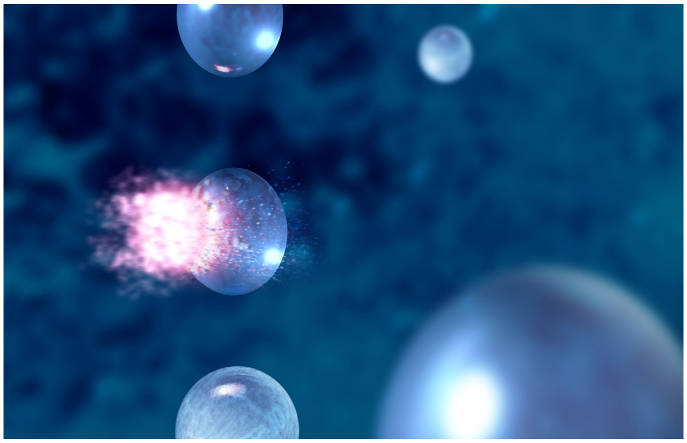
SLAC NATIONAL ACCELERATOR LABORATORY

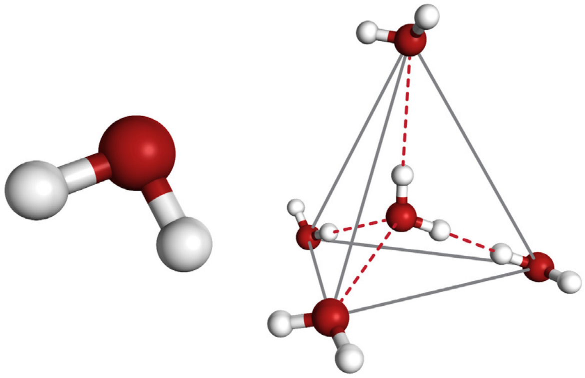
Science Highlight

A First Dip Into Water's 'No Man's Land'

Scientists recorded a first glimpse of how liquid water molecules behave at temperatures down to minus 51 degrees Fahrenheit, within an elusive "no man's land" where water's strange properties are super-amplified. The research promises to improve our understanding of water's unique attributes at more natural temperatures that are relevant to global ocean currents, climate and biology.



An X-ray laser pulse at LCLS probes a supercooled water droplet (center left). The speed and brightness of the X-ray pulses allowed researchers to study water molecules in the instant before freezing.



Water molecules, such as the one modeled at left, rapidly move toward a pyramidal structure, right, when supercooled.

Not Your Typical Liquid

We all learn in school that water freezes at 32 degrees Fahrenheit. But scientists have known for some time that water can remain liquid at much lower temperatures. Now, SLAC's Linac Coherent Light Source (LCLS) X-ray laser has allowed them to examine the molecular structure of liquid water under these exotic conditions for the first time. The results were published in *Nature*.

"Water is not only essential for life as we know it, but it also has very strange properties compared to most other liquids," said Anders Nilsson of the SUNCAT Center for Interface Science and Catalysis, a joint SLAC/Stanford institute, and leader of the research. "Thanks to LCLS, we have finally been able to enter this cold zone that should provide new information about the unique nature of water."

Despite its simple molecular structure, water has many weird traits: Its solid form is less dense than its liquid form, which is why ice floats; it can absorb a large amount of heat, which is carried long distances by ocean currents and has a profound impact on climate; and its peculiar density profile prevents oceans and lakes from freezing solid all the way to the bottom, allowing fish to survive the winter.

These traits are amplified when purified water is supercooled. When water is very pure, with nothing to seed the formation of ice crystals, it can remain liquid at much lower temperatures than normal. For decades scientists have sought to better explore what happens to water molecules at temperatures below minus 42 degrees, but they had to rely largely on theory and modeling. The temperature range of water from about minus 42 to minus 172 degrees has been dubbed "no man's land."

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Rapid Fire Laser Captures Rapid Change

Now, LCLS, with X-ray laser pulses just quadrillionths of a second long, allows researchers to capture rapid-fire snapshots showing how water's molecular structure continuously transforms as it enters this realm, and what happens in the instant before it freezes. The results show that these structural changes accelerate more dramatically than theoretical models had predicted.

For this experiment, researchers produced a steady flow of tiny water droplets in a vacuum chamber. As the drops traveled toward the laser beam, some of their liquid rapidly evaporated, supercooling the remaining liquid. (The same process cools us when we sweat.) By adjusting the distance the droplets traveled, the researchers were able to fine-tune the temperatures they reached on arrival at the X-ray laser beam.

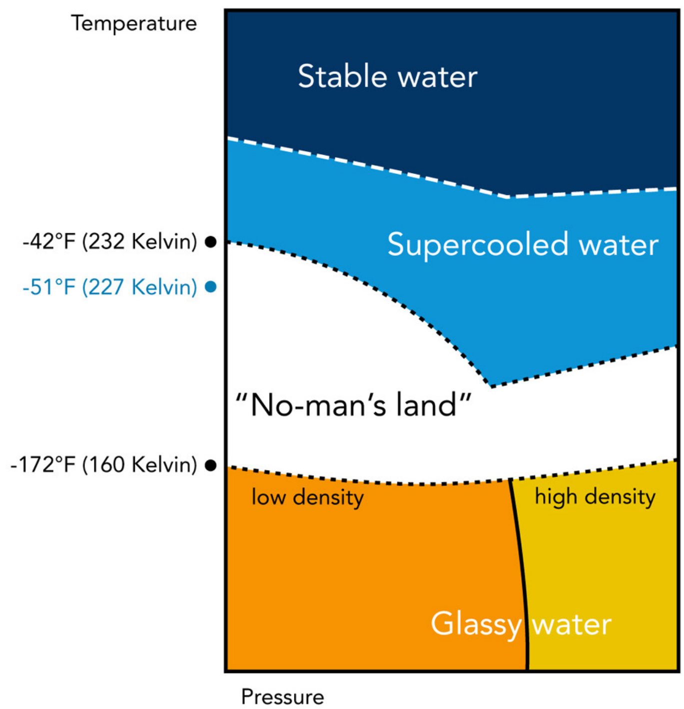
Colder Still

Nilsson's team hopes to dive to even colder temperatures where water morphs into a glassy, non-crystalline solid. They also want to determine whether supercooled water reaches a critical point where its unusual properties peak, and to pinpoint the temperature at which this occurs.

"Our dream is to follow these dynamics as far as we can," Nilsson said. "Eventually our understanding of what's happening here in no man's land will help us fundamentally understand water in all conditions."

Scientists at SLAC's Linac Coherent Light Source, Stanford Synchrotron Radiation Lightsource and Stanford PULSE Institute; Stockholm University; Germany's DESY laboratory; the Helmholtz Center for Materials and Energy in Germany; and Stony Brook University in New York also contributed to the research. The work was partially funded by the U.S. Department of Energy Office of Science, the SLAC Laboratory Directed Research and Development Program and the Swedish Research Council.

Citation: J. A. Sellberg et al., Nature, 19 June 2014 (10.1038/nature13266)



This diagram illustrates the rough boundaries of "no man's land," a temperature region where supercooled water is difficult to study because of rapid ice formation. Using SLAC's Linac Coherent Light Source, scientists dipped down to minus 51 degrees Fahrenheit and made the first structural measurements of liquid water in this mysterious region, where water's unusual properties are amplified. (SLAC National Accelerator Laboratory, Ultrafast Chemical Physics Group/University of Glasgow, Scotland)

For More Information

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