Physicists resolve a paradox of quantum theory

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University of Toronto quantum physicists Jeff Lundeen and Aephraim Steinberg have shown that Hardy's paradox, a proposal that has confounded physicists for over a decade, can be confirmed and ultimately resolved, a task which had seemingly been impossible to perform.

"For nearly a century, the widespread interpretation of quantum mechanics suggests that everything is uncertain until it is observed, and that observation inevitably alters reality," says Professor Steinberg. "However, in the 1990s, a technique known as 'interaction-free measurement' seemed to promise the ability to 'see without looking,' as a *Scientific American* article put it at the time. But when Lucien Hardy proposed that one could never reliably make inferences about past events which hadn't been directly observed, a paradox emerged which suggested that whenever one attempted to reason about the past in this way they would be led into error."

Over the course of nearly two years of work, Steinberg and then-student Jeff Lundeen, now a research associate at the National Research Council of Canada, built a complicated quantum optical experiment and developed new theoretical tools. In essence, they combined Hardy's Paradox with a new theory known as weak measurement proposed by Tel Aviv University physicist Yakir Aharonov, showing that in one sense, one can indeed talk about the past, resolving the paradox. Weak measurement is a tool whereby the presence of a detector is less than the level of uncertainty around what is being measured, so that there is an

imperceptible impact on the experiment. "We found that all of the seemingly paradoxical conclusions in Hardy's Paradox can, in fact, be experimentally verified," says Steinberg, "but that the use of weak measurement removes the contradiction."

"Until recently, it seemed impossible to carry out Hardy's proposal in practice, let alone to confirm or resolve the paradox," he says. "We have finally been able to do so, and to apply Aharonov's methods to the problem, showing that there is a way, even in quantum mechanics, in which one can quite consistently discuss past events even after they are over and done. Weak measurement finds what is there without disturbing it."

The findings are published online today in an article titled "Experimental Joint Weak Measurement on a Photon Pair as a Probe of Hardy's Paradox" in the January 16 issue of the Physical Review of Letters at link.aps.org/abstract/PRL/v102/e020404 .

Source: University of Toronto