Closing 'Free Will' Loophole From Bell's Theorem

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MIT researchers writing in the journal *Physical Review Letters* are proposing an experiment that could test Bell's theorem.

According to the scientists, the experiment could test the 50-year-old theorem to determine whether our universe is based on textbook laws of classical physics or less-tangible probabilities of quantum physics.

Physicist John Bell wrote in 1964 that if the universe is based on classical physics, the measurement of one entangled particle should not affect the measurement of the other, which is a theory known as locality. The physicist created a mathematical formula for locality, and showed scenarios that violated this formula, showing predictions of quantum mechanics.

Scientists have been testing Bell's theorem by measuring the properties of entangled quantum particles in the laboratory. These experiments have shown that these particles are correlated more strongly than would be expected under the laws of classical physics.

Physicists have also identified several loopholes in Bell's theorem, suggesting that while the outcomes of these experiments support quantum mechanics, they may reflect unknown "hidden variables" that give the illusion of a quantum mechanics, but are really explained better in classical physics terms.

Two major loopholes have been closed, but a third has remained that physicists refer to as "setting independence" or "free will." This loophole proposes that a particle detector's settings may "conspire" events in shared casual past of the detectors, which implies that a physicist running the experiment does not have complete free will in choosing each detector's settings.

The MIT team is proposing an experiment to close this third loophole by determining a particle detector's settings using distant quasars that formed billions of years ago. Essentially, if two quasars on opposite sides of the sky are sufficiently distant from each other, they would have been out of causal contact since the Big Bang fourteen billion years ago.

During the experiment, a detector would measure the property of a particle, while another detector does the same for the other particle. Just after the particles are generated, scientists would use telescopic observations of distant quasars to determine which properties each detector will measure of a respective particle. The first quasar would determine the settings to detect the first particle, the second quasar would determine the same of the second particle.

"I think it's fair to say this [loophole] is the final frontier, logically speaking, that stands between this enormously impressive accumulated experimental evidence and the interpretation of that evidence saying the world is governed by quantum mechanics," MIT's David Kaiser, the Germeshausen Professor of the History of Science and senior lecturer in the Department of Physics, told MIT's Jennifer Chu.

Physicist Michael Hall, who was not a part of the study, said that the team's proposal is the first detailed analysis of how an experiment could be carried out in practice, using current technology.

"It is therefore a big step to closing the loophole once and for all," said Hall, a research fellow in the Centre for Quantum Dynamics at Griffith University in Australia. "I am sure there will be strong interest in conducting such an experiment, which combines cosmic distances with microscopic quantum effects — and most likely involving an unusual collaboration between quantum physicists and astronomers."

The MIT team hopes that since they have put forth an experimental approach, other scientists will actually perform the experiment by using observations of distant quasars.