

Schrödinger's cat explained

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Cartoon. Credit: Bill Proud (used with permission)

In 1935, E. Schrödinger proposed his well-known cat thought experiment suggesting, but not explaining, how a measurement transforms the probable states of an atom into the actual state of a cat (alive or dead). Rather than applying quantum mechanics (the previous approach usually taken), I offer an out-of-the-box, logically consistent explanation using metrology (the science of physical measurement).

In formal quantum mechanics, an atom (or other entity) is in a superposition, or probabilistic combination of all possible states. In this widely accepted view, each state is possible and no state is actual until a measurement occurs. How does a measurement change multiple probable states into one actual state? E. Schrödinger's tongue-in-cheek thought experiment explores this by proposing a comparison of an atom's quantum superposition to the physical measurement of a cat's state.

The following is all the information Schrödinger provided on his thought experiment: "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."

Schrödinger's experiment first appears to contrast the two distributions, the probabilistic time distribution of an atom's state and a cat's binary state (alive or dead) by correlating two observations (measurements): an atom's decay and a cat's death. In fact, by virtue of the apparatus, the actual time of each cat's death is a fixed time after the time of an atom's decay (due to the "diabolical device"). Schrödinger proposed the mean time of each of these equal but time-shifted distributions as one hour. With a mean time of one hour the maximum extent of every cat's actual time of death, distribution is estimated to be two hours.

Next, Schrödinger proposed one observation of the cat's state by a human at one hour. This is a one-time observation of a third distribution, the observed state of one cat over time. This may be compared with the cat's actual state (second distribution). This comparison is more interesting, as it appears to describe the measurement of a cat's state.

L. Euler defines all measurements as relative: "It is not possible to determine or measure one quantity other than by assuming that another quantity of the same type is known and determining the ratio between the quantity being measured and that quantity." The accuracy of each human observation of a cat is adjusted by calibration that correlates the measuring apparatus intervals (in this experiment, the time between observations) to a time reference (e.g., one second). This time reference is a non-local intermediate required to maintain Euler's relative quantity ratios.

The third distribution of each cat's observed time of death is correlated both to the actual time of death and to how often the human observes the cat (i.e., the time between human observations). In Schrödinger's experiment this time between observations is given as one hour. Then the accuracy of this one observation is +/- one hour relative to any possible cat's actual time of death (about a two-hour span).

When the times proposed (both one hour) are applied, the third distribution of the time between observations is uncorrelated to the first distribution of the atom's decay time. This occurs because the accuracy +/- one hour of the time between observations is close to as wide as an atom's decay distribution (two hours). This thought experiment, as presented, is two equal but time-shifted distributions of the atom's decay and cat's actual death (one ψ function) and one uncorrelated human observation (a different function). However, this experiment has drawn interest for 85 years because physical reality does not allow for the cat's state to be a superposition. What is missing?

The first human observation of a dead cat after an observation of life is measured in time relative to the beginning of the experiment (alive cat). These observations of the time of death identify that the distribution over multiple experiments is correlated with the ψ function of an atom's probabilities and that the state of each cat is binary. The actual time of death and the observed time of death are different. Because the observed time of death is also correlated to the time between observations and the time reference defined.

Consider the experiment when the observer (or measuring apparatus) counts the number of times the cat is examined. These observations result in a sequence of alive states ended by one dead state during the about two-hour maximum time to complete one experiment. Counting this sequence of alive observation generates a magnitude, but not a measurement correlated to a physical reference as Euler requires. Such a measurement requires defining and controlling the time between observations, which requires the calibration of the observer/measuring apparatus to a time reference.

As an example in Schrödinger's experiment, calibration would be setting and maintaining the time between observations to 10s (s = second, the time reference). Then the maximum variation of the observed time of death correlated to the actual time of death is $\pm 10s$ (i.e., accuracy). The count of observations is uncorrelated to any reference, and therefore not a relative measurement as Euler defined. Applying calibration, this count changes into a sum of the counted time between observations, where each time between observations is correlated to a time reference (second).

Calibration is required to observe a cat's time of death (i.e., a relative measurement). Schrödinger was correct—there is one ψ function of both the atom and the actual cat's state. But there is also a relative measurement including calibration to a reference which produces the

observed cat's state. A relative measurement, which is physical reality, exists only when the second function occurs. Since quantum mechanics does not treat a reference, it cannot represent a relative measurement. Without a relative measurement, the most we can see are the probabilities of a superposition.

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More information: 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).

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