Debunking and closing quantum entanglement 'loopholes'

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(PhysOrg.com) -- An international team of physicists, including a scientist based at The University of Queensland, has recently closed an additional 'loophole' in a test explaining one of science's strangest phenomena -- quantum entanglement.

Quantum entanglement is a phenomenon that connects two particles (for example, photons) in such a way that changes to one of the particles are reflected instantly in the other, even if they are light-years apart.

“Despite the enormous success of quantum mechanics, its completeness is experimentally still unproven after more than 75 years,” said Dr Alessandro Fedrizzi (now in UQ's School of Mathematics and Physics).

Dr Fedrizzi co-wrote the findings of the study together with a team from the Institute for Quantum Optics and Quantum Information, and the University of Vienna in Austria, led by Professor Anton Zeilinger.

In 1935, physicists Albert Einstein, Boris Podolsky and Nathan Rosen (EPR) argued in a now-famous paper that “(t)he quantum mechanical description of physical reality is incomplete”.

According to EPR, “hidden variables” must exist to explain the unintuitive results of experiments with entangled particles.

In 1964, John Bell developed his famous Bell Inequality as the basis to test for the existence of these hidden variables.

In an experiment, this inequality demonstrates that quantum correlations can be stronger than that explained by the local hidden variable theory earlier proposed by EPR.

In practice, this is achieved by performing measurements on two separated quantum particles.

Numerous Bell tests have concluded in favour of the principles of quantum mechanics, but some researchers still question the tests' validity due to perceived "loopholes", namely, the detection loophole (not all particles can be detected), the locality loophole (the outcomes or settings of one measurement could influence the outcomes of another measurement), and the freedom of choice loophole (the choice of the settings themselves could influence or be influenced by the hidden variables carried by the particle pair).

In their study, published online on November 1, 2010 in the Proceedings of the National Academy of Sciences, the team conducted a Bell test that eliminated two of these loopholes: locality, and, for the first time, freedom of choice.

The researchers distributed entangled photons between two islands in the Atlantic Ocean.

To close both loopholes, they carefully located and timed the photon emission events, setting choices (which were generated by quantum number generators), and measurements (which were implemented by fast electro-optical switches).

In four 600-second long measurements carried out over a distance of 144km, the researchers conducted measurements on 19,917 photon pairs, which significantly violated Bell's Inequality, in favour of quantum mechanics.

The authors concluded that the experiment represents the closest to a loophole-free Bell test to date.

“We are still chasing a loophole-free Bell experiment and we probably will be for a while," Dr Fedrizzi said.

"Closing the freedom of choice loophole has however, narrowed down the potential classical theories explaining quantum mechanics and is an essential step towards closing this important chapter in science.”

More information: The paper, “Violation of local realism with freedom of choice,” by Thomas Scheidl et al., can be found online at: www.pnas.org/content/early/201 … /1002780107.abstract

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