A Proof that thermal interpretation of QM is wrong

Demystifier · Today at 4:19 AM
Today at 4:19 AM
Demystifier
Science Advisor | Insights Author | 2018 Award

Preface

After a lengthy discussion of the thermal interpretation of quantum physics in https://www.physicsforums.com/threads/the-thermal-interpretation-of-quantum-physics.967116/ , now I think I can prove that it is wrong, i.e. that it doesn't solve the measurement problem in a way it claims it does. Since the following is supposed to be a final proof, I don't want it to be lost among many other posts in the thread above. That's why I open a separate thread.

Introduction

Here I want to prove that the thermal interpretation, contrary to its claim, cannot solve the measurement problem. For definiteness I will present the measurement problem in the form of the Schrodinger cat paradox, but it can be presented in other forms as well. I will prove that the Schrodinger cat "paradox" is a true paradox within the thermal interpretation that does not have a solution within that interpretation.

Let $\rho^{(\mathrm{cat})}$ be the density matrix describing the cat degrees of freedom. In principle, it is determined by the density matrix ρ of the whole Universe as

$$\rho^{(\mathrm{cat})} = \mathrm{Tr}_{\mathrm{no\ cat}}\rho$$

where $\mathrm{Tr}_{\mathrm{no\ cat}}$ denotes the trace over all degrees of freedom except the degrees of freedom of the cat. Since $\rho^{(\mathrm{cat})}$ describes an open system, it's dynamics is very complicated and nonlinear. Since the details of influence of the environment "no cat" degrees of freedom on the cat are not known in practice, the evolution of $\rho^{(\mathrm{cat})}$ in practice can be described by stochastic equations. The thermal interpretation conjectures (without an actual proof) that this complicated, nonlinear and effectively stochastic evolution can explain why the superposition of an alive and a dead cat is unstable, so that the system exhibits a fast decay towards an either dead cat or alive cat. Here I prove that this conjecture is wrong.

The central idea of my proof is to consider the problem from the point of view of the whole Universe, instead from the point of view of the cat. Even though the whole Universe is in principle much more complicated than the cat, this actually simplifies the analysis because it is known that the whole universe evolves unitarily, given by the unitary evolution operator

$$U(t) = e^{-iHt}$$

where H is the Hamiltonian of the Universe.

The proof

Let $\rho(t)$ be the density matrix of the whole Universe. In general, it evolves with time according to $\rho(t) = U(t)\rho(0)U^{\dagger}(t)$.

Now suppose that initially $\rho(0) = \rho_{\mathrm{alive}}$, where ρ_{alive} is the state of the Universe with an alive cat. The alive state is stable, i.e. the cat who is initially alive will stay alive for a long time. Hence we can write

$$U(t)\rho_{\rm alive}U^\dagger(t)=\rho_{\rm alive}(t)$$

where $\rho_{\rm alive}(t)$ is the state of the Universe with a cat alive during a long time. Similarly, if initially $\rho(0)=\rho_{\rm dead}$ then we have a dead cat for a long time, so we can write

$$U(t)\rho_{\rm dead}U^\dagger(t)=\rho_{\rm dead}(t)$$

But what if initially we have the superposition of a dead and an alive cat? It is certainly possible as an initial condition, but the question is what happens with such a superposition later? Is it stable or unstable? To simplify the analysis we shall assume that the initial superposition is incoherent, i.e. that

$$\rho(0)=\frac{1}{2}\rho_{\rm alive}+\frac{1}{2}\rho_{\rm dead}$$

without the interference term. (We shall show later that inclusion of the interference terms does not change the final results.) Hence the linearity of evolution for the whole Universe implies

$$U(t)\rho(0)U^\dagger(t)=\frac{1}{2}\rho_{\rm alive}(t)+\frac{1}{2}\rho_{\rm dead}(t)$$

This proves that the superposition is stable, i.e. that there is no decay to $\rho_{\rm alive}(t)$ or $\rho_{\rm dead}(t)$.

Now what about beables in the thermal interpretation? All beables in the thermal interpretation are of the form

$$\langle O(t)\rangle={\rm Tr}O\rho(t)$$

where O are hermitian observables. So if O is a cat observable that describes some actual properties of the cat, we see that the actual property of the cat is

$$\langle O(t)\rangle = \frac{\langle O(t)\rangle_{\rm alive} + \langle O(t)\rangle_{\rm dead}}{2}$$

which is neither $\langle O(t)\rangle_{\rm alive} = {\rm Tr} O\rho_{\rm alive}(t)$ nor $\langle O(t)\rangle_{\rm dead} = {\rm Tr} O\rho_{\rm dead}(t)$. This proves that beables of the thermal interpretation cannot solve the Schrodinger cat paradox. By a straightforward generalization of this proof, one can see that thermal interpretation cannot resolve the measurement problem of quantum physics in general.

Note that the cat beable can also be written as

$$\langle O(t)\rangle = {\rm Tr}_{\rm cat} O\rho^{\rm (cat)}(t)$$

where $\rho^{\rm (cat)}(t)$ (given by the first equation in **Introduction** above) satisfies a nonlinear equation and ${\rm Tr}_{\rm cat}$ denotes tracing over cat degrees of freedom. The thermal interpretation conjectures that this nonlinearity can somehow cause the decay towards an either dead or alive cat. What our proof shows is that this conjecture is not true, which is a consequence of the fact that the Universe as a whole obeys a linear evolution. No matter how complicated and apparently stochastic behavior of a subsystem may be, the unitary evolution of the whole Universe implies that it cannot solve the measurement problem within the thermal interpretation.

Finally a note on the ignored interference terms. If the initial state of the Universe is a coherent superposition

$$\frac{|{\rm alive}\rangle + |{\rm dead}\rangle}{\sqrt{2}}$$

then the initial $\rho(0)$ has the additional interference term

$$\rho_{\rm interf} = \frac{1}{2}|{\rm alive}\rangle\langle{\rm dead}| + \frac{1}{2}|{\rm dead}\rangle\langle{\rm alive}|$$

In principle this contributes to beables via terms of the form

$$\mathrm{Tr} O|\mathrm{alive}\rangle\langle\mathrm{dead}|$$

However, if O is an observable that distinguishes a dead cat from an alive one, then terms of the above form are negligible. For instance, if the dead cat is distinguished from an alive one by having a closed/open eye, then O can be taken to be the position operator x describing the position of the eyelid, while $|\mathrm{alive}\rangle$ and $|\mathrm{dead}\rangle$ are proportional to two different eigenstates of x , in which case it's easy to see that the term above vanishes.

Last edited: 16 minutes ago

Today at 4:41 AM #2

A. Neumaier

Science Advisor | Insights Author

:5,792
:2,043

Demystifier said:

Finally a note on the ignored interference te the initial state of the Universe is a coherent superposition

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then the initial $\rho(0)$ has the additional interference term

$$\rho_{\text{Deaf}} = \frac{1}{2}|\text{alive}\rangle\langle\text{dead}| + \frac{1}{2}|\text{dead}\rangle\langle\text{alive}|$$

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In your final note, which is the only part relevant to the problem, you assumed the link between measurement results of O and eigenstates, which is not valid in the thermal interpretation.

That's not essential at all. Alternatively, I can take $|\mathrm{dead}\rangle$ and $|\mathrm{alive}\rangle$ to be proportional to two macroscopically different coherent states $|p, x_1\rangle$ and $|p, x_2\rangle$, in which case my argument that the interfernce term is negligible applies without having position eigenstates.

Today at 5:09 AM #4

Mentz114
Gold Member
:5,269
: 240

Demystifier said:

But what if initially we have the superposition of a dead and an alive cat? It is certainly possible as an initial condition, but the question is what happens with such a superposition

You are assuming this ridiculous fallacy without any physical justification or evidence. There is no such thing.

Today at 5:16 AM #5

Demystifier
Science Advisor | Insights Author | 2018 Award
:9,618
:2,688

Mentz114 said:

are assuming this ridiculous fallacy without any physical justification or evidence. There is no such thing.

If you are suspicious about cats (despite the fact that Schrodinger proved that it is possible if Schrodinger equation is always true) , consider spin in a superposition up and down. The proof doesn't change.

Today at 5:43 AM #6

A. Neumaier
Science Advisor | Insights Author
:5,792
:2,043

> That's not essential at all. Alternatively, I can take $|\mathrm{dead}\rangle$ and $|\mathrm{alive}\rangle$ to be proportional to two macroscopically different coherent states $|p, x_1\rangle$ and $|p, x_2\rangle$, in which case my argument that the interfernce term is negligible applies without having position eigenstates.

But then your argument about properties is no longer valid. O is not a quantity you can freely choose in your argument.

44 minutes ago #7

stevendaryl
Staff Emeritus | Science Advisor | Insights Author
:8,255
:2,441

Mentz114 said: ↑

You are assuming this ridiculous fallacy without any physical justification or evidence. There is no such thing.

That's harsh, and also unhelpful (I think). It's true that there aren't actual states $|alive\rangle$ and $|dead\rangle$, but is this oversimplification important for the point @Demystifier is making? If so, can you show how a more careful treatment of cats would lead to a different conclusion? If not, then your remark is unhelpful.

What I think a more careful treatment would like is something like this:

Presumably, a macroscopic configuration (a description at the level of cats and cyanide canisters) corresponds to some equivalence class of microscopic states. Some microscopic states are incompatible with there being a live cat. So I assume that for a macroscopic configuration c (a description of the locations, types, shapes, and health of cats and so forth) there is a corresponding projection operator Π_c such that if microstate $|\psi\rangle$ is compatible with configuration c, then $\Pi_c|\psi\rangle = |\psi\rangle$, and if $|\psi\rangle$ is incompatible with c, then $\Pi_c|\psi\rangle = 0$.

Then instead of talking about the states $|alive\rangle$ and $|dead\rangle$, we can talk about the projection operators.

stevendaryl
Staff Emeritus | Science Advisor | Insights Author

#8

:8,255
:2,441

Demystifier said: ↑

But what if initially we have the superposition of a dead and an alive cat? It is certainly possible as an initial condition, but the question is what happens with such a superposition later? Is it stable or unstable? To simplify the analysis we shall assume that the initial superposition is incoherent, i.e. that

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This proves that the superposition is stable, i.e. that there is no decay to $\rho_{\rm alive}(t)$ or $\rho_{\rm dead}(t)$.

I don't know about the thermal interpretation, but in some interpretations of quantum mechanics, the density matrix is interpreted to include subjective uncertainty. So being a mix of "alive" and "dead" is compatible with the cat being alive or dead, and you just don't know which (until you peek, to resolve the subjective uncertainty).

If you consider the "density matrix of the universe" to be the most complete information there can be about the state of the universe, then I guess that out isn't possible.

I don't know about the thermal interpretation, but in some interpretations of quantum mechanics, the density matrix is interpreted to include subjective uncertainty.

That's not the case with thermal interpretation.

4 minutes ago #10

Demystifier Science Advisor | Insights Author | 2018 Award

:9,618
:2,688

A. Neumaier said:

But then your argument about properties is no longer valid. O is not a quantity you can freely choose in your argument.

All my argument requires is that O is a quantity that distinguishes a dead cat from an alive one. This requirement is indeed necessary if one wants the corresponding beable to determine whether the cat is dead or alive.

U

R Neumaier Thermal Interpretation of QM, valid?

N J Interpretation of QM that psiontic, local, and has collapse?

There is no Copenhagen interpretation of QM

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