Squishy Bedrock

Can we apply quantum mechanics to the whole universe?

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Conference Idea: Can we apply quantum mechanics to the whole universe? March 21, 2008

Quantum mechanics stuck physicists with the uncomfortable notion of "observers" – and scientists have been forced to reckon with these indispensable interlopers in ever wider interpretations of quantum mechanics ever since.

It hasn't been easy. Not only does the act of observation change the very thing being observed, but in the classical interpretation of quantum mechanics, observation is necessary to make the world assume a positive form at all:

CHRISTOPHER ISHAM
Imperial College

Without observers, the world would exist in a bizarre state of "quantum uncertainty," like Schrödinger's famous half-alive, half-dead cat. But so far, physicists have mostly succeeded, deepening their understanding of quantum mechanics as they went.

Until, that is, scientists tried to apply quantum mechanics to the biggest system of all. As Christopher Isham of Imperial College in London points out, "If you want to apply it to the whole universe, then where's the observer?"

No one could have been around to observe, for example, the Big Bang. So, today, theorists are struggling to interpret quantum mechanics in a way to avoid the paradox of a seemingly necessary – but impossible – "universe observer."

For some, the puzzle leads to a fantastic vision of new universes splitting off with every quantum interaction. But others are not persuaded. The conundrum, they say, spells the death of quantum mechanics.

The Probability of One

Until the development of quantum mechanics, determinism was generally considered the bedrock of science: If you do the same experiment twice, the same thing will happen. Science was the business of predicting what that something would be.

> We're in a strange situation: Our best theory of nature is considered false by the overwhelming majority of physicists.
>
> *- David Deutsch*

But quantum mechanics turned that bedrock squishy. The theory said that the same experiment could generate different results, at least on the tiniest scales of subatomic particles. So scientists had to accept a consolation prize. While they couldn't predict the exact outcome of a quantum experiment, they could at least compute the probability of one result or another – quite accurately as it turns out.

Suppose physicists calculate that a particle has equal odds of ending up with its spin "up" or "down" in a particular experiment. Ordinarily, this means that if they repeat the experiment over and over, about half the time the particle have spin up and about half the time its spin will be down. Quantum mechanics succeeds again.

But, when applied to the whole universe, this interpretation has little meaning: the universe is not a repeatable experiment. "'Universe' implies that it's unique, there's one of them, it happened once and only once," says Leonard Susskind of Stanford University. "To apply a theory based on probability and statistics to a phenomenon that happens once and only once and that we can only see from the inside seems to some of us a very strange and operationally ill-defined idea."

LEONARD SUSSKIND
Stanford University

Susskind offered as an analogy a gambler placing odds on the winner of the presidential election. "It doesn't really mean anything," Susskind says, because the election will be run only once, with only one winner. The bet really only describes how surprised the gambler would be by any particular outcome.

The same argument holds for probabilistic statements about the nature of the universe as a whole. "It seems a little strange to some of us that the laws of nature would be talking about nothing more than whether you and I would be surprised," Susskind says. "That's all we're left with in probability theory when we can't do repeated experiments."

One of Infinitely Many?

A way out of this conundrum is to declare that the universe isn't unique after all. In this view, each time a quantum interaction happens, a new universe splits off – one for each possible outcome. In that case, when a physicist declares that odds are even that a particle will have spin up at the end of an experiment, she means that an equal number of particles will have each outcome somewhere in the multitude of universes.

DAVID DEUTSCH
Oxford University

An infinite number of continually subdividing universes, termed "parallel universes," also resolves the conundrum around observation: Objects are never in a state of quantum uncertainty, so observers aren't needed to force the probabilities into certainties. Instead, all the possibilities happen in at least one of the universes; the observer simply exists in the particular universe having the particular outcome – but not the others.

"Quantum mechanics leads you inexorably to the parallel universes interpretation," says David Deutsch of Oxford University, and he cites both theoretical and experimental evidence. Despite their name, parallel universes continue to interact, he says, as shown in the laboratory. So rejecting parallel universes, in his view, requires rejecting quantum mechanics itself, which he describes as "the most overwhelmingly corroborated theory in the history of science, both empirically and theoretically."

Nonetheless, and to Deutsch's puzzlement, most physicists don't like the parallel universe hypothesis. "So we're in a strange situation," he says, "where our best theory of nature is considered false by the overwhelming majority of physicists."

Lost Chances

Doubters say their skepticism is grounded in fundamental problems with the parallel universe hypothesis. "I think it just falls down flat on the question of probability," says Adrian Kent of the University of Cambridge. "If everything possible actually happens, it doesn't seem to make sense to say that the probability of one is 1/3 and the other is 2/3. They both happen."

Kent doesn't so much mind doing without probabilities, but he says, "We've lost the scientific content of quantum theory, which is the ability to make predictions and explain data. Now we have a story in which everything possible in the future will happen and everything possible did happen in the past. We certainly can't say that things look roughly the way they do because it has to be that way, or even because there's a high probability of it."

Still, Kent says, "It would be fascinating if [the parallel universe interpretation] did work. It would mean that the world is much, much more bizarre and weird than we thought even after we learned quantum theory," he says. "But my conclusion is that the fundamental problems of quantum mechanics just are fundamental and can't be gotten rid of, and eventually we're going to just have to change the theory itself to resolve the problems."

In other words, a solution to the missing universe observer – which may vindicate quantum mechanics or fell it – is likely to be found through, naturally, observation.