This week

NASA

Parallel universes born again

We might have to start getting used to the idea that many worlds make quantum sense

Apply quantum mechanics to the universe and this is what you get

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IF YOU think of yourself as unique, think again. The days when physicists could ignore the concept of parallel universes may have come to an end. If that doesn't send a shudder down your spine, think of it this way: our world is just one of many. You are just one version of many.

David Deutsch at the University of Oxford and colleagues have shown that key equations of quantum mechanics arise from the mathematics of parallel universes. "This work will go down as one of the most important developments in the history of science," says Andy Albrecht, a physicist at the University of California at Davis. In one parallel universe, at least, it will – whether it does in our one remains to be seen.

The "many worlds" interpretation of quantum mechanics was proposed 50 years ago by Hugh Everett, a graduate student at Princeton University. Rather than apply one set of rules to the subatomic quantum world and another to the larger-scale everyday world, as physicists tend to do, Everett wanted to apply quantum mechanical equations to everything. This had some startling consequences.

According to quantum mechanics, particles do not have set properties before they are observed. Instead, particles are described by "wave functions" representing many mutually contradictory properties. It is only when an observer measures a property that the particle somehow settles into one of these multiple options. The paradox is exemplified by Schrödinger's cat – the famous thought experiment in which a cat in a box can be said to be both alive and dead. It is traditionally thought that the act of observation, opening the box to check the cat, is what forces it to settle into a state, living or dead.

If, as Everett argued, quantum mechanics is applied to the whole universe, then it too should exist in a multitude of separate states. There would be a "multiverse" of parallel universes – one for every physical possibility. So when you open the box holding Schrödinger's cat, the universe splits, forming two new "yous" – one whose future involves viewing the live cat and the other who sees the dead cat.

Dismissed by the scientific establishment as ridiculous for decades, the many-worlds scenario may at last come in from the cold thanks to Deutsch's work.

The biggest criticism levelled at many worlds was that it seemed to make a puzzle about the outcomes of quantum

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experiments even worse. Physicists can predict the probability of getting a certain outcome from a quantum experiment from the square of its wave function, according to the Born rule. Nobody can explain why this rule works, it simply fits with experimental observations. The problem was there seemed to be no place for the Born rule in the multiverse. In fact, there didn't seem to be any space for any probabilities at all, says Deutsch.

"You toss a coin, but what does it mean to say that the probability of it coming up heads is 50 per cent?" Deutsch asks. "According to Everett, both outcomes must happen."

In the mid-1990s, Deutsch set out to put the uncertainty we see in quantum mechanical experiments back into the many-worlds scenario. Now, with additional work by Simon Saunders and David Wallace, also at Oxford, he believes they have succeeded. The trick is to examine a quantum experiment while excluding probability theory and accepting the many-worlds interpretation.

The multiverse has a branching structure, created as the universe splits into parallel versions of itself. The thickness of the branches can be calculated solely using deterministic equations, getting around the uncertainties usually associated with quantum physics. What the Oxford gang found is that the branching structure exactly reproduces the peculiar probabilities predicted by the Born rule. The branching also gives the illusion of probabilistic outcomes to measurements.

Deutsch believes this solves the problem of the origin of quantum probability once and for all. "Probabilities used to be regarded as the biggest problem for Everett, but ironically, they are now its most powerful success," he says.

"We've cleared up the obscurities and come up with a pretty clear verdict that Everett works," says Saunders, who is presenting the work with Wallace at the Many Worlds at 50 conference at the Perimeter Institute for Theoretical Physics in Waterloo, Canada, this week. "It's a dramatic turnaround and it means that people now have to discuss Everett seriously."

Albrecht agrees that the work will shake up physicists' worlds. "Many people are uncomfortable about the probabilities at the heart of quantum mechanics and attempt to get rid of quantum mechanics because of it," he says. "But this greatly amplifies the fundamental place of quantum mechanics in our understanding of the physical world."

> "This work will go down as one of the most important developments in the history of science"

David Papineau, a philosopher of physics at King's College London, says that he has been converted from scepticism about many worlds to belief, based on its potential to one day solve this puzzle of quantum probabilities. He adds, though, that the work by Deutsch, Wallace and Saunders must now be scrutinised. "It's an ambitious claim and so we have to be careful," he says. For Papineau, the problem is whether a belief in parallel universes should affect the way we live our everyday lives (see "Just another universe").

Max Tegmark at the Massachusetts Institute of Technology has long been a fan of the many-worlds scenario. But while he believes the new work on probability should help convince physicists of its reality, it will never be enough to win over die-hard sceptics. "The critique of many worlds is shifting from 'it makes no sense and I hate it' to simply 'I hate it'," he says.

David Albert, a philosopher of physics at Columbia University, New York, is sceptical. He argues there is good reason to be wary because the Oxford group may be guilty of sleight of hand. "When you first hear about this you feel euphoric," he says. "But then you think, maybe this is too good to be true." He believes that it is irrelevant that Deutsch and his colleagues can show that branching universes give the illusion of probabilistic outcomes to measurements. What we really want to know, says Albert, is why this branching happens in the first place. "They have answered a question, but I think it's the wrong question," he says.

Wojciech Zurek at the Los Alamos National Laboratory in New Mexico believes that the Born rule is exactly the right question to tackle. However, he believes that it can be answered without resorting to parallel universes. Zurek points out that Everett never used the term "many worlds" in his papers, and says that his work can be interpreted in less controversial ways.

Zurek is also inspired by Everett's ideas, particularly his insight that quantum mechanics must be applied to the entire universe rather than a limited quantum realm. He interprets this to mean that quantum entanglement – the process in which quantum particles can become inextricably linked and act in unison no matter how far apart they are – is a fundamental ingredient of quantum physics. Zurek has already used this property to explain why we see a single objective reality when we make a measurement of a quantum state (*New Scientist*, 30 June, p 18). Zurek says that entanglement can also be used to derive the Born rule (www.arxiv.org/abs/0707.2832).

"I could not have derived probability without using Everett," says Zurek, who is also presenting his work at the conference. "But at no point am I forced to assign equal reality to all other versions of the universe in the many-worlds scenario."

For Tegmark, the fact that many worlds is sparking such debate, 50 years after its conception, is a triumph in itself. He believes that physicists interested in quantum computing and cosmology are now warming to it. Will the majority be won over? "That depends on what parallel universe you live in," he says. ●

JUST ANOTHER UNIVERSE

Like Schrödinger's cat, you're locked in a box with a vial of poison gas. If a radioactive atom decays before someone opens the box to observe you, the gas will be released. According to the multiverse picture, in one future "you" will live, because the atom has not decayed, and in another "you" will die. So, should you be worried?

The issue of how we should feel and act when faced with a constantly splitting identity will be addressed by David Papineau of King's College London at a conference on the many-worlds scenario in Waterloo, Canada this week.

To start with, Papineau considers feelings of guilt and hope in the multiverse. Suppose that you are driving recklessly and narrowly avoid crashing into another car. "You might think 'lucky escape', but you should be feeling guilty about the passengers your other self has killed," says Papineau.

He also questions the use of hope. "You hope your football team will win a match, but that's meaningless – they both win and lose," he says.

Although each of our descendant selves is equally real, thankfully Papineau argues that their fates shouldn't affect our choices before we make them. We should be just as reluctant, or excited, about climbing into Schrödinger's box in the many-worlds picture, as we would be if we believed that only one outcome is actually realised.

Simon Saunders at the University of Oxford doesn't think that Papineau is wrong, but does think he is asking too much of us. "The multiverse will drive you crazy if you really think about how it affects your life, and I can't live like that," he says. His solution? "I'll just accept Everett and then think about something else, to save my sanity."