Jupiter and Saturn full of liquid metal helium

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Saturn. Photo by: NASA

(PhysOrg.com) -- A strange, metal brew lies buried deep within Jupiter and Saturn, according to a new study by researchers at the University of California, Berkeley, and in London.

The study, published in this week's online edition of the journal *Proceedings of the National Academy of Sciences*, demonstrates that metallic helium is less rare than was previously thought and is produced under the kinds of conditions present at the centers of giant, gaseous planets, mixing with metal hydrogen and forming a liquid metal alloy.

"This is a breakthrough in terms of our understanding of materials, and

that's important because in order to understand the long-term evolution of planets, we need to know more about their properties deep down," said Raymond Jeanloz, professor of astronomy and of earth and planetary science at UC Berkeley and one of the authors of the study. "The finding is also interesting from the point of view of understanding why materials are the way they are, and what determines their stability and their physical and chemical properties."

Jeanloz studies pressures tens of millions of times greater than Earth's atmospheric pressure - the kinds of forces felt inside Jupiter and Saturn, so called "gas giants" that lack a solid surface. The core of the Earth, which is small and dense compared to the cores of these gas giants, contains pressures of about 3.5 million times atmospheric pressure. Pressures at Jupiter's core, for example, reach 70 million times Earth's atmospheric pressure, the planet's massive size more than offsetting its low density. The cores of Jupiter and Saturn are a balmy 10,000 to 20,000 degrees Celsius, two to four times hotter than the surface of the sun.

In this study, Jeanloz and Lars Stixrude, earth sciences professor at University College London, took a closer look at what happens to helium under such extreme conditions.

Most studies of materials in gaseous planets have focused on hydrogen, Jeanloz said, because it is the predominant element of both these planets and the universe. But even though hydrogen is the lightest element, its behavior is fairly complicated due to its tendency to form molecules of two bonded hydrogen atoms, Jeanloz said. Jeanloz and Stixrude wanted to study a simpler element, to more easily understand the effects of extreme temperatures and pressure.

So, they picked helium, the second most abundant element, which comprises five to 10 percent of the universe. They used theories based

on quantum mechanics to calculate the behavior of helium under different pressures and temperatures. Although these equations are only approximations, Stixrude said, the researchers' predictions closely matched experimental results for lower pressures.

Under Earthly conditions, helium is a colorless, see-through, electrically insulating gas. But under the kinds of pressure and temperature found at the centers of Jupiter and Saturn, the researchers found that helium turns into a liquid metal, like mercury.

"You can imagine this liquid looking like mercury, only less reflective," Jeanloz said.

The finding was a surprise, as scientists had assumed that high pressures and high temperatures would make metallization of elements such as helium more difficult, not easier, Jeanloz said. He and his colleagues had previously found that helium starts to have some metal-like qualities in experiments at extremely high pressure, but they have not yet been able to experiment with helium under the conditions found inside giant planets.

A metal's key characteristic is its ability to conduct electricity, meaning electrons can flow through it like water flowing unimpeded down a riverbed.

"High temperatures make the atoms jiggle around, and so people thought that raising the heat would deflect the electrons, like putting enough rocks in a stream to block the flow of water," Jeanloz said. "The scattering caused by atoms was thought to make it harder for the electrons to flow down the stream."

But it turns out that the atoms' jostling also creates new ways for the electrons to move, almost as if new crevices had opened in the ground

for the river's flow, Jeanloz said.

Scientists recently discovered that hydrogen metalizes under lower temperatures and pressures than was previously appreciated. The dogma in the field was that the characteristics of hydrogen and helium were different enough that the two wouldn't mix inside giant gaseous planets, Jeanloz said. The researchers' findings, however, indicate that the two elements probably do mix, forming a metal alloy like brass, but liquid.

This finding also speaks to one of the many mysteries of these large planets, Stixrude said. More energy is emitted from Jupiter and Saturn than they absorb from the sun, and scientists don't understand where it comes from. One of the prevailing theories is that droplets of helium condense out of the planets' outer atmospheres and fall to their centers as "helium rain," releasing gravitational energy. But Jeanloz and Stixrude's findings show that helium and hydrogen are probably a more homogenous mix than was previously suspected, meaning that helium rain is unlikely.

"Now, we have to look elsewhere for this energy source," Stixrude said.

Provided by UC Berkeley

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