

Physicists verify quantum spookiness: variation on classic test of entanglement closes loopholes

Science News, September 19, 2015

It's official: Quantum mechanics is spooky.

A new experiment provides the best evidence yet that the commonsense concept of locality--that an event on Earth can't immediately influence what happens on Mars, for instance--doesn't apply in the quantum realm.

Researchers have long thought that quantum theory is nonlocal. But airtight experimental confirmation has been difficult to achieve. Now a new paper, posted online August 26 at arXiv.org, closes two loopholes that had cast a smidgen of doubt on previous results from a crucial test.

"Nonlocality is so fundamental and so important for our worldview of quantum mechanics that it's important to achieve such a result," says Nicolas Gisin, a quantum physicist at the University of Geneva. An apparatus similar to the one used in the new experiment could be used to build extremely secure communication networks.

The experiment performed a version of a test proposed by physicist John Bell half a century ago to demonstrate nonlocality in quantum physics. Nonlocality is the hallmark of a phenomenon called entanglement, in which particles--say, a pair of electrons--can be coordinated regardless of the distance between them. An experimenter who determines the spin of an entangled electron immediately knows what the spin of the other electron will be, even though it's essentially spinning in multiple directions simultaneously before it is measured. It's as if entangled particles are parts of one whole: "If you measure one part, the entire system shivers," Gisin says.

[ILLUSTRATION OMITTED]

Einstein famously decried this "spooky action at a distance." He and other physicists wondered whether a theory more fundamental than quantum mechanics could explain phenomena such as entanglement while preserving locality. In 1964, Bell devised a test that would resolve the dispute. Experimenters would separate entangled particles and independently make any of several measurements on them. Bell showed that there is a limit to the degree those measurement outcomes could match if the world behaves locally.

The new Bell test, by quantum physicist Bas Hensen of Delft University of Technology in the Netherlands and colleagues, required two diamond chips that were placed in labs nearly 1.3 kilometers apart. Each chip contained a tiny defect with an electron inside. The researchers zapped the diamonds with lasers, which spurred each chip to emit a photon that was entangled with the electron. Those photons were sent to a third lab (located between the other labs) and fed through a

beam splitter. Whenever detectors at the ends of the beam splitter captured two photons at the same time, there was a transfer of entanglement--now the electrons in the two chips were entangled with each other. Then the researchers randomly performed one of two measurements on the electrons' spin. The physicists confirmed that the outcomes of those measurements matched more often than Bell's limit.

While the result supports other tests of Bell's limit over the last four decades, this experiment avoids two pervasive pitfalls. Tests in the 1970s used inefficient detectors that could measure only a small percentage of the entangled particles that passed through them. More recent experiments used nearly perfect detectors, but the entangled particles were close enough together that in principle they could conspire by exchanging light-speed signals. This experiment is the first to overcome both loopholes: The detectors are good, and measurements are made before one electron would have a chance to "communicate" with the other.

Matthew Leifer, a quantum physicist at the Perimeter Institute for Theoretical Physics in Waterloo, Canada, praises the experiment. But, he notes, it took a long time to establish entanglement between electrons--the researchers needed more than nine days to collect 245 data points. He says that a more efficient version would be needed to create secret quantum keys and exchange information securely.

Caption: Ultimate Bell test A new experiment confirmed quantum spookiness by measuring the spins of entangled electrons inside diamonds. First, lasers spur each diamond to emit a photon. When detectors at a central station simultaneously detect photons, the diamonds' electrons are entangled. Physicists randomly make one of two measurements on each electron and compare the results.

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Source Citation

Grant, Andrew. "Physicists verify quantum spookiness: variation on classic test of entanglement closes loopholes." *Science News* 19 Sept. 2015: 12. *Science in Context*. Web. 9 Aug. 2016.

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Gale Document Number: GALE|A429499391