The hidden error in the standard Quantum Mechanics

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In the standard Quantum Mechanics (QM) there exists certain assumption (which I call the *von Neuman axiom*, see [1]) stating that an ensemble in the pure state is homogeneous. This means that all members of this ensemble are in the same individual state. Equivalently we can say that each pure state is an individual state (the term individual state means the state of an individual system). The von Neumann axiom is really hidden in QM: everyone who says "let us consider the system in the state ψ" unconsciously uses this axiom.

In this note I am going to show that the von Neumann axiom is false. This also means that the standard interpretation of the wave function as the state of the individual system is in general false. In the ontic/epistemic terminology this means that the ontic interpretation of the wave function cannot be true.

There are four arguments for this statement (all these arguments are known):

- The classical argument
- The Bell inequality (BI) argument
- The Collapse argument
- The duplicity argument

The classical argument. We consider two possible states of an individual (alive) cat – the state φ localized in Tokyo and the state ψ localized in Paris. The superposition Ψ of these two states cannot be the possible state of this *individual* cat (perhaps Ψ can be the state of an ensemble of cats). The proof: the diameter of the support of this *individual* cat is smaller than, say, 2 meters. If the support of the cat intersects Tokyo, then the support of this cat cannot intersect Paris. This contradicts to the fact that the support of Ψ intersects both Tokyo and Paris.

The BI argument. The von Neumann axiom implies the realism of QM and in particular so-called counterfactual definiteness (see [6]). Using assumption of the locality of QM together with von Neumann axiom one can derive BI. BI contradicts to the QM, so that one obtains the nonlocality of QM. But Quantum Theory (= QM + Special Relativity) requires the locality.

The Collapse argument. From the von Neumann axiom it follows the Collapse rule: during the measurement the state of the system collapses to one of eigenstates. The Collapse process is in general nonlocal (e.g. in the EPR situation the measurement of the Alice` particle changes immediately the state of the Bob`s particle). This nonlocality contradicts to the locality of Quantum Theory.

The duplicity argument. The von Neumann axiom states that each pure state can be considered as the individual state of some individual system. Let us consider a finite set of individual systems (in some individual states). It is possible to construct an ensemble by taking together these individual systems with some weights. The state of this ensemble will be the probabilistic combination of states of these individual systems. Two different probabilistic combinations must lead to the different states of resulting ensembles. It is well-known that there exist situations where two different probabilistic combinations lead to the ensembles in the same state and this creates a contradiction since two ensembles in the same state must be equal.

Thus the von Neumann axiom must be false and we have to look for its modification. I have proposed to choose the opposite possibility: to require that

Any two different individual states must be orthogonal.

I have called this statement the anti-von Neumann axiom (see [2]) and this axiom is the starting point for the axiomatic definition of the modified QM (see [3]). The anti-von Neumann axiom implies that the set of individual states is either the orthonormal base of the Hilbert space of the system or a subset of some orthonormal base.

There are three fundamental meta-theorems describing the relation between standard QM and the modified QM (I call these assertions meta-theorems since they describe the properties of theories).

Meta-theorem A: the experimental consequences of the modified QM are the same as the experimental consequences of the standard QM (with the von Neumann axiom). The proof can be found in [3]. The idea of the proof: the predictions of QM are probabilistic and are related to ensembles and not to the individual systems (this is stated in the well-known operational formulation of QM).

Meta-theorem B: in the modified QM it is not possible to derive any form of BI. The proof: in any proof of BI it is necessary to consider individual states from at least two different orthonormal bases. But by the anti-von Neumann axiom this is not possible since the set of individual states is limited to only one orthonormal base.

Meta-theorem C: in the modified QM it is possible to give the local explanation of the EPR correlations (i.e. the fact that Alice and Bob obtain always the opposite results of the measurements in the case of the same settings). The proof can be found in [4].

Only having proved the meta-theorem C it is possible to state that the modification of QM is local.

With respect to the question of the ontic resp. epistemic nature of the wave function (see [5]) the modified QM takes the intermediate position. Some pure states are individual (i.e. ontic) but other pure states are not individual (i.e. they are epistemic). The modified QM should be considered as hybrid, i.e. ontic-epistemic.

Thus the meaning of the wave function in the modified QM is hybrid – some pure states are ontic and some are epistemic. We have also shown that the ontic interpretation of the wave function cannot be true.

Conclusions:

- We have shown that the (implicitly assumed) von Neumann axiom is false and that the ontic interpretation of the wave function cannot be true
- We have proposed the modified QM based on the anti-von Neumann axiom and we have shown the relation between the standard QM and the modified QM. The status of the wave function in the modified QM is hybrid, i.e. ontic-epistemic.

References:

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