Open Peer Review on Qeios

Determining When Schrödinger's Cats Die

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Funding: No specific funding was received for this work.

Potential competing interests: No potential competing interests to declare.

Abstract

E. Schrödinger proposed a thought experiment to illustrate the discontinuity, not currently explained, that appears in quantum mechanics when a measurement occurs. Schrödinger's cats in his thought experiment appear to be both alive and dead. This unreasonable appearance has not been satisfactorily explained before. Calibration, which is required in metrology, is not included in physics theory. Schrödinger's thought experiment is explained by including calibration in measurement theory.

Determining When Schrödinger's Cats Die[i]

In 1935, Schrödinger proposed this thought experiment:[ii]

> *"One can even set up quite ridiculous cases. A cat is penned up in a steel chamber, along with the following diabolical 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 one 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 which 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 ψ 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."*

One way to understand his thought experiment uses many experimental runs, destroying one cat in each run. After each run the diabolical device is reset and another unfortunate cat is penned in for the next run. The diabolical device is assumed to cause each cat's death a short fixed time after an atom's decay. An atom in each run has a 0.5 probability of decaying at one hour from the start. The continuous ψ (wave) function of this system is illustrated by the two hat shaped (^) curves in the figures (for drawing simplicity). Any two curves where the mean of all the atom's probability of decay was 0.5 at 1 hour would fit Schrödinger's description.

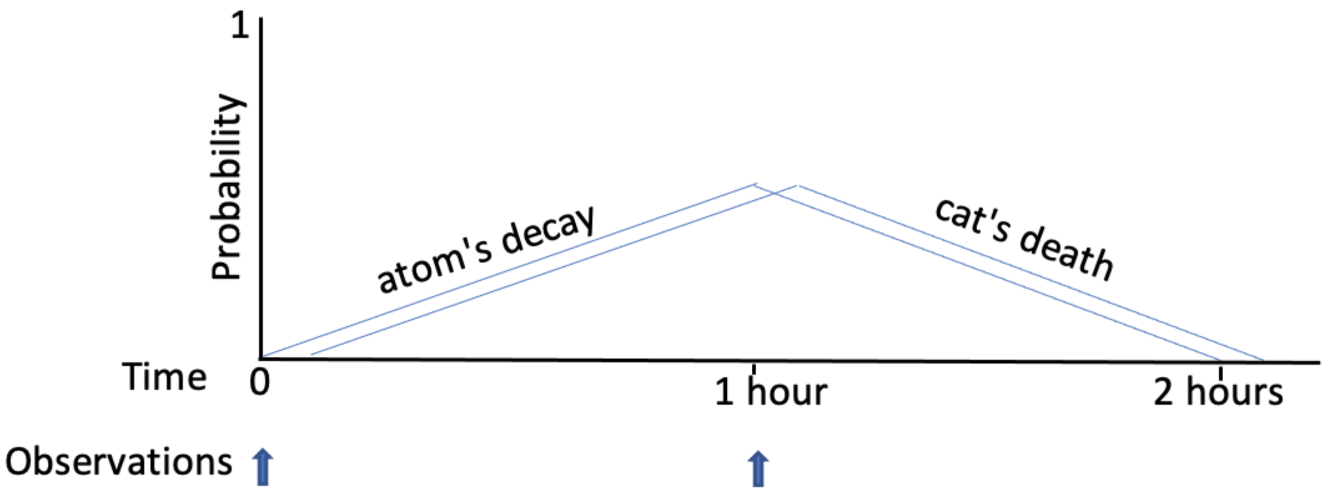

Fig. 1. When Schrödinger's cats die.

Each experimental run establishes one atom's decay time and one cat's time of death. Many experimental runs produce the two parallel, offset and hat shaped curves. Fig. 1 and Fig. 2 assume the maximum distribution of each atom's decay and each cat's time of death is approximately 2 hours which maximizes the perplexing effect. However, assuming both maximum distributions to be longer or shorter does not fundamentally change the following analysis.

Many experimental runs establish the continuous curves of the two observables and represent theψ function. However, each measurement result is quite different. At the bottom of Fig. 1 the two upward bold arrows indicate when a human measures each cat in each run. The first time is when a cat is penned into the diabolical device (time 0) and the second time is at 1 hour, near the middle of the approximate 2 hour range of the distribution. These two measurements are made using a measurement instrument calibrated to a one hour time unit (e.g., a timer which sounds at one hour).

Each cat's actual time of death is shown as a point on the curves in Fig. 1, but is only measured with a precision of +/- one hour. The actual time of death occurs over the two hour range. The two measurement results identify that in half the runs the cat is still alive when measured at 1 hour, and in half the runs the cat is already dead at 1 hour.

This thought experiment is perplexing because the measurement unit (one hour) determines the precision (+/- one hour) which is similar to the approximate two hour range of the maximum distribution. Half the cats, when measured at one hour, are alive. And half, when measured at one hour, are dead, but not the same cats. What Schrödinger has described is an imprecise measurement process.

Consider Fig. 2, which changes Schrödinger's statement, "If one has left this entire system to itself for an hour,...", to 10 minutes (time unit). Now the human's measurements occur every 10 minutes (10 minutes = 1/6 factor of the one hour unit standard) which is a more precise calibration relative to the two hour distribution. Then the measured time of death occurs within +/-10 minutes (precision) of the actual time of death. Dividing the time unit (one hour) into even smaller states increases the precision of the measurement result of each cat's time of death.

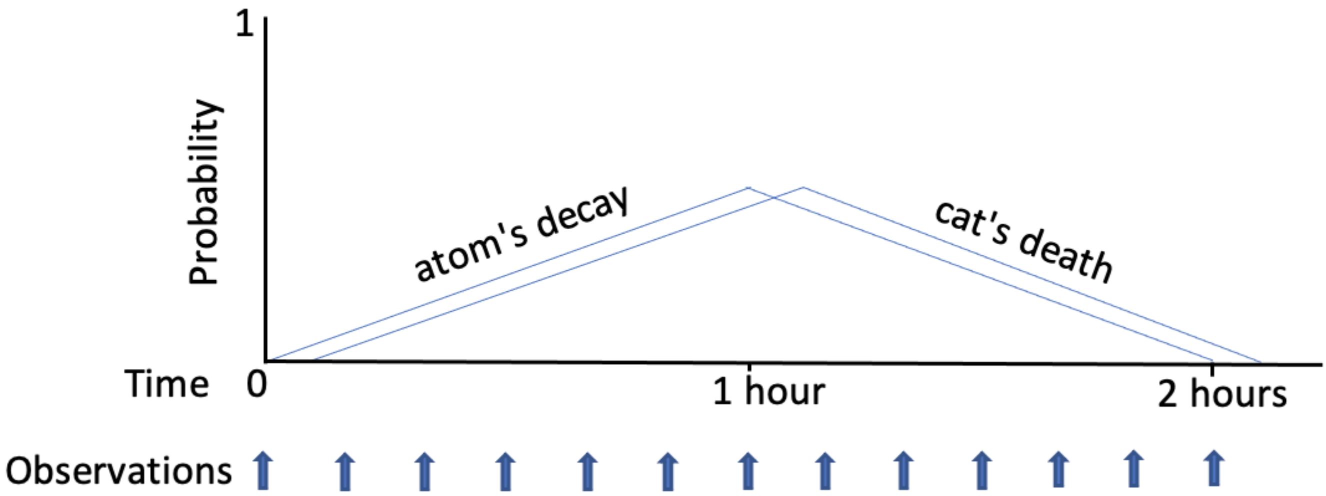

Fig. 2. After recalibration, when Schrödinger's cats die.

Fig. 2 illustrates that in Schrödinger's thought experiment, the measurement result precision is determined by the time interval between the human observations. In all physical measurements the precision of a measurement instrument's interval is determined by the calibration of the interval. A calibration process divides each measurement instrument interval (which is often determined to be a unit standard or factor thereof) into a number of equal value states determining the number of states in each interval relative to a defined standard unit. A precise measurement result (i.e., precision smaller than a unit) of an observable in units, in theory or experment, can only be produced by a measurement instrument calibrated into smaller states than a unit.

Thus, Schrödinger's experiment actually identifies that when calibration is imprecise, a single measurement result is also imprecise. However, calibration in current physics theory is treated as an experimental process that only improves the precision of a physical measurement instrument.[iii] This treatment asumes each unit can be exact in theory, which ignores

Heisenberg uncertainty.[iv]

The ψ function represents a superposition of all the atom's decays and each of many cats' time of death, in a continuous vector space. However, a single cat's time of death (a physical reality) occurs in a quantized vector space. Schrödinger's experiment illustrates that the states of a quantized vector space are defined by calibration. This suggests that correlating the states defined by calibration with the stationary states of a quantum measurement will improve the understanding of all measurement systems.

Notes

[i] An earlier version of this paper (without the figures) appeared on the blog ScienceX June 17, 2020. https://sciencex.com/news/2020-06-schrdinger-cat.html?utm_source=nwletter&utm_medium=email&utm_campaign=daily-nwletter

[ii] E. Schrödinger, "The Present Situation in Quantum Mechanics". First published in German in Naturwissenschaften 23, 1935. This translation (J. D. Trimmer) first appeared in the *Proceedings of the American Philosophical Society*, 124, 323–38 (1980). This paragraph is the complete information Schrödinger supplied on this thought experiment.

[iii] D. H. Krantz, R. D. Luce, P. Suppes, A. Tversky,*Foundations of Measurement*, Academic Press, New York, 1971, Vol. 1, page 32. “The construction and calibration of measuring devices is a major activity, but it lies rather far from the sorts of qualitative theories we examine here”.

[iv] K. Krechmer. (2023). Quantum Mechanical and Classic Measurement Result Quantities are Equal (Even though their Numerical Values are Not). Qeios. doi:10.32388/AOXTC5. A formal measurement function which includes uncertainty is developed in this preprint.