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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 fully understood, that appears in quantum mechanics when a measurement process occurs. The 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 treated in physics theory. This paper illustrates how calibration to a non-local time standard explains the alive and dead appearance of Schrödinger's cats.

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."*

The operation of Schrödinger's thought experiment includes 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 causes 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. This system, as shown by the two hat shaped (^) curves in the figures, is represented by one ψ (wave) function. 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.

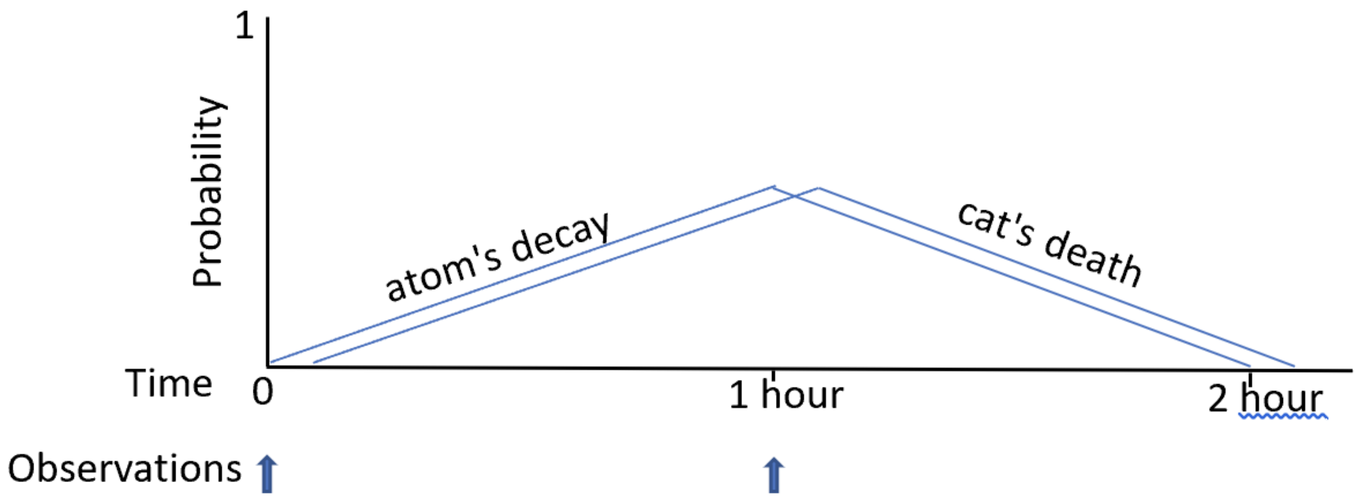

Fig. 1. When Schrödinger's cats die.

Each experimental run establishes one point representing one atom's decay time and one point representing one cat's time of death. Many experimental runs produce the two parallel, offset and hat shaped curves as shown in Fig. 1. At the bottom of Fig. 1 the upward bold arrows indicate the two times when a human observes each cat in each run. 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.

What the experimental runs establish and what is observed are quite different. There are two human observations of each cat's property, the first when a cat is penned into the diabolical device (time 0) and the second time at 1 hour, near the middle of the approximate 2 hour range of the distribution. These two observations represent an imprecise time measuring 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 observed with a precision of +/- one hour. The actual time of death occurs over the two hour range. The two observations only identify that in half the runs the cat is still alive when observed at 1 hour, and in half the runs the cat is already dead at 1 hour.

This thought experiment is perplexing because the measuring unit (one hour) determines the precision (+/- one hour) which is equal to the approximate two hour range of the distribution. Half the cats, when observed at one hour, are alive and half, when observed 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 observations occur every 10 minutes (10 minutes = 1/6 factor of the one hour time unit) which is a more precise calibration relative to the two hour distribution. Then the observed time of death occurs within +/-10 minutes (precision) of the actual time of death. Dividing the time standard (one hour) into smaller states increases the precision of the measurement result of each cat's time of death.

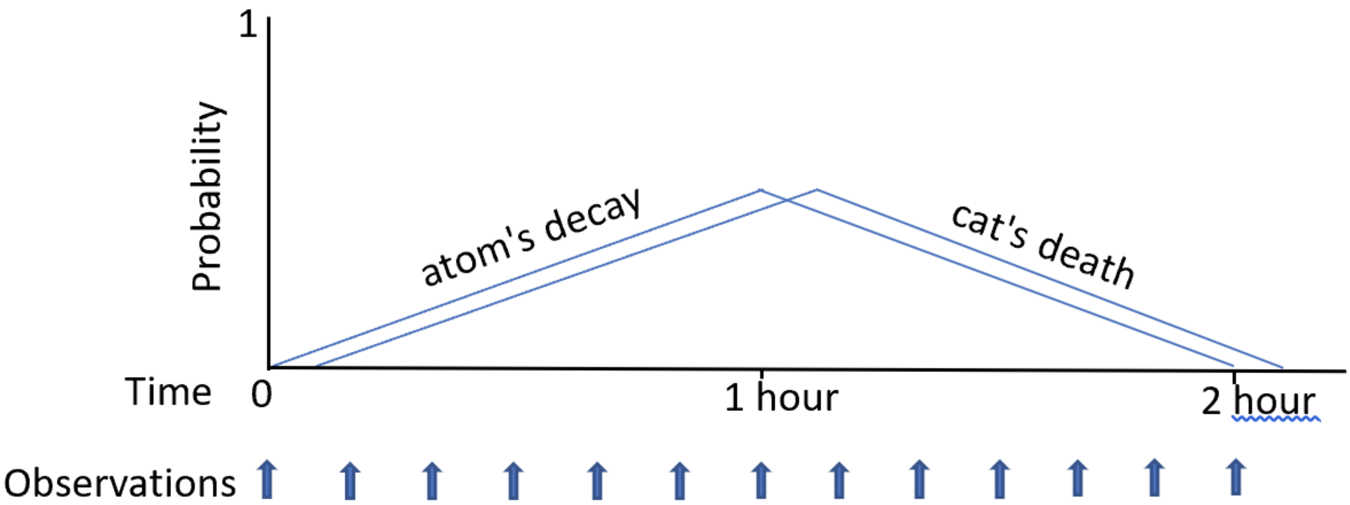

Fig. 2. After recalibration, when Schrödinger's cats die.

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 measuring instrument's unit is determined by the calibration of the unit to a standard. A calibration process divides each unit into equal value states and compares the number of states in each unit to a standard or factor thereof (e.g., one hour). Without noise or distortion, the minimum state value set by calibration determines the measuring precision.

Thus, Schrödinger's experiment actually identifies that when calibration is imprecise, the measurement result is also imprecise. Currently, calibration in physics theory is treated only as an experimental process that adjusts a physical measuring instrument.[iii] Treating calibration as empirical is only valid for measurement results where the states established by calibration are considered infinitesimal.

A precise (smaller than a unit) measurement of a observable's property in units, in theory or practice, can only be produced by a measuring instrument calibrated into smaller states than a unit.[iv] The very first calibration process to a standard even defines the property measured (a cat's death, mass, length, time, spin, etc.). As example, the cat's death could be defined as a lack of movement, breathing, or heart beat. The very first calibration process defines which.

Each atom's decay and each cat's property are represented by one ψ function. However, all measurement process also require that the property a measuring instrument measures, occurs in units, which are divided into states defined by calibration to a standard, even the time of death of a cat. This suggests that including calibration in the theory of a measurement may improve the understanding of a measurement process.

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, Relative measurement theory (RMT), *Measurement*, 116, 2018, pp. 77-82.