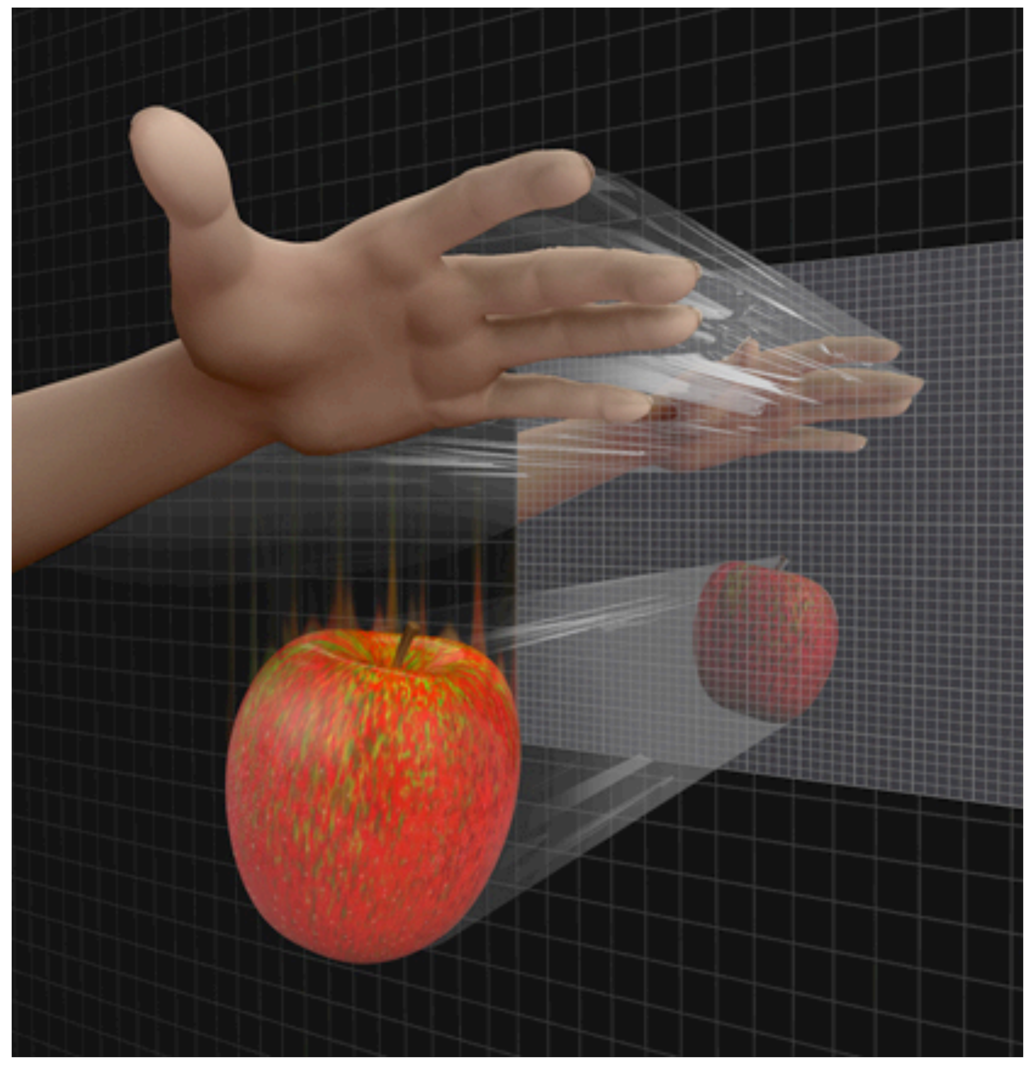
Are there parallel universes?

UNIVERSITY OF CAMBRIDGE

Quantum mechanics seems to suggest that particles can be in several places at once. What implications might such a strange prediction have?



Parallel universes or a collapsing reality?

One of the strangest predictions of quantum mechanics is that at very small scales reality is fuzzy. Little particles, for example electrons, don't need to be either here or there, they can be in several places at once. And they can also simultaneously possess other properties we would normally deem mutually exclusive. When this happens physicists say that the particles are in a *superposition* of several different *states*.

Experiments have confirmed that superposition is real. Even molecules as large as buckyballs, which consist of 60 carbon atoms, can indeed be in several places at once.

This immediately raises an obvious question. Why, when we look for a particle (when we measure its position), do we only ever find it in one place? This is the famous *measurement problem* of quantum mechanics. More dramatically, since we are all made up of particles, why are we ourselves (apparently) only ever in one place?

Quantum mechanics does not give an answer to this question and there is no consensus among physicists as to how this measurement miracle comes about. But there are several schools of thought that try and provide an answer.

Collapsing reality

One of them suggests that when we make a measurement (such as looking where a particle is) the superposition somehow collapses and only one of the superposed states remains real. Reality might be fuzzy at the tiniest scales, but as soon as something larger interferes, an experimenter or a measurement device, it is forced down one route only.

The collapse idea raises an interesting question: what is a measurement? Some physicists have toyed with the idea that a measurement requires an observer and that it is the consciousness of the observer that causes the collapse (which then begs the question of whether a snail, say, has enough consciousness to collapse reality). But this approach has largely fallen out of favour. Instead, a measurement is defined as an interaction between the system you're measuring and the measuring device.

The challenge for advocates of the collapse approach is to come up with models that describe the workings of the collapse — how exactly does it happen and what causes it? That's the subject of much ongoing research.

Parallel universes?

The other possibility is one that requires a deep breath. Perhaps all the possible outcomes of a measurement are equally real: when you make the measurement the world splits into different branches. In each branch a copy of you sees the particle in one of the possible locations.

This *many-worlds* idea was first proposed by the physicist Hugh Everett in 1957. It might seem crazy, but it is rooted in the maths that underlies quantum mechanics. The equations of quantum mechanics don't indicate that something special should happen at the point of measurement, so why not let them run their course and see what happens? The maths suggests that if a particle is in a superposition of being in two different locations A and B, the person doing a measurement then goes into a superposition of seeing it at A and seeing it at B.

Physicists making measurements are not the only things that can cause reality to split – other processes in nature can effectively act as measurements. Thus you can imagine this branching game as having gone on since the beginning of time. The Universe may have started out in a simple quantum state, but then quickly have turned into a superposition of lots of configurations of galaxies. In some of these branches the Earth would have formed and in some of them it wouldn't. And in some of them we would have evolved and in some we wouldn't. In Everett's view all the different branches of the world, and all the different copies of you, are equally real.

Why do we never see those other, shadowy versions of ourselves? It is possible to detect superposition in systems consisting of a small number of particles. But as soon as the system interacts with the outside world, with photons or cosmic rays whizzing past, any perceptible interference between the superposition states “leaks out” into the wider world and dissipates. As a result the observer sees only one definite outcome when looking at large systems. The idea is that this process, called *decoherence*, happens incredibly fast, within a fraction of a second, so that we're never aware of it. Physicists are still debating whether decoherence can really justify the many-worlds view.

Collapse models and the Everett view are among the most prominent interpretations of quantum mechanics, but there are others too. The truth is that we simply don't yet know what really goes on in the physical world and how to interpret the mathematical formalism that describes it so well. What seems certain is that we have to radically expand our view of the world, but this wouldn't be the first time: who would have believed a thousand years ago that the Earth is just a tiny spherical speck in a vast expanding Universe?

This poster content is adapted from the articles “Are there parallel universes” and “Schrödinger’s equation: what does it mean?”, based on interviews with Dr Nazim Bouatta, Postdoctoral Research Fellow at DAMTP, Dr Adrian Kent, Reader in Quantum Physics at DAMTP and Dr Jeremy Butterfield, Senior Research Fellow at Trinity College, Cambridge.The articles are published in Plus (plus.maths.org), a free online magazine exploring the fascinating world of mathematics.
Plus is part of the University of Cambridge’s Millennium Mathematics Project.