

# Physicists prove 'quantum spookiness' and start chasing Schrodinger's cat

October 26 2015, by Peter Mosley



It's proven: the universe is weird. Robert Couse-Baker/Flickr, CC BY-ND

The world of quantum mechanics is weird. Objects that are far apart can influence each other in what Albert Einstein called "spooky action at a distance", and cats can potentially [be dead and alive](#) at the same time. For decades, scientists have tried to prove that these effects are not just mathematical quirks, but real properties of the physical world.

And they are getting somewhere. Researchers have [finally proven in a](#)

[new study](#) that the link between particles at a distance reflects how the universe behaves, rather than being an experimental artefact. Meanwhile, another [team of researchers](#) have set out to show that a living creature, albeit a bacterium, can be in two different quantum states at the same time – just like the cat in Schrödinger's thought experiment.

## Bell's inequality test

But let's begin with the paper, published in *Nature*, which proves that the world is inherently spooky. All systems described by [quantum mechanics](#) can display so-called entanglement. For example an electron, like a coin, can spin in two directions (up and down). But two electrons can be entangled so that a measurement of the spin of one electron will define the spin of the other.

According to quantum mechanics, the spin of one electron cannot be known in advance of a measurement yet will be perfectly correlated with the other, even if it is in a distant location. Einstein didn't like this because it seemed to imply that the information can be sent from one electron to the other instantaneously – breaking [a rule](#) that says nothing can travel faster than the speed of light. He instead thought that there were "[hidden variables](#)" encoded in each electron that could determine the result if only we could access them.

But in the 1960s, Northern Irish scientist [John Bell](#) came up with a method to test Einstein's theory. "[Bell's inequality](#)" is satisfied only if actions in one location cannot affect another instantly and the outcomes of measurements are well-defined beforehand – something dubbed "[local realism](#)".

Bell showed, theoretically, that quantum entanglement would violate his inequality test but local realist theories containing Einstein's hidden variables would not. This is because the link between entangled particles

is stronger than Einstein wanted to believe. So if the measured correlation between pairs of particles from an experiment was above a certain threshold, it would be incompatible with hidden variables and entanglement would win the day.

The desire to test this in the lab has driven huge experimental advances in the 51 years since Bell's paper. However, all implementations of Bell tests to date have [contained loopholes](#) that have left some wiggle room for the universe to obey local realist theories.

One of these was that the efficiency of the measurements was too low (known as the detection loophole). Although the data obtained violated Bell's inequality test, it may not be a representative sample of a complete set due because some photons in the experiment couldn't be detected. Another loophole was that the measurements were too slow (the locality loophole). If the measurement devices were able to communicate via some unknown, slower-than-light channel they could share information and influence the outcome of the impending measurement.

The new study is the first experiment to simultaneously close both of these loopholes in a test of Bell's inequality. The scientists used a laser to make two specific electrons, each within a diamond located over 1km apart, to increase their energy and emit a particle of light (a photon), which was entangled with the state of the electron. The photons were then sent through an optical fibre to be united at a third location. If they arrived at just the same time, the photons would interact with each other and become entangled – meaning their remote electron buddies would become entangled too.

The electrons' spins were then measured to test Bell's inequality. The two loopholes were closed by ensuring that the efficiency and speed of the read-out were sufficiently high. As a result, the team were able to demonstrate conclusively that the universe does not obey local realism:

the outcomes of measurements cannot be known in advance, and half of an entangled state can exert [spooky action](#) on its remote partner.

## Physics' famous feline

Entanglement is not the only type of unusual quantum behaviour. Another effect, known as superposition, is the ability of a particle to exist in two states (for example spin or even location) simultaneously, and is now regularly observed in laboratories around the world. For example, electrons have been known to travel through two slits at the same time – when we are not watching. The minute we observe each slit to catch this behaviour in action, the particle chooses just one.

However, we do not directly observe these effects in daily life. For example, my glass cannot be in two places at once or I would struggle to drink. But because we don't encounter such bizarre things, it would seem logical that at some scale things "switch over" from the weird world of the quantum to our familiar everyday.

But what is the scale at which this switch happens? If we had a technically perfect experiment, would we be able to observe large objects in these superposition states? This is the question posed by Schrödinger's thought experiment in which a cat is placed in a sealed box with a flask of poison and a single radioactive atom, which will undergo decay at a random time. If the atom decays, the flask is broken and the cat is poisoned; if it does not, the cat lives on. By waiting for the atom to decay, does the cat exist in both states at once as the atom does? We know that when we open the box, we must find the cat alive or dead, but is it a property of the universe or the observer that makes the cat "choose" its state?

Back to the team preparing to address this very question. [Their proposal](#) involves putting a bacterium rather than a cat in a state of superposition.

Recent technical advances based on [superconducting microwave resonators](#) – devices used to detect radiation and for quantum computation – have enabled physicists to observe quantum effects in tiny flexible aluminium membranes (known as micromechanical oscillators) coupled to the circuits.

Tiny membranes count as large objects in the world of quantum physics because, even with a mass of only 50 picograms (50 trillionth of a gram), they contain hundreds of billions of atoms. However, these resonators have to be cooled to within a fraction of absolute zero ( $-273^{\circ}\text{C}$ ) before any quantum behaviour emerges. Otherwise thermal vibrations mask the effects.

The team plans to put a bacterium on top of such a membrane, which would then be cooled to its lowest state of energy. The membrane would then be placed into a superposition of two different states of motion: two different types of oscillations. They aim to show that the effect of the bacterium on the properties of the oscillator would be minimal, with the oscillator effectively behaving as if the bacterium were not there. In this way, the bacterium would effectively be in two states of motion at once. The researchers also plan to entangle the position of the bacterium with the spin of an electron inside it.

The proposed experiment would be impressive – but mainly for showing that quantum mechanics holds true for objects bigger than subatomic particles. But it seems unlikely to answer whether Schrödinger's cat can be alive and dead at the same time because the [bacterium](#) would remain in a constant glass-like state of cryopreservation. If this were the cat, it would exist in suspended animation rather than in a superposition of simultaneous life and death.

*This story is published courtesy of [The Conversation](#) (under Creative Commons-Attribution/No derivatives).*

## Source: The Conversation

Citation: Physicists prove 'quantum spookiness' and start chasing Schrodinger's cat (2015, October 26) retrieved 9 April 2024 from <https://phys.org/news/2015-10-physicists-quantum-spookiness-schrodinger-cat.html>

<p>This document is subject to copyright. Apart from any fair dealing for the purpose of private study or research, no part may be reproduced without the written permission. The content is provided for information purposes only.</p>
--