"Physical quantity" and "Physical reality" in Quantum Mechanics: an epistemological path.

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We reconsider briefly the relation between "physical quantity" and "physical reality" in the light of recent interpretations of Quantum Mechanics. We argue, that these interpretations are conditioned from the epistemological relation between these two fundamental concepts. In detail, the choice as ontic level of the concept affects the relative interpretation. We note, for instance, that the informational view of quantum mechanics (primacy of the subjectivity) is due mainly to the evidence of the "random" physical quantities as ontic element. We will analyze four positions: Einstein, Rovelli, d’Espagnat and Zeilinger.

INTRODUCTION

What do we mean with physical quantities? In quantum mechanics they play a central role, specifically in a measurement process. Physical quantities give us information on the state of a physical system. What do we mean instead with physical reality? We have not any clear definition. There are many hypothesis on their relation, most important (Einstein position), was the tentative to establish a perfect "isomorphism". We are interested to analyze this possible relation. We retain fundamental this debate, because the evolution of the two concepts are strictly linked with the foundations of physical laws. We will utilize the foundations of Quantum Theory as useful tool to go at the heart of the problem.

Realism

We need to give a "general" definition of "realism". There are many forms of realism, stronger and weaker. Realism, roughly speaking, is the belief that there exists an objective world out there independent of our observations. The doctrines of realism are divided into a number of varieties: ontological, semantical, epistemological, axiological, methodological. Ontological studies the nature of reality, especially problems concerning existence, semantical is interested in the relation between language and reality. Epistemological investigates the possibility nature and scope of human knowledge. The question of the aims of enquiry is one of the subject of axiology, while methodological studies the best, or most effective means of attaining knowledge. In synthesis:

• (ontological): Which entities are real? Is there a mind-independent world?
• (semantical): Is truth an objective language-world relation?
• (epistemological): Is knowledge about the world possible?

• (axiological): Is truth one of the aims of enquiry?
• (methodological): What are the best methods for pursuing knowledge.

In this paper, we are interested to "ontological realism", specifically the ontological realism in quantum mechanics. We will analyze four significative positions: Einstein, Rovelli, d’Espagnat and Zeilinger. In advance we can say that, starting from Einstein to Zeilinger, we will assist to a gradual disappearance of the physical reality (and their relative isomorphism).

PHYSICAL QUANTITY AND PHYSICAL REALITY IN: EINSTEIN, ROVELLI, D’ESPAGNAT, ZEILINGER

Einstein position[1]:

If, without in any way disturbing a system, we can predict with certainty (i.e., with probability equal to unity) the value of a physical quantity, then there exists an element of physical reality corresponding to this physical quantity.

This was the basic conjecture of the EPR argument with the primary objective to prove the incompleteness of QM. The original paper used entangled pairs of particles states wave, whose function cannot be written as tensor products. Instead of using the quite general configuration, usually is considered an entangled pairs of spin- particles that are prepared, following Bohm[2], in the so-called singlet state that is rotation invariant and given along any vector by:

\[ \Psi(x_1, x_2) = \frac{1}{\sqrt{2}} (|+\rangle_1 \otimes |-\rangle_2 - |-\rangle_1 \otimes |+\rangle_2) \]

The above citation lead us to analyze two mentioned fundamental concepts: (i) physical quantity and (ii) physical reality. We retain the debate on these two notions completely opened, because we have not any univocal and deep definition. The importance of the above statement, to us, is the following strong epistemological affirmation:
The perfect "isomorphism" between two assumptions (e.g. Einstein position)

Physical quantity (measurable) without correspondence in the physical reality (e.g. Zeilinger position)

Physical quantity (measurable) with "veiled" correspondence in the physical reality (e.g. d'Espagnat position)

Unmeasurable physical quantity with possible existence in the physical reality.

Unmeasurable physical quantity with any existence in the physical reality.

Of course, Philosophers can to ascribe these epistemological positions to philosophical schools. Here, we can easily do many questions, for instance, (i)what is a physical reality unmeasurable? (ii)Is it possible that all physical quantities are measurable? (iii) What is a physical quantity without the correspondent physical reality? How, we can go on? There are some interesting works, for instance, the relational quantum mechanics.

Rovelli position[3]:

Rovelli departs radically from such strict Einstein realism, the physical reality is taken to be formed by the individual quantum events through which interacting systems (objects) affect one another. Quantum events exist only in interactions and the reality of each quantum event is only relative to the system involved in the interaction. In Relational QM, the preferred observer is abandoned. Indeed, it is a fundamental assumption of this approach that nothing distinguishes a priori, systems and observers: any physical system provides a potential observer, and physics concerns what can be said about nature on the basis of the information that any physical system can, in principle, have. Different observers can of course exchange information, but we must not forget that such information exchange is itself a quantum mechanical interaction. An exchange of information is therefore a quantum measurement performed by one observing system A upon another observing system B.

These considerations are based on the following basic concepts[3]:

The physical theory is concerned with relations between physical systems. In particular, it is concerned with the description that observers give about observed systems. Following our hypothesis (i.e. All systems are equivalent: Nothing a priori distinguishes observer systems from quantum systems. If the observer O can give a description of the system S, then it is also legitimate for an observer O' to give a quantum description of the system formed by the observer O), we reject any fundamental or metaphysical distinctions as: system/observer, quantum system/classical system, physical system/consciousness. We assume the existence of an ensemble of systems, each of which can be equivalently considered as an observing system or as an observed system. A system (observing system) may have information about another system (observed system). Information is exchanged via physical interactions. The actual process through which information is collected and stored is not of particular interest here, but can be physically described in any specific instance.

Rovelli position, lead us to think the following epistemological implications:

(i) rejection of individual object

(ii) rejection of individual intrinsic properties

Some consequence: (a) is not possible to give a definition of the individual object in a spatio-temporal location, (b) is not possible to characterize the properties of the objects, in order to distinguish from the other ones. In other words, if we adopt the interaction like basic level of the physical reality, we accept the philosophy of the relations and:

(i) we renounce at the possible existence of intrinsic properties.

(ii) and we accept relational properties (math models).

We remember, for instance, that a mathematical model based on the relationist principle accept that the position of an object can only be defined respect to other matter. We do not venture in the philosophical implications of the relationalism (i.e. the monism which affirm that there are not distinction a priori between physical entities). An important advantage of these approaches is the possibility to eliminate the privileged role of the observer. This is the importance of Rovelli’s approach to quantum mechanics. In details, Rovelli[2] claim that QM itself drives us to the relational perspective, and the founding postulate of relational quantum mechanics is to stipulate that we shall not talk about properties of
systems in the abstract, but only of properties of systems relative to one system, we can never juxtapose properties relative to different systems. Relational QM is not the claim that reality is described by the collection of all properties relative to all systems, rather, reality admits one description per each (observing) system, each such description is internally consistent. As Einstein’s original motivation with EPR was not to question locality, but rather to question the completeness of QM, so the relation interpretation can be interpreted as the discovery of the incompleteness of the description of reality that any single observer can give: in this particular sense, relational QM can be said to show the “incompleteness” of single-observer Copenhagen QM.

Rovelli’s approach seems do not venture in the clarification of two notions: physical quantity and physical reality. As we have seen, he retain fundamental the relation between systems. The math nature of the relation is the real problem. Of course, we can ask: math law of what?

d’Espagnat position[4]:

"defines his philosophical view as open realism; existence precedes knowledge; something exists independently of us even if it cannot be described". According d’Espagnat, we are unable to describe the physical reality, but he admit his existence. For this reason, respect our analysis, is not clear this position, according d’Espagnat, we can trust only of physical quantities but we have not any tool to verify their correspondence in the physical world.

Zeilinger position[5]:

The individuality notion have introduced recently radical interpretation of quantum mechanics. The forced equivalence is between information and individuality (and not between physical quantity and physical reality), this is Zeilinger[2] view. He put forward an idea which connects the concept of information with the notion of elementary systems:

First we note that our description of the physical world is represented by propositions. Any physical object can be described by a set of true propositions. Second, we have knowledge or information about an object only through observations. It does not make any sense to talk about reality without the information about it. Any complex object which is represented by numerous propositions can be decomposed into constituent systems which need fewer propositions to be specified. The process of subdividing reaches its limit when the individual subsystems only represent a single proposition, and such a system is denoted as an elementary system. (qubit of modern quantum physics).

In short, random physical quantity is the main fundamental rule to fix any correspondence with the physical reality. Opposite Einstein’s position.

CONCLUSION

We have analyzed, how starting from the genuine realism we have reached a genuine subjectivism. The physical reality step by step is gradually disappearance. The physical reality is replaced by the subject. We ascribe this evolution to the unclear epistemological relation between physical quantity and physical reality, so, the interpretation of quantum mechanics is not only due to the analysis of the formalism. Finally, we conclude with a paradoxical question: Was Einstein a realist? As we have seen, he was the only real ”idealist” because, he did not give up to research the physical reality.

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[4] d’Espagnat B. On physics and philosophy. Princeton University Press (2006)
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