Material May Demonstrate Long-Sought 'Liquid' Magnetic State

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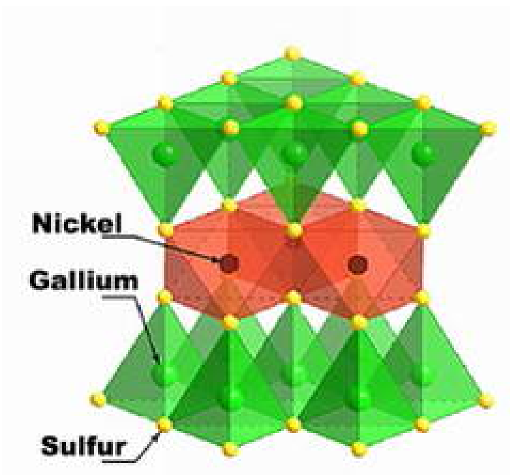

A novel material that may demonstrate a highly unusual "liquid" magnetic state at extremely low temperatures has been discovered by a team of Japanese and U.S. researchers, according to research published in the Sept. 9 issue of *Science*.

Image: A crystal diagram shows the triangle-shaped atomic structure of nickel gallium sulfide, which may have an unusual magnetic "liquid" state at low temperatures. Red spheres represent nickel, green spheres are gallium, and yellow are sulfur. Credit: S. Nakatsuji et al., Science, 9/9/2005

The material, nickel gallium sulfide ($NiGa_2S_4$), was synthesized by scientists at Kyoto University. Its properties were studied by both the Japanese team and by researchers from The Johns Hopkins University and the University of Maryland at the Commerce Department's National Institute of Standards and Technology.

The scientists studied the polycrystalline sample using both X-rays and neutrons as probes to understand its structure and properties. The neutron experiments were conducted at the NIST Center for Neutron Research in Gaithersburg, Md.

The team found that the triangular arrangement of the material's atoms appears to prevent alignment of magnetic "spins," the characteristic of electrons that produces magnetism. A "liquid" magnetic state occurs when magnetic spins fluctuate in a disorderedly, fluid-like arrangement that does not produce an overall magnetic force. The state was first proposed as theoretically possible about 30 years ago. A liquid magnetic state may be related to the similarly fluid way that electrons flow without resistance in superconducting materials.

According to Collin Broholm, a professor in the Department of Physics and Astronomy in Johns Hopkins' Krieger School of Arts and Sciences, "The current work shows that at an instant in time the material looks like a magnetic liquid, but whether there are fluctuations in time, as in a liquid, remains to be seen."

Each electron can be thought of as a tiny bar magnet. The direction of its "north" pole is its spin. "An ordered pattern of spins generally uses less energy," says Broholm, "but the triangular crystal structure prevents this from happening in this material."

The team conducted its neutron experiments with an instrument called a "disk chopper spectrometer." The only one of its kind in North America, the instrument sends bursts of neutrons of the same wavelength through a sample. More than 900 detectors arranged in a large semicircle then determine exactly where and when the neutrons emerge, providing information key to mapping electron spins.

"The energy range and resolution we can achieve with this instrument is ideal for studying magnetic systems," said Yiming Qiu, a NIST guest researcher from the University of Maryland.

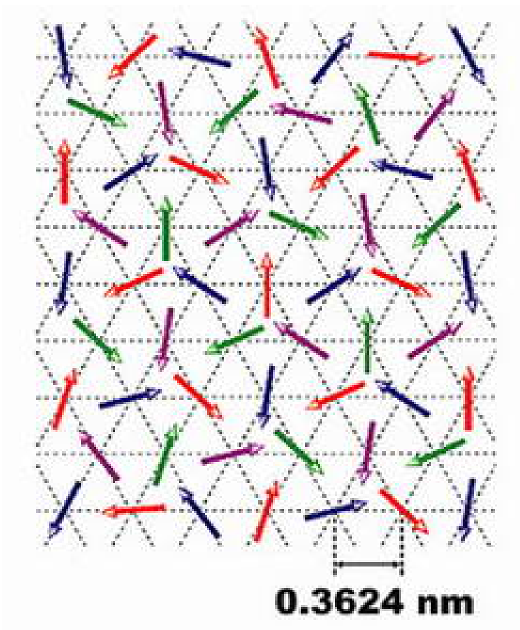

Image: Multi-colored arrows show the disordered array of magnetic spins of electrons within nickel gallium sulfide. The data were collected by precisely measuring the timing and change in direction of neutrons as they were passed through the material. Credit: S. Nakatsuji et al., Science, 9/9/2005

The wavelength of the slowed-down (cold) neutrons available at the NIST facility — less than 1 nanometer (billionth of a meter) — also allows the researchers to study nanoscale magnetic properties too small to be measured with other methods.

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S. Nakatsuji, Y. Nambu, H. Tonomura, O. Sakai, S. Jonas, C. Broholm, H. Tsunetsugu, Y. Qiu, Y. Maeno. "Spin Disorder on a triangular lattice." *Science*, Sept. 9, 2005.

Source: Johns Hopkins University