# Schrödinger's cat in a realist quantum mechanics

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**Abstract.** There is no paradox with Schrödinger's cat in a realist interpretation. In particular, a closer look at the temporal aspect shows that the two macroscopic wave functions (alive and dead) of Schrödinger's cat are not to be compared with two superposed parts of a microscopic quantum wave function.

**Keywords:** Schrödinger's cat, macroscopic states, superposition

In the thought experiment of Schrödinger's cat in the box [1] consider the superposition

$$c_1\psi_1 + c_2\psi_2, \tag{1}$$

where $\psi_1$ is the wave function of the alive and $\psi_2$ that of the dead cat. Actually $\psi_1$ may contain the alive cat together with the undecayed radioactive nucleus and $\psi_2$ the dead cat together with the decayed nucleus, but we neglect this because in our present argumentation it is not essential.

The probability of finding, in a measurement (opening the box), an alive cat is $|c_1\psi_1|^2$ and that of the dead cat $|c_2\psi_2|^2$. So there seems to be no objection to write the wave function of the cat inside the closed box as the superposition (1), where $\psi_1$ and $\psi_2$ are probability amplitudes and (1) is the wave function of neither a dead nor an alive cat but a superposition of both.

Now take the stand of a realist interpretation, where the particles are wavepackets, $\psi$ represents real matter, and reduction (collapse) is independent of measurement [2], [3]. And should the cat die, this occurs during a definite short time interval around, say, $t_0$, even if nobody takes notice of it. The wavepackets $\psi_1$ and $\psi_2$ here represent still the same cat (either definitely alive or definitely dead) but *at different times*: $\psi_1$ before $t_0$, $\psi_2$ after $t_0$. The superposition (1) then superposes the same real object at different times. If we accepted this we would also have to accept the superposition of an electron wavepacket of today with the same packet of tomorrow. Such a superposition is however nowhere met, *not even for microscopic objects*, in the formalism of quantum mechanics, independent of the particular interpretation adopted. The less it can justify the superposition (1) of the macroscopic cat wavepackets.

What is considered in the $\gamma$ emission process of the radioactive nucleus is the transition amplitude $T = \Big(\phi_2(t_2),\, U(t_2,t_1)\phi_1(t_1)\Big)$, in which $U(t_2,t_1)\phi_1(t_1)$ means the wavepacket $\phi_1(t_2)$ at the time $t_2 > t_1$, after its unitary temporal development from $t_1$ to $t_2$, and $T$ includes the reduction of $\phi_1(t_2)$ to $\phi_2(t_2)$. There is no superposition of $\phi_1(t_1)$ and $\phi_2(t_2)$ as they stand [4], [5].

The decay of the nucleus releases the poison and initiates a process in the cat which ends with its death. This process can in principle be described by the (many-particle) Schrödinger equation plus possible 'internal' reductions among the wavepackets representing the atoms etc. that make up the cat's body [2, Chap. 3].

This is quite different from cases like the Stern-Gerlach experiment. There, a hydrogen atom passes through an inhomogeneous magnetic field, and its wave function is fanned out into a superposition of two spatially separated parts, a spin-up part and a spin-down part. The parts reach the screen beyond the magnetic field at the same time, and there the superposition is reduced to one part only. In the Copenhagen view one then compares the spin up part with the alive and the spin down part with the dead cat, and the reduction in the screen with the opening of the cat's box. In realism the difference to the cat wave functions is, however, that both atom wave functions together represent the atom *at the same time.*

Thus, although the superposition (1) for the cat is rejected in a realist interpretation, this does not mean that there is no superposition at all of wavepackets representing macroscopic objects. The restriction is that these wavepackets must represent something that really exists *at the same time.* Examples can be seen in [6]. Ref. [7] reports on molecules of $1.7 \times 10^{-23}$ kg ($\approx 10^4$ protons) and 5 nm diameter that pass through gratings with slit separation (period) of 266 nm, where interference effects between the parts coming from different slits are indeed observed. Experiments with even larger objects are under way [6], though one difficulty of observing interferences with ever greater objects, such as the cat as a whole, is the increasing importance of environmental decoherence.

## References

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