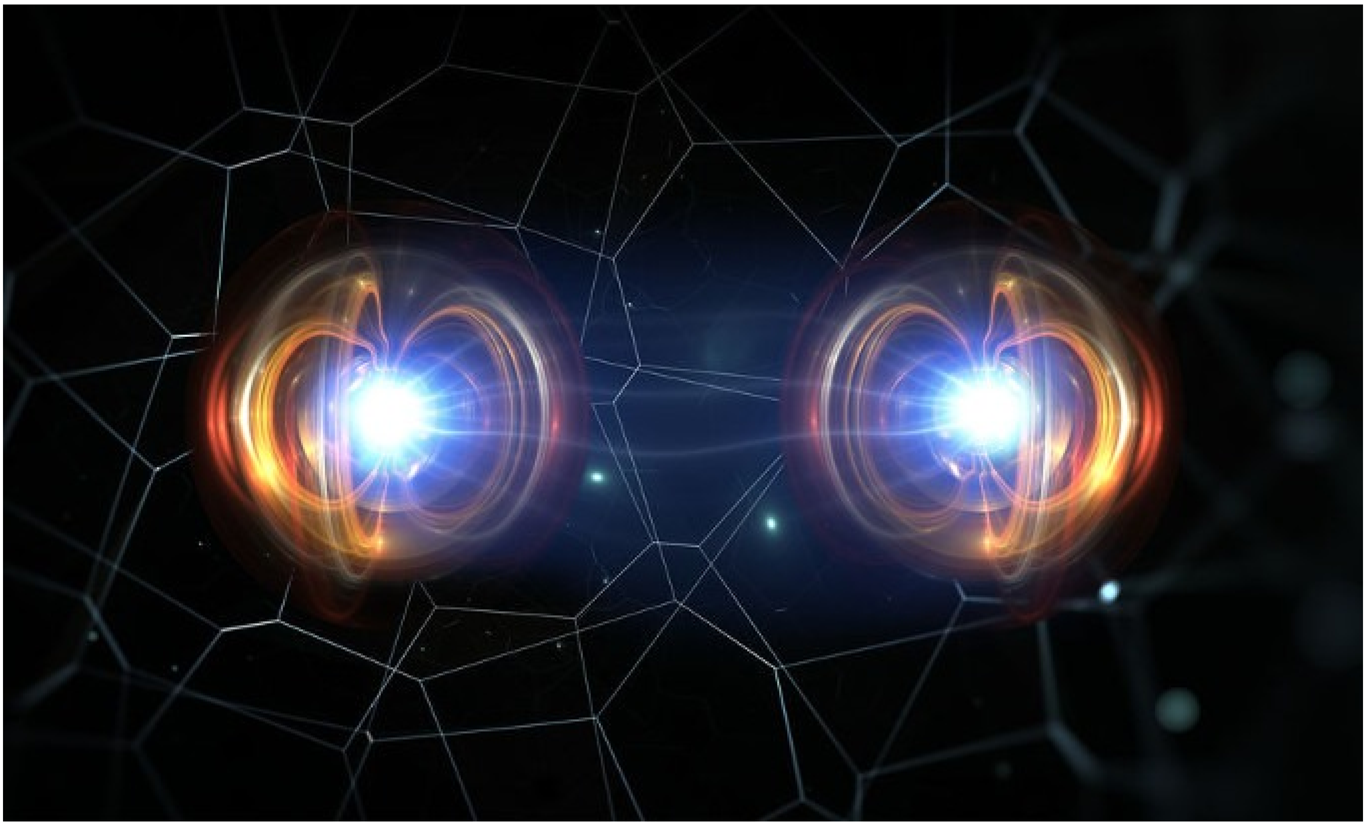
New Quantum Paradox Throws The Foundations of Observed Reality Into Question



By Eric Cavalcanti | Live Science

If a tree falls in a forest and no one is there to hear it, does it make a sound? Perhaps not, some say.

And if someone *is* there to hear it? If you think that means it obviously *did* make a sound, you might need to revise that opinion.

We have found a new paradox in quantum mechanics – one of our two most fundamental scientific theories, together with Einstein's theory of relativity – that throws doubt on some common-sense ideas about physical reality.

Quantum mechanics vs. common sense

Take a look at these three statements:

- When someone observes an event happening, it *really* happened.
- It is possible to make free choices, or at least, statistically random choices.
- A choice made in one place can't instantly affect a distant event. (Physicists call this "locality".)

These are all intuitive ideas and widely believed even by physicists. But our research, published in Nature Physics, shows they cannot all be true – or quantum mechanics itself must break down at some level.

This is the strongest result yet in a long series of discoveries in quantum mechanics that have upended our ideas about reality. To understand why it's so important, let's look at this history.

The battle for reality

Quantum mechanics works extremely well to describe the behavior of tiny objects, such as atoms or particles of light (photons). But that behavior is … very odd.

In many cases, quantum theory doesn't give definite answers to questions such as "where is this particle right now?" Instead, it only provides probabilities for where the particle might be found when it is observed.

For Niels Bohr, one of the founders of the theory a century ago, that's not because we lack information, but because physical properties like "position" don't actually exist until they are measured.

And what's more, because some properties of a particle can't be perfectly observed simultaneously – such as position and velocity – they can’t be *real* simultaneously.

No less a figure than Albert Einstein found this idea untenable. In a 1935 article with fellow theorists Boris Podolsky and Nathan Rosen, he argued there must be more to reality than what quantum mechanics could describe.

The article considered a pair of distant particles in a special state now known as an “entangled” state. When the same property (say, position or velocity) is measured on both entangled particles, the result will be random – but there will be a correlation between the results from each particle.

For example, an observer measuring the position of the first particle could perfectly predict the result of measuring the position of the distant one, without even touching it. Or the observer could choose to predict the velocity instead. This had a natural explanation, they argued, if both properties existed before being measured, contrary to Bohr’s interpretation.

However, in 1964 Northern Irish physicist John Bell found Einstein’s argument broke down if you carried out a more complicated combination of *different* measurements on the two particles.

Bell showed that if the two observers randomly and independently choose between measuring one or another property of their particles, like position or velocity, the average results cannot be explained in any theory where both position and velocity were pre-existing local properties.

That sounds incredible, but experiments have now conclusively demonstrated Bell’s correlations do occur. For many physicists, this is evidence that Bohr was right: physical properties don’t exist until they are measured.

But that raises the crucial question: what is so special about a “measurement”?

The observer observed

In 1961, the Hungarian-American theoretical physicist Eugene Wigner devised a thought experiment to show what’s so tricky about the idea of measurement.

He considered a situation in which his friend goes into a tightly sealed lab and performs a measurement on a quantum particle – its position, say.

However, Wigner noticed that if he applied the equations of quantum mechanics to describe this situation from the outside, the result was quite different. Instead of the friend’s measurement making the particle’s position real, from Wigner’s perspective the friend becomes entangled with the particle and infected with the uncertainty that surrounds it.

This is similar to Schrödinger’s famous cat, a thought experiment in which the fate of a cat in a box becomes entangled with a random quantum event.

For Wigner, this was an absurd conclusion. Instead, he believed that once the consciousness of an observer becomes involved, the entanglement would “collapse” to make the friend’s observation definite.

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