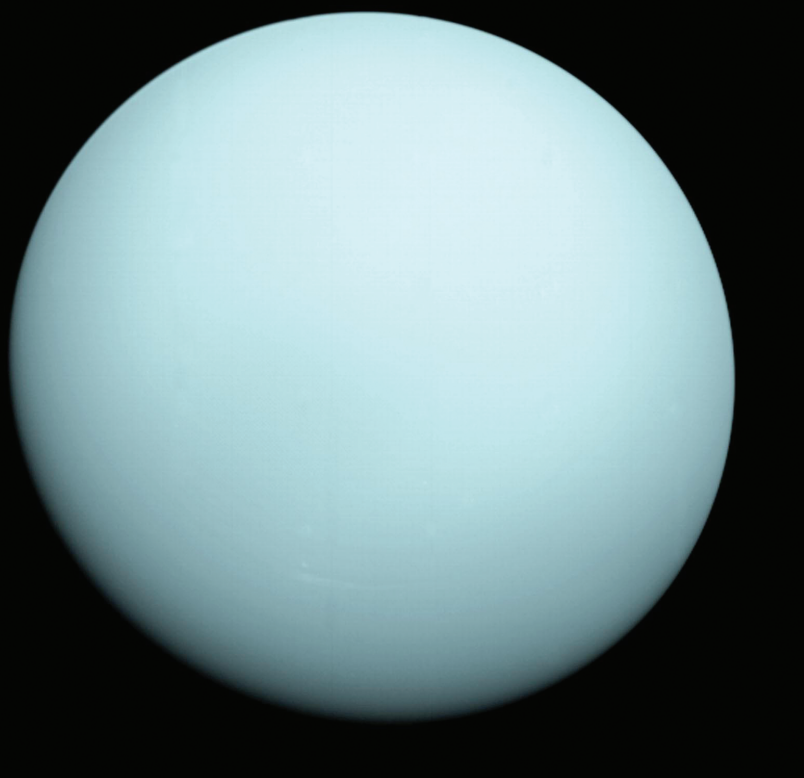




Uranus (pictured) and Neptune may be full of molten, rocky magma, not water ice.

PLANETARY SCIENCE

Uranus and Neptune may not be 'ice giants' after all

A growing number of theories propose Uranus and Neptune are rocky worlds **HANNAH RICHTER**

For decades, elementary students learned the same tale of the Solar System: first come rocky terrestrial planets such as Earth, followed by gas giants such as Jupiter and ice giants such as Neptune, with lovable Pluto bringing up the rear. Then 20 years ago, planetary scientists downgraded Pluto to a "dwarf planet." And now, they say, it's time to revisit our idea of Neptune and Uranus, too—for the so-called ice giants likely contain very little ice.

The term is "a little bit misleading," says Ravit Helled, a planetary scientist at the University of Zürich. "We really don't know what these planets are made of." She and her colleagues do, however, have ideas, ranging from magma oceans to soups of icy methane.

Uranus and Neptune were first called ice giants because they orbit past the Solar System's so-called ice lines: the points beyond which water, ammonia, carbon monoxide, and other volatile molecules exist as

solids rather than gases. If this region abounded with frozen water during the early Solar System, then Uranus and Neptune's interiors might consist mostly of water, squeezed by the pressure of the planets' gravity into a hot "supercritical" soup.

But the only measurements of Uranus and Neptune from up close happened 40 years ago during NASA's Voyager 2 mission, and those data are too sparse to confirm the picture. More recently, studies of Pluto and other small bodies beyond Neptune's orbit showed their interiors hold far less "ice"—supercritical mixes of compounds such as water and ammonia—than scientists expected, at most one-half of the worlds' rocky content.

The evidence that Uranus and Neptune must be icy is "all indirect, it's all circumstantial," says Jonathan Fortney, a planetary astrophysicist at the University of California (UC), Santa Cruz. "This was always in the back of people's minds: that the planets could be more complicated."

Knowing what our outermost planets consist of could reveal which materials were present in the Solar System's earliest days and farthest reaches. And it could hold clues to worlds beyond the Solar System, because planets slightly smaller than Neptune are the most common kind in the galaxy, Helled says. "We have these representatives in our own Solar System, and we realize that we don't know what they are made of."

As a result, researchers have come up with a smorgasbord of ideas about what's inside our outermost planets. The newest, posted as a preprint last week and currently in review at *The Astrophysical Journal*, suggests that Uranus and Neptune hold oceans of molten rock.

Studies of exoplanets inspired the idea, explains Edward Young, a planetary scientist at UC Los Angeles. When he modeled so-called sub-Neptunes as having an iron core, a rocky mantle, and a gaseous hydrogen envelope, the materials began to mix, lowering the rock's melting point and forming worlds of molten magma. Even though sub-Neptunes orbit their host stars more closely than Uranus and Neptune, "we thought, well, why should the formation of the ice giants and the sub-Neptunes be fundamentally different?" Young says.

So he and his colleagues tweaked their models to match Uranus's and Neptune's observed gravities and densities. Indeed, worlds with soupy magma oceans resulted—no ice required. This kind of magma would be nothing like what oozes from Earth's volcanoes: Instead, it would be a fluid pent up under extreme pressure, with huge amounts of hydrogen and some helium dissolved within it. This mélange could stay hot for billions of years, insulated by the planets' thick, hydrogen-rich atmospheres.

This conception of Uranus and Neptune, Young says, amounts to "a rethinking of the astrophysics and the settings in which they were formed," wherein the outer planetary disk might have had much less ice than once thought.

Young's theory isn't an outlier. Roberto Tejada Arevalo, a recent astrophysics Ph.D. at Princeton University, modeled the interiors of Neptune and Uranus to explain why Neptune emits more internal heat than Uranus does. He found that a supercritical magma interior with water, ammonia, methane, and helium mixed in could

match the outer planets' heat measurements and other observed properties. Both his scenario and Young's require rock, ice, and gases to blend well, like vinegar and oil shaken into salad dressing, at the extreme pressures and temperatures inside Uranus and Neptune. That's far from certain, he says. "There are so many mysteries with these planets."

Uri Malamud, a planetary scientist at the Technion-Israel Institute of Technology, thinks the planets' interiors may still be rich in ice—but ice mainly of methane, not water. When he and colleagues simulated the formation of hundreds of thousands of Neptune-like worlds while varying the amounts of the chemical building blocks present in the early Solar System, the best matches to Uranus and Neptune, in radius and mass, emerged when large amounts of soot mixed with hydrogen-based atmospheres. The carbon and hydrogen reacted to form methane that ended up in the planets' innards in a liquid state. Magma oceans didn't form because the planets' materials weren't set up to mix well, leaving any rock in a more stratified layer. "They're just different ideas about what might be possible," Malamud says.

In her own modeling, Leiden University astronomy Ph.D. candidate Vanesa Ramírez found that Uranus and Neptune should be more than 60% rock, which she also envisions as a more stratified outer layer. But recent measurements of Uranus with the Atacama Large Millimeter/submillimeter Array telescope show high carbon monoxide levels indicative of an interior chock-full of the gas. Many internal makeups, Ramírez says, could explain the observation. "We are still discovering these planets," she says.

The only way to solve the mystery is to visit them, researchers say, and measure their gravity and magnetic fields and atmospheres up close. Indeed, in a priority-setting decadal survey published by the National Academies in 2023, planetary scientists put an orbiter and probe mission to Uranus at the top of their wish list. "We really need a flagship mission," Helled says, "to put all these pieces of the puzzle together."

In the meantime, researchers can tinker with these planets' misnomer. Young prefers "miscible giants," after the way he thinks the planets' materials mix. Malamud, Ramirez, and Helled offer "subgiants," "minor giants," and "outer giants," respectively, after the planets' sizes and distances. And Arevalo proposes "metal giants" because the planets abound with "metals"—astronomy-speak for all elements heavier than hydrogen and helium.

Yet agreeing on a new term for the planets may prove as hard as sending spacecraft there. A few years back, Fortney served on a group brainstorming future ice giant missions. "There were 10 of us in a room for a week," he says. "We didn't agree on any better names." □

Hannah Richter is a freelance science journalist based in Washington, D.C., covering Earth and space.

The Beltsville Agricultural Research Center is one of the U.S. Department of Agriculture's largest scientific campuses.



U.S. SCIENCE

USDA accelerates plan to close its flagship scientific campus

Agency says closing the research center will improve efficiency, but skeptics argue it will undercut research critical to farmers

JOANNA THOMPSON

When honey bee researcher Zachary Lamas learned in early 2025 that bee-

keepers across the country had just lost upward of 60% of their colonies, he sprang into action. Within 2 days, Lamas was on a plane from Maryland, where he worked at the U.S. Department of Agriculture's (USDA's) Beltsville Agricultural Research Center (BARC), to California to sample bees and identify what was ailing them. After weeks of work, he and his team determined the main culprit was viruses spread by pesticide-resistant varroa mites, a growing threat to bee health.

"If you know anything about the government, that is amazing," says John Turpin, director of pollinator health at agricultural company Strong Microbials. He and others worry farmers will no longer be able to count on that kind of response in the future. USDA has accelerated a plan to dismantle BARC, and on 29 June its bee researchers were told their lab will relocate to Fargo, North Dakota. They were given 30 days to decide whether to accept the new posting.

USDA announced plans 1 year ago to close BARC—a sprawling, 2600-hectare campus home to experimental agricultural facilities and labs where hundreds of researchers study invasive pests, cow genetics, bee biology, water conservation, and



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