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Entanglement loophole closed

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Physicists have ruled out a mundane explanation for a weird effect known as entanglement, once again confirming the bizarre predictions of quantum physics.

In entanglement, two particles are inextricably linked so that measuring a property of one instantly reveals information about the other, no matter how far apart the two particles are. Many experiments have confirmed this eerie connection.

Few physicists doubt that these strange properties are real, but some skeptics still look for ways to explain the weirdness with normal, nonquantum effects. In response, experimental physicists have been working on ruling out nonquantum explanations, in other words, closing the “loopholes” in quantum theory. A recent experiment described online the week of October 25 in the Proceedings of the National Academy of Sciences is the latest in an effort to close all the proposed loopholes and definitively show that quantum mechanics can’t be brushed away with alternative explanations.

“The question is extremely deep. It’s at the bottom at how our world is built,” says study coauthor Johannes Kofler of the Austrian Academy of Sciences and the University of Vienna. “And therefore I think it’s worth the effort of getting it as loophole-free as we can.”

In the new study, Kofler and his colleagues experimented on photons that can be polarized in either a horizontal or a vertical orientation. Photons can be entangled in such a way that their polarization directions are linked, so that if one photon is vertically polarized the other is vertical too. Yet a photon’s polarization is unknown, even to itself, until an instrument checks to see if the direction is vertical or horizontal. Entanglement is so weird because it allows a pair of photons separated by a great distance to instantly “decide” on the same polarization without communicating.

The freedom-of-choice loophole argues that maybe the widely separated photons in an experiment aren’t communicating, but the machines used to generate them and measure their polarizations are. Such a conspiracy (a sensor sending a “gimme a vertical photon” message to the source or vice versa) could influence the outcome of the experiment and make it appear that there is a quantum link.

The Austrian team used laboratories on the Canary Islands, off the northwest coast of Africa. One station, on the island of La Palma, had both a source of entangled photons and, about 1 kilometer away, a photon detector hooked up to a random number generator that told the instrument what kind of polarization to look for. A second photon detector, also hooked up to a random number generator, was located on the island of Tenerife, 144 kilometers away from the source on La Palma.

This setup prevented any conspiracy between the photon emitter and either of the detectors. Even the 1-kilometer distance was far enough to guarantee that a signal traveling at light speed between the photon emitter and the detector would arrive too late to affect the experiment’s outcome.

“The bottom line is that you should choose the settings at places and times such that not even the speed of light can travel to the source, and vice versa,” Kofler says. “If the device that produces the entangled particles is telling the setting generator what to measure, then there is an easy way out.”

There was no easy way out. Pairs of entangled photons always had correlated polarizations at both detectors.

The new study is a small advance in closing loopholes in quantum experiments, says physicist Charles Bennett of IBM’s Watson Research Center in Yorktown Heights, N.Y. The likelihood that a random number generator sitting in a laboratory could signal to a photon generator to produce results that mimic entangled photons is “implausible,” he says. “Nevertheless, such a miniconspiracy could explain the entanglement results, and so is worthy of excluding by experiments of this type.”