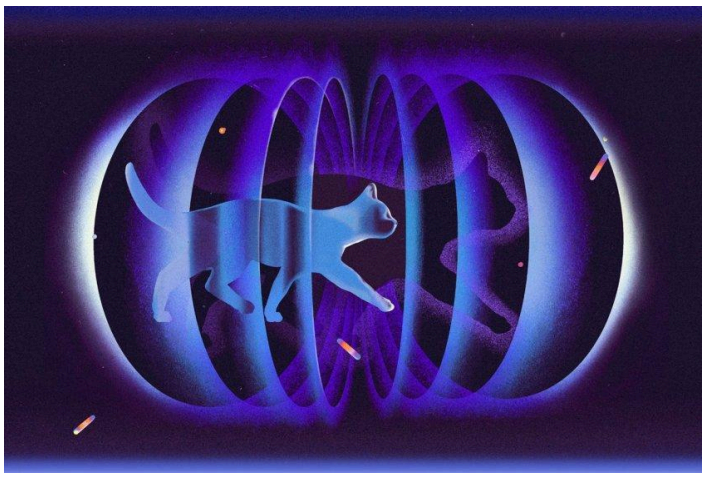
Is Schrödinger’s cat both dead and alive? No, it’s just haunted by its past

A radical new approach suggests some of quantum theory’s most bizarre and inexplicable effects might be down to physics failing to account properly for time

By Karmela Padavic-Callaghan on November 9, 2026



Ada Zielinska

Today, for breakfast, I had a smoothie. This isn’t unusual: I drink the same smoothie every weekday morning. At some point in the past, I discovered I particularly liked it and made it a habit. It is a simple example of something that makes intuitive sense – that our past experiences determine our present actions, and they, in turn, determine our future trajectories.

But what if I told you that the past never actually existed? Or, at least, that it doesn’t matter? It sounds left field, but I would only be channelling an assumption that lurks within many laws of physics largely unchallenged: that the present moment is all we need to know about to predict the future. Without making this assumption, the amount of information you need to predict the future is at risk of dramatically blowing up, rapidly making it impractical to say anything at all.

Or so we thought. Now, there’s a move afoot to reclaim the past for physics. Its proponents think that could resolve long-standing questions at the core of quantum theory, such as why it is so weird as it is, but equally not as weird as it could be – and, along the way, clarify the true nature of time itself. “I think it’s a big deal. I think it will be a big thing for the foundations of physics,” says quantum information researcher Jacob Biamonte at École de Technologie Supérieure in Montreal.

To begin to understand how physics cancelled the past, imagine a game of marbles. To predict where any marble will be in a second's time, all we need to know is its current position, speed and direction of travel, all effectively ignorant of the marble's deep past. We then roll the relevant physical laws – in this case, Isaac Newton's laws of motion – forward into the future. We don't need to know anything about the collisions that brought the marble to its present position – luckily, as calculating the myriad past possibilities might rapidly overwhelm our computational ability.

The marble's present is agnostic about its past, and its past is largely immaterial in determining its future, so long as we know about the present. It is like saying that all that matters with my smoothie choice is that memories of past mornings are stored in my present mind. Even if the past vanished entirely, I can continue my breakfast routine. In this way of thinking, there's no way of telling if the universe began just 5 minutes ago.

This principle of neglecting the past is called Markovianity, after Andrey Markov, the Russian mathematician who laid the groundwork for the idea. And it is everywhere in physics – even in quantum theory, our best stab at characterising how the weird realm of particles behaves.

Unlike objects in the classical world, quantum particles can appear to be in a mix of different states at once – in multiple positions, for example. This leads to dramas such as the infamous Schrödinger's cat thought experiment, in which a cat is kept in a box in a quantum "superposition" of being alive and dead. Each of the two states can be assigned its own probability, encoded in a mathematical object called the quantum wave function.

Just as with classical mechanics, standard quantum mechanics doesn't much care about the cat's past. As far as its future goes, there are two possibilities. You can keep the box closed, in which case, all you can say is a matter of percentages – the cat could be alive or dead and currently seems to be existentially fuzzy. Or you open the box, in which case, the cat's wave function "collapses" into a single, definitive state and the animal is definitively dead or alive, too.

Schrödinger's cat lifted the lid on a load of problems that physicists and philosophers have anguished over in the century since the inception of quantum mechanics. What physically happens when you open the box – is it you who somehow potentially kills the cat? What about the nanosecond when you have just barely moved the lid – is the cat somehow slightly less mixed at this time? What, indeed, does anything about the wave function say about the cat in the real, physical world? Is the wave function itself "real"? "It's been 100 years, and we still don't have a consensus on the right way to think about quantum theory," says philosopher David Glick at the University of California, Davis.

Jacob Barandes, a philosopher of physics at Harvard University, thinks he has identified the problem. He says that the shenanigans surrounding the wave function are merely a smokescreen, behind which the true culprit for the cat's bizarre situation is hiding: the influence of the past.



What actually happens when Schrödinger's cat is in the box? Westend61 GmbH/Alamy

In a paper published last year, he showed that something like quantum theory can be built on equations for inherently probabilistic, non-Markovian processes that are always influenced by their past. In this world, cats are never simultaneously dead and alive; rather, everything is inherently chancy, and the past indispensable.

Here, the wave function doesn't represent any physical reality, but is just a form of mathematical bookkeeping for all the ways in which the past touches the cat from across time. Let's go back to our marble and make it quantum. Barandes likens this marble's wave function to a collection of "ghost marbles". Each of these ghost marbles embodies the real quantum marble's state but, say, 1 second ago – or 2, or 3, or as far back as you like. "Each ghost marble is a little weird. It's invisible. It's unobservable," says Barandes. But if you have information about the ghost marbles, you can predict what the real marble can do next. Consequently, the world that contains real and ghost marbles seems to follow tractable, Markovian laws, because everything about the real marble's past is encoded in the ghost marbles' present. The price of pretending that the past doesn't matter is filling the universe with ghosts. The quantum wave function is just an elegant arrangement of such spectres.

Barandes thinks our mistake is to read physical reality into this spooky parlour trick. In his alternative framework, quantum peculiarities such as superposition states and wave function collapse are consequences of treating the wave function as something overly real. We can't know what state Schrödinger's cat is in, not because its state is somehow existentially fuzzy, but because quantum objects are inherently a little random. "They're always behaving probabilistically, in a chancy way that depends on the past," says Barandes. Acts of measurement, such as opening the cat's box, aren't special, but merely physical interactions that make the object "forget" some of this past, suppressing some of its chanciness and history-ladenness.

This picture provides a way to counter the objection that calculations become intractable if you must account for the whole prior history of the universe. In standard quantum theory, it is well accepted that as objects get larger and interact with more of their environment, they lose their

quantumness. In Barandes's picture, that maps onto objects relinquishing some of their past and becoming more Markovian as the past recedes into the distance.

His framework hasn't yet produced a distinct, experimentally testable prediction, but it has already had one notable win: explaining the degree to which quantum objects can be correlated, thanks to the phenomenon of quantum entanglement.

When two quantum objects are entangled, the results of measurements of their properties maintain a correlation, even if they are first pulled very far apart. These correlations are stronger than would be possible with any non-quantum connection – by a maximum of about 41 per cent, a number known as the Tsirelson bound. Mathematician Boris Tsirelson derived this number in 1980 from standard quantum theory, but Barandes says it had never been explained beyond being a quirk of complicated mathematics. Later, in 1994, physicists Sandu Popescu and Daniel Rohrlich showed that some hypothetical theories could, in principle, achieve correlations 100 per cent greater than non-quantum theories without information being exchanged faster than light speed, which would contradict Albert Einstein's special theory of relativity. "Forty-one per cent is not even half of 100 per cent, so why so little?" asks Barandes.

His framework elegantly brings this back to the speed of light. In a universe of quantum marbles, each marble moves in its slightly random and history-laden way, but because it can't move or communicate with other marbles faster than light, those parts of its past that lie beyond a horizon of influence set by the speed of light can be neglected. Working with David Kagan and Mahmudul Hasan at the University of Massachusetts Dartmouth, Barandes has calculated that this constraint is exactly what keeps the strength of quantum correlations from exceeding the Tsirelson bound.

Simon Milz, a physicist at Heriot-Watt University in the UK, is intrigued. Standard quantum theory is very abstract and mysterious, so there is value in uncovering processes that offer some underlying picture, he says – and the Tsirelson bound is one of the most talked-about things in quantum information theory. "It's quite an interesting thing to find a new principle that leads to it," says Milz.

David Wallace, a philosopher of physics at the University of Pittsburgh in Pennsylvania, echoes that. But he is uncertain how far Barandes's approach can go, in particular because of the way it denies the wave function any physical reality. Standard quantum theory works incredibly well as a description of our world, he says. "If you just take quantum mechanics as we find it, there doesn't seem to be any way to read it that doesn't basically commit you to the wave function representing physical goings-on," he says.

He would like to see the framework reproduce more complex calculations, such as from quantum field theories that underpin the standard model of particle physics. Historically, this is where non-standard interpretations or reformulations of quantum physics have tended to fail. Barandes says that his framework ought to work for quantum fields, and he plans to extend his work in this direction.

His isn't a lone, quixotic quest to bring the past back into physics. Cristian Mariani at the University of Italian Switzerland in Lugano works on an unorthodox approach to quantum theory known as spontaneous collapse. It depicts wave function collapse as something that doesn't happen only when you try to measure things, but can spontaneously occur at any time. Spontaneous collapse models produce predictions that are distinct from those of standard quantum theory, but no experiment has yet provided enough reason to reject standard quantum mechanics in favour of spontaneous collapse. But if quantum laws are amended in a non-Markovian way, allowing spontaneous collapse models to become history-laden, then new experimental tests open up, says Mariani.

Questioning the role of Markovianity in quantum physics is important in itself, he says. "In physics, and in philosophy of physics, this was the kind of assumption that we made without explicitly defending it." In part, that's because of the mathematical complexities of non-Markovian theories, and the enduring appeal to philosophers of Occam's razor, the idea that the simplest solutions are the best. Grappling with the assumption might lead researchers to rethink the nature of physical laws themselves, says Mariani.

It isn't just our understanding of quantum theory that could be sharpened up, either; so could our conceptions of time and the significance of the present moment. Until the 20th century, philosophers had long argued that the present moment is privileged. In the sense that the past has ceased to be and the future is yet to exist, you might indeed argue that only the present can claim to be truly real. This point of view is known as presentism, and it depicts us as observers living on a wavefront of "now", ploughing from the past into the future.



Physicists are unclear about the true meaning of now. Getty Images

Einstein's space- and time-warping theories of relativity seemed to put paid to that privileging of the present. Within relativity, it is impossible to get all observers to even agree on a single, simultaneous "now". The alternative view, which Einstein's relativity is more friendly towards, is called eternalism. It states that all of the past, present and future exist simultaneously. We exist at a fixed point in this block of space and time, and the flow of time past us is essentially an illusion.

Since the advent of Einstein's relativity, "most people think that presentism is always on the defensive", says philosopher David Builes at Princeton University. In 2025, he and his Princeton colleague Michele Odisseas Impagnatiello went on the offensive, arguing that presentism is backed by centuries of experiments whose outcomes haven't deviated from predictions of Markovian laws of physics that only really require that the present be real. "This isn't an argument from the armchair; it's an empirical argument," says Impagnatiello. Conversely, the pair argue, if a non-Markovian, history-laden interpretation of quantum physics prevails, it will force them to abandon presentism.

We're a long way off any such proof as yet. "Ideally, we would have a case in which a non-Markovian interpretation is superior in the sense that it makes novel predictions that orthodox quantum mechanics doesn't make," says Impagnatiello – a view echoed by Wallace.

Barandes says that one place where his framework may touch the world of experiments is in quantum computing. Quantum computers derive enhanced capabilities through superposition and entanglement effects that, in Barandes's view, are all really fronts for influences of the past. "A quantum computer is secretly a non-Markovian computer," he says. "It's not just the present arrangement of the bits that matters, but also the past arrangements." There are currently only a few cases where researchers have unambiguously proved that using quantum computers is the only way to solve a particular problem. Thinking about them in a non-Markovian way might lead to the identification of new situations in which they are clear game changers, says Barandes.

Glick agrees there is general value in seeing how far weakening or dropping the Markovian assumption can get us, even if other descriptions of nature never get fully ruled out. "At a certain point, we might find that, well, it's better to drop that assumption, that then we get a more fruitful result," he says. "That's not a direct, empirical kind of confirmation or disconfirmation, but this is how science often works."

Taking the past seriously touches the foundations of physics in a sweeping and profound way, and that makes it worth pursuing, says Barandes. "I think that this framework may have something to tell us about the way the world really is," he says. "As a philosopher, I care about that." It's certainly food for thought as I prepare my morning smoothie.