The nonlocality vs. nonrealism: the critical discussion and a new proposal.

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Abstract. We discuss the three options: the psi-ontic option, the psi-epistemic option and the novel psi-hybrid option.

With Bell inequalities (BI) there is a problem. They are in contradiction with Quantum Mechanics (QM) and also with the experiments. Both locality and realism must be assumed in their derivations. (Instead of the realism one can assume the so-called counterfactual definiteness.) This means that both locality and realism are necessary assumptions in the proof of BI. There are two possibilities to make BI un-derivable: either to reject the locality or to reject the realism.

(Recently there were published results [5] supporting the idea that the right choice is to reject the realism. But up to now the final version of these results seems not to be achieved.)

The nonlocality approach was studied in hundreds (perhaps thousands) papers during last 50 years while the nonrealism approach was considered only in general terms and there are (as I know) only some concrete explicit proposals: the modified QM (see [1]) and the minimal nonrealism version of QM (see [6]).

I think that such a situation is not fair with respect to the nonrealism approach and that the nonrealism position should be considered as serious as the nonlocality position and it should be studied equally seriously.

This situation is incorrect from the point of view of the scientific methodology: the nonrealism position cannot be rejected on the scientific grounds (PBR theorem uses many unjustified assumptions, mainly the assumption of ontological models) it should be studied as well as the opposite position. (On the other hand, the nonlocality position has the serious drawback that the nonlocality contradicts the Special Relativity.)

In the taxonomy given below (see [4]) I do not consider the question of the completeness since it is irrelevant for the present purposes.

The realism position ("the wave function represents the state of the individual system") is equivalent to the von Neumann axiom ("the ensemble in a pure state is homogeneous"). It is often denoted as the psi-ontic position. This position has many serious drawbacks: it implies the Collapse rule, it creates the Measurement problem, the Schrodinger cat paradox etc. Nevertheless, it make a part of the standard QM.

The opposite position – the nonrealism position, called also as the psi-epistemic position assumes that the wave function represents the state of an ensemble (this was Einstein`s opinion). It is known also as the statistical interpretation of QM. The problem with this position is the missing concept of an individual system and its possible individual state: there are only ensembles. Recently it is also considered as the operational approach to QM.

Quite recently there was proposed the third possibility which is intermediate between realism and nonrealism positions – it is called the psi-hybrid position. It was proposed as a bases of the modified QM in [1] and it assumes that some wave functions represent individual states of the system (psi-ontic states) while others wave functions represent states of ensembles (psi-epistemic states). Typically the set of individual states is the orthogonal base of the system`s Hilbert space. This position is psi-hybrid, i.e. ontic-epistemic.

The psi-hybrid position takes the best of both others positions:

(i) It excludes the derivation of Bell inequalities and thus does not lead to the nonlocality (see [2], meta-theorem B)
(ii) There is no Collapse problem (it is replaced by the Selection process (see [1], [3])
(iii) There is a possibility to solve the Measurement problem (see [1], [3])
(iv) It contains the concept of an individual system and its individual state (the set of individual states is the small subset of the set of pure states)
(v) It is possible to give the local explanation of the EPR correlations (see [3]) – it is shown that there is the anti-correlation between the two individual states of measurement apparatuses in the EPT experiment (without the need of the pre-determination)
(vi) The important fact is the statement that modified QM has the same experimental consequences as the standard QM (see [1], [2]). This means that the choice between the standard QM and the modified QM depends only on theoretical properties of these theories and it cannot be resolved by the experiment. This is rather strange situation but it seems to be the real fact.

In general, the realism position is equivalent to the von Neumann axiom. Let us assume the (very mild) hypothesis that individual states generate the system`s Hilbert space. Under this hypothesis the von Neumann axiom is equivalent to the individual superposition principle ("the superposition of individual states represents an individual state"). It follows that the negation of the realism implies the negation of the individual superposition principle.

I think that it is not sufficient to consider the nonrealism (i.e. the psi-epistemic) option on the general (abstract) level but that it will be more useful to study the concrete and explicit version of QM, such as the modified QM or the minimal nonrealism version of QM.

There are some arguments against the nonrealism option: no-go theorems like the PBR theorem etc. I think that the best way is to construct the viable modification of QM and to show that this modification is (hopefully) consistent and that it produces the same predictions as the standard QM. I tried to do this for the modified QM (and also for minimal non-realistd version of QM) – see [1] and [6].

Conclusions. Besides the two known options, psi-ontic and psi-epistemic options there exists a novel psi-hybrid option which exhibits quite interesting properties.

References

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