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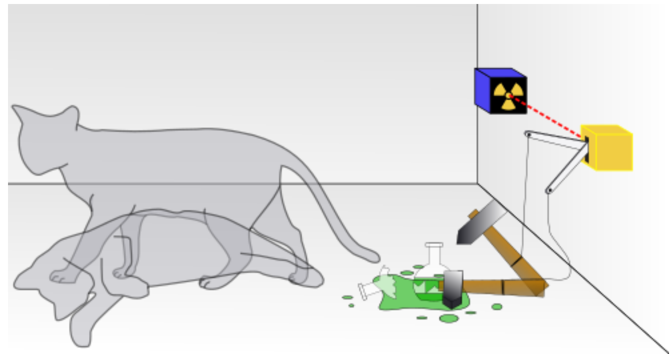
Schrödinger's cat

In quantum mechanics, **Schrödinger's cat** is a thought experiment that illustrates a paradox of quantum superposition. In the thought experiment, a hypothetical cat may be considered simultaneously both alive and dead as a result of its fate being linked to a random subatomic event that may or may not occur.



Schrödinger's cat: a cat, a flask of poison, and a radioactive source are placed in a sealed box. If an internal monitor (e.g. Geiger counter) detects radioactivity (i.e. a single atom decaying), the flask is shattered, releasing the poison, which kills the cat. The Copenhagen interpretation of quantum mechanics implies that, after a while, the cat is *simultaneously* alive *and* dead. Yet, when one looks in the box, one sees the cat *either* alive *or* dead, not both alive *and* dead. This poses the question of when exactly quantum superposition ends and reality resolves into one possibility or the other.

This thought experiment was devised by physicist Erwin Schrödinger in 1935,[1] in a discussion with Albert Einstein,[2] to illustrate what Schrödinger saw as the problems of the Copenhagen interpretation of quantum mechanics. The scenario is often featured in theoretical discussions of the interpretations of quantum mechanics, particularly in situations involving the measurement problem.

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Origin and motivation

A life-size cat figure in the garden of Huttenstrasse 9, Zurich, where Erwin Schrödinger lived 1921–1926. Depending on the light conditions, the cat appears either alive or dead.

Schrödinger intended his thought experiment as a discussion of the EPR article—named after its authors Einstein, Podolsky, and Rosen—in 1935.[3][4] The EPR article highlighted the counterintuitive nature of quantum superpositions, in which a quantum system such as an atom or photon can exist as a combination of multiple states corresponding to different possible outcomes.

The prevailing theory, called the Copenhagen interpretation, says that a quantum system remains in superposition until it interacts with, or is observed by the external world. When this happens, the superposition collapses into one or another of the possible definite states. The EPR experiment shows that a system with multiple particles separated by large distances can be in such a superposition. Schrödinger and Einstein exchanged letters about Einstein's EPR article, in the course of which Einstein pointed out that the state of an unstable keg of gunpowder will, after a while, contain a superposition of both exploded and unexploded states.[4]

To further illustrate, Schrödinger described how one could, in principle, create a superposition in a large-scale system by making it dependent on a quantum particle that was in a superposition. He proposed a scenario with a cat in a locked steel chamber, wherein the cat's life or death depended on the state of a radioactive atom, whether it had decayed and emitted radiation or not. According to Schrödinger, the Copenhagen interpretation implies that *the cat remains both alive and dead* until the state has been observed. Schrödinger did not wish to promote the idea of dead-and-live cats as a serious possibility; on the contrary, he intended the example to illustrate the absurdity of the existing view of quantum mechanics.[1] The idea that quantum superpositions of macroscopic states could be possible led to the Many-worlds interpretation of quantum theory.

Since Schrödinger's time, various interpretations of the mathematics of quantum mechanics have been advanced by physicists, some of which regard the "alive and dead" cat superposition as quite real, others do not.[5][6] Intended as a critique of the Copenhagen interpretation (the prevailing orthodoxy in 1935), the Schrödinger's cat thought experiment remains a touchstone for modern interpretations of quantum mechanics and can be used to illustrate and compare their strengths and weaknesses.[7]

Thought experiment

Schrödinger wrote:[1][8]

> One can even set up quite ridiculous cases. A cat is penned up in a steel chamber, along with the following device (which must be secured against direct interference by the cat): in a Geiger counter, there is a tiny bit of radioactive substance, so small, that perhaps in the course of the hour one of the atoms decays, but also, with equal probability, perhaps none; if it happens, the counter tube discharges and through a relay releases a hammer that shatters a small flask of hydrocyanic acid. If one has left this entire system to itself for an

> hour, one would say that the cat still lives if meanwhile no atom has decayed. The first atomic decay would have poisoned it. The psi-function of the entire system would express this by having in it the living and dead cat (pardon the expression) mixed or smeared out in equal parts.
>
> It is typical of these cases that an indeterminacy originally restricted to the atomic domain becomes transformed into macroscopic indeterminacy, which can then be resolved by direct observation. That prevents us from so naïvely accepting as valid a "blurred model" for representing reality. In itself, it would not embody anything unclear or contradictory. There is a difference between a shaky or out-of-focus photograph and a snapshot of clouds and fog banks.

Schrödinger's famous thought experiment poses the question, "*when* does a quantum system stop existing as a superposition of states and become one or the other?" (More technically, when does the actual quantum state stop being a non-trivial linear combination of states, each of which resembles different classical states, and instead begin to have a unique classical description?) If the cat survives, it remembers only being alive. But explanations of the EPR experiments that are consistent with standard microscopic quantum mechanics require that macroscopic objects, such as cats and notebooks, do not always have unique classical descriptions. The thought experiment illustrates this apparent paradox. Our intuition says that no observer can be in more than one state simultaneously—yet the cat, it seems from the thought experiment, can be in such a condition. Is the cat required to be an observer, or does its existence in a single well-defined classical state require another external observer? Each alternative seemed absurd to Einstein, who was impressed by the ability of the thought experiment to highlight these issues. In a letter to Schrödinger dated 1950, he wrote:

> You are the only contemporary physicist, besides Laue, who sees that one cannot get around the assumption of reality, if only one is honest. Most of them simply do not see what sort of risky game they are playing with reality—reality as something independent of what is experimentally established. Their interpretation is, however, refuted most elegantly by your system of radioactive atom + amplifier + charge of gun powder + cat in a box, in which the psi-function of the system contains both the cat alive and blown to bits. Nobody really doubts that the presence or absence of the cat is something independent of the act of observation.[9]

Note that the charge of gunpowder is not mentioned in Schrödinger's setup, which uses a Geiger counter as an amplifier and hydrocyanic poison instead of gunpowder. The gunpowder had been mentioned in Einstein's original suggestion to Schrödinger 15 years before, and Einstein carried it forward to the present discussion.[4]

Interpretations

Since Schrödinger's time, other interpretations of quantum mechanics have been proposed that give different answers to the questions posed by Schrödinger's cat of how long superpositions last and when (or *whether*) they collapse.

Copenhagen interpretation

A commonly held interpretation of quantum mechanics is the Copenhagen interpretation.[10] In the Copenhagen interpretation, a system stops being a superposition of states and becomes either one or the other when an observation takes place. This thought experiment makes apparent the fact that the nature of measurement, or observation, is not well-defined in this interpretation. The experiment can be interpreted to mean that while the box is closed, the system simultaneously exists in a superposition of the states "decayed nucleus/dead cat" and "undecayed nucleus/living cat", and that only when the box is opened and an observation performed does the wave function collapse into one of the two states.

Von Neumann interpretation

In 1932 John von Neumann described in his book *Mathematical Foundations* a pattern where the radioactive source is observed by a device, which itself is observed by another device, and so on. It makes no difference in the predictions of quantum theory where along this chain of causal effects the superposition collapses.[11] This potentially infinite chain could be broken if the last device is replaced by a conscious observer. This solved the problem because it was claimed that an individual's consciousness cannot be multiple.[12] Neumann asserted that a conscious observer is necessary for collapse to one or the other (e.g. either a live cat or a dead cat) of the terms on the right-hand side of a wave function. This interpretation was later adopted by Eugene Wigner, who then rejected the interpretation in a thought experiment known as Wigner's friend.[13]

Wigner supposed that a friend opened the box and observed the cat without telling anyone. From Wigner's conscious perspective, the friend is now part of the wave function and has seen a live cat and seen a dead cat. To a third person's conscious perspective, Wigner himself becomes part of the wave function once Wigner learns the outcome from the friend. This could be extended indefinitely.[13]

Bohr's interpretation

One of the main scientists associated with the Copenhagen interpretation, Niels Bohr, offered an interpretation that is independent of a subjective observer-induced collapse of the wave function, or of measurement; instead, an "irreversible" or effectively irreversible process causes the decay of quantum coherence which imparts the classical behavior of "observation" or "measurement".[14][15][16][17] Thus, Schrödinger's cat would be either dead or alive long before the box is observed.[18]

A resolution of the paradox is that the triggering of the Geiger counter counts as a measurement of the state of the radioactive substance. Because a measurement has already occurred deciding the state of the cat, the subsequent observation by a human records only what has already occurred.[19] Analysis of an actual experiment by Roger Carpenter and A. J. Anderson found that measurement alone (for example by a Geiger counter) is sufficient to collapse a quantum wave function before any human knows of the result.[20] The apparatus indicates one of two colors depending on the outcome. The human observer sees which color is indicated, but they don't consciously know which outcome the color represents. A second human, the one who set up the apparatus, is told of the color and becomes conscious of the outcome, and the box is opened to check if the outcome matches.[11] However, it is disputed whether merely observing the color counts as a conscious observation of the outcome.[21]

Many-worlds interpretation and consistent histories

In 1957, Hugh Everett formulated the many-worlds interpretation of quantum mechanics, which does not single out observation as a special process. In the many-worlds interpretation, both alive and dead states of the cat persist after the box is opened, but are decoherent from each other. In other words, when the box is opened, the observer and the possibly-dead cat split into an observer looking at a box with a dead cat, and an observer looking at a box with a live cat. But since the dead and alive states are decoherent, there is no effective communication or interaction between them.


The quantum-mechanical "Schrödinger's cat" paradox according to the many-worlds interpretation. In this interpretation, every event is a branch point. The cat is both alive and dead—regardless of whether the box is opened—but the "alive" and "dead" cats are in different branches of the universe that are equally real but cannot interact with each other.

When opening the box, the observer becomes entangled with the cat, so "observer states" corresponding to the cat's being alive and dead are formed; each observer state is entangled or linked with the cat so that the "observation of the cat's state" and the "cat's state" correspond with each other. Quantum decoherence ensures that the different outcomes have no interaction with each other. The same mechanism of quantum decoherence is also important for the interpretation in terms of consistent histories. Only the "dead cat" or the "live cat" can be a part of a consistent history in this interpretation. Decoherence is generally considered to prevent simultaneous observation of multiple states.[22][23]

A variant of the Schrödinger's cat experiment, known as the quantum suicide machine, has been proposed by cosmologist Max Tegmark. It examines the Schrödinger's cat experiment from the point of view of the cat, and argues that by using this approach, one may be able to distinguish between the Copenhagen interpretation and many-worlds.

Ensemble interpretation

The ensemble interpretation states that superpositions are nothing but subensembles of a larger statistical ensemble. The state vector would not apply to individual cat experiments, but only to the statistics of many similarly prepared cat experiments. Proponents of this interpretation state that this makes the Schrödinger's cat paradox a trivial matter, or a non-issue.

This interpretation serves to *discard* the idea that a single physical system in quantum mechanics has a mathematical description that corresponds to it in any way.[24]

Relational interpretation

The relational interpretation makes no fundamental distinction between the human experimenter, the cat, or the apparatus, or between animate and inanimate systems; all are quantum systems governed by the same rules of wavefunction evolution, and all may be considered "observers". But the relational interpretation allows that different observers can give different accounts of the same series of events, depending on the information they have about the system.[25] The cat can be considered an observer of the apparatus; meanwhile, the experimenter can be considered another observer of the system in the box (the cat plus the apparatus). Before the box is opened, the cat, by nature of its being alive or dead, has information about the state of the apparatus (the atom has either decayed or not decayed); but the experimenter does not have information about the state of the box contents. In this way, the two observers simultaneously have different accounts of the situation: To the cat, the wavefunction of the apparatus has appeared to "collapse"; to the experimenter, the contents of the box appear to be in superposition. Not until the box is opened, and both observers have the same information about what happened, do both system states appear to "collapse" into the same definite result, a cat that is either alive or dead.

Transactional interpretation

In the transactional interpretation the apparatus emits an advanced wave backward in time, which combined with the wave that the source emits forward in time, forms a standing wave. The waves are seen as physically real, and the apparatus is considered an "observer". In the transactional interpretation, the collapse of the wavefunction is "atemporal" and occurs along the whole transaction between the source and the apparatus. The cat is never in superposition. Rather the cat is only in one state at any particular time, regardless of when the human experimenter looks in the box. The transactional interpretation resolves this quantum paradox.[26]

Zeno effects

The Zeno effect is known to cause delays to any changes from the initial state.

On the other hand, the anti-Zeno effect accelerates the changes. For example, if you peek a look into the cat box frequently you may either cause delays to the fateful choice or, conversely, accelerate it. Both the Zeno effect and the anti-Zeno effect are real and known to happen to real atoms. The quantum system being measured must be strongly coupled to the surrounding environment (in this case to the apparatus, the experiment room ... etc.) in order to obtain more accurate information. But while there is no information passed to the outside world, it is considered to be a *quasi-measurement*, but as soon as the information about the cat's well-being is passed on to the outside world (by peeking into the box) quasi-measurement turns into measurement. Quasi-measurements, like measurements, cause the Zeno effects.[27] Zeno effects teach us that even without peeking into the box, the death of the cat would have been delayed or accelerated anyway due to its environment.

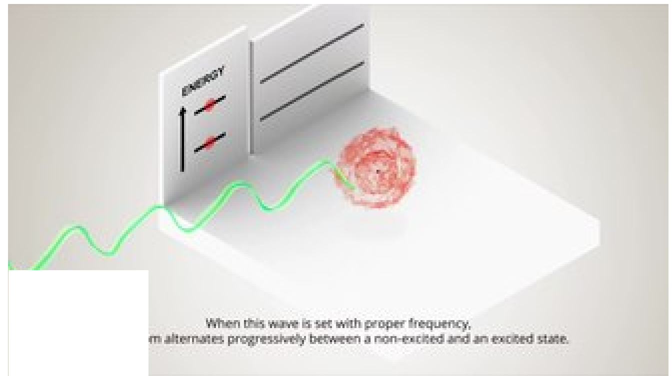
Objective collapse theories

According to objective collapse theories, superpositions are destroyed spontaneously (irrespective of external observation), when some objective physical threshold (of time, mass, temperature, irreversibility, etc.) is reached. Thus, the cat would be expected to have settled into a definite state long before the box is opened. This could loosely be phrased as "the cat observes itself", or "the environment observes the cat".

Objective collapse theories require a modification of standard quantum mechanics to allow superpositions to be destroyed by the process of time evolution.[28] These models could ideally be tested by creating mesoscopic superposition states in the experiment. For instance, energy cat states has been proposed as a precise detector of the quantum gravity related energy decoherence models.[29]

Applications and tests

The experiment as described is a purely theoretical one, and the machine proposed is not known to have been constructed. However, successful experiments involving similar principles, e.g. superpositions of relatively large (by the standards of quantum physics) objects have been performed.[30] These experiments do not show that a cat-sized object can be superposed, but the known upper limit on "cat states" has been pushed upwards by them. In many cases the state is short-lived, even when cooled to near absolute zero.



Schrödinger's cat quantum superposition of states and effect of the environment through decoherence

- A "cat state" has been achieved with photons.[31]
- A beryllium ion has been trapped in a superposed state.[32]
- An experiment involving a superconducting quantum interference device ("SQUID") has been linked to the theme of the thought experiment: "The superposition state does not correspond to a billion electrons flowing one way and a billion others flowing the other way. Superconducting electrons move en masse. All the superconducting electrons in the SQUID flow both ways around the loop at once when they are in the Schrödinger's cat state."[33]
- A piezoelectric "tuning fork" has been constructed, which can be placed into a superposition of vibrating and non vibrating states. The resonator comprises about 10 trillion atoms.[34]
- An experiment involving a flu virus has been proposed.[35]
- An experiment involving a bacterium and an electromechanical oscillator has been proposed.[36]

In quantum computing the phrase "cat state" sometimes refers to the GHZ state, wherein several qubits are in an equal superposition of all being 0 and all being 1; e.g.,

$$|\psi\rangle = \frac{1}{\sqrt{2}}\bigg(|00\ldots0\rangle + |11\ldots1\rangle\bigg).$$

According to at least one proposal, it may be possible to determine the state of the cat *before* observing it.[37][38]

Extensions

Prominent physicists have gone so far as to suggest that astronomers observing dark energy in the universe in 1998 may have "reduced its life expectancy" through a pseudo-Schrödinger's cat scenario, although this is a controversial viewpoint.[39][40]

In August 2020, physicists presented studies involving interpretations of quantum mechanics that are related to the Schrödinger's cat and Wigner's friend paradoxes, resulting in conclusions that challenge seemingly established assumptions about reality.[41][42][43]

See also

- Basis function
- Complementarity (physics)
- Double-slit experiment
- Elitzur–Vaidman bomb tester

- Heisenberg cut
- Modal realism
- Observer effect (physics)
- Schroedinbug
- Schrödinger's cat in popular culture

References

1. Schrödinger, Erwin (November 1935). "Die gegenwärtige Situation in der Quantenmechanik (The present situation in quantum mechanics)". *Naturwissenschaften*. **23** (48): 807–812. Bibcode:1935NW.....23..807S (https://ui.adsabs.harvard.edu/abs/1935NW.....23..807S). doi:10.1007/BF01491891 (https://doi.org/10.1007%2FBF01491891). S2CID 206795705 (https://api.semanticscholar.org/CorpusID:206795705).
2. Fine, Arthur. "The Einstein-Podolsky-Rosen Argument in Quantum Theory" (https://plato.stanford.edu/entries/qt-epr/). *Stanford Encyclopedia of Philosophy*. Retrieved 11 June 2020.
3. Can Quantum-Mechanical Description of Physical Reality Be Considered Complete? (http://prola.aps.org/abstract/PR/v47/i10/p777_1) Archived (https://web.archive.org/web/20060208145129/http://prola.aps.org/abstract/PR/v47/i10/p777_1) 2006-02-08 at the Wayback Machine A. Einstein, B. Podolsky, and N. Rosen, Phys. Rev. 47, 777 (1935)
4. Fine, Arthur (2017). "The Einstein-Podolsky-Rosen Argument in Quantum Theory" (https://plato.stanford.edu/entries/qt-epr/). *Stanford Encyclopedia of Philosophy*. Stanford University. Retrieved 11 April 2021.
5. Polkinghorne, J. C. (1985). *The Quantum World* (https://books.google.com/books?id=Ip4JPYnLrtEC&q=%22schrodinger's+cat%22+%22alive+dead&pg=PA67). Princeton University Press. p. 67. ISBN 0691023883. Archived (https://web.archive.org/web/20150519001623/https://books.google.com/books?id=Ip4JPYnLrtEC&pg=PA67&dq=%22schrodinger's+cat%22+%22alive+dead) from the original on 2015-05-19.
6. Tetlow, Philip (2012). *Understanding Information and Computation: From Einstein to Web Science* (https://books.google.com/books?id=Rk7O3EG0Xn4C&q=%22alive+and+dead%22&pg=PA321). Gower Publishing, Ltd. p. 321. ISBN 978-1409440406. Archived (https://web.archive.org/web/20150519001741/https://books.google.com/books?id=Rk7O3EG0Xn4C&pg=PA321&dq=%22alive+and+dead%22) from the original on 2015-05-19.
7. Lazarou, Dimitris (2007). "Interpretation of quantum theory - An overview". arXiv:0712.3466 (https://arxiv.org/abs/0712.3466) [quant-ph (https://arxiv.org/archive/quant-ph)].
8. Trimmer, John D. (1980). "The Present Situation in Quantum Mechanics: A Translation of Schrödinger's "Cat Paradox" Paper". *Proceedings of the American Philosophical Society*. **124** (5): 323–338. JSTOR 986572 (https://www.jstor.org/stable/986572). Reproduced with some inaccuracies here: Schroedinger: "The Present Situation in Quantum Mechanics." 5. Are the Variables Really Blurred? (https://archive.today/20121204184041/http://www.tuhh.de/rzt/rzt/it/QM/cat.html#sect5)
9. Maxwell, Nicholas (1 January 1993). "Induction and Scientific Realism: Einstein versus van Fraassen Part Three: Einstein, Aim-Oriented Empiricism and the Discovery of Special and General Relativity". *The British Journal for the Philosophy of Science*. **44** (2): 275–305. doi:10.1093/bjps/44.2.275 (https://doi.org/10.1093%2Fbjps%2F44.2.275). JSTOR 687649 (https://www.jstor.org/stable/687649).
10. Wimmel, Hermann (1992). *Quantum physics & observed reality: a critical interpretation of quantum mechanics* (https://books.google.com/books?id=-4sJ_fgyZJEC&pg=PA2). World Scientific. p. 2. ISBN 978-981-02-1010-6. Archived (https://web.archive.org/web/20130520185205/http://books.google.com/books?id=-4sJ_fgyZJEC&pg=PA2) from the original on 20 May 2013. Retrieved 9 May 2011.

11. Hobson, Art (2017). *Tales of the Quantum: Understanding Physics' Most Fundamental Theory* (https://www.google.com/books/edition/Tales_of_the_Quantum/mGduDQAAQBAJ?hl=en&gbpv=0). New York, NY: Oxford University Press. pp. 200–202. ISBN 9780190679637. Retrieved April 8, 2022.
12. Omnès, Roland (1999). *Understanding Quantum Mechanics* (https://www.google.com/books/edition/Understanding_Quantum_Mechanics/XET_DwAAQBAJ?hl=en&gbpv=0). Princeton, New Jersey: Princeton University Press. pp. 60–62. ISBN 0-691-00435-8. Retrieved April 8, 2022.
13. Levin, Frank S. (2017). *Surfing the Quantum World* (https://www.google.com/books/edition/Surfing_the_Quantum_World/Y1w-DwAAQBAJ?hl=en&gbpv=0). New York, NY: Oxford University Press. pp. 229–232. ISBN 978-0-19-880827-5. Retrieved April 8, 2022.
14. John Bell (1990). "Against 'measurement' ". *Physics World*. **3** (8): 33–41. doi:10.1088/2058-7058/3/8/26 (https://doi.org/10.1088%2F2058-7058%2F3%2F8%2F26).
15. Niels Bohr (1985) [May 16, 1947]. Jørgen Kalckar (ed.). *Foundations of Quantum Physics I (1926-1932)* (https://www.nbarchive.dk/publications/bcw/). Niels Bohr: Collected Works. Vol. 6. pp. 451–454.
16. Stig Stenholm (1983). "To fathom space and time". In Pierre Meystre (ed.). *Quantum Optics, Experimental Gravitation, and Measurement Theory*. Plenum Press. p. 121. "The role of irreversibility in the theory of measurement has been emphasized by many. Only this way can a permanent record be obtained. The fact that separate pointer positions must be of the asymptotic nature usually associated with irreversibility has been utilized in the measurement theory of Daneri, Loinger and Prosperi (1962). It has been accepted as a formal representation of Bohr's ideas by Rosenfeld (1966)."
17. Fritz Haake (April 1, 1993). "Classical motion of meter variables in the quantum theory of measurement". *Physical Review A*. **47** (4): 2506–2517. Bibcode:1993PhRvA..47.2506H (https://ui.adsabs.harvard.edu/abs/1993PhRvA..47.2506H). doi:10.1103/PhysRevA.47.2506 (https://doi.org/10.1103%2FPhysRevA.47.2506). PMID 9909217 (https://pubmed.ncbi.nlm.nih.gov/9909217).
18. Faye, J (2008-01-24). "Copenhagen Interpretation of Quantum Mechanics" (http://plato.stanford.edu/entries/qm-copenhagen/). *Stanford Encyclopedia of Philosophy*. The Metaphysics Research Lab Center for the Study of Language and Information, Stanford University. Retrieved 2010-09-19.
19. Puri, Ravinder R. (2017). *Non-Relativistic Quantum Mechanics* (https://www.google.com/books/edition/Non_Relativistic_Quantum_Mechanics/qDbSDgAAQBAJ?hl=en&gbpv=0). Cambridge, United Kingdom: Cambridge University Press. p. 146. ISBN 978-1-107-16436-9. Retrieved April 8, 2022.
20. Carpenter RHS, Anderson AJ (2006). "The death of Schroedinger's cat and of consciousness-based wave-function collapse" (https://web.archive.org/web/20061130173850/http://www.ensmp.fr/aflb/AFLB-311/aflb311m387.pdf) (PDF). *Annales de la Fondation Louis de Broglie*. **31** (1): 45–52. Archived from the original (http://www.ensmp.fr/aflb/AFLB-311/aflb311m387.pdf) (PDF) on 2006-11-30. Retrieved 2010-09-10.
21. Okón E, Sebastián MA (2016). "How to Back up or Refute Quantum Theories of Consciousness". *Mind and Matter*. **14** (1): 25–49.
22. Zurek, Wojciech H. (2003). "Decoherence, einselection, and the quantum origins of the classical". *Reviews of Modern Physics*. **75** (3): 715. arXiv:quant-ph/0105127 (https://arxiv.org/abs/quant-ph/0105127). Bibcode:2003RvMP...75..715Z (https://ui.adsabs.harvard.edu/abs/2003RvMP...75..715Z). doi:10.1103/revmodphys.75.715 (https://doi.org/10.1103%2Frevmodphys.75.715). S2CID 14759237 (https://api.semanticscholar.org/CorpusID:14759237).
23. Wojciech H. Zurek, "Decoherence and the transition from quantum to classical", *Physics Today*, 44, pp. 36–44 (1991)

24. Smolin, Lee (October 2012). "A real ensemble interpretation of quantum mechanics". *Foundations of Physics*. **42** (10): 1239–1261. arXiv:1104.2822 (https://arxiv.org/abs/1104.2822). Bibcode:2012FoPh...42.1239S (https://ui.adsabs.harvard.edu/abs/2012FoPh...42.1239S). doi:10.1007/s10701-012-9666-4 (https://doi.org/10.1007%2Fs10701-012-9666-4). ISSN 0015-9018 (https://www.worldcat.org/issn/0015-9018). S2CID 118505566 (https://api.semanticscholar.org/CorpusID:118505566).
25. Rovelli, Carlo (1996). "Relational Quantum Mechanics". *International Journal of Theoretical Physics*. **35** (8): 1637–1678. arXiv:quant-ph/9609002 (https://arxiv.org/abs/quant-ph/9609002). Bibcode:1996IJTP...35.1637R (https://ui.adsabs.harvard.edu/abs/1996IJTP...35.1637R). doi:10.1007/BF02302261 (https://doi.org/10.1007%2FBF02302261). S2CID 16325959 (https://api.semanticscholar.org/CorpusID:16325959).
26. Cramer, John G. (July 1986). *The transactional interpretation of quantum mechanics* (https://www.researchgate.net/publication/280926546). Vol. 58. Reviews of Modern Physics. pp. 647–685.
27. "How the quantum Zeno effect impacts Schrodinger's cat" (https://phys.org/news/2017-06-quantum-zeno-effect-impacts-schroedinger.html). *phys.org*. Archived (https://web.archive.org/web/20170617153012/https://phys.org/news/2017-06-quantum-zeno-effect-impacts-schroedinger.html) from the original on 17 June 2017. Retrieved 18 June 2017.
28. Okon, Elias; Sudarsky, Daniel (2014-02-01). "Benefits of Objective Collapse Models for Cosmology and Quantum Gravity". *Foundations of Physics*. **44** (2): 114–143. arXiv:1309.1730 (https://arxiv.org/abs/1309.1730). Bibcode:2014FoPh...44..114O (https://ui.adsabs.harvard.edu/abs/2014FoPh...44..114O). doi:10.1007/s10701-014-9772-6 (https://doi.org/10.1007%2Fs10701-014-9772-6). ISSN 1572-9516 (https://www.worldcat.org/issn/1572-9516). S2CID 67831520 (https://api.semanticscholar.org/CorpusID:67831520).
29. Khazali, Mohammadsadegh; Lau, Hon Wai; Humeniuk, Adam; Simon, Christoph (2016-08-11). "Large energy superpositions via Rydberg dressing" (https://dx.doi.org/10.1103/physreva.94.023408). *Physical Review A*. **94** (2): 023408. arXiv:1509.01303 (https://arxiv.org/abs/1509.01303). Bibcode:2016PhRvA..94b3408K (https://ui.adsabs.harvard.edu/abs/2016PhRvA..94b3408K). doi:10.1103/physreva.94.023408 (https://doi.org/10.1103%2Fphysreva.94.023408). ISSN 2469-9926 (https://www.worldcat.org/issn/2469-9926). S2CID 118364289 (https://api.semanticscholar.org/CorpusID:118364289).
30. "What is the world's biggest Schrodinger cat?" (http://physics.stackexchange.com/questions/3309/what-is-the-worlds-biggest-schrodinger-cat). *stackexchange.com*. Archived (https://web.archive.org/web/20120108000629/http://physics.stackexchange.com/questions/3309/what-is-the-worlds-biggest-schrodinger-cat) from the original on 2012-01-08.
31. "Schrödinger's Cat Now Made Of Light" (http://www.science20.com/news_articles/schr%C3%B6dingers_cat_now_made_light). *www.science20.com*. 27 August 2014. Archived (https://web.archive.org/web/20120318091956/http://www.science20.com/news_articles/schr%C3%B6dingers_cat_now_made_light) from the original on 18 March 2012.
32. C. Monroe, et al. *A "Schrödinger Cat" Superposition State of an Atom* (http://www.quantumsciencephilippines.com/seminar/seminar-topics/SchrodingerCatAtom.pdf) Archived (https://web.archive.org/web/20120107013418/http://www.quantumsciencephilippines.com/seminar/seminar-topics/SchrodingerCatAtom.pdf) 2012-01-07 at the Wayback Machine
33. "Physics World: *Schrödinger's cat comes into view*" (https://physicsworld.com/a/schrodingers-cat-comes-into-view/).
34. Scientific American : *Macro-Weirdness: "Quantum Microphone" Puts Naked-Eye Object in 2 Places at Once: A new device tests the limits of Schrödinger's cat* (http://www.scientificamerican.com/article.cfm?id=quantum-microphone) Archived (https://web.archive.org/web/20120319021316/http://www.scientificamerican.com/article.cfm?id=quantum-microphone) 2012-03-19 at the Wayback Machine

35. arXiv, Emerging Technology from the. "How to Create Quantum Superpositions of Living Things" (https://www.technologyreview.com/2009/09/10/210037/how-to-create-quantum-superpositions-of-living-things/).
36. "Could 'Schrödinger's bacterium' be placed in a quantum superposition?" (http://physicsworld.com/cws/article/news/2015/sep/21/could-schrodingers-bacterium-be-placed-in-a-quantum-superposition). *physicsworld.com*. Archived (https://web.archive.org/web/20160730174613/http://physicsworld.com/cws/article/news/2015/sep/21/could-schrodingers-bacterium-be-placed-in-a-quantum-superposition) from the original on 2016-07-30.
37. Najjar, Dana (7 November 2019). "Physicists Can Finally Peek at Schrödinger's Cat Without Killing It Forever" (https://www.livescience.com/schrodingers-cat-can-be-peeked-at.html). *Live Science*. Retrieved 7 November 2019.
38. Patekar, Kartik; Hofmann, Holger F. (2019). "The role of system–meter entanglement in controlling the resolution and decoherence of quantum measurements" (https://doi.org/10.1088%2F1367-2630%2Fab4451). *New Journal of Physics*. **21** (10): 103006. arXiv:1905.09978 (https://arxiv.org/abs/1905.09978). Bibcode:2019NJPh...21j3006P (https://ui.adsabs.harvard.edu/abs/2019NJPh...21j3006P). doi:10.1088/1367-2630/ab4451 (https://doi.org/10.1088%2F1367-2630%2Fab4451).
39. Chown, Marcus (2007-11-22). "Has observing the universe hastened its end?" (https://www.newscientist.com/article/mg19626313-800-has-observing-the-universe-hastened-its-end/). *New Scientist*. Archived (https://web.archive.org/web/20160310002305/https://www.newscientist.com/article/mg19626313-800-has-observing-the-universe-hastened-its-end/) from the original on 2016-03-10. Retrieved 2007-11-25.
40. Krauss, Lawrence M.; James Dent (April 30, 2008). "Late Time Behavior of False Vacuum Decay: Possible Implications for Cosmology and Metastable Inflating States". *Phys. Rev. Lett*. US. **100** (17): 171301. arXiv:0711.1821 (https://arxiv.org/abs/0711.1821). Bibcode:2008PhRvL.100q1301K (https://ui.adsabs.harvard.edu/abs/2008PhRvL.100q1301K). doi:10.1103/PhysRevLett.100.171301 (https://doi.org/10.1103%2FPhysRevLett.100.171301). PMID 18518269 (https://pubmed.ncbi.nlm.nih.gov/18518269). S2CID 30028648 (https://api.semanticscholar.org/CorpusID:30028648).
41. Merali, Zeeya (17 August 2020). "This Twist on Schrödinger's Cat Paradox Has Major Implications for Quantum Theory - A laboratory demonstration of the classic "Wigner's friend" thought experiment could overturn cherished assumptions about reality" (https://www.scientificamerican.com/article/this-twist-on-schroedingers-cat-paradox-has-major-implications-for-quantum-theory/). *Scientific American*. Retrieved 17 August 2020.
42. Musser, George (17 August 2020). "Quantum paradox points to shaky foundations of reality" (https://www.sciencemag.org/news/2020/08/quantum-paradox-points-shaky-foundations-reality). *Science Magazine*. Retrieved 17 August 2020.
43. Bong, Kok-Wei; et al. (17 August 2020). "A strong no-go theorem on the Wigner's friend paradox" (https://doi.org/10.1038%2Fs41567-020-0990-x). *Nature Physics*. **27** (12): 1199–1205. arXiv:1907.05607 (https://arxiv.org/abs/1907.05607). Bibcode:2020NatPh..16.1199B (https://ui.adsabs.harvard.edu/abs/2020NatPh..16.1199B). doi:10.1038/s41567-020-0990-x (https://doi.org/10.1038%2Fs41567-020-0990-x).

Further reading

- Einstein, Albert; Podolsky, Boris; Rosen, Nathan (15 May 1935). "Can Quantum-Mechanical Description of Physical Reality Be Considered Complete?" (https://doi.org/10.1103%2FPhysRev.47.777). *Physical Review*. **47** (10): 777–780. Bibcode:1935PhRv...47..777E (https://ui.adsabs.harvard.edu/abs/1935PhRv...47..777E). doi:10.1103/PhysRev.47.777 (https://doi.org/10.1103%2FPhysRev.47.777).

- Leggett, Tony (August 2000). "New Life for Schrödinger's Cat" (https://jrfriedman.people.amherst.edu/Leggett%20Physics%20World%20article/PW%20article.pdf) (PDF). Physics World. pp. 23–24. Retrieved 28 February 2020. An article on experiments with "cat state" superpositions in superconducting rings, in which the electrons go around the ring in two directions simultaneously.
- Trimmer, John D. (1980). "The Present Situation in Quantum Mechanics: A Translation of Schrödinger's "Cat Paradox" Paper". *Proceedings of the American Philosophical Society*. **124** (5): 323–338. JSTOR 986572 (https://www.jstor.org/stable/986572).(registration required)
- Yam, Phillip (October 9, 2012). "Bringing Schrödinger's Cat to Life" (https://www.scientificamerican.com/article/bringing-schrodingers-quantum-cat-to-life/). *Scientific American*. Retrieved 28 February 2020. A description of investigations of quantum "cat states" and wave function collapse by Serge Haroche and David J. Wineland, for which they won the 2012 Nobel Prize in Physics.

External links

- A spoken word version of this article (created from a revision of the article dated 2013-08-12).
- *Schrödinger's Cat (http://www.informationphilosopher.com/solutions/experiments/schrodingerscat/)* from the Information Philosopher.
- Schrödinger's Cat - Sixty Symbols (http://www.sixtysymbols.com/videos/schrodinger.htm) - a video published by the University of Nottingham.
- Schrödinger's Cat (https://soundcloud.com/siftpodcast/schr-dingers-cat) - a podcast produced by Sift.