A new concept of the truth in quantum mechanics and the individual superposition principle

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Abstract.

Using a new concept of the truth in quantum mechanics we show that the individual superposition principle is scientifically unfounded.

1. Introduction.

It may happen that two different theories are empirically indistinguishable. In quantum mechanics (QM) this has happened. The old example is the Bohmian mechanics which is theoretically different from QM but empirically equivalent to QM.

A recent example of this type is the modified QM introduced in [1] which is theoretically different from QM but which gives the same empirical predictions as QM (this is proved in [1]).

Such a situation where there exist two different theories which are empirically indistinguishable is rather special and this is the topic of the paper.

It is not possible to discriminate among empirically indistinguishable theories. This implies that the concept of the truth must be in such situations redefined. The true statement in QM is a statement which is true in any theory which is empirically equivalent to QM. The undecidable statement in QM is a statement which is true only in some theories empirically equivalent to QM (but not in all such theories).

Then we shall show that the superposition principle in QM can have two forms: the collective superposition principle and the individual superposition principle. We shall show that the individual superposition principle is undecidable in QM. This implies that the individual superposition principle is scientifically unfounded.[1]

[1] The collective superposition principle is a trivial consequence of axioms of QM.

The role of the individual superposition principle is essential in many foundational problems of QM: the Schroedinger's cat paradox, the measurement problem etc. The fact that the individual superposition principle is not true in QM may help to solve these problems.

2. A new concept of a truth in QM.

The concept of a truth in QM must be redefined in the situation where different theories can have the same empirical content.

Definition 1. Two theories are empirically equivalent if their empirical predictions are identical.

Definition 2. The QMversion is each theory which is empirically equivalent to QM.

It is important to understand that both definitions do not use the concept of the experimental verification. Only the concept of the empirical predictions of a given theory is used. This means that the concept of empirically equivalent theories depends only on these theories and does not depend on experiments.

QMversions are empirically indistinguishable so that we should redefine the concept of the truth.

Definition 3.

(i) The statement S is true in QM if S is true in each QMversion.
(ii) The statement S is undecidable in QM if S is true in some QMversion but S is false in some other QMversion.
(iii) The statement S is false in QM if S is false in each QMversion.

I.e. the undecidable statement means the empirically undecidable statement.

Let us note again that these concepts are purely theoretical, they do not depend on any experiments.

It is clear that every empirical prediction of QM is the true statement.

There are following basic consequences of these concepts.

Theorem 1.

(i) The true statement is scientifically well-founded.
(ii) The undecidable statement is not scientifically well-founded and should be considered as the scientifically unfounded statement.

Proof. (i) In this case the statement is true in all QMversions so that the choice of the QMversion is irrelevant. (ii) In this case the truth of the statement depends on the QMversion and since no QMversion is empirically preferred we have to conclude that this statement is unfounded.

This means that only true statements can be considered as the scientifically well-founded statements.

Theorem 2. The empirical success of QM **does not imply** that QM is true – it implies **only** that some QMversion may be true.

Proof. All QMversions are equally supported by the empirical success of QM. Then we cannot say that some of them is better supported than the other QMversion. Assuming that at least two QMversions are different (e.g. the standard QM and the modified QM) we cannot state that certain QMversion is true since there is no empirical criterion to discriminate among QMversions.

This means that it is not possible to choose the "right" QMversion (i.e. the choice based on the empirical evidence is impossible) since all QMversions are empirically equivalent.

It is clear that the choice among QMversions cannot be based on the empirical evidence, but there may exist some theoretical principles which can help us to make a choice among QMversions (or at least, to limit the set of QMversions).

We list two theoretical principles which could be considered: the locality principle (based on the success of the Theory of relativity) and the no-measurement principle (see Bell [2]) which requires that the concept of a measurement should not make a part of axioms of QM.

In each case, these "metaphysical" postulates can limit the set of QMversions, but there will be probably still more than one QMversion. The reasonable standpoint is to consider all QMversions as equivalent.

3. The superposition principle.

Based on the previous considerations of the truth in QM we shall argue that the individual superposition principle is an uncertain statement in QM.

Now we shall consider the superposition principle in QM in more details. It is possible to define two forms of the superposition principle: the collective form and the individual form. By the *collective state* in QM we consider any possible state of an ensemble described by the density operator in the system's Hilbert space.

The *pure state* is a state generated by some vector from the Hilbert space. It is clear that the superposition of two pure states is generated by the linear combination of two vectors, so that the result is again the pure state. This implies that the *collective superposition principle* is a trivial consequence of basic axioms of QM: the linear combination of two pure states is a pure state.

The *individual superposition principle* requires the concept of an *individual state*. This is usually defined using the concept of a homogeneous ensemble. The ensemble is in a *homogeneous state* if all elements of this ensemble are in the same *individual state* (von Neumann [3]). But this is clearly the circular definition.

We shall assume that for each system there is defined a set of individual states which is a subset of the set of all pure states. Each individual state can be considered as the state of some individual system. In QM it is supposed that each pure state is an individual state. (This means that each wave function describes a possible state of an individual system.)

Then the individual superposition principle says that the superposition of any two individual states is an individual state. It is clear that the individual superposition principle is satisfied in QM.

On the other hand, in the modified QM it is assumed that any two different individual states must be orthogonal (see [1], i.e. the set of all individual states is a subset of some orthogonal base). This implies that in the modified QM the individual superposition principle does not hold: any non-trivial superposition of two different individual states is not an individual state (see [1]).

Using the fact (proved in [1]) that the modified QM is empirically equivalent to QM we obtain the following theorem.

Theorem 3.

(i) The individual superposition principle is an undecidable statement in QM.
(ii) The empirical success of QM does not imply the validity of the individual superposition principle.

Proof. (i) The individual superposition principle holds in the standard QM, but it does not hold in the modified QM which is the QMversion. (ii) This is a consequence of the theorem 2 and its proof.

This means that the individual superposition principle is not a scientifically well-founded statement and it should be considered as an unfounded statement.

Remark 1. (Occam`s razor).

Now we shall discuss the well-known Occam`s razor which state that having two explanations of some phenomenon, the simpler explanation should be preferred. We think that the Occam`s razor cannot be applied in the rigorous science. There are at least five arguments against it:

(i) The rigorous and exact formulation of Occam`s razor has not been proposed
(ii) The rigorous and exact formulation of the concept of “simplicity” has not been proposed

(iii) It is not clear that Nature prefers the simplicity – there are many situations in science where Nature prefers the complexity

These arguments are in the agreement with the authoritative statement from Wikipedia: “In science, Occam's razor is used as a heuristic technique (discovery tool) to guide scientists in the development of theoretical models, rather than as an arbiter between published models.” (see [4], page 1).

We consider Occam`s razor as the scientifically inapplicable, in principle unfounded speculative idea.

There is no connection between the concept of the empirical equivalence and Occam`s razor: our definition of the empirical equivalence of two theories is purely theoretical, while Occam`s razor is applicable to two explanations of some concrete observed phenomenon. Our concept of an empirical equivalence has no relation to any observation or experiment. Moreover, our concepts: the empirical equivalence, QMversions, the true statements and the undecidable statements are exactly formulated, so that they can be applied in empirical sciences.

4. The principle of objectivity.

We have solved the problem of different theories which have the same empirical content in the way which is clearly *opposite* to the Occam`s razor.

The idea of Occam`s razor is to choose the “right” QM in some way, while our idea is to consider all QMversions on the same footing and to consider as true statements only those statements which are true in all QMversions. This means that any of these empirically equivalent QMversions has the same chance to be the hypothetical “right” QM theory.

What is the “right” QM cannot be known: the choice cannot be obtained by the empirical study and additional a priori principles are not sufficiently established.

The general idea of possible a priori principles is doubtful in principle: QM is an empirical theory and it should be based on the empirical evidence and not on some speculative a priori principles.

At the base of these considerations we can formulate Theorem 2(ii) as a general principle.

The principle of objectivity.

(i) No undecidable statement in QM can be considered as a true statement resp. as a false statement.

(ii) The idea that there exists certain (currently unknown) QMversion which is really “true” should be rejected (i.e. the idea of the preferred QMversion should be rejected).

We have obtained in Theorem 3(i) that the individual superposition principle is an undecidable statement in QM, so that it cannot be considered as a true statement in QM. We do not assert that the individual superposition principle is false, we only obtained that this principle is neither true nor false.

But then the individual superposition principle cannot be used in the sequence of argumentation. For example, the famous Schroedinger cat paradox is based on the use of the individual superposition principle and thus the derivation of this paradox is not scientifically well-founded. All paradoxes based on the use of the individual superposition principle must be considered as a result of the incorrect derivation.

The principle of objectivity must be considered as a *direct opposition* to the Occam`s razor: the Occam`s razor looks for the specification of the "right" QMversion while the principle of objectivity rejects any idea of the existence of "right" QMversion.

5. Conclusions.

We have obtained following results

(i) We have defined a new concept of the truth in QM.
(ii) We have shown that the undecidable statements are not scientifically well-founded.
(iii) We have shown that the empirical success of QM does not imply the validity of QM.
(iv) We have shown that the **individual superposition principle is scientifically unfounded**.
(v) We have shown that the empirical success of QM does not imply the validity of the individual superposition principle.

There are important consequences with respect to the previous papers concerning the individual superposition principle.

(i) In the paper [5] the starting point was the principle of anti-superposition. The basic argument was based on the common sense excluding the individual superposition of states of macro-objects. Here we have proved that the individual superposition principle is scientifically unfounded statement in general.
(ii) In the paper [6] the starting point was also the negation of the individual superposition principle based on the common sense arguments.
(iii) The same is true for the paper [1]

We think that the fact that the individual superposition principle is an undecidable statement in QM must have important consequences for QM in general.

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