Essay

Entanglement & MWI of Quantum Mechanics

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Abstract

According to Many Worlds Interpretation ("MWI", Everett, 1957), the terms of an entangled state describe something that really exist; the state does not just refer to the probabilities of results that would be obtained if measurement takes place. We argue in this essay from conceptual point of view the relationship between quantum entanglement and and MWI. The debate is still open and we suggest that the objective Bayesian interpretation of quantum probability could be an interesting approach to solve this fundamental question.

Keywords: Philosophy of quantum mechanics, entanglement, non-locality.

1 Quantum Entanglement and MWI

The meaning given to an entangled state by the many-worlds interpretation (Everett, 1959) could add new elements useful in our analysis. According to this interpretation, the terms of an entangled state describe something that really exist; the state does not just refer to the probabilities of results that would be obtained if measurement takes place. The different terms in an entangled state can be interpreted as showing that the universe branches into a number of different worlds. What are really important are the ***correlations***. The main ingredient is thus the relative state.

Let us say that an observer O is going to perform a measure of the observable B on the system S being in a superposition state: $|\mathbf{S}\rangle = \alpha|\varphi_B\rangle + \beta|\phi_B\rangle$; where $|\varphi_B\rangle$ and $|\phi_B\rangle$ are eigenstates of B. Before the measurement is performed, the state of the composite system (Observer plus System) is

$$|\mathbf{O}{+}\mathbf{S}\rangle^0 = |Ready\rangle_O(\alpha|\varphi_B\rangle_S + \beta|\phi_B\rangle_S).$$

After the measurement (according to Shrödinger equation evolution) the composite system will be in a state

$$|\mathbf{O}{+}\mathbf{S}\rangle^1 = \alpha|\varphi_B\rangle_O|\varphi_B\rangle_S + \beta|\phi_B\rangle_O|\phi_B\rangle_S$$

where the observer results entangled with the observed system.

The physical meaning, according this interpretation, relies on the *correlations*. Each component

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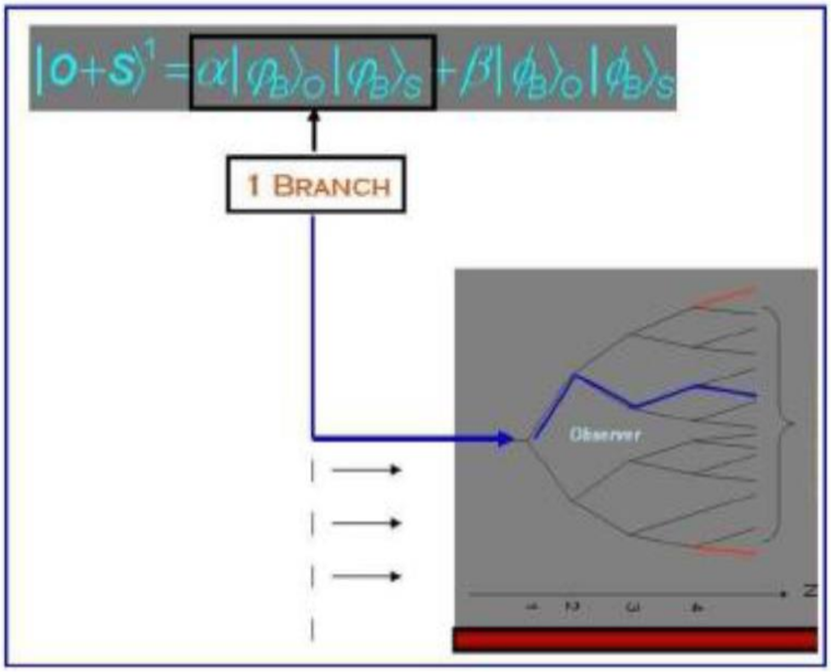

Figure 1: Branches

of the wave function is called branch [fig. 3.1], and the branching is responsible for our experiences. These are the consequences of the fact that there is not interaction between branches, but every subsystem can only interact with the other subsystems states that are in the same branch. In this way, the quantum "world" is always decomposable into system and observer. The basic idea is that their correlations defines a preferred set of basis vectors. The relevance of quantum correlations has been stressed also in Cerf.(Cerf, 1997). There, it was claimed that only correlations, not the correlata of a QS, are physically accessible, but we have to include the observer as one of its parts. As a consequence, quantum reality is "real" in the sense that QM completely and deterministically describes the evolution of a closed system (not just its wavefunction), and that the statistical character arises from the fact that an observer, because he is part of the closed system, is offered an incomplete view of the QS he attempts to measure. Therefore, the quantum universe is deterministic as Einstein's physical reality demands, but must include the observer as one of its parts due to the inseparability of entangled quantum states.

As we have seen this interpretation, the world we live in is continually branching, into multiple near-copies corresponding to different possible measurement outcomes. Unitary quantum dynamical laws describe the evolution of all these branches simultaneously. The definite measurement records that we observe, remember and communicate, are just characteristics of individual branches. Then, the development of all quantum systems are governed by the same unitary dynamical laws and hence develop completely deterministically and linearly. In this context, the wavefunction describes real properties, so that all speculations about determinism, causality, quantum jumps and collapse of wavefunction are unnecessary. When a microscopic QS interacts with a macroscopic apparatus, decoherence drives the ”collapse” of the wave function (FAPP for all practical purposes).

All possible outcomes of any measurement are regarded as real but we perceive only a specific outcome, because the state of my brain as part of the QS is strongly **correlated** with the outcome. In this context, the evolution of the wave function is deterministic, we are unable to predict with certainty the outcome of an experiment to be performed in the future. We do not know what branch of the wavefunction we will end up on, so we are unable to predict our future state of mind, thus, while the global picture of the universe is in a sense deterministic from my own local perspective from within the system we perceive quantum mechanical randomness. There is problem, within this approach is not yet fully explained the quantum mechanical rules to computing probabilities. The main problem is the derivation of the Born rule. **The problem of probability in this view of QM arises because the splitting of worlds seem unrelated to the Born probabilities.** The challenge of this interpretation is, therefore, to show that it predicts the existence of probability in the context of completely unitary time evolution. The debate on this question remain open, for instance **(objective) Bayesian interpretation** of quantum probability could be an interesting approach to solve the question.

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