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Through simple system studies, researchers are unearthing a new quantum state of matter

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Researchers at the University of Pittsburgh have made advances in better understanding correlated quantum matter that could change technology as we know it, according to a study published in the Nov. 20 edition of *Nature*.

W. Vincent Liu, associate professor of physics in Pitt's Department of Physics and Astronomy, in collaboration with researchers from the University of Maryland and the University of Hamburg in England, has been studying topological states in order to advance quantum computing, a method that harnesses the power of atoms and molecules for computational tasks. Through his research, Liu and his team have been studying orbital degrees of freedom and nano-Kelvin cold atoms in optical lattices (a set of standing wave lasers) to better understand new quantum states of matter.

From that research, a surprising topological semimetal has emerged.

"We never expected a result like this based on previous studies," said Liu. "We were surprised to find that such a simple system could reveal itself as a new type of topological state—an insulator that shares the same properties as a quantum Hall state in solid materials."

Since the discovery of the quantum Hall effect by Klaus Van Klitzing in 1985, researchers like Liu have been particularly interested in studying topological states of matter, that is, properties of space unchanged under continuous deformations or distortions such as bending and stretching. The quantum Hall effect proved that when a magnetic field is applied perpendicular to the direction a current is flowing through a metal, a voltage is developed in the third perpendicular direction. Liu's work has yielded similar yet remarkably different results.

"This new quantum state is very reminiscent of quantum Hall edge states," said Liu. "It shares the same surface appearance, but the mechanism is entirely different: This Hall-like state is driven by interaction, not by an applied magnetic field."

Liu and his collaborators have come up with a specific experimental design of optical lattices and tested the topological semimetal state by loading very cold atoms onto this "checkerboard" lattice. Generally, these tests result in two or more domains with opposite orbital currents; therefore the angular momentum remains at zero. However, in Liu's study, the atoms formed global rotations, which broke time-reversal symmetry: The momentum was higher, and the currents were not opposite.

"By studying these orbital degrees of freedom, we were able to discover liquid matter that had no origins within solid-state electronic materials," said Liu.

Liu says this liquid matter could potentially lead toward topological quantum computers and new quantum devices for topological quantum telecommunication. Next, he and his team plan to measure quantities for a cold-atom system to check these predicted quantum-like properties.

Provided by University of Pittsburgh

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