Do we distil reality from the quantum fog or does it exist without us?

Quantum objects exist as clouds of possibilities, only manifesting as something definite when we look at them. The implication is that we make reality – but objectivity may yet be rescued

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QUANTUM stuff, whether single atoms, electrons or photons of light, is notorious for seeming to be here, there and everywhere – and indeed everything – all at once. It exists as clouds of possibilities, manifested in a beast you can't get around when contemplating quantum mysteries: the wave function.

On one level, the wave function is just a mathematical expression that lets you calculate the probability a particle will manifest in a particular location, say. The mystery is the way the maths says that, once you look at it, the wave function "collapses" to leave something definite we can all agree on. This creates the picture of the world that our classically trained eyes see. But how does the mathematics relate to the reality before the measurement – and what exactly, if anything, does the act of measurement change?

Erwin Schrödinger expressed the unease we might feel about apparently "making" reality when he mused about a cat inside a box that might or might not have been killed by a random quantum process inside it. Before you look, he asked, is the cat dead and alive at the same time?

The orthodox take on quantum theory, known as the Copenhagen interpretation, says yes: the maths adds up, so just shut up and calculate. "From a practical point of view, it works perfectly," says Angelo Bassi, a theoretical physicist at the University of Trieste in Italy. "But from a fundamental point of view, why should the wave function collapse?"

Some physicists argue that it all makes complete sense if you think of the wave function as a way to predict what might happen. It changes with time, just like a weather forecast. "The universe is not made of wave functions, just as it is not made of weather forecasts," says Christopher Fuchs at the University of Massachusetts, a leading advocate for an interpretation of quantum theory known as quantum Bayesianism, or QBism.

For QBists like Fuchs, quantum theory is a tool for us to better navigate the world, not a description of the world as it exists independent of our presence. So of course the wave function collapses – and how could it be anything other than us doing the collapsing?

Or you can go to the opposite extreme and say that the wave function doesn’t collapse at all. In the many worlds interpretation, every possible outcome of a measurement encoded in the wave function happens in different universes. No one collapses anything at the point of measurement – the world just splits, carrying us with it into one particular branch.

If you prefer an answer that gives us a hope of understanding physical reality, and doesn’t invoke a multiverse that we can never hope to observe, there is yet another option: that wave functions collapse spontaneously, without the influence of observers. This “objective collapse” was first proposed in the 1970s, but has enjoyed a revival in recent years largely because it promises to submit to empirical testing. “The other interpretations simply aim at reinterpreting the wave function,” says Bassi, who is a proponent.

In this picture, the chances of an atom’s wave function collapsing on its own is so small that you might have to wait billions of years to see it. Group enough of them together, however, and it rises dramatically. The cumulative effect would be a kind of faint background “noise” of collapsing wave functions that a sensitive enough detector might pick up.

"Testing the large-scale limit of quantum mechanics", or TEQ, is a project that aims to do just that, and perhaps write the observer out of quantum theory for good. Designed specifically to look for collapse noise, the project involves levitating a bead of glass a few nanometres wide using electric fields, watching its motion closely. The latest version was delayed, but Hendrik Ulbricht at the University of Southampton, UK, who is leading the experiment, expects results within a year. "We are all very excited," he says.

Looking for noise isn't something physicists typically do. "Usually, we suppress the noise as much as possible, because the physics is in the signal," says Ulbricht. But there is an interesting precedent. When astronomers Robert Wilson and Arno Penzias first detected an all-pervasive background radio signal in 1964, they thought it might be coming from New York City, from other galaxies or even from nearby pigeons. Finally, they realised they had discovered the cosmic microwave background, relic radiation left over from the big bang. "There could be a similar story with these collapse models," says Ulbricht.