

# Schrödinger's Cats Superposition and Measured Time<sup>1</sup>

by

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*Abstract: The wave equation in quantum mechanics represents a superposition all the probabilities of an atom's time of decay. Schrödinger's thought experiment creates a one-to-one correlation between each different atoms' time of decay and each cats' time of death. Fig. 1 relates the quantum superposition of all the probable states of atoms/cats to the individual observations of each cat's death which form a time distribution.*

*Fig. 1 also identifies that observing the cats once at one hour is very imprecise. The distribution of dead cats may be seen as a cumulative linear distribution centered at one hour. With each observation in the middle of a +/- one hour distribution (the measurement scale's precision is +/- one hour), all that is known is: in half the observations a cat is dead and in half the observations a cat is alive, but not the same cats. This is the maximum possible imprecision in this 2 hour experiment. This imprecision causes a single cat to appear to be both alive and dead, a paradox. This paradox disappears and the concept of a measurement scale's precision becomes clearer, when the scale's precision is increased by observing each cat every 10 minutes.*

## Schrödinger's Cats Superposition and Measured Time

Background on Schrödinger's cat from Wikipedia<sup>2</sup>: "Fundamentally, the Schrödinger's cat experiment asks how long quantum superpositions last and when (or *whether*) they collapse [into experimental measurement results]. Different interpretations of the mathematics of quantum mechanics have been proposed that give different explanations for this process, but Schrödinger's cat remains an unsolved problem in physics." This paper presents a metrology interpretation of the quantum measurement process which offers a resolution to this problem and others.

Schrödinger's complete description of his thought experiment:<sup>3</sup>

"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  $\psi$  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."

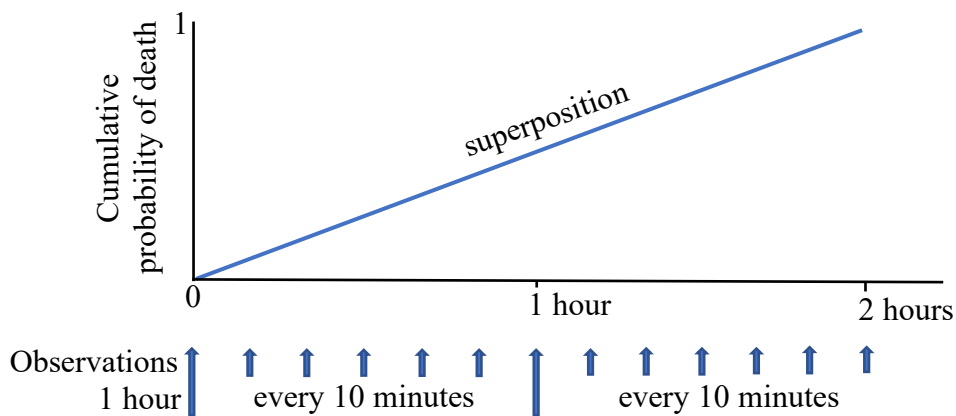


Fig. 1 When Schrödinger's cats die.

In quantum mechanics, the wave ( $\psi$ ) function of an atom, a superposition of all of an atom's states in Hilbert space, is a complete description of the atom's decay. Fig. 1 relates this superposition of probabilities (the  $\psi$  function) to the distribution of the physical states of different atoms/cats which occur over time. A metrology measurement result of the physical state of one atom/cat consists of a numerical value (in Schrödinger's example the binary representation of alive or dead) and a time interval (in his example an hour).

In each experimental run of Schrödinger's diabolical device another atom decays and another unfortunate cat dies with a one-to-one correlation. In Schrödinger's thought experiment, an atom in each

run has a 0.5 probability of decaying after one hour. Then the  $\psi$  function of the experimental system (a cumulative distribution function) could produce the diagonal line shown in Fig. 1 (completely uniform events) or it might produce other probability distributions. As Schrödinger recognized, considering different probability distributions does not significantly change his thought experiment.

Each experimental run ends with one cat's death. A very large number of experimental runs produce the distribution (diagonal line) which is also the  $\psi$  function's superposition. This distribution of experimental run results is a cumulative distribution of completely uniform events which assumes the maximum distribution time is twice the 0.5 probability distribution time (i.e., a linear distribution). Again, assuming the maximum distribution to be longer or shorter than 2 hours does not significantly change the thought experiment.

At the bottom of Fig. 1 the two long bold upward arrows indicate when a human observes 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 one hour, the middle of the two hour range of the distribution. Each cat's actual time of death is one point on the diagonal line, but is only observed with a precision of  $\pm$  one hour.

This thought experiment is paradoxical because the one hour time interval is the same as the measurement's precision ( $\pm$  one hour). With just the two human observation times all that is known is: half the cats, when observed at one hour, are alive. And half, when observed at one hour, are dead, but not the same physical cats.

Consider changing Schrödinger's statement, "If one has left this entire system to itself for an hour,...", to 10 minutes. Then the short bold arrows at the bottom of Fig. 1 represent eleven additional observations. Now the human's observations occur every 10 minutes (10 minutes, or a 6x increase in the scale's precision). Then the observed time of death occurs within  $\pm 10$  minutes of the actual time of death. Dividing the 10 minute reference units into even smaller, but still equal units, further increases the precision of each measurement of each cat's time of death.

In metrology, an observation becomes a measurement when the results are a numerical value (with an accuracy) which is the sum of a set of intervals (with a precision). Each interval represents a unit (e.g., one hour) on a measurement instrument's scale. The precision of each interval of a scale is determined by calibration which, most rigorously, divides each interval into smaller calibration resolution intervals and compares each interval of a scale to a unit reference/standard or factor thereof, which is exact. Then the precision of each interval of the measurement scale is defined, i.e., the intervals have in practice and the units represented as intervals on the scale each have in theory, a  $\pm$  precision determined by the smallest calibration resolution. It is often considered good metrology practice for calibration resolution to be  $< 1/10$  of the minimum measurement scale's interval.

Thus, Schrödinger's thought experiment in metrology identifies that without dividing the human's observation intervals into smaller intervals relative to the hour interval, a measurement of the cat's state (alive or dead) is not valid. However, in Representational Measurement Theory<sup>4</sup> (RepMT) calibration is treated as an empirical process (does not exist in theory) that only adjusts an experimental measurement instrument's intervals precisely enough for the measurement in practice. Schrödinger's cat paradox identifies that the precision of a measurement instrument's scale always has an effect on measurement results.

In RepMT (therefore all of physics), each interval of the scale of a measurement instrument is assumed to be equal to the next. This cannot be valid in theory without additional comparisons (i.e., calibration) and certainly is not valid in metrology. In metrology only the reference/standard is exact (perfect precision), not the intervals of a measurement instrument scale. The intervals of a scale become closer to equal ( $\pm$  precision) only by calibration. Each interval must be divided into calibration resolution intervals and correlated to a reference/standard to determine the  $\pm$  precision of each interval of the measurement instrument's scale.

RepMT (without calibration) incorrectly assumes the intervals of a scale are equal in theory, which incorrectly assumes the correlation between each interval and a reference/standard unit or factor thereof can be perfect in theory. Both assumptions ignore Heisenberg uncertainty in quantum mechanics. Although Heisenberg uncertainty is a very small measurement change, it is significantly increased by the effects of the Central Limit Theorem (CLT).<sup>5</sup> CLT identifies that repetitive measurement results of an unchanged observable expand into a normal distribution independent of noise (external) or distortion (internal) of a measurement system.<sup>6</sup>

Especially when the numerical value is two (e.g., particle spin up or down) and the size of the measurement scale's intervals are small (e.g., many quantum measurement experiments), repetitive experimental measurement results (numerical value and interval representing a unit) of an unchanged observable likely will not be the same (and therefore do not commute) because the measurement results are imprecise in the same manner as in Schrödinger's thought experiment.<sup>7</sup> The inclusion of calibration in a new measurement theory<sup>8</sup> resolves these differences (i.e., measurement problems) between quantum and classical measurements.

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<sup>1</sup> An earlier version of this paper appeared on the blog ScienceX June 17, 2020. [https://sciencex.com/news/2020-06-schrödinger-cat.html?utm\\_source=nwletter&utm\\_medium=email&utm\\_campaign=daily-nwletter](https://sciencex.com/news/2020-06-schrödinger-cat.html?utm_source=nwletter&utm_medium=email&utm_campaign=daily-nwletter). Other versions appear on the preprint site Qeios.com.

<sup>2</sup> Wikipedia (Nov 29, 2023) [https://en.wikipedia.org/wiki/Schr%C3%B6dinger%27s\\_cat](https://en.wikipedia.org/wiki/Schr%C3%B6dinger%27s_cat)

<sup>3</sup> 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 his thought experiment.

<sup>4</sup> D. H. Krantz, R. D. Luce, P. Suppes, A. Tversky, *Foundations of Measurement*, Academic Press, New York, 1971, Vol. 1, page 32. This three volume set is considered the foundational work on Representational Measurement Theory. "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".

<sup>5</sup> A. Lyon, Why are Normal Distributions Normal? *British Journal of the Philosophy of Science*, 65 (2014), 621–649.

<sup>6</sup> K. Krechmer, The Measurement of Superpositions, Feb. 2026, preprint available at:

<https://www.qeios.com/read/SH5D0Z.2>. Section 5.3 formally develops the cause of normal distributions.

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<sup>7</sup> K. Krechmer, Measurement Mechanics, August 2024, preprint on Qeios <https://www.qeios.com/read/EFJP80>. Section 10 provides full explanations of different measurement problems.

<sup>8</sup> K. Krechmer, Relative measurement theory (RMT), Measurement, 116 (2018), pp. 77-82. This paper formally developed the relationship between measurement precision and Heisenberg's uncertainty.