the 29 June observations shows that the trend remains intact. Young calculates that the current atmospheric pressure at Pluto's surface is 22 microbars (0.022 pascals), or 22-millionths the pressure at sea level on Earth.

But on 14 July, New Horizons measured Pluto's surface pressure as much lower than that — just 5 microbars. "How we link the two, we're still working on," says Cathy Olkin, a deputy project scientist for New Horizons at SwRI.

Part of the discrepancy between the spacecraft's observation and past estimates could be due to the indirect way that astronomers derive the value from Earth-based observations. These studies measure pressure some 50–75 kilometres above the dwarf planet's surface, and researchers use assumptions about the atmosphere's structure to calculate what that number translates to at the ground.

By contrast, New Horizons measured surface pressure directly by determining how strongly radio waves, beamed from antennas on Earth, bent as they passed through Pluto's atmosphere and arrived at the spacecraft on the far side of the dwarf planet.

> *"We may be looking at the first test of these models, not an atmospheric collapse."*

The next challenge is to figure out which of several competing models that describe Pluto's atmosphere can best reconcile the Earth-based measurements and what New Horizons measured at the surface.

"We may be looking at the first test of these models, not an atmospheric collapse or some spectacularly freaky physics," says Ivan Linscott, a physicist at Stanford University in California and co-leader of the New Horizons radio measurement. "The jury's still out."

Clues may yet come from New Horizons. About 95% of the data collected in its Pluto fly-by, including much of the information from the radio measurement, is still on board. Slow transmission speeds mean that the team will have to wait months for the rest of it to arrive. The transmission of images, which has been on pause since soon after the 14 July fly-by, will resume on 5 September.

And in late October, mission controllers will ignite the spacecraft's engines in a series of burns to set it on course for its next destination: an object called 2014 MU69, which is about 45 kilometres across and lies in the Kuiper belt, a collection of small bodies orbiting beyond Neptune. New Horizons is set to pass within about 12,000 kilometres of the object on New Year's Day 2019. ■

QUANTUM PHYSICS

Toughest test yet for quantum 'spookiness'

Experiment plugs loopholes in previous demonstrations of 'action at a distance' and could make data encryption safer.

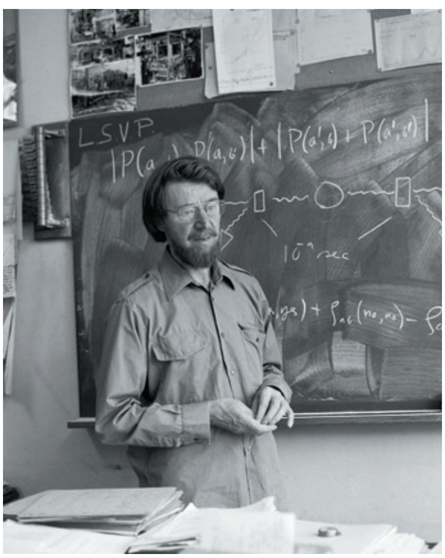
BY ZEEYA MERALI

It's a bad day both for Albert Einstein and for hackers. Physicists say that they have made the most rigorous demonstration yet of the quantum 'spooky action at a distance' effect that the German physicist famously hated — in which manipulating one object instantaneously seems to affect another one far away.

The experiment could be the final nail in the coffin for theories that are more intuitive than standard quantum mechanics. It could also enable engineers to develop a new suite of ultrasecure cryptographic devices. "From a fundamental point of view, this is truly history-making," says Nicolas Gisin, a quantum physicist at the University of Geneva in Switzerland.

In quantum mechanics, objects can be in multiple states simultaneously: an atom can be in two places at once, for example. Measuring an object forces it to snap into a well-defined state. The properties of different objects also can become 'entangled', meaning that when one such object is measured, the state of its entangled twin also becomes set.

This idea galled Einstein because it seemed that this ghostly influence would travel instantaneously — contravening the universal rule that nothing can travel faster than the speed of light. He proposed that quantum particles do have set properties, called hidden variables, before they are measured, and that even though those variables cannot be accessed they pre-program entangled particles to behave in correlated ways.



John Bell devised a test to show that nature does not 'hide variables' as Einstein had proposed.

CERN

In the 1960s, physicist John Bell proposed a test that could discriminate between Einstein's hidden variables and spooky action at a distance[1]. He calculated that hidden variables can explain correlations only up to some maximum limit. If that level is exceeded, then Einstein's model must be wrong.

The first experiment suggesting that this was the case was carried out in 1981 (ref. 2). Many more have been performed since, always coming down on the side of spookiness — but each has had loopholes that meant that physicists have never been able to fully close the door on Einstein's view. Experiments that use entangled photons are prone to the 'detection loophole': not all photons produced in the experiment are detected, and sometimes as many as 80% are lost. Experimenters therefore have to assume that the photons they capture are representative of the entire set.

To get around the detection loophole, physicists often use particles that are easier to keep track of than are photons, such as atoms. But it is tough to place atoms far apart without destroying their entanglement. This opens the 'communication loophole': if the entangled atoms are too close together, then, in principle, measurements made on one could affect the other without violating the speed-of-light limit.

ENTANGLEMENT SWAPPING

In the latest paper[3], which was submitted to the arXiv preprint repository on 24 August and has not yet been peer reviewed, Ronald Hanson of Delft University of Technology and his colleagues report the first Bell experiment that closes both the detection and the communication loopholes. The team used a cunning technique called entanglement swapping to combine the benefits of using both light and matter. The researchers started with two unentangled electrons sitting in diamond crystals in different labs on the Delft campus, 1.3 kilometres apart. Each electron was individually entangled with a photon, and both those photons were then zipped to a third location. There, the two photons were entangled with each other — and this caused both their partner electrons to become entangled, too.

This did not work every time. In total, the team managed to generate 245 entangled pairs of electrons over the course of nine days. The team's measurements exceeded Bell's bound, once again supporting the standard quantum view. Moreover, the experiment closed both loopholes at once: because the electrons were easy to monitor, the detection loophole was not an issue, and they were separated by enough distance to also close the communication loophole.

"It is a truly ingenious and beautiful experiment," says Anton Zeilinger, a physicist at the Vienna Centre for Quantum Science and Technology.

Matthew Leifer, a quantum physicist at the Perimeter Institute for Theoretical Physics in Waterloo, Canada, says that he would not be surprised to see one of the authors of the paper share a Nobel prize in the next few years. "It's that exciting."

A loophole-free Bell test also has implications for quantum cryptography, says Leifer. Companies already sell systems that use quantum mechanics to block eavesdroppers. The systems produce entangled pairs of photons, sending one photon in each pair to one user and the other photon to a second user. The two users then turn these photons into a cryptographic key that only they know.

But loopholes — and the detection loophole in particular — mean that malicious companies could sell devices that fool users into thinking that they are getting quantum-entangled particles, when they are instead being given keys that the company can use to spy on them. In 1991, quantum physicist Artur Ekert observed[4] that integrating a Bell test into the system would ensure a genuine quantum process. For this to be valid, however, the Bell test must be free of any loopholes. The Delft experiment "is the final proof that quantum cryptography can be unconditionally secure", says Zeilinger.

In practice, the technique will be hard to implement, because so far it has generated entangled electrons at a very slow pace.

Zeilinger also notes that there remains a last, somewhat philosophical, loophole, first identified by Bell himself: the possibility that hidden variables could somehow manipulate the experimenters' choices of what properties to measure, tricking them into thinking quantum theory is correct. ■

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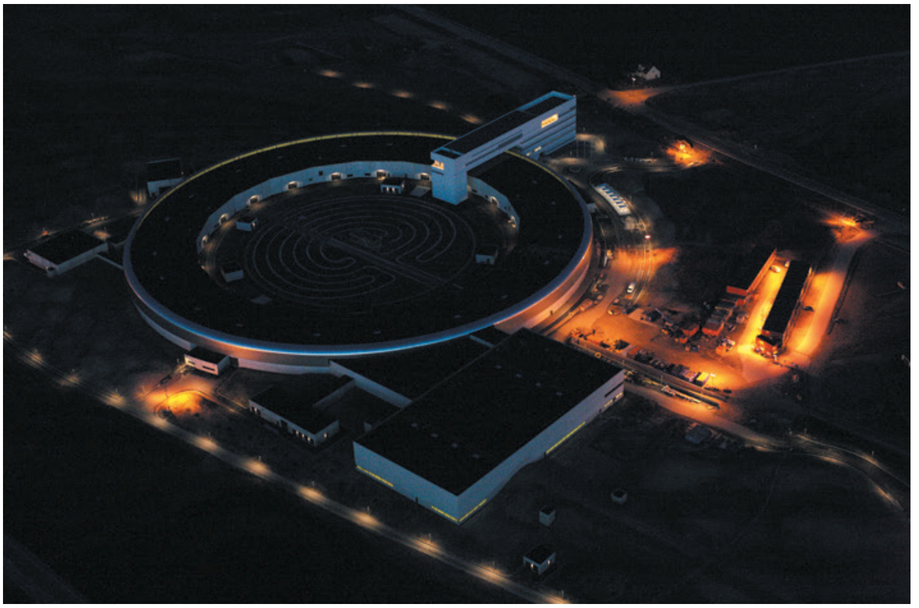

The next-generation synchrotron at Lund in Sweden has passed its first test.

TECHNOLOGY

X-ray science gets an upgrade

Swedish synchrotron promises super-bright beams and will open up new avenues for researchers.

BY DAVIDE CASTELVECCHI

In what researchers hope marks the start of a new era for X-ray science, electrons have begun circulating in a next-generation synchrotron in Lund, Sweden. This machine promises to lower the costs of X-ray-light sources around the world, while improving their performance and enabling experiments that were not possible before.

Synchrotrons are particle accelerators that produce X-rays that are used in research ranging from structural biology to materials science. At 10 p.m. local time on 25 August, the first bunches of electrons began circulating inside a new 528-metre-long, 3-gigaelectronvolt (GeV) machine at the MAX IV facility in Lund, project director Christoph Quitmann told *Nature*. MAX IV is the first 'fourth-generation' synchrotron in the world.

Getting the first beam is an absolutely crucial first step" in demonstrating fourth-generation technology, says Chris Jacobsen, an X-ray physicist at the Argonne National Laboratory in Lemont, Illinois. MAX IV, he says, is "leading the world towards a new path in synchrotron light sources".

In synchrotrons, bunches of electrons circulate at nearly the speed of light inside a ring-shaped vacuum tube. Powerful 'bending' magnets steer the electrons around the rings, and 'focusing' magnets push them together against their mutual repulsion. The electrons then pass through special magnets that shake them sideways to produce pulses of X-rays, known as synchrotron radiation.

Fourth-generation light sources promise to squeeze the electrons into tighter bunches, leading to X-ray pulses that concentrate more photons into a tighter, brighter beam. This means that it will take just minutes for researchers to do experiments that could take days on a third-generation machine, Jacobsen says.

FOURTH GENERATION

Eventually, beams from fourth-generation machines could enable materials scientists to observe chemical reactions inside a battery as they happen, or structural biologists to reveal the structure of proteins from smaller protein crystals than those needed at existing light sources.

The crucial innovation in the fourth-generation machines is to employ a narrower ▶