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.: Light from Ancient Quasars Helps Confirm Quantum Mechanics of Entanglement

CAMBRIDGE, Mass., Aug. 23, 2018 — An international research team has extended the case for **quantum** entanglement, further limiting the possibility that a freedom-of-choice loophole might reveal that such correlations could have a classical explanation.

The team, comprising researchers from MIT, the Austrian Academy of Sciences, and the University of Vienna, as well as physicists from Harvey Mudd College and the University of California, San Diego, used distant quasars to determine the measurements to be made on pairs of entangled photons. One quasar emitted its light 7.8 billion years ago and the other, 12.2 billion years ago. The team found correlations among more than 30,000 pairs of photons, to a degree that far exceeded the limit that Bell originally calculated for a classically based mechanism.

The quasar dates back to less than one billion years after the Big Bang. Courtesy of NASA/ESA/G.Bacon, STScI.

“The Earth is about 4.5 billion years old, so any alternative mechanism — different from quantum mechanics — that might have produced our results by exploiting this loophole would’ve had to be in place long before even there was a planet Earth, let alone an MIT,” said MIT professor David Kaiser. "So we’ve pushed any alternative explanations back to very early in cosmic history."

In January 2018, the team began collecting data from two large, 4-meter-wide telescopes: the William Herschel Telescope and the Telescopio Nazionale Galileo, both situated on the same mountain in the Canary Islands and separated by about a kilometer.

Meanwhile, researchers at a station located between the two telescopes created pairs of entangled photons and beamed particles from each pair in opposite directions toward each telescope.

In the fraction of a second before each entangled photon reached its detector, the instrumentation determined whether a single photon arriving from the quasar was more red or blue, a measurement that then automatically adjusted the angle of a polarizer that ultimately received and detected the incoming entangled photon.

The researchers ran their experiment twice, each for around 15 minutes and with two different pairs of quasars. For each run, they measured 17,663 and 12,420 pairs of entangled photons, respectively. Within hours of closing the telescope domes and looking through preliminary data, the team could tell there were strong correlations among the photon pairs, beyond the limit that Bell calculated, indicating that the photons were correlated in a quantum-mechanical manner.

MIT professor Alan Guth led a more detailed analysis to calculate the chance, however slight, that a classical mechanism could have produced the correlations the team observed.

He calculated that, for the best of the two runs, the probability that a mechanism based on classical physics could have achieved the observed correlation was about 10 to the minus 20 — that is, about one part in one hundred billion billion.

“We certainly made it unbelievably implausible that a local realistic theory could be underlying the physics of the universe,” Guth said.

There is still a small opening for the freedom-of-choice loophole. To limit it even further, the team is entertaining ideas of looking even further back in time, using sources such as cosmic microwave background photons that were emitted as leftover radiation immediately following the Big Bang, though such experiments would present a host of new technical challenges.

“It is fun to think about new types of experiments we can design in the future, but for now, we are very pleased that we were able to address this particular loophole so dramatically,” Kaiser said. "Our experiment with quasars puts extremely tight constraints on various alternatives to quantum mechanics. As strange as quantum mechanics may seem, it continues to match every experimental test we can devise."

The research was published in Physical Review Letters (doi: 10.1103/PhysRevLett.121.080403).

GLOSSARY

astronomy

The scientific observation of celestial radiation that has reached the vicinity of Earth, and the interpretation of these observations to determine the characteristics of the extraterrestrial bodies and phenomena that have emitted the radiation.

quantum

Smallest amount into which the energy of a wave can be divided. The quantum is proportional to the frequency of the wave. See photon.