually becomes a lot like play dough."

While the ice lab's focus has been on other worlds, the research has applications close to home. "Knowing more about the thermal and mechanical properties of ice will help us create better models of Earth's ice sheets," Castillo said. "It will also improve our ability to analyze ice cores -- one of the most important records we have of Earth's past climate."

Castillo recently began organizing an informal ice research network at JPL to share information and support ongoing studies. "We have experts here on most topics relating to ice, whether it is terrestrial, planetary, astrophysical, observed, modeled, explored, sea ice, lake ice, ice with organics and biological cells, clathrates, polar ice, permafrost, snow, cloud ice or cryogenic non-water ices," said Castillo. "They're doing cutting-edge research on a wide range of issues from climate change on Earth to habitability in the solar system and beyond."

"Even though we work on different types of ice and for different applications, we're all dealing with a fascinating material," Castillo said. "Ice is found nearly everywhere in the universe and comes in many forms. Where there is ice, there is often water, and where there is water, there is the possibility of life."

Source: NASA/JPL

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