NATURE | NEWS

Physicists snatch a peep into quantum paradox

Measurement-induced collapse of quantum wavefunction captured in slow motion.

Eugenie Samuel Reich

09 October 2013

It is the most fundamental, and yet also the strangest postulate of the theory of quantum mechanics: the idea that a quantum system will catastrophically collapse from a blend of several possible quantum states to just one the moment it is measured by an experimentalist.

In textbooks on quantum mechanics, the collapse is depicted as sudden and irreversible. It is also extremely counterintuitive. Researchers have struggled to understand how a measurement can profoundly alter the state that an object is in, rather than just allowing us to learn about an objective reality.

A new experiment[1] sheds some light on this question through the use of weak measurements — indirect probes of quantum systems that tweak a wavefunction slightly while providing partial information about its state, avoiding a sudden collapse.

Atomic and solid-state physicist Kater Murch of the University of California, Berkeley, and his colleagues performed a series of weak measurements on a superconducting circuit that was in a superposition — a combination of two quantum states. They did this by monitoring microwaves that had passed through a box containing the circuit, based on the fact that the circuit's electrical oscillations alter the state of the microwaves as they pass through the box. Over a couple of microseconds, those weak measurements captured snapshots of the state of the circuit as it gradually changed from a superposition to just one of the states within that superposition — as if charting the collapse of a quantum wavefunction in slow motion.

Although equivalent experiments have been done on the quantum states of photons of light, this is the first time such work has been done in a typically noisier solid-state system. “It demonstrates how much progress we’ve made in the solid state in the past 10 years,” says Murch. “Finally, systems are so pure that we can rival experiments in photons.”

Slow-motion movie

The team also found that decoherence, the process by which noise in the environment causes quantum states to decay, can be minimized by repeated weak measurements. Murch says that the microwaves used to probe the superconducting circuit can be thought of as its environment because they are the predominant thing interacting with it. By monitoring the environment, the fluctuations in the microwaves become a known quantity rather than a source of unknown noise.

That enables the quantum state to remain pure, as Murch and his demonstrated — a finding that has a practical consequence. Quantum bits used for computation can be encoded in the state of a superconducting circuit, as they were in the present experiment, but they can also be made from the quantum state of a trapped ion or of an impurity in a crystal. Being able to sustain the coherence of a quantum bit in a solid-state system by making weak measurements ought to be possible in other experimental hardware too. “It’s a very general idea,” says quantum theorist Andrew Jordan at the University of Rochester, New York.

Theorist Alexander Korotkov of the University of California, Riverside, adds that the measurements can be thought of as a kind of 'quantum steering' that helps to keep the system evolving along a quantum path, casting light on the intrinsically gradual nature of any measurement process. "In real life nothing happens instantaneously,” he says.

Nature | doi:10.1038/nature.2013.13899

References

1. Murch, K. W., Weber, S. J., Macklin, C. & Siddiqi, I. *Nature* **502**, 211–214 (2013).