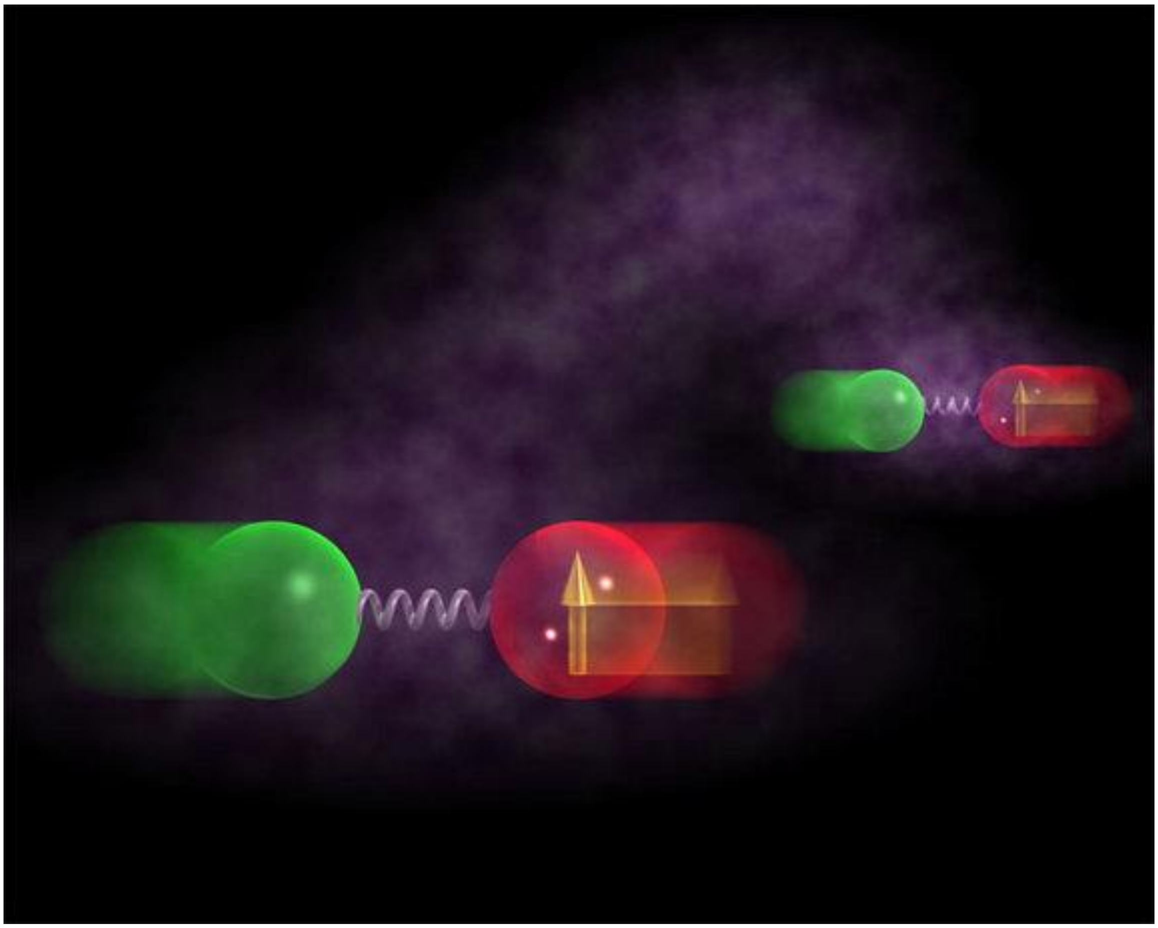
Loophole in Spooky Quantum Entanglement Theory Closed

by Tia Ghose, Senior Writer | April 17, 2013 03:44pm ET



According to quantum mechanics, two or more particles can become "entangled" so that even after they are separated in space, when an action is performed on one particle, the other particle responds immediately. (Shown here, two entangled mechanical oscillators made up of two pairs of trapped ions.)
Credit: John Jost and Jason Amini

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The weird way entangled particles stay connected even when separated by large distances — a phenomenon Albert Einstein called "spooky" — has been confirmed once again, this time with a key loophole in the experiment eliminated.

The results from the new experiment confirm one of the wildest predictions of quantum mechanics: that a pair of "entangled" particles, once measured, can somehow instantly communicate with each other so that their states always match.

"Quantum mechanics is a wonderful theory that scientists use very successfully," said study co-author Marissa Giustina, a physicist at the University of Vienna. "But it makes some strange predictions." [How Quantum Entanglement Works (Infographic)]

But the new experiment goes further than past studies by eliminating one of the major loopholes in entanglement experiments.

The findings were published April 14 in the journal Nature.

Spooky phenomenon

Since the 1930s, physicists have been troubled by some of the bizarre implications of quantum mechanics. Namely, when they measured the wave orientation of a particle, such as a photon, as horizontal, its entangled partner would have a correlated orientation— such as an opposite, vertical orientation — at the same instant.

The implications were that individual entangled particles don't exist in a particular state until they are measured, and that, once measured, the particles could somehow communicate their state to each other at a rate faster than the speed of light — which seemed to violate Einstein's theory of relativity. (Recent research suggests the entangled particles interact at a speed that's 10,000 times faster than the speed of light.)

In a 1935 paper, Einstein and his colleagues noted that one way to get around spooky action at a distance would be to assume that each particle always traveled with some hidden knowledge of the other's state before the particles were measured.

But in 1964, Irish physicist John Stewart Bell proposed a mathematical way to check whether hidden variables or weird non-locality (the idea that entangled particles can communicate faster than the speed of light) explained the behaviors. Since then, scientists have used Bell's tests to demonstrate non-locality.

But all of these tests relied on three assumptions, or loopholes: that the source of the photons and the detector weren't somehow communicating, that the photon detectors weren't communicating, and that the particles physicists measured were representative of the ones that they didn’t measure. If any of the assumptions was wrong, in theory, the hidden-variables explanation could still be right.

Better detector

For the current study, Giustina and her colleagues redid the experiment with entangled photons, or particles of light. This time, however, they didn't have to rely on the assumption that the photons they caught were representative of the ones that got away.

The physicists were able to eliminate the loophole using a different version of Bell's check so that it didn't require an assumption of fair sampling. They also eliminated the loophole by catching many more photons using ultrasensitive, superconducting photon detectors kept near absolute zero. Every time a photon hit the detector, it caused an increase in the electrical resistance to current.

And although most physicists now accept the strange laws of quantum mechanics, the new experiment makes it even harder to claim that hidden variables — those yet to be dreamed up by scientists — explain particles' strange behavior.