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Epistemic and ontic interpretation of quantum mechanics: Quantum information theory and Husserl's phenomenology

The opposite between Einstein's and Bohr's approach towards quantum mechanics has been often described as the opposite between an ontic and an epistemic approach towards quantum mechanics. On the one hand Bohr's more epistemic approach had the advantage of originating directly from the experiments and their most direct interpretation, without considering traditional notions about real and existing, and thus became the basis for physical interpretations of quantum mechanics. On the other hand more or less all ontic approaches (e.g. many worlds, hidden variables) originated from the opposition to the epistemic interpretation and not from its continuation or complementation. Both approaches stay unconnected within (more or less) all present interpretations, even though the differences between them do not put them in opposition. On the contrary, a complete interpretation should certainly consider both of them.

From my point of view an interesting possibility for exceeding this perceived opposition could be offered by quantum information theory, which is essentially based on the epistemic approach, but at the same time, because of its connection with philosophical tradition, offers a possibility for a connection with Husserl's phenomenological approach and therewith a possible basis for the foundation of an epistemic-ontic interpretation of quantum mechanics.

Epistemic interpretation of quantum mechanics – quantum information theory

Quantum information theory as essentially epistemic is based on the hypothesis that »quantum physics is only indirectly a science of reality but more immediately a science of knowledge.«[1]

Information is seen as the fundamental element of the physical description of nature and as information is everything we can say about reality (Wirklichkeit), it is meaningful to see both of them as one and the same. The main hypothesis of quantum information theory is that one most elementary system can carry just one bit of information. And the most fundamental characteristic of information is that it cannot be endlessly divisible, which also offers a possible answer to the Wheeler's question "Why quantum?": we essentially comprehend the Nature in the form of the information, which is fundamentally finitely divisible. Therefore Nature (as we comprehend it) is essentially quantisized.

But since the approach of quantum information theory is fundamentally epistemic, the objectivity of the information cannot be taken as self-evident on the basis of the common, from us independently existing outer world, as was the fact in classical physics. The randomness in quantum-mechanical processes, completely independent from the observer, and extremely high accurateness and objectivity in the estimation of the probability, indicate that it is not (only) the closed system of the (subjective) observer's information we are talking about, but that they rely on the, from us independent, reality. Nevertheless, the objectivity of the quantum world can be taken into account only on the basis of certain invariants, and of

[1] Brukner, Časlav, Zeilinger, Anton: *Quantum Physics as a Science of Information*, in: "Quo Vadis Quantum Mechanics?", edited by A. Elitzur, S. Dolev, N. Kolenda, Berliner, Heidelber, New York : Springer (2005): 55.

the inter-subjective agreement about the gained information and their meaning. On this basis it is possible to exceed the solipsism and to conclude that information, independent from us, forms the objective reality, so that the outer world (in that sense) exists. But still, since this approach is merely epistemic, there is no direct connection between the information and “that something this information is about”. On this basis we can speak about an objective inter-subjective world of information, however we can not speak about an objective outer world that this information is about. If information is all that exist, then there is nothing this information is about. And on this point the supplementation of this complex epistemic approach by a philosophical-ontic interpretation, seems fruitful for further and wider explanation.

Connections with philosophical systems

A) Immanuel Kant

The relationship between the observer, the observation and the observed has not been seen as particularly important in classical physics, where objects of physical observation and their independence from the observer have been taken for granted. On the contrary, this question has always been seen as crucial in philosophy and has very often been built into complex philosophical systems. Therefore, one could say that quantum mechanics has not really opened a new problem, but has shed light on an old philosophical problem from a physical side. This opens a possibility for more complex processing of the problem, but since all traditional philosophical systems deal with these questions only with respect to classical physics, one has to be very careful while transmitting certain philosophical approaches to the quantum field.

An important, complex and systematic philosophical treatment of the relationship between the observer and the observed is represented in Kant’s *Critique of Pure Reason*. As his philosophy had an important place in the general education at the time, these questions were recognized as important in physics and as his systematic, mainly epistemic approach offered an interesting basis for further reasoning, some parts of his approach have become, more or less directly and complexly, involved in physical reasoning about these questions.

In *Critique of Pure Reason* Kant emphasizes that what observe are not "things-in-themselves", but phenomena (“things-for-us”). For something to become an object of knowledge, it must be experienced, and an experience is structured by our minds. So causality, time and space are not the conditions of the experienced world, but are forms of our cognition (space and time are forms of perceiving and causality is a form of knowing). The relationship between “things-in-themselves” and phenomena is therefore not causal.

Kant's method, his distinction between phenomena and “things-in-itself”, has offered an basis for the consideration of the relationship between the observer, his information about the observed, and the observed. However, as Grete Herman already emphasized in the dialog with Heisenberg and Weizsäcker, in Kant’s philosophy the place of the physical object is solely on the side of phenomena, so the difference between the-thing-in-itself and the phenomena, as developed by Kant, cannot be transmitted to the relationship between the physical object and the information about it, if one stays in accordance with Kant’s philosophical system. Therefore even though Kant’s approach is mainly epistemic, his philosophical system as such is incompatible with quantum physics or at least with its epistemic interpretations, since ontic interpretations are much closer to classical views on the relationship between the observer an the observed. Nevertheless, his method – his refined relationship between the phenomenon and "thing-in-itself" – is compatible with (orthodox) epistemic interpretations of quantum mechanics. His definition of the relationship between the two (even though transmitted from the relationship between "thing-in-itself" and phenomenon to the relationship between observed and information) has been, with more or less awareness of its source and more or less completely, frequently integrated into epistemic quantum interpretations. This can be seen in quantum information theory and its interpretation of the relationship between the information and "that something this information is about".

However, more than 200 years old Kant's philosophical system has been since its formation frequently re-considered within the field of philosophy. The lack of permeability between the "thing-in-itself" and the phenomena, which can not be causally connected, even though some kind of connection between the two exists (»...though we cannot know these objects as things in themselves, we must yet be in a position at least to think them as things in themselves; otherwise we should be landed in the absurd conclusion that there can be appearance without anything that appears.«[2]), has been recognized as one of the most problematic parts of his system.

Because the main features of the relationship between the information and "that-something-this-information-is-about" in quantum information theory are quite similar to Kant's definition of relationship between the phenomena and the "thing-in-itself", the problems that this kind of approach faces are similar as well. Information is meaningful only as long it is information about something, but if information is everything it is, what is the information about?

B) Edmund Husserl

In the philosophical field an answer was provided by Husserl's approach towards the observer and the observed within his phenomenology. His approach, while still mainly epistemic, maintains the permeability between the "thing-in-itself" and the phenomenon. Despite later criticisms and additions to his system, his construct of phenomenon being essentially related to both: the observation (or the one observing) and to the observed itself, has remained intact to this day. For Husserl phenomenon means: the object as has been given to me by itself, but essentially to me, in the way to have a meaning (exactly) to me. Husserl's phenomenon still depends on the observer's cognition but at the same time on the observed as well. The connection between the two is causal.

As such Husserl's philosophical approach towards the relationship between the phenomenon and the "thing-in-itself" (again as by Kant it is not the whole philosophical system that is transmitted, but solely his approach towards this relationship) seems as an interesting possibility for the substitution of quantum information theory's description of the relationship between the information and "that something information is about" within quantum reality.

The connection between quantum information theory and Husserl's phenomenological approach towards the relationship between the observation and the observed gives the

[2] Kant, Immanuel, *Critique of Pure Reason*, Transl. Palgrave Macmillan, Basingstoke, Hampshire: Macmillan Publishers Limited (2010): Bxxvi-xxvii.

following result: information and "that something this information is about" within quantum information theory are causally connected – information represents the direct answer to the question about the observed (information as the ″eigen value″ in the case of the description of the measurement in Hilbert space), the basis for this information is, however, the observed itself (the "quantum system" in the case of the description of the measurement inside Hilbert space). This connection makes the information meaningful (it is information about something, for example the value of the position or of the polarization of the (observed) photon) and supplements the merely epistemic quantum-information approach with an ontic approach, without introducing further quantum realism.

Epistemic and ontic interpretation of quantum mechanics – further derivations

Based on the presented possibility of ontic-epistemic interpretations of quantum mechanics some further philosophical-physical issues can be detailed. Beside the relationship between the observation and the observed, also the relationship between the two and the observer has been frequently considered in philosophy, but has not been particularly important in classical physics, while it has been recognized as relevant in quantum physics. The presented ontic-epistemic approach offers the following considerations of the relationship between the information and the "that something this information is about" (the observed) on the one side and the observer on the other side – they are both in two ways connected to the observer:

1. To the observer as observer *per se*, as to the one for whom they have a meaning. There the observer and his way of comprehension can be seen as the answer to the question "Why information" and, to it connected, Wheeler's question "Why quantum?".
2. To the observer as to the part of an environment, as to the one, who, by trying to get any information, already (necessary) has an influence on the observed and on the information about it.

The first connection is merely epistemic. The information has a meaning as information only as long it is information for someone. Its form depends on the conditions of our cognition, since the fact that everything we comprehend is given in the form of information is most probably based in the preconditions of our comprehension. However, the second connection is merely ontic. Since information is always information about something, in the case of the measurement not only our information about the observed system is changed, but the observed system as entangled with the measurement apparatus (and thus with our classical system) as well. This process has been described by decoherence.

Both connections emphasize the transition from quantum to classical. Decoherence of the observed quantum system and thus its connection with our classical environment makes it possible to describe it in our classical language and to transmit some characteristics of our classical system to it. Apart from decoherence that offers the basis for an ontic description of this transition, this transition is mainly epistemic.

Concepts that we know from our every-day experience are classical concepts, since we know they rely on complex systems, but we do not have any reason to connect them with coherent quantum systems. Any direct observation would cause decoherence and would thus a-priori disable the observation of the coherent quantum system. An abstract mathematical description of the coherent quantum system is a meaningful operationalistic description of the system we are not directly connected to (which is not directly observed). On the other hand, any interpretation of this description based on the usage of classical concepts has no basis. It is meaningless to speak about the “real existence” of the wave function, or to describe coherent quantum system within the concepts of time and space, since these are classical concepts, based on our everyday experiences in the world of complex decohered systems.

However, another important consideration of the transition from quantum to classical is based on the logical postulate, that to describe something it is necessary to be outside the described set. This postulate operationalistically explains the cut between quantum and classical in the process of measurement and is thus (more or less) identical to Heisenberg’s consideration of this problem known as “Heisenberg cut”. This cut is a necessary condition for the possibility of empirical knowledge and is as such operationalistic, but not arbitrary. On the one hand the choice depends on the nature of experiment, and on the other hand, since quantum description is universal, while classical physics can describe only complex classical systems, the cut cannot be shifted arbitrary in the direction of the atomic system.

Conclusion

Reconsideration of quantum information theory within continental philosophy offers a possibility for ontic supplementation of a merely epistemic quantum information theory. In that way information could be understood as information about something, as information about the observed. Consequently the firm answer how to exceed solipsism and gain common objectivity of a quantum mechanical description is offered, without introducing further realism. However, the information is (still) the only answer we can get to the question about the observed and it makes no sense to speak about any pre-given properties, since there is no basis for the transmission of classical concepts on coherent quantum systems before measurement.