ASYMMETRY DUE TO QUANTUM COLLAPSE

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ABSTRACT

This poster points out an internal tension between quantum collapse and expressions which set eigenstates equal to superposition states in a different basis and thereby imply that pre-measurement and immediate post-measurement states are of the same kind. Its resolution appears to be either to discard the collapse postulate or to consider such states to be of distinct kinds with respect to their association with a superposition of properties.

OVERVIEW

Quantum collapse is a postulate in orthodox quantum mechanics, but it is poorly understood, though much has been written about it [1]. Here we point out that it also leads to a subtle internal tension in the theory when it is considered in conjunction with expressions that equate eigenstates with superposition states in a different basis because such expressions are consistent with a symmetry between states and observables under quantum superposition that is broken by quantum collapse. The tension can be relieved either by discarding the collapse postulate or by keeping it and considering pre-measurement and immediate post-measurement states to be of distinct kinds, in which case quantum collapse must be considered a transformation between two kinds of states.

The basic strategy employed here is to convert a standard quantum mechanical relation into a logical equivalence, and then show that the imposition of the collapse postulate makes it possible to formulate an argument such that the truth value of the conclusion depends on which of the implications that are part of the equivalence is used, from which it is then possible to derive a contradiction.

THE SET-UP

Consider a 2-level spin state such $|+\mathbf{x}\rangle$

$$|+\mathbf{x}\rangle = \frac{1}{\sqrt{2}}|+\mathbf{z}\rangle + \frac{1}{\sqrt{2}}|-\mathbf{z}\rangle \tag{1}$$

Convert into a logical equivalence and re-express as a conjunction of two implications:

$$|\Psi\rangle = |+\mathbf{x}\rangle \Leftarrow |\Psi\rangle = \frac{1}{\sqrt{2}}|+\mathbf{z}\rangle + \frac{1}{\sqrt{2}}|-\mathbf{z}\rangle$$

$$\wedge$$

$$|\Psi\rangle = |+\mathbf{x}\rangle \Rightarrow |\Psi\rangle = \frac{1}{\sqrt{2}}|+\mathbf{z}\rangle + \frac{1}{\sqrt{2}}|-\mathbf{z}\rangle$$

If the symmetry existed, then an operator $\hat{s}_{(+z)+(-z)}$ could produce both observables in a single measurement, but the collapse postulate prevents this.

THE PROBLEM IN A NUTSHELL

Argument	Truth Values of Premises	Truth Value of Conclusion
$M \wedge N \wedge (Q \Rightarrow P) : R$	True, True, True	True
$M \wedge N \wedge (P \Rightarrow Q) : R$	True, True, True	False

A truth table for the arguments for which the axioms of QM, the collapse postulate and each of the two conjoined implications serve as premises. The symbols M, N, P, Q and R are defined as follows:

M : The standard axioms of quantum mechanics, as found in any introductory textbook e.g. [3], *sans* collapse postulate

N : "Upon a measurement, a state $|\Psi\rangle$ reduces to an eigenstate $|\psi_i\rangle$ in the basis of measurement outcomes."

$P : |\Psi\rangle = |+\mathbf{x}\rangle$

$Q : |\Psi\rangle = \frac{1}{\sqrt{2}}|+\mathbf{z}\rangle + \frac{1}{\sqrt{2}}|-\mathbf{z}\rangle$

R :"It is possible to prepare a state $|\Psi\rangle$ such that the operator $\hat{s}_\Psi$ produces all the eigenvalues associated with the eigenstates of $|\Psi\rangle$ in the implied basis (i.e. the basis that appears after the implication sign) in a single measurement."

The problem, in a nutshell, is that if the truth value assignments in the above arguments are correct and the logical equivalence in (2) is true, then it is possible to construct the argument $M \wedge N \wedge (Q \equiv P) : R \wedge (\sim R)$, where $\sim R$ is the negation of R

POSSIBLE RESOLUTIONS

1. **Drop the Collapse Postulate:**
   - Renders R true for either implication
   - Absence of collapse postulate removes tensions between two parts of theory
   - Reminiscent of Everettian Interpretations
   - But: True Value for R leaves possibility open that observers in some branches should observe superpositions of eigenvalues
   - Attempts to fix this may re-introduce the problem in a different guise
2. **Keep Postulate, but consider pre-measurement and immediate post-measurement states to be distinct kinds of states**
   - Renders R false for either implication
   - Distinction must consider immediate post-measurement states to no longer be vectors in Hilbert Space, so that Statements like P and Q do not apply to them any longer
   - Domain of applicability of equation (1) shrinks to pre-measurement states only
   - Symmetry breaking of Quantum Collapse manifests itself directly in character of the system's state
   - R becomes internally inconsistent because it is a statement about pre-measurement kinds of states (due to reference to P and Q) which does not apply to them but to immediate post-measurement kinds of states (because only these are associated with eigenvalues).
   - To symbolically distinguish between these, underline immediate post-measurement states
   - example: $\frac{1}{\sqrt{2}}|+\mathbf{z}\rangle + \frac{1}{\sqrt{2}}|-\mathbf{z}\rangle \longrightarrow |\underline{+\mathbf{x}}\rangle$
   - This is in contrast to standard Quantum mechanics, which recognizes no intrinsic distinction between these kinds of states
   - Quantum Collapse must be thought of as a *transformation between two kinds of states*

CONCLUSION

The arguments presented here suggest that any interpretation of quantum mechanics which contains the collapse postulate but fails to make an intrinsic distinction between pre-measurement and immediate post-measurement states with respect to the quantum superposition is ruled out. While such a distinction will seem unfamiliar, it may open an approach to better understand the physical process behind quantum collapse. In particular, one possibility is that underlying this distinction is a corresponding distinction between the concepts of mass in quantum physics and in classical physics, and in particular general relativity [8]. A framework meant to help 'make sense' out of quantum mechanics in which these distinctions are key features can be found in [9].

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