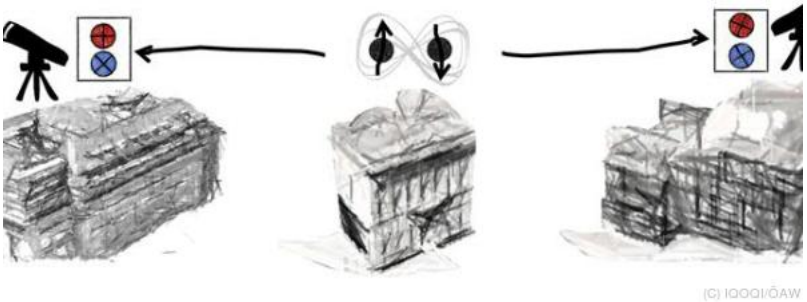


Schematic representation of the Cosmic-Bell test © IQOQI / ÖAW

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# Quantum entanglement for the first time confirmed by starlight

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Wien (ÖAW) - Quantum physicists of the Austrian Academy of Sciences around Anton Zeilinger were able to provide a decisive proof of quantum contraction with the help of 600-year-old cosmic light particles. In the journal "Physical Review Letters" the researchers are now reporting on their new experiment, which they carried out with telescopes at three locations in Vienna.

"Does the moon exist even when no one is looking?" Many assumptions of quantum mechanics fundamentally contradict the classical laws of physics, which is why Albert Einstein had put this question into the room in response. For, in fact, particles that accept their properties only when one looks, and thus a reality that does not exist independently of the observer, is difficult to reconcile with our world view.

**Starlight of the Milky Way refutes Einstein**

Einstein regarded the quantum-physical phenomenon of entanglement as particularly skeptical. It states that the measurement on one of two particles instantaneously determines the undefined state of the other particle, regardless of how far apart they are, and although no information is exchanged between the two. Einstein described this strange correlation as "spooky distance" and was looking for hitherto hidden variables, in order to explain them still with the physics of Newton.

But Einstein was mistaken, as a new experiment by scientists around Anton Zeilinger from the Institute for Quantum Optics and Quantum Information (IQOQI) of the Austrian Academy of Sciences (ÖAW) shows. In a recent publication in the journal "Physical Review Letters", the researchers report how, in a "Cosmic Bell Test", using 600-year-old light from two stars from opposite directions of the Milky Way, could conceal hidden variables as an explanation for the quantum entanglement.

**Free choice as a loophole**

As early as 1964, the Nordic physicist John Stewart Bell (1928-1990) had formulated a proposal on how the quantum-physical entanglement can be tested experimentally. Since then, many of these Bell tests have been carried out world-wide and have been able to prove the "spooky long-distance effect". However, all these experiments contained so-called "loopholes", so that skeletal skepticism could not yet be completely disproved.

"One of these loopholes is the 'loophole of free choice'", says ÖAW researcher Johannes Handsteiner, the first author of the new study. This means that the particles and the measuring device could have had a causal effect before the experiment. The measured correlation of the particles would then no longer happen by chance. "In order to exclude a prior 'agreement' between the particle and the measuring device, the precise setting of the latter must be chosen freely and independently of the particles," explains Steiner.

**600 years old photons as random generators**

While in earlier experiments the choice was made with ground-based random generators, or, as was recently the case with the so-called "Big Bell Test", by means of thousands of random human decisions, the Viennese researchers - for the first time in the history of the Bell tests - have stellar light sources To control their "Cosmic Bell Test".

In their experiments, the researchers first generated interlaced photon pairs in the IQOQI laboratory and sent them from the Hedy-Lamarr telescope on the roof of the ÖAW Institute to separate measuring stations at the Austrian National Bank and the University of Natural Resources and Applied Life Sciences, Vienna. There were astronomical telescopes to capture starlight. With this starlight, the settings for the measurement of entangled particles were then controlled.

The idea behind this, which is based on the considerations of the physicist David Kaiser and colleagues of the US Massachusetts Institute of Technology (MIT): Each individual stellar light particle determines the setting of the measurement on the star by its color, which was fixed at its star Earth. Since these photons are taken from stars that are years apart from each other as well as from the earth, the choice of the measurement setting should have taken place 600 years ago, long before the experiment was carried out in Vienna.

"With the Cosmic Bell test, we were able to close the 'loophole of free choice' by 16 orders of magnitude against previous Bell tests," says quantum physicist Anton Zeilinger. "The likelihood that there are hidden variables that could lead to the entanglement is thus even lower than before, because an influence on the measurement result would have had to take place well before Gutenberg's invention of book printing."

For future experiments, the researchers are planning to go step by step back in the past - if possible up to a time just after the Big Bang.

In addition to the ÖAW, scientists from the MIT - Massachusetts Institute of Technology, NASA, the German Max Planck Institute for Quantum Optics, Californian Harvey Mudd Colleges and the Chinese School of Computer also took part in the successful experiment.

**PUBLICATION**

"Cosmic Bell Test: Measurement Settings from Milky Way Stars". Johannes Handsteiner, Andrew S. Friedman, Dominique Rauch, Jason Gallicchio, Bo Liu, Hannes Hosp, Johannes Kofler, David Bricher, Matthias Fink, Calvin Leung, Anthony Mark, Hien T. Nguyen, Isabella Sanders, Fabian Steinlechner, Rupert Ursin, Sören Wengerowsky, Alan H. Guth, David I. Kaiser, Thomas Scheidl, Anton Zeilinger. Physical Review Letters, 2017.

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