Quantum reality, Darwinian style

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CHARLES DARWIN would have been proud. His ideas on natural selection are being used to resolve one of the deepest questions in quantum mechanics: how does an objective reality emerge from the quantum world?

In quantum mechanics, particles exist in so-called superposition states, in which they have many mutually contradictory properties. It's only when an observer measures the properties that the particle somehow settles into one of these multiple options. "Quantum mechanics is a beautiful theory, but it's a pain in the neck when you're trying to reconcile it with what you see around you," says Robin Blume-Kohout at the Los Alamos National Laboratory in New Mexico.

At a meeting in Copenhagen in 1927, two of the founders of quantum mechanics, Niels Bohr and Werner Heisenberg, suggested that until quantum particles are observed they exist as "wave functions" that can contain a superposition of many properties. But when an observer makes a measurement, the wave function collapses – yielding a particle that behaves classically.

This view makes many uncomfortable, however, for it raises the question of whether our universe exists when nobody is looking at it (*New Scientist*, 23 June, p 30). Blume-Kohout and his colleague Woljciech Zurek think that an objective universe does exist, as long as an environment is there to act as a witness.

They and their colleagues have formulated a mechanism which takes out the role of the observer. They dub this theory "quantum Darwinism" because the environment decides which quantum properties are the fittest and will ultimately survive to be viewed by people.

We already know that the environment affects quantum particles – just ask any physicist trying to build a quantum computer, says Blume-Kohout. For instance, fragile quantum states are easily disrupted by heat from the surroundings.

"Instead of thinking of the environment as something negative that makes it hard for us to measure quantum information, we realised it is actually the thing that allows us to measure reality," says Blume-Kohout. "After all, if I want to measure the properties of an ion in the lab I don't reach out and touch it – I interact with the electromagnetic field between us, and the environment carries information to me."

According to quantum Darwinism, a given environment will make some quantum properties more stable than others. As the quantum system interacts with the environment, many copies of that stable, "fitter" state will be created throughout the environment. "You can think of the environment as an active witness: a reporter who doesn't just passively observe, but chooses what information to report," says Blume-Kohout.

When humans make measurements, it's most likely they will interact with one of these stable recorded copies, rather than directly with the actual quantum system. That explains why, when multiple observers make their measurements, they all see the same result. "That's how objective reality emerges," says Blume-Kohout.

To test the idea, Blume-Kohout and Zurek built a computer model of an oscillating quantum object interacting with its environment. "You can think of our quantum oscillator as a bowling ball on a chain, swinging back and forth like a pendulum," says Blume-Kohout.

At the start of the experiment the bowling ball simultaneously exists in every possible location through which it can move. The environment is modelled by a thousand other oscillators, like ping-pong balls suspended by strings, each controlled to swing with different frequencies (www.arxiv.org/abs/0704.3615).

Blume-Kohout and Zurek set the bowling ball swinging, as dictated by quantum mechanics. They then measured what – if any – quantum information about the bowling ball could be found by examining the ping-pong balls. What they found was that the bowling ball's wave function appeared to have collapsed, and each ping-pong ball contained the same record of the bowling ball's position. "It made no difference if we looked at five ping-pong balls or 999 – we still retrieved the same position information, suggesting that multiple redundant records had been made." The environment was indeed acting as the arbiter of reality.

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Klaas Landsman, at Radboud University in Nijmegen, the Netherlands, likes the quantum Darwinism explanation. "Most attempts at explaining wave-function collapse are philosophical, but this is a down-to-Earth answer based on the hard-boiled calculations and simulations," he says. "I think it's the most satisfying answer yet." ●