Agreeing to disagree

A recent poll has highlighted physicists' differing views over the interpretation of fundamental aspects of quantum theory, but **Maximilian Schlosshauer** argues that it might not be so bad

"If all this damned quantum jumping were really to stay," Erwin Schrödinger complained to his colleague Niels Bohr in 1926, "I should be sorry I ever got involved with quantum theory." Schrödinger, like Bohr, was a founding father of quantum theory, which had just turned our view of the world upside down. But he was not alone in his discomfort. Albert Einstein, too, spent years arguing with Bohr over whether atomic events are fundamentally random or if quantum theory really is all we can say about physical reality. Indeed, he once wrote that the theory reminded him of "the system of delusions of an exceedingly intelligent paranoiac".

Today quantum theory underlies all modern technology: from transistors, light-emitting diodes and photovoltaics, to nuclear power, magnetic-resonance imaging, lasers and atomic clocks. It is a seemingly inexhaustible source of new ideas and applications. Quantum-information science, for example, is a fresh take on information processing, and promises computers faster than anything we could currently imagine.

No-one, of course, would dispute the immense successes of quantum theory. But looking at the heart of quantum theory itself, are we any closer to agreeing what it is trying to tell us about nature? Or has nothing really changed since the 1920s?

Multiple choices

Traunkirchen in Austria is a picture-postcard village. Sitting by a pristine lake and surrounded by the snow-capped peaks of the Alps, it was the perfect setting for a conference in July 2011 on "quantum physics and the nature of reality". Together with Johannes Kofler from the Max Planck Institute of Quantum Optics and Anton Zeilinger from the University of Vienna, I polled nearly three dozen leading physicists, philosophers and mathematicians about their views on quantum theory.

The questionnaires consisted of 16 multiple-choice questions that probed the whole spectrum of fundamental questions about quantum theory. Knowing how

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God does not play dice Einstein disagreed that at a quantum level the universe is random.

Quantum physics has moved from philosophy to concrete action

fierce debates can be regarding the foundations of quantum theory, we knew that we should expect disagreement, but some of the results, which we recently analysed, surprised even us seasoned quantum physicists (arXiv:1301.1069).

The respondents were sharply divided on questions that Bohr and Einstein quarrelled about. For example, when we asked whether the physical properties of objects are well defined before these properties are actually measured, half of the respondents said that sometimes they were, while the other half answered with a categorical "no". And when we asked how best to interpret the wave functions that physicists use to calculate the probabilities of their measurement results, a quarter of respondents said the wave functions are something akin to a physical property. A quarter said they are merely a representation of what we know about the object, while a third preferred a mixture of the two options.

But what surprised us most were not so much the disagreements as the precious patches of common ground that our poll brought to light. Quantum theory tells us with great accuracy how likely it is for an atom to decay at a certain time, but it does not tell us when it will actually decay – the individual event, when it happens, seems to come out of nowhere. Einstein could not accept the idea of a universe in which events truly randomly fall out one way or the other, famously declaring that "God doesn't play dice." But Einstein's reservations didn't seem to faze our respondents. A two-thirds majority declared Einstein's view wrong and randomness a fundamental concept in nature, and half thought that the randomness we see in quantum phenomena is indeed fundamental and irreducible: that there is no "hidden hand"– no gambling God – governing these events.

The challenge ahead

So what can we learn from our poll? One thing is clear: quantum physics has moved from philosophical debates to concrete action. Quantum-information science, hailed by an overwhelming majority as a breath of fresh air, is being put to use in looking at old problems from a new angle. It has helped us not only to get a better understanding of what we can do with quantum theory, but also to find new ways of understanding the theory itself. Various new interpretations based around quantum information have popped up in the last decade, and our poll shows them rivalling the traditional interpretations. And instead of just slapping an interpretation on a ready-made theory, people now try to actually derive quantum theory from simple, physical principles – a new take on the theory that a majority in our poll found useful.

Nearly 90 years after Schrödinger's exasperated cry about "this damned quantum jumping", the jumping goes on and it has got us to an awful lot of new places. In fact, two-thirds of our respondents see no limit for quantum theory's reach. They think it should be possible, in principle at least, to put not only single atoms into quantum superpositions, but also everyday objects such as a football, or even living organisms. Indeed, this is the kind of situation Schrödinger had ridiculed in his famous paradox, in which quantum theory forces a cat into an otherworldly state of dead and alive. What Schrödinger had intended as a *reductio ad absurdum* has today become just another challenge to experimentalists.

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