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Physicists make strides in understanding quantum entanglement

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This is a kagome lattice. Credit: N. Mori

While some theoretical physicists make predictions about astrophysics and the behavior of stars and galaxies, others work in the realm of the very small, which includes quantum physics. Such is the case at UC Santa Barbara, where theoretical physicists at the Kavli Institute for Theoretical Physics (KITP) cover the range of questions in physics.

Recently, theoretical physicists at KITP have made important strides in studying a concept in quantum physics called quantum entanglement, in which electron spins are entangled with each other. Using computers to calculate the extreme version of quantum entanglement — how the spin of every electron in certain electronic materials could be entangled with another electron's spin — the research team found a way to predict this characteristic. Future applications of the research are expected to benefit fields such as information technology.

"Quantum entanglement is a strange and non-intuitive aspect of the quantum theory of matter, which has puzzled and intrigued physicists since the earliest days of the quantum theory," said Leon Balents, senior author of a recent paper on this topic published in the journal Nature Physics. Balents is a professor of physics and a permanent member of KITP.

Quantum entanglement represents the extent to which measurement of one part of a system affects the state of another; for example, measurement of one electron influences the state of another that may be far away, explained Balents. In recent years, scientists have realized that entanglement of electrons is present in varying degrees in solid materials. Taking this notion to the extreme is the "quantum spin liquid," a state of matter in which every electron spin is entangled with another.

Balents said that quantum spin liquids are being sought in experiments on natural and artificial minerals. A key question posed by physicists is how to calculate theoretically which materials are quantum spin liquids. "In our paper, we provide an answer to this question, showing that a precise quantitative measure of 'long-range' entanglement can be calculated for realistic models of electronic materials," said Balents.

"Our results provide a smoking gun signature of this special type of entanglement that determines whether or not a given material is a quantum spin liquid," explained Balents. The results prove that an emblematic example of this type of problem — material with electron spins residing on the "kagome lattice" — is indeed a quantum spin liquid, according to Balents. The kagome lattice is a pattern of electron spins named after a type of Japanese fishing basket that this arrangement of spins resembles.

"We expect the technique we developed to have broad applications in the search for these unique quantum states, which in the future may have remarkable applications in information technologies," said Balents.

Provided by University of California - Santa Barbara

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