Kwiat's Kwest: Settling – Once and For All – Einstein's Final Frontier

fq(x) News

Paul Kwiat thinks it's time to close the loopholes and test Einstein's greatest speculation – the EPR paradox – a difficult task that has never been done successfully before.

by MIKE MARTIN

FQXi Awardee: Paul Kwiat, University of Illinois — July 27, 2007

Physicist Paul Kwiat is a daring fellow.

With a grant worth about $90.000 from The Foundational Questions Institute, he's tackling an intellectual triple whammy that – if his team can pull it off – will be a scientific feat worthy of fabled magician Harry Houdini.

Kwiat plans 1) a long-awaited experiment to test 2) a much-heralded theory about 3) one of the greatest conjectures in scientific history.

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>
> *- Paul Kwiat*

Spooooky Claims

The conjecture originated from no less an icon than Albert Einstein, and generated a derisive quip almost as legendary as the master himself.

Quantum mechanics – one of the 20th century's most successful theories – suffered from "spooky action at a distance," Einstein said. It seemed as if an unseen hand manipulated quantum phenomena, leading Einstein to label the theory as "incomplete."

Scores of detractors, including some of the greatest minds in 20th century physics, said that Einstein was wrong. But Einstein held his ground and, with coworkers Nathan Rosen and Boris Podolsky, authored the last great work of his life, on the so-called Einstein-Podolsky-Rosen paradox, or EPR for short.

Thirty years after EPR, an obscure British physicist named John Bell became a scientific superstar by showing that EPR and quantum mechanics did not always agree in their predictions.

Bell suggested an irrefutable way to test EPR, and in 1982, French experimentalist Alain Aspect showed that Bell was right about Einstein being wrong – almost. Loopholes plagued Aspect's experiments, just as they've hindered experimentalists ever since.

But as far as Paul Kwiat is concerned, it's time to close the loopholes and test Einstein's greatest speculation "loophole-free."

Einstein's Ghost

EPR has slipped through more loopholes than a good tax attorney, even 42 years after Bell's Theory.

EPR says that, like twin siblings, twin quantum particles, such as electrons, can have an uncanny and instantaneous influence on one another, even if separated by light-years of empty space. Needless to say, EPR presents a paradox: in this interpretation at least, quantum mechanics appears to allow distantly separated objects to instantly affect one another, seemingly violating special relativity's mandate that no signal or influence can travel faster than the speed of light. Since both quantum mechanics and special relativity have stood up to repeated tests, and are not understood to contradict each other, the EPR interpretation is problematic at best.

Ghosts, spooks – and, as the adage goes, extraordinary claims – require extraordinary proof. But for attempts to test EPR and its elegant twin, Bell's Theory, the only extraordinary thing has been the presence of one or more loopholes.

"Myriad experiments have been performed which support this bizarre quantum mechanical conclusion, yet in fact no experiment to date has incontrovertibly ruled out EPR's notion of reality," Kwiat says. "Every experiment thus far has possessed one or more loopholes arising from experimental assumptions." And experiments with loopholes are still compatible with EPR.

TESTING EINSTEIN'S GREATEST SPECULATION
Paul Kwiat

Enter the goal of Kwiat's quest: a "completely loophole-free" test.

Closing the Loopholes

Kwiat and his University of Illinois at Urbana-Champaign research team want to close a "detection loophole" and a "timing loophole" using specially prepared photons and super-sensitive detectors.

Former Kwiat team member Joe Altepeter describes the test as a roll of the dice.

"It's just common sense that someone on a distant planet can't influence or predict a dice roll better than someone nearby," says Altepeter, now at Northwestern University's Center for Photonic Communication and Computation. "Without any information to or from the vicinity of the dice roller, it would be impossible to influence or predict the outcome. But a loophole-free test of Bell's Theory would do just that."

John Bell himself framed a "very clear" experiment to test his theory about EPR. "But at the time," Altepeter notes, "it was totally infeasible to perform in a lab." To make the experiment possible, "some changes had to be made," he explains.

For example, Bell suggested using electrons in his experiment; Kwiat's team will use photons. They'll also "analyze the data slightly differently to reflect more sophisticated techniques which have been developed since 1965," Altepeter says. "Essentially though, it's pretty much the same experiment Bell envisioned."

"Closing the loopholes would be welcome simply to put any lingering worries to rest," says Rutgers University philosophy of physics professor Tim Maudlin, who's authored several books and papers on quantum spooks.

Reviewing Kwiat's proposal, Maudlin says he has "every reason to suppose that the experiment is feasible."

The Houdini Laboratry

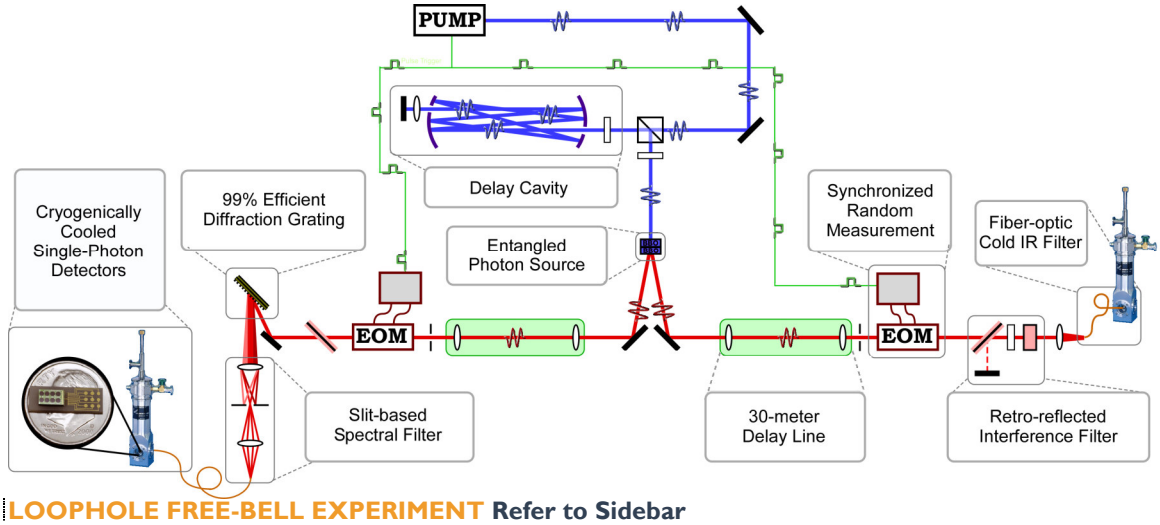
Einstein's scientific record has been nothing short of magical.

For over a hundred years, researchers have subjected his theories to many challenges.

His special theory of relativity – and history's most famous equation, E = mc2 – has survived numerous experiments with aplomb. Its equally well-regarded cousin, the General Theory of Relativity, produces confirmation after confirmation of Einstein's prescience, even in the deepest, darkest, most forbidding regions of the cosmos.

It may be apropos then to compare Paul Kwiat's quest to contradict Einstein's last great thought experiment with an acrobatic twist of Houdini's wand.

After all, Altepeter says, the specially prepared photons Kwiat wants to use are "the closest thing to real magic I've ever seen."



LOOPHOLE FREE-BELL EXPERIMENT Refer to Sidebar

Loophole Free-Bell Experiment

This figure diagrams the actual loophole-free Bell experiment being set up in Professor Kwiat's lab. To perform a loophole-free Bell test, you need two things: First, you need to create pairs of entangled particles and then separate them. Second, you need to quickly perform random and very precise measurements on those separated particles before they have a chance to "conspire" with each other via some unknown, light-speed communication method. To create entangled photons, we start with a PUMP laser, which intermittently outputs high-energy pulses of light (shown in blue). At the same time the PUMP outputs electrical pulses (shown in green) which will be used to correctly time the fast, random measurements. Because light travels faster than electrical pulses, we delay the blue pulses in a "Delay Cavity" before sending them to the "Entangled Photon Source". (This source is a pair of special crystals which split high-energy pump pulses into pairs of low-energy entangled photons, which are shown in red.) These entangled photons are sent far apart from each other using "Delay Lines" before being randomly measured. This measurement needs to be very efficient to close all loopholes. Fast electro-optic modulators ("EOM's") to provide a random measurement.

Cutting-edge technology (either diffraction gratings or interference filters) make sure that exactly the right color of light is measured.

Special devices cooled to -267 degrees C (-449 degrees F) finally detect the individual photons. When thousands of these photon detections are compared to each other and to the random measurements that were made, they can be simplified into a few numbers, numbers which will finally have a chance to violate---without any loopholes---Bell's inequality.