QUANTUM PHYSICS

# Two slits, one hell of a quantum conundrum

**Philip Ball** lauds a study of a famous experiment and the insights it offers into a thoroughly maddening theory.

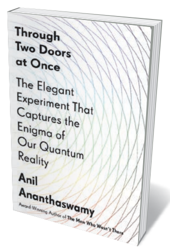
According to the eminent physicist Richard Feynman, the quantum double-slit experiment puts us "up against the paradoxes and mysteries and peculiarities of nature". By Feynman's logic, if we could understand what is going on in this deceptively simple experiment, we would penetrate to the heart of quantum theory — and perhaps all its puzzles would dissolve.

That's the premise of *Through Two Doors at Once*. Science writer Anil Ananthaswamy focuses on this single experiment, which has taken many forms since quantum mechanics debuted in the early twentieth century with the work of Max Planck, Albert Einstein, Niels Bohr and others. In some versions, nature seems magically to discern our intentions before we enact them — or perhaps retroactively to alter the past. In others, the outcome seems dependent on what we know, not what we do. In yet others, we can deduce something about a system without looking at it. All in all, the double-slit experiment seems, to borrow from Feynman again, "screwy".

The original experiment, as Ananthaswamy notes, was classical, conducted by British polymath Thomas Young in the early 1800s to show that light is a wave. He passed light through two closely spaced parallel slits in a screen, and on the far side saw several bright bands. This, he realized, was an 'interference' pattern. Caused by the interaction of waves emanating from the openings, it's not unlike the pattern that appears when two pebbles are dropped into water and the ripples they create add to or dampen each other's peaks and troughs. With ordinary particles, the slits would act more like stencils for sprayed paint, creating two defined bands.

We now know that quantum particles create such an interference pattern, too — evidence that they have a wave-like nature. Postulated in 1924 by French physicist Louis de Broglie, this idea was verified for electrons a few years later by US physicists Clinton Davisson and Lester Germer. Even large molecules such as buckminsterfullerene — made of 60 carbon atoms — will behave in this way.

You can get used to that. What's odd is that the interference pattern remains — accumulating over many particle impacts — even if particles go through the slits one at a time. The particles seem to interfere with themselves. Odder, the pattern vanishes if we use a detector to measure which slit the particle goes through: it's truly particle-like, with no more waviness. Oddest of all, that remains true if we delay the measurement until after the particle has traversed the slits (but before it hits the screen). And if we make the measurement but then delete the result without looking at it, interference returns.




**Through Two Doors at Once: The Elegant Experiment That Captures the Enigma of Our Quantum Reality**
ANIL ANANTHASWAMY
*Dutton (2018)*

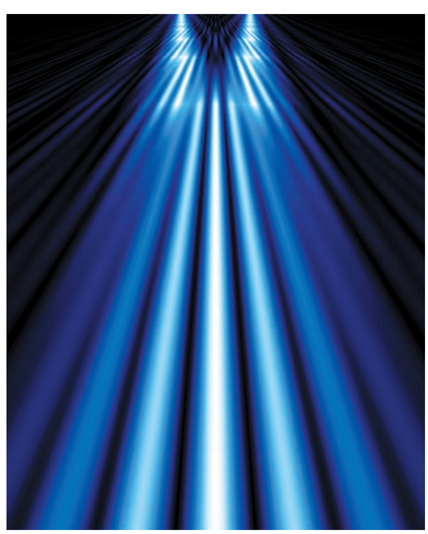
It's not the physical act of measurement that seems to make the difference, but the "act of noticing", as physicist Carl von Weizsäcker (who worked closely with quantum pioneer Werner Heisenberg) put it in 1941. Ananthaswamy explains that this is what is so strange about quantum mechanics: it can seem impossible to eliminate a decisive role for our conscious intervention in the outcome of experiments. That fact drove physicist Eugene Wigner to suppose at one point that the mind itself causes the 'collapse' that turns a wave into a particle.

Ananthaswamy offers some of the most lucid explanations I've seen of other interpretations. Bohr's answer was that quantum mechanics doesn't let us say anything about the particle's 'path' — one slit or two — before it is measured. The role of the theory, said Bohr, is to furnish predictions of measurement outcomes; in that regard, it has never been found to fail. (However, he did not, as is often implied, deny that there is any physical reality beyond measurement.) Yet this does feel rather unsatisfactory. Ananthaswamy seems tempted by the alternative idea offered by David Bohm in the 1950s. Here, quantum objects are both particle and wave, the wave somehow 'piloting' the particle through space while being sensitive to influences beyond the particle's location. But Ananthaswamy concludes that "physics has yet to complete its passage through the double-slit experiment. The case remains unsolved."

With apologies to researchers convinced that they have the answer, this is true: there is no consensus. At any rate, Bohr was right to advise caution in how we use language. There is nothing in quantum mechanics as it stands, shorn of interpretation, that lets us speak of particles becoming waves or taking two paths at once. And there is no reason to regard the wavefunction as more or less than an abstraction. This mathematical function, which embodies all we can know about a quantum object (and features in the iconic equation devised by Erwin Schrödinger to describe the object's wave-like behaviour) was characterized rather nicely by physicist Roland Omnès. He called it "the fuel of a machine that manufactures probabilities" — that is, probabilities of measurement outcomes.

Refracting all of quantum mechanics through the double slits is both a strength and a weakness of *Through Two Doors at Once*. It brings unity to a knotty subject, but downplays some important strands. Those include John Bell's 1964 thought experiment on the nature of quantum entanglement (conducted for real many times since the 1970s); the role of decoherence in the emergence of classical physics from quantum phenomena (adduced in the 1970s and 1980s); and the emphasis on information and causality in the past two decades. Still, given that popularization of quantum mechanics seems to be the flavour of the month — summoning Adam Becker's 2018 book *What is Real?*, Jean Bricmont's 2017 *Quantum Sense and Nonsense*, a forthcoming book by physicist Sean Carroll, and my own 2018 *Beyond Weird* — there's no lack of a wider perspective.

And we need that. Ananthaswamy's conclusion — that perhaps all the major interpretations are "touching the truth in their own way" — is not a shrugging capitulation. It's a well-advised commitment to pluralism, shared with Becker's book and mine. For now, uncertainty seems the wisest position in the quantum world. ■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**Bands of light in the double-slit experiment.**

**Philip Ball** *is a writer based in London.*
*e-mail: p.ball@btinternet.com*