Killing Schrödinger's Cat:
Why Macroscopic Quantum Superpositions Are Impossible In Principle

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The Schrodinger's Cat and Wigner's Friend thought experiments, which logically follow from the universality of quantum mechanics at all scales, have been repeatedly characterized as possible in principle, if perhaps difficult or impossible for all practical purposes. I show in this paper why these experiments, and interesting macroscopic superpositions in general, are actually impossible in principle. First, no macroscopic superposition can be created via the slow process of natural quantum packet dispersion because all macroscopic objects are inundated with decohering interactions that constantly localize them. Second, the SC/WF thought experiments depend on von Neumann-style amplification to achieve quickly what quantum dispersion achieves slowly. Finally, I show why such amplification cannot produce a macroscopic quantum superposition of an object relative to an external observer, no matter how well isolated the object from the observer, because: the object and observer are already well correlated to each other; and reducing their correlations to allow the object to achieve a macroscopic superposition relative to the observer is equally impossible, in principle, as creating a macroscopic superposition via the process of natural quantum dispersion.

I. INTRODUCTION

Setting aside that Schrodinger himself introduced his hypothetical cat specifically to point out the absurdity of treating his linear, deterministic equation as applying universally, there is no shortage of academic literature that treats Schrodinger's Cat (and its conscious cousin, Wigner's Friend) as possible in principle, even if difficult or impossible for all practical purposes [1, 2, 4–16].

The reasoning goes something like this: over the past century, the "size" of quantum superpositions (both in coherence length and mass of the object) produced in laboratories has increased; extrapolating into the future, interesting macroscopic superpositions may eventually be produced, subject only to technological limitations. And while there are good reasons to be skeptical of such optimism, the possibility does not seem to have been ruled out yet. Pedagogically, the Schrodinger's Cat and Wigner's Friend thought experiments have been disastrous, doing little to solve the measurement problem or address the "Heisenberg cut" that separates the quantum and classical worlds and leaving untold numbers of physics and philosophy students wondering what it would feel like to experience a superposition of being dead and alive, or of having multiple distinct mental states. Worse, as thought experiments designed to elucidate quantum mechanics, they have succeeded only in further obfuscation.

It's time to kill the cat.

I will argue in this paper that the Schrodinger's Cat ("SC") and Wigner's Friend ("WF") experiments are impossible *in principle*. Both experiments posit the creation of quantum superpositions[1] of macroscopic objects in very different states. It is known that a macroscopic superposition would very quickly decohere into a probabilistic mixture due to unavoidable interaction with fields, photons, and other particles in the surrounding environment [1, 2]. Because the decoherence time for massive objects is always significantly shorter than the amount of time necessary to produce such a superposition via wave packet dispersion, the viability of the SC/WF thought experiments depends on whether a macroscopic superposition could be quickly created by amplification of a quantum object. The purpose of this paper is to show why such an amplification does not render these experiments possible, even in principle.

[1] Since it can be argued that all measurements are fundamentally of position, I will, in this analysis, discuss superpositions in the position basis without loss of generality.

II. QUANTUM SUPERPOSITIONS

A. Facts vs. Knowledge

In a Young's double-slit interference experiment, if an object traversing the two slits is spatially coherent over a width larger than that spanning those slits, and if no other object in the universe (such as a particle) gets correlated (i.e., entangled) with its passage via one slit or the other, then the later detection of that object can be predicted probabilistically using the rules of quantum mechanics, which depend on interference between quantum wave states. However, if a particle does get correlated with passage of the object via one slit or the other, then the later detection of that object can be predicted with the rules of *classical* probability, even if the correlated particle is reflected by the object toward black space and is irretrievable.

To rephrase: whether or not there is a fact about the object's passage through one slit or the other, as embedded in correlation(s)/entanglement(s) with other object(s) in the universe, manifests itself in different rules for making probabilistic predictions. In the first case, the lack of a fact about the object's passage through one slit or the other means that the object was in a superposition over the slits. This situation manifests itself in the application of quantum probability rules – i.e., the combination of complex amplitude fields *prior* to determining the probability distribution by taking the square of the norm of the combined fields. In sharp contrast, in the second case, the existence of a fact about the object's passage through one slit or the other means that the object was not in a superposition over the slits. This situation manifests itself in the application of classical probability rules, even if the object's later detection location is not correlated to (and thus provides no information about) which slit it traversed. In other words, in the second case, a fact exists about which slit the object traversed, embedded in the object's correlation with the particle, whether or not anyone knows or could know that fact. That is, interaction with a particle at the slits decoheres the object's previously coherent quantum waves so that they no longer interfere, and the resulting detection distribution will simply be the classical result: the sum of the distribution resulting from passage via one slit with the distribution resulting from passage via the other slit.[2]

In a very real sense, quantum mechanics is fundamentally about making probabilistic predictions that depend on whether interference effects from terms in a coherent superposition are relevant. Like all probability rules, a statistically significant ensemble is necessary to obtain useful information. A measurement on any object will always yield a result that is consistent with that object's not having been in a superposition; only by measuring many identically prepared objects may the presence of a superposition appear in the form of an interference pattern. So whether a particular object is, in fact, in a superposition of states may not be knowable by subsequently measuring it.

Knowable or not, whether a superposition exists is indeed a question of fact – it either does or does not exist. Consider an object A that is well correlated in location to an object B; in other words, relative to object A, there is a fact about the location of object B (within some tolerance, of course) and object B is not in a location superposition relative to object A. (Conversely, relative to object B, there is a fact about the location of object A and object A is not in a location superposition relative to object B.) Object A may be well correlated to object B whether or not object A "knows" the location of B or can perform an interference experiment on an adequate sampling of identically prepared objects to show that object B is not in a location superposition relative to object A. The means by which objects A and B became well correlated is irrelevant, but may be due to prior interactions with each other and each other's fields (electromagnetic, gravitational, etc.), mutual interaction with other objects and their fields, and so forth. Now consider an object C that is well correlated in location to object B; object C must also be well correlated to object A. That is, if object C is not in a location superposition relative to object B, then it is not in a location superposition relative to object A, whether or not object A "knows" anything about object C or can perform an interference experiment to test whether object C is in a location superposition relative to object A.

B. Creating a Superposition

Nature – thanks to the Heisenberg Uncertainty Principle – creates superpositions ubiquitously. Quantum uncertainty, loosely defined as $\Delta x(m\Delta v) \geq \hbar/2$, guarantees dispersion of quantum wave packets, thus increasing the size of location superpositions over time. However, interactions with fields, photons, and other particles ever-present in the universe constantly "measure" the locations of objects and thus decohere these superpositions into probabilistic mixtures [1, 2]. This decoherence explains both why we don't observe superpositions in our normal macroscopic world and also why visible interference patterns from quantum superpositions of non-photon objects[3] are so difficult to create.

For instance, let's consider the non-trivial process, first performed in 1927, of producing an electron in superposition state $\frac{1}{\sqrt{2}}(|A\rangle + |B\rangle)$, where $|A\rangle$ is the wave function of the electron traversing slit A while $|B\rangle$ is the wave function of the electron traversing adjacent slit B in a double-slit plate. Electrons, one at a time, are passed through (and thus localized by) an initial collimating slit; quantum uncertainty results in dispersion of each electron's wave state at a rate inversely proportional to the width of the collimating slit. If the process is designed so that adequate time elapses before the electron's wave function reaches the double-slit plate, and without an intervening decoherence event with another object, the electron's wave will be approximately spatially coherent over a width wider than that spanned by both slits. If the electron then traverses the double-slit plate, its wave function becomes the superposition $\frac{1}{\sqrt{2}}(|A\rangle+|B\rangle)$. If each electron is then detected at a detector located sufficiently downstream from the double-slit plate, again without an intervening decoherence event with another object, the

[2] Assuming that the particle's interaction with the object does not correlate the object to a particular location *within* a slit, the distribution resulting from the object's passage via that slit (a Fraunhofer distribution in the far field) is itself the result of quantum mechanical dispersion of the object's wave function *a la* quantum uncertainty.

[3] Interference effects of photons are actually quite easy to observe in part because photons do not self-interact and thus are not decohered by other radiation. Prior to the invention of lasers, a dense source of coherent photons, which confirmed light's wave-like behavior, came directly from the sun.

spatial probability distribution of that electron's detection will be calculable consistent with the lack of a fact about which slit the electron traversed. This lack of "which-slit" information in the form of decohering correlations with other objects in the universe means that the electron's superposition coherence was maintained, and thus the rules of quantum mechanics (and not classical probability) would apply to probability distribution calculations.[4]

Because the dispersion of an object's wave function is directly proportional to Planck's constant and inversely proportional to its mass, the ability to demonstrate the wave-like behavior of electrons is in large part thanks to the electron's extremely small mass. The same method of producing superpositions – waiting for quantum uncertainty to work its magic – has been used to produce location superpositions of objects as large as C_{60} molecules [3]. However, the more massive the object, the slower the spread of its wave function and the more time is available for an event to decohere any possible superposition.

C. Creating a *Macroscopic* Superposition

Consider the difficulty in performing a double-slit interference experiment on something as tiny as a dust particle.[5] Let's assume that it is a $50\mu m$ diameter sphere with a density of $1000kg/m^3$ and an impact with a green photon ($\lambda \approx 500nm$) has just localized it. How long will it take for its location "fuzziness" to exceed its own diameter (which would be the absolute minimum spatial coherence allowing for passage through a double-slit plate)? Letting $\Delta v = \hbar/2m\Delta x \approx 10^{-18}m/s$, it would take 5x$10^{13}$ seconds (about 1.5 million years) for the location uncertainty to reach a spread of $50\mu m$.[6] In other words, if we sent a dust particle into deep space, its location relative to other objects in the universe is so well defined due to its correlations to those objects that it would take over a million years for the universe to "forget" where the dust particle is to a resolution allowing for the execution of a double-slit interference experiment.[7] In this case, information in the universe would still exist to localize the dust particle to a resolution of around $50\mu m$, but not less. Unfortunately, this rough calculation depends on a huge assumption: that new correlation information isn't created in that very long window of time. In reality, the universe is full of particles and photons that constantly bathe (and thus localize) objects.

Thus there is a trade-off in the delocalization caused by natural quantum dispersion and localizing "measurements" caused by interactions with the plethora of stuff whizzing through space. This trade-off is heavily dependent on the size of the object; a tiny object (like an electron) disperses quickly due to its low mass and experiences a low interaction rate with other objects, allowing an electron to more easily demonstrate interference effects. On the other hand, a larger object disperses more slowly while suffering a much higher interaction rate with other objects. These observations can be quantified in terms of coherence lengths: for a particular decoherence source acting on a particular object, what is the largest "fuzziness" we might expect in the object's center of mass? And, if we're hoping to do a double-slit interference experiment, does this fuzziness exceed the object's diameter?

Ref. [1] calculates coherence lengths (roughly "the largest distance from the diagonal where the spatial density matrix has non-negligible components") for a $10\mu m$ dust particle and a bowling ball caused by various decoherence sources, as shown in Table I. Even in deep space, cosmic microwave background ("CMB") radiation alone will localize the dust particle to a dimension many orders of magnitude smaller than its diameter, thus ruling out any possibility for that object to become adequately delocalized relative to the universe to perform an interference experiment. The prospects are far worse for a bowling ball-sized cat. The question is not whether a macroscopic quantum superposition could arise through the natural dispersion of quantum uncertainty – it can't, not even in principle. Instead, the question is whether a macroscopic quantum superposition could be created quickly through *amplification*.

TABLE I. Some values of coherence lengths for a $10\mu m$ dust particle and a bowling ball caused by various decoherence sources, given by [1].

Decoherence source	$10\mu m$ dust	Bowling ball
300K air @ 1 atm	$10^{-17}m$	$10^{-21}m$
300K air in lab vacuum	$10^{-13}m$	$10^{-18}m$
Sunlight on Earth	$10^{-12}m$	$10^{-17}m$
300K photons on Earth	$10^{-12}m$	$10^{-16}m$
CMB radiation	$10^{-8}m$	$10^{-14}m$
Solar neutrinos	n/a	$10^{-13}m$

It is often claimed that quantum mechanics is universally applicable at all scales – i.e., so-called "reduction" or "collapse" of the wave function when a microscopic

[4] Indeed, the existence of "which-slit" information – that is, the existence of a correlating fact about the passage of the electron through one slit or the other – is incompatible with existence of a superposition at the double-slit plane.

[5] The word "macroscopic" has been abused in the literature, with the phrase "Schrodinger Cat-type" state often applied to "mesoscopic" objects that are much smaller than what is visible with the naked eye. The purpose of this paper is to address the in-principle possibility of an actual cat or person in a superposition state, so as a bare bones requirement a "macroscopic" object is one that can be seen with the naked eye, such as a dust particle.

[6] Macroscopic systems tend to be in "nearly minimum uncertainty states." [1]

[7] This estimate completely neglects the additional time necessary to subsequently measure an interference pattern.

quantum object interactions with a macroscopic measuring device is only apparent.[8] The claimed universality of quantum mechanics implies that the interaction of one system, in quantum superposition, with another system entangles them to produce a composite quantum superposition. The size of this superposition then gets amplified in a "von Neumann chain" indefinitely so that the eigenstates of the original superposition get correlated to much larger macroscopically distinct eigenstates of the composite system. Thus, if quantum mechanics is truly universal, then amplification of a microscopic superposition should produce a macroscopic superposition, predictions on which should be governed by the rules of quantum mechanics, not classical probabilities. In other words, the purported universality of quantum mechanics allows quantum amplification to speed up the prohibitively slow natural growth of quantum uncertainty.

Imagine an observer who wants to measure an object's quantum state in some basis $\{|n\rangle\}$. The object's initial quantum state $|\Psi^{obj}\rangle$ can be written as a superposition over eigenstates in that basis, so that $|\Psi^{obj}\rangle = \sum c_n |n\rangle$, with c_n as complex amplitudes. Assuming the measurement apparatus is set up properly – i.e., it is designed to actually indicate to the observer an outcome corresponding to measurement of the object in the chosen basis – then a series of events must occur to entangle the object with elements of the measurement apparatus. This is broadly called "amplification" because the causal chain tends to grow in size so that the end state of the measurement apparatus is some large "macroscopic" state that the observer can then observe. If we let the quantum state of the measurement apparatus be written as a causal chain of K intermediary systems $|\Psi^{(i)}\rangle$, with $\left|\Psi_0^{(i)}\right\rangle$ being its initial state and $\left|\Psi_n^{(i)}\right\rangle$ being a state (often called a "pointer" state if macroscopic) that correlates to state $|n\rangle$ of the quantum object, and if we let the state of the observer be written as $|\Psi^{obs}\rangle$, then the universality of quantum mechanics implies that the measurement process will evolve as follows:

$$\begin{aligned}
&\left|\Psi^{obj}\right\rangle \left|\Psi_0^1\right\rangle \left|\Psi_0^2\right\rangle \cdots \left|\Psi_0^K\right\rangle \left|\Psi_0^{obs}\right\rangle \\
=\ & \sum c_n |n\rangle \left|\Psi_0^1\right\rangle \left|\Psi_0^2\right\rangle \cdots \left|\Psi_0^K\right\rangle \left|\Psi_0^{obs}\right\rangle \\
\longrightarrow & \sum c_n |n\rangle \left|\Psi_n^1\right\rangle \left|\Psi_0^2\right\rangle \cdots \left|\Psi_0^K\right\rangle \left|\Psi_0^{obs}\right\rangle \\
\longrightarrow & \sum c_n |n\rangle \left|\Psi_n^1\right\rangle \left|\Psi_n^2\right\rangle \cdots \left|\Psi_0^K\right\rangle \left|\Psi_0^{obs}\right\rangle \\
& \vdots \\
\longrightarrow & \sum c_n |n\rangle \left|\Psi_n^1\right\rangle \left|\Psi_n^2\right\rangle \cdots \left|\Psi_n^K\right\rangle \left|\Psi_0^{obs}\right\rangle \\
\longrightarrow & \sum c_n |n\rangle \left|\Psi_n^1\right\rangle \left|\Psi_n^2\right\rangle \cdots \left|\Psi_n^K\right\rangle \left|\Psi_n^{obs}\right\rangle
\end{aligned} \tag{1}$$

In other words, without some sort of physically real wave state collapse event at some point before observation by the observer, the measurement (and ultimate observation) of the quantum object is nothing more than amplification by growing entanglement among interacting systems, the end result being a superposition that includes the measurement device *and* the observer.

While the series of events does take time, it is relatively fast: in less than a second, for instance, the (microscopic) object's state can be amplified to a macroscopic state including the measurement device and observer. Imagine that intermediary system $|\Psi^K\rangle$ has macroscopic "pointer" states that differ in location by something macroscopic, such as 1cm. Of course, a quantum superposition of that system over those pointer states, through natural quantum dispersion, has already been shown to be impossible, even in principle, because the process is far too slow; interactions with objects and fields throughout the universe constantly decohere the superposition and localize the pointer. However, if Eq. 1 is correct, then a microscopic quantum superposition ($|\Psi^{obj}\rangle$) can be amplified to a macroscopic quantum superposition (e.g., $|\Psi^K\rangle$) nearly instantaneously. The claimed universality of quantum mechanics seems to permit a loophole.

Notice also in Eq. 1 that while $|\Psi_n^{obs}\rangle$ corresponds to an observer who reports having measured the quantum object in state $|n\rangle$ (by way of observing $|\Psi_n^K\rangle$, for example), if we consider the system relative to an outside "superobserver" who has not yet observed the observer, the entire system (object + measurement device + observer) is still in a superposition. Only through a decoherence event with the superobserver does the superobserver get entangled with the system.[9] Until that point, if Eq. 1 is correct, the system is still in a superposition, a fact

[8] Evidentiary support for the strictly unitary evolution of quantum wave states comes from the observation that the predictions of quantum mechanics have been extraordinarily accurate even for objects as large as C_{60} molecules. However, this simply is not evidence for the applicability of quantum mechanics at significantly larger scales, which is actually in direct conflict with the empirical observation that the rules of classical probability, *not* quantum mechanics, apply to nearly every aspect of our real-world experience.

[9] There is no "collapse" of the wave function in Eq. 1, nor does the notion of decoherence necessarily require a nonlinear collapse of the wave function. Relative to an observer represented by $|\Psi_n^{obs}\rangle$, the wave state of the system appears to have collapsed into an eigenstate in which the quantum object has been measured in state $|n\rangle$, a phenomenon dubbed "apparent" collapse or reduction. And relative to the superobserver prior to a decoherence event with the system, the wave state of the system is still in superposition. Even when the superobserver does interact (and

that the superobserver should *in principle* be able to confirm through an appropriate interference experiment.[10] Whether such an experiment is actually possible, Eq. 1 implies that the observer is, in fact, in a superposition state, leading uncountably many physics and philosophy students to wonder what such a macroscopic superposition would look like, or even how it might feel to be the observer.

Enter Schrodinger's Cat: a cat is placed in a box in which the outcome of a tiny measurement gets amplified so that one outcome results in a dead cat while the other outcome keeps the cat alive. For example, a Geiger counter measures a radioisotope so that if it "clicks" in a given time period, a vial of poison is opened. Just before we open the box to look, there's been enough time for the poison to kill the cat, so we should expect to see either a live or dead cat. Here's the catch: the "tiny measurement" is on an object that is in quantum superposition, to which the rules of classical probability do not apply.

So does the quantum superposition grow and eventually entangle with the cat, in which case, just prior to our opening the box, the cat is itself in a superposition of "dead" and "alive" states? Or does the superposition, before entangling with the cat, reduce to a probabilistic mixture, such as through a nonlinear collapse of the wave function? If the cat is in a superposition just prior to our opening the box, then there just is no objective fact about whether the cat is dead or alive, and our opening the box is what collapses (or, relative to us, *apparently* collapses) the entangled wave state, allowing the universe to then randomly "choose" a dead or live cat according to the probabilities of the mixed state. However, if the cat is in a mixed state prior to our opening the box, then there is an objective fact about whether it is dead or alive – but we just don't know the fact until we open the box. So the question really comes down to this: do we apply classical probability or quantum mechanics to Schrodinger's Cat? Or: just prior to our opening the box, is Schrodinger's Cat in a coherent superposition or a probabilistic mixed state?

Assume for the moment that a macroscopic SC superposition existed. Of course, it would instantly decohere due to constant measurement by fields and particles. To overcome this shortcoming, one might posit hypothetical isolation around a SC experiment to shield it, at least temporarily, from interactions between the cat and universe that would decohere the cat's superposition by correlating the cat's state with the state of objects external to the isolation.[11] Whether or not it is possible in principle to adequately isolate a SC experiment to prevent immediate decoherence, there is a much bigger problem: how to produce a SC superposition in the first place. Since such a state cannot, even in principle, be produced by the slow growth of quantum uncertainty, could amplification make possible what is otherwise impossible?

III. CAN QUANTUM AMPLIFICATION PRODUCE SCHRODINGER'S CAT?

Consider a SC experiment comprising a box containing cat C, measurement device M, and so forth, the experiment set up by an external superobserver S.[12] At time t_0, the box is thermally and informationally isolated so that no photons or other particles, correlated to other objects in the universe, can correlate to the events inside the box and thus prematurely decohere a quantum superposition. The box has been placed in deep intergalactic space where the spacetime has essentially zero curvature to prevent the possibility that gravitons could correlate to the events inside the box. In general, all possible precautions are taken to prevent premature decoherence of any resulting macroscopic superposition inside the box. When the experiment begins at t_0, a tiny object is in a location superposition $\frac{1}{\sqrt{2}}(|A\rangle + |B\rangle)$, where eigenstates $|A\rangle$ and $|B\rangle$ correspond to locations A and B separated by distance d.

The measurement device M has a macroscopic indicator pointer that is configured to be located in position M_A (e.g., pointing to the letter "A") when the measurement device is in state $|M_A\rangle$ and located in position M_B (e.g., pointing to the letter "B") when the measurement device is in state $|M_B\rangle$. The experiment is designed so that the object remains in superposition until time t_1, when the location of the tiny object is measured by amplification by the measuring device M so that measurement of the object at location A would result in the measuring device evolving to $|M_A\rangle$, while a measurement at location B would result in the measuring device evolving to $|M_B\rangle$. Finally, the experiment is designed so that

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entangle) with the system, the universality of quantum mechanics implies that the superobserver becomes part of the larger superposition, even though individual superobserver eigenstates would report observing that the quantum object has been measured in a particular eigenstate.

[10] This assertion, which pervades the literature on SC/WF, is extremely misleading. First, interference can only be shown by repeating an experiment on identically prepared systems until interference can be confirmed to statistical significance. It is not clear how that could be done, even in principle, for a macroscopic system, and quantum no-cloning prevents the outright copying of quantum states. Second, measuring the composite system of Eq. 1 in a basis correlating to basis $\{|n\rangle\}$ would not allow testing for interference because no measurement result could distinguish the pure state from a probabilistic mixed state. It is not clear that it would be possible, even in principle, to measure the system in a basis that could distinguish them.

[11] It is not clear that this would even be possible in principle, thanks to neutrinos which are notoriously difficult to shield.

[12] An extension of the SC experiment, the WF experiment posits a (presumably conscious) person in a superposition of mental states, in which case superobserver S might be replaced by Wigner W and cat C might be replaced by Wigner's friend WF. While SC is arguably the more well-known thought experiment, the WF experiment adds the interesting dimension of conscious awareness.

location of the macroscopic indicator pointer at position M_A would result, at later time t_2, in a live cat in state $|live\rangle$, while location at position M_B would result in a dead cat in state $|dead\rangle$. Here's the question: at time t_2, is the resulting system described by the superposition $\frac{1}{\sqrt{2}}(|A\rangle|M_A\rangle|live\rangle + |B\rangle|M_B\rangle|dead\rangle)$, or by the mixed state of 50% $|A\rangle|M_A\rangle|live\rangle$ and 50% $|B\rangle|M_B\rangle|dead\rangle$?

Relative to the *box*, the system is in a mixed state: it contains either a live or dead cat. At time t_0, the measuring device, the cat, and the box are already well correlated with each other; the only thing that is not well correlated is the tiny object.[13] But as soon as anything in the box correlates to the tiny object's location at A or B, a superposition no longer exists and a mixed (i.e., non-quantum) state emerges. At time t_1, the combination of the object with the measuring device has already reduced to the mixed state 50% $|A\rangle|M_A\rangle$ and 50% $|B\rangle|M_B\rangle$. Clearly by later time t_2 the cat is, indeed, either dead or alive and not in a quantum superposition relative to the box.

This is not in dispute. What is in dispute is whether the system is describable by a superposition or a mixed state relative to external superobserver S. Whether or not the system is in a superposition prior to observation by S, what is certain is that once S looks inside the box, a live or dead cat will be found. Observation in the basis $\{|A\rangle|M_A\rangle|live\rangle, |B\rangle|M_B\rangle|dead\rangle\}$ will not distinguish a superposition from a mixed state. Setting aside technological problems involved with actually distinguishing a macroscopic superposition from a mixed state, ultimately it must be conceded that just prior to observation (or, more accurately, a decohering entanglement with S), the system is, in fact, either in a superposition or a mixed state relative to S. Is a superposition actually possible?

No. The in-principle possibility of the SC (or WF) experiment depends on two statements that I will show to be incompatible: a) the system is in a mixed state relative to the box; and b) the system is in a superposition relative to superobserver S. When superobserver S set up the experiment at time t_0, the box (containing the cat C and measuring device M inside) was already extremely well correlated to S and the rest of the universe. Those correlations don't magically disappear by "isolating," no matter the extent to which the experiment is isolated. In fact, thanks to the tiny magnitude of Planck's constant, quantum uncertainty guarantees that position correlations are quite robust and long-lasting, and the development of quantum "fuzziness" becomes more and more difficult as the mass of an object increases.

Thus, if the tiny object is in a superposition at time t_0 relative to the box, then it is also in a superposition relative to S, who is already well correlated with the box. Conversely, if there had been a fact at t_0 about the object's location at A or B relative to the box (in which case it wasn't in a superposition relative to the box), then there would also have been a fact at t_0 about the object's location at A or B relative to superobserver S (in which case there wouldn't have been a superposition relative to S) – whether or not S knows this.

Because the object's superposition has decohered to a mixed state relative to the box by time t_1 (in which case there is a fact, relative to the box, about the object's location at A or B), the only way for a fact about its location to *not* exist relative to S is if quantum fuzziness between the box and S exceeds the distance d between A and B. In other words, the only way for the tiny object at t_1 to be in a location superposition, relative to S, that spans distance d is if the location correlations between the box and S do not localize them relative to each other to within a resolution of d.

But S and the box were already extremely well correlated to each other (i.e., presumably to within a resolution much better than d) at time t_0. In order for the system at t_1 to be in a mixed state relative to the box and a superposition relative to S, the correlations between the box and S must deteriorate in that time interval to accommodate a quantum uncertainty of distance d. Let's assume that the distance d separating locations A and B is the microscopic distance of $1\mu m$. If the entire SC experiment has a mass of 10kg, it would take around 3 quadrillion years – or 200,000 times longer than the current age of the universe – for the box to become delocalized from S and the rest of the universe by $1\mu m$, but only if it could somehow avoid even a single decoherence event. Impossible. Note from Table I that cosmic microwave background alone would prevent a bowling ball-sized object from achieving a fuzziness larger than about 10fm.

Consequently, the box will necessarily be localized relative to the rest of the universe (including superobserver S) to a precision much, much smaller than the distance d that distinguishes eigenstates $|A\rangle$ and $|B\rangle$ of the tiny object in superposition. Thus, when the measuring device inside the box decoheres the superposition of the tiny object relative to the box, *it also does so relative to S and the rest of the universe.* If there is a fact about the tiny object's position (say, in location A) relative to the box, then there is also necessarily a fact about its position relative to S – i.e., decoherence within the box necessitates decoherence in general. Superobserver S may not *know* its position until he opens the box and looks, but the fact of its having a position exists before that moment. When a new fact emerges about the tiny object's location due to interaction and correlation with the measuring device inside the box, that new fact eliminates the quantum superposition relative to the rest of the universe, too.

This conclusion does not change by arbitrarily reducing the distance d. By making d very, very small, and given enough time and adequate information isolation be-

[13] That's not entirely true. The tiny object is indeed well correlated to everything in the box in the sense that it will *not* be detected in other locations X, Y, Z, etc.; instead, by design of the experiment, the only lack of correlation (and lack of fact) is whether it is located at A or B.

tween S and the box, eventually localization of the tiny object relative to the box might not localize it relative to the universe. That may be true prior to amplification by the measuring device at time t_1. However, to make the SC experiment work, we must amplify whatever distance distinguishes eigenstates $|A\rangle$ and $|B\rangle$ to some large macroscopic distance. For instance, the macroscopic measuring device has eigenstates $|M_A\rangle$ and $|M_B\rangle$ which are necessarily distinguishable over a macroscopic distance. If the indicator in pointer state $|M_A\rangle$ is located, say, 1cm from the indicator in pointer state $|M_B\rangle$, then the only way for the measuring device to exist in a mixed state relative to the box and a superposition relative to superobserver S is for the quantum uncertainty between the box and S to exceed 1cm. Because the box and S are (and always will be) well correlated to within a tolerance many orders of magnitude smaller than 1cm, the existence of a fact about the position of the indicator relative to the box implies the existence of a fact about the position of the indicator relative to S. The measuring device simply cannot be in a macroscopic superposition relative to S.

At the extreme end, to sustain a superposition of the cat over states $|live\rangle$ and $|dead\rangle$ relative to S would require quantum uncertainty between the box and S to exceed the dimension of the cat itself. After all, any fact, relative to S, that would distinguish one cat state over the other would decohere the superposition. If there is, for example, an atom in a blood cell that would have been in the cat's head in state $|live\rangle$ at a particular time that is instead in its tail in state $|dead\rangle$, then quantum fuzziness would be required to span the cat's length so that superobserver S could correctly state that there is no fact about the cat being dead or alive and that it was, therefore, in a superposition of states $|live\rangle$ and $|dead\rangle$.

What this tells us is that quantum amplification does not create a loophole for producing interesting macroscopic superpositions. If there is no physical possibility, even in principle, of creating a macroscopic quantum superposition by sending a kilogram-scale object into deep space and waiting for quantum fuzziness to appear – whether or not you try to "isolate" it – then you can't stuff a kilogram-scale cat in a box and depend on quantum amplification to outsmart nature. There simply is no way, even in principle, to adequately isolate a macroscopic object (cat included) to allow the existence of a macroscopic quantum superposition.

IV. CONCLUDING REMARKS

Schrodinger's Cat and Wigner's Friend have been a bane on the education and fundamental understandings of countless students. With little more justification than unflinching faith in the universality of quantum mechanics at all scales, the SC/WF experiments have been repeatedly characterized as possible in principle, if difficult in practice, with the burden of proving their impossibility shifted to the skeptics. I have attempted to assume that burden in this paper.

Specifically, I started by pointing out that no macroscopic superposition could be created simply by relying on the slow process of natural quantum dispersion because macroscopic objects (anywhere in the universe) are inundated with decohering interactions that constantly localize them. I then discussed how the SC/WF thought experiments depend on von Neumann-style amplification to achieve quickly what quantum dispersion achieves slowly. Finally, I showed why such amplification cannot produce a macroscopic quantum superposition of an object relative to an external observer, no matter how well isolated the object from the observer, because: the object and observer are already well correlated to each other; and reducing their correlations to allow the object to maintain a macroscopic superposition relative to the observer is equally impossible, in principle, as creating a macroscopic superposition via the process of natural quantum dispersion. Therefore, amplification of a quantum state does not provide a loophole to make viable the otherwise in-principle impossible task of creating Schrodinger's Cat or Wigner's Friend.

[1] Tegmark, M., 1993. Apparent wave function collapse caused by scattering. *Foundations of Physics Letters*, 6(6), pp.571-590.

[2] Joos, E., Zeh, H.D., Kiefer, C., Giulini, D.J., Kupsch, J. and Stamatescu, I.O., 2013. *Decoherence and the appearance of a classical world in quantum theory.* Springer Science & Business Media.

[3] Arndt, M., Nairz, O., Vos-Andreae, J., Keller, C., Van der Zouw, G. and Zeilinger, A., 1999. Wave–particle duality of C 60 molecules. *nature*, 401(6754), pp.680-682.

[4] Penrose, R., 1989. *The Emperor's New Mind: Concerning Computers, Minds, and the Law of Physics.* Oxford University Press.

[5] Aaronson, S., 2016. The Ghost in the Quantum Turing Machine. In: *The Once and Future Turing: Computing the World.* Cambridge University Press.

[6] Okón, E. and Sebastián, M.A., 2016. How to back up or refute quantum theories of consciousness. *Mind and Matter*, 14(1), pp.25-49.

[7] Yin, Z.Q. and Li, T., 2017. Bringing quantum mechanics to life: from Schrödinger's cat to Schrödinger's microbe. *Contemporary Physics*, 58(2), pp.119-139.

[8] Romero-Isart, O., Juan, M.L., Quidant, R. and Cirac, J.I., 2010. Toward quantum superposition of living organisms. *New Journal of Physics*, 12(3), p.033015.

[9] Maccone, L., 2009. Quantum solution to the arrow-of-time dilemma. *Physical review letters*, 103(8), p.080401.

[10] Deutsch, D., 1985. Quantum theory as a universal physical theory. *International Journal of Theoretical Physics*, 24(1), pp.1-41.

[11] Salom, I., 2018. To the rescue of Copenhagen interpretation. *arXiv preprint arXiv:1809.01746.*

[12] Relaño, A., 2020. Decoherence framework for Wigner's-friend experiments. *Physical Review A*, 101(3), p.032107.

[13] Brukner, Č., 2018. A no-go theorem for observer-independent facts. *Entropy*, 20(5), p.350.

[14] Frauchiger, D. and Renner, R., 2018. Quantum theory cannot consistently describe the use of itself. *Nature communications*, 9(1), pp.1-10.

[15] Proietti, M., Pickston, A., Graffitti, F., Barrow, P., Kundys, D., Branciard, C., Ringbauer, M. and Fedrizzi, A., 2019. Experimental test of local observer independence. *Science advances*, 5(9), p.eaaw9832.

[16] Mari, A., De Palma, G. and Giovannetti, V., 2016. Experiments testing macroscopic quantum superpositions must be slow. *Scientific reports*, 6, p.22777.