Review

Jens Hebor, *The Standard Conception as Genuine Quantum Realism*. Odense: University Press of Southern Denmark 2005, 231 s.

Quantum Realism: The Interpretation of an Interpretation?

Every physical theory needs an interpretation. Physical theories are meant to represent something different from themselves, and it is characteristic of them that they are expressed in terms of mathematics, which implies that the mathematical symbols must be assigned a physical meaning in order for these theories to be relevant for a physical description of some particular phenomenon. This form of interpretation is the proper physical reading. Another more global form of interpretation is the metaphysical construal of a theory. It attempts to understand what the basic formulas tell us about the world and whether we should be realist or antirealist with respect to the theory and entities in question.

In general a physical interpretation operates by relating the mathematical symbols with already well-known physical terms based on representational conventions. The trained physicist therefore understands the use of the mathematical symbols in the context of a specific theory without being involved in any act of interpretation. This he does to the extent that the representational conventions are part of the physical practise and background knowledge as is the case as long as the theory is used within its standard repertoire of applications. But a new theory may introduce mathematical terms which have no counterparts in old theories. A nice example is the Dirac matrice. It stands for spin in quantum mechanics which is not identical with the classical angular momentum. Here one cannot rely on the classical convention in reaching an understanding of what the symbol stands for or what it means. Physicists must keep on interpreting the meaning until a common understanding of that expression crystallizes. This happens when its representational structure is laid down with respect the experimental practise and physical data.

The situation is quite different with respect to the metaphysical interpretation of a theory. All metaphysical interpretations are grossly underdetermined by data and will always be. Whereas a physical interpretation eventually becomes established as the shared understanding of a particular physical theory, a metaphysical interpretation is always debatable without further empirical findings.

In philosophy of physics there is an ongoing metaphysical dispute about whether the standard theory of quantum mechanics should be interpreted realistically or non-realistically, and if it should be interpreted realistically, what kind of realist ontology one might coherently extract from the mathematical formalism. The motivation hereof is based on two insights. On the one hand, a literal mathematical interpretation identifies physical reality with a mathematical model of operators. Such a model is the abstract Hilbert space. On the other hand, a literal physical reading takes the physical understanding of the theory on face value. This suggests a physical reality very different from the world of classical physics. It is a reality which consists of value-indefiniteness, superposition, entanglement, intrinsic probabilities, and measurement collapse. In both cases, it leaves us with an understanding of physical reality which is very unfamiliar. Therefore, many philosophers, regardless of their overall attitude to realism and non-realism, do not think of any of them as constituting a satisfactory metaphysical understanding.

In his book *The Standard Conception as Genuine Realism*, the Danish philosopher Jens Hebor takes part in this debate. As the title indicates, Hebor is a proponent of a realist interpretation of quantum mechanics. He urges that the quantum formalism should be interpreted realistically and that the only correct realist interpretation corresponds with what he takes to be the standard interpretation. "By the standard conception of quantum mechanics I refer to the rational core of what is often called the Copenhagen interpretation or the orthodox view." (p.13) The standard conception includes, according to Hebor, value-indefiniteness, superposition, entanglement, non-separability, intrinsic probability, and measurement collapse. Other realist interpretations such like the many-world-interpretation, the Bohmian interpretation, and the modal interpretation are dismissed as absurd or incoherent.

To reach his goal Hebor makes clear that we must distinguish between realism and ontology as well as between realism as such and classical realism. Realism is compatible with many different ontologies, i.e. theories about the nature and structure of the world. Realism is merely the metaphysical view that no matter what is claimed to exist, it exists independently of the human mind or cognitive capacity. Hebor takes it to be a fallacy, which he calls the ontology-realism fallacy, i.e. associating a definite ontology with realism. Thus, he argues that physical realism cannot, and should not, be identified with classical realism. I completely agree. Hebor also argues that even classical realism may cover different ontologies. I concur too.

What then is classical realism? It is a set of requirements which an interpretation of any physical theory has to meet to be called a classical interpretation of that theory. Some of these requirements have their origin in our common sense view of reality which rests on our common practise of identification, discrimination and interaction. According to Hebor, classical realism can be characterized by ten different features or requirements. These are briefly: (1) *Classical state-observable structure* which implies that physical quantities (properties) are measurable in principle. In other words, physical quantities are observables. (2) *Value-definiteness*, i.e. every observable has a definite value at all times. (3) *Space-time dependence*. Classical observables are defined on space and time in the sense that they are a function thereof. (4) *Non-superposition of states*. A physical system always has a definite state so that any observable pertaining to that state is always definite and determinate. (5) *Separability*. In a composite system which consists of spatially separated subsystems each and every subsystem will be in a definite state. (6) *Continuity*. All interactions are continuous in nature such that all those values represented by real numbers exist between the initial and final state of a system. (7) *Classical description*. All observed systems can be described as if they are unobserved, and if not, it is possible to correct for the possible influences due to the observation. (8) *Completeness*. All observables pertaining to a system (at any other time) are determined by the present state of the system. (9)

Objectivity. A physical description of a physical system is objective in the sense that the description represents the system as it really is. And (10) *Classical realism*. This is the core assumption according to which physical systems exist independently of any description and they are always in a definite state having definite values. Some of these requirements are more epistemological than ontological, none of them are controversial, but I find Hebor's attempt to make a structured explication of these requirements of much value because it paves the way to a constructive discussion of quantum ontology and possible realist interpretations of quantum mechanics.

It is worth mentioning that it is not only classical physical theories, like Newtonian mechanics, thermodynamics, statistical mechanics and Maxwellian electrodynamics, which arguably fit the interpretation of classical realism. Also the theory of special theory of relativity and the theory of general relativity can in general be given such an interpretation, even though there are some problems in connections with the general theory of relativity. But when it comes to quantum mechanics, it is no longer possible to keep a classical understanding.

I think Hebor provides us with a realist interpretation of quantum mechanics which is both original and independent of other realist interpretations of quantum mechanics. What he does, in my opinion, is rather straightforward: he looks at the quantum formalism and sees what it takes to give a realist interpretation of the formalism bearing in mind its physical interpretation. He figures that out by taking the physically interpreted formalism at face value as a possible metaphysical interpretation, and then he regards it as the only genuine realist interpretation of quantum phenomena. Here he has done a pretty good job, I think, since he is perhaps the first philosopher who has taken seriously the full philosophical consequences of such a literal reading. Not only does he argue that quantum systems are real, but so are quantum states with dislocalized position and indeterminate momentum, superposition, entanglement, and quantum collapse. I wonder, however, why he does not discuss in this connection Ghirardi, Rimini, and Weber (GRW) theory of the collapse of the wave function. This theory is not a part of standard quantum mechanics although it seems to contain some of the features Hebor attributes to the orthodox theory.

In addition – and indeed in most beautiful support of his own account – Hebor rejects other acclaimed realist interpretations for being incoherent. Much of this criticism reflects beliefs with which other philosophers can associate themselves. Hebor takes issue with the many-world interpretation, the decoherence view, the modal view, and the Bohmian theory. Some of the criticism is well-taken; especially with regards to the many world interpretation and the Bohmian theory, other parts are perhaps less convincing such as his criticism of the modal and the decoherence view. I shall leave the more technical issues aside. I will only make one substantial remark concerning Hebors' handling of these other realist approaches, namely that he states his own reservations too presumptuously as if there exists a proof of his own view and a disproof of those he disagrees with. Nobody in the wide world can prove or disprove a metaphysical interpretation. In general, metaphysics is a shaky business.

In my opinion Hebor has given a very coherent interpretation of quantum mechanics in which he takes many aspects into considerably technical considerations. Apart from technical details, I think, nonetheless, that his over-all view can be called into question in two ways. First, what are the philosophical arguments for being a full-blown realist about scientific theories, and say, not only a realist about entities? Second, is it correct that the standard conception of quantum mechanics, as Hebor understands it, was seen by Bohr as a realist interpretation?

Many philosophers believe that physical theories are empirically underdetermined by data. In my opinion this also holds in the domain of the quantum world. There are revival theories to the orthodox quantum mechanics which does not merely signal another interpretation of the standard theory like the many world interpretation or the modal interpretation. Bohm's theory of a quantum potential is such an alternative theory which gives the same kind of predictions as the orthodox quantum theory. Both theories assume the existence of atomic particles, but interpreted realistically they attribute to the system very different properties. Thus, Hebor's argument still needs some very strong arguments showing that one should be realist concerning the orthodox theory of quantum mechanics, arguments which he does not present to us in the present book. Rather, regarding Bohr's view as an example of entity realism, as does Henry Folse, seems a much more compelling view because this makes neither quantum mechanics nor Bohm's theory literally true.

Realism occurs with different commitments. It may come in degrees and contain other than an ontological component. One may be a realist about ontology but not with respect to semantics or epistemology. Such a realist would not hold the same form of realism as one who is a realist with respect to ontology, semantics and epistemology. But Hebor's view of realism is not particularly complex. According to him, realism merely maintains the existence of a mind-independent world whose properties are what they are independently of our cognitive capacity. From his realist interpretation of the standard quantum theory it is evident that he takes a realistic approach to semantics and epistemology as well.

The title of the book clearly shows that Hebor believes that it is not only the orthodox theory of quantum mechanics which can be given a wholly realist understanding. He also holds that the *standard conception is a realist interpretation of the quantum world*, assuming furthermore that the rational core of the Copenhagen interpretation is the only coherent realist understanding. In all fairness he admits that physicists like Bohr, Heisenberg, Pauli and Born – who each saw himself as a spokesperson for the spirit of Copenhagen – have given different explanations of what that implied. Bohr is nevertheless the person whom everybody regards as the "spiritual" leader. When it comes to a close reading of Bohr's work, Hebor is not sufficiently attentive to detail. It would require a closer scrutiny to persuasively defend a view that differs from most other realist as well as antirealist readings of Bohr.

On p. 51 he says: "Now, without going too much into the issue here it may be emphasized that Bohr definitely was a realist about quantum systems … and about Planck's constant." Every contemporary philosopher who has studied Bohr's work is likely to accept this. Hebor then continues: "Bohr didn't say very much about states and observables and what he said was typically in the form of a warning against pictorial readings of the state vector." This is correct too. But he adds: "I do think, however, that Bohr actually was a realist about these items … too – even though Bohr of course was not a classical realist concerning the relation betweens states and observables … I think that Bohr ought to be a realist concerning these items, too, if his understanding of quantum mechanics is to be at all coherent." But what if Bohr were an entity realist and a theory antirealist, then would he be incoherent?

Some philosophers, including myself, see Bohr as a realist about system but an antirealist about states without being incoherent. But I think that everybody must admit that Bohr is notoriously opaque in his writings and that some of his wordings may be interpreted one way or the other. It is impossible to give a satisfactory documentation of my own understanding at this place, but let me make a couple of comments on another of Hebor's passages concerning Bohr and quantum states. On p. 55 he develops his claim a bit further:

"Later Bohr referred to the state vector as "giving the symbolic representation of [the system's] state" … which of course means that (1) the system *has a state*, (2) the state is *represented by the state vector*, but (3) the representation is *symbolic*, that is, it is not visualizable. It should also be clear that, when Bohr uses the word "symbolic", it definitely does not mean e.g. "purely mathematical" (in that case *symbolic representation* would be a *contradictio in adjecto*) and hence does not commit Bohr to some kind of anti-realism about states."

Naturally enough, a representation must represent something different from itself. The way Hebor sees it is that the state vector gets its physical significance and reality in conjecture with operators; i.e., symbols for *possible* observations.

So the question is what Bohr meant by calling the state vector or the wave function a *symbolic* representation. Usually symbolic language stands in contrast to literal language. Bohr associated the latter form of representation with what can be visualized in space and time. Quantum systems are not vizualizable because they cannot be tracked down in space and time as classical systems. The reason is according to Bohr that the mathematical formulation of quantum states consists of imaginary numbers. Thus, the state vector is symbolic. But what if "symbolic" means that the state vector's representational function should not be taken literally but be considered as a *tool* of calculation of probabilities of observables? Let me present one quotation of Bohr's in which he directly says what I just have indicated:

"The entire formalism is to be considered as a tool for deriving predictions of definite or statistical character, as regards information obtainable under experimental conditions described in classical terms and specified by means of parameters entering into the algebraic or differential equations of which the matrices or the wave-functions, respectively, are solutions. These symbols themselves, as is indicated already by the use of imaginary numbers, are not susceptible to pictorial interpretation; and even derived real functions like densities and currents are only to be regarded as expressing the probabilities for the occurrence of individual events observable under well-defined experimental conditions." (Bohr 1948[1998]: 144)

Also consider the following: (a) in many places Bohr talks about the mathematical formalism of quantum mechanics as the mathematical *symbolism*, and he talks about *symbolic operators*; (b) concerning the aim of science Bohr says: "In our description of nature the purpose is not to disclose the real essence of phenomena, but only to track down as far as possible relations between the manifold aspects of our experience" (Bohr 1929[1985]: 18); (c) "within the frame of the quantum mechanical formalism, according to which no well defined use of the concept of "state" can be made as referring to the object separate from the body with which it has been in contact, until *the external conditions involved in the definition of this concept* are unambiguously fixed by a further suitable control of the auxiliary body" (Bohr 1938b[1998]: 102, my emphasis) – in other words, it makes no sense to say that a quantum system has a definite kinematical or dynamical state prior to any measurement. Hence we can only ascribe a certain state to a system given those circumstances where we epistemically have access to their realization. Based one these and other considerations, I still think it makes good sense to argue that Bohr was a realist with respect to atomic systems but antirealist with respect to their states.

As a consequence of his realist position on the state vector, Hebor believes that the state of superposition collapses when a measurement is performed on the system. Says he: "As the states are real, the change of state is real too, so collapse is a real physical process." (p.66) But if it is correct, as I have argued, that Bohr was not a realist concerning quantum states, it follows that Bohr didn't believe that the measurement of a quantum system creates a collapse of the wave function. Sure, had he embraced state vector realism and operator realism, he should also by necessity have the collapse of the wave function. But he never did that. In fact, I don't know of any place where Bohr talks about the collapse of the wave function. Hebor's attitude is very Popperian at this point since he seems to regard probabilities as a kind of objective propensities. If Bohr thought that the state vector-cum-operator formalism represented the real *physical* (in contrast to logical) possibilities of observation and that a measurement reduces one of these objective possibilities to actuality when it results in an eigenvalue of the measured observable, why did he not say that explicitly? Rather Bohr had the opinion that the state vector-cum-operator represented the *logical* conditions under which it made sense to ascribe a kinematic or a dynamic property to the system. The actual measurement then gives us the *physical* condition under which we correctly can ascribe a particular such property. It was because of this reason and this alone that he called the state vector and the operators symbolic.

Besides our major disagreement, I also have some minor, but formal, complaints about the book. I find it rather tedious to read a small book containing 230 pages of which 60 pages are notes. It is too demanding of a reader to stop his reading very minute or so. An author does not have to tell the world everything he has read and doesn't like. In my opinion it should be more or less a golden rule that what cannot be incorporated into the main text should be left out. I also wonder why Hebor hasn't acknowledged the person who acted as the linguistic editor of his English text in the Preface. Finally an

Index would have helped that reader who wants to study the book more closely.

In his attempt to give a realist interpretation of the orthodox quantum mechanics Hebor has written an impressive book which deserved an international readership. Even though he is self-taught in both physics and mathematics, he masters the mathematical foundation of the discussion apart from showing great philosophical common sense. Whatever our differences on Bohr and quantum mechanics might be, I think that his book demonstrates an innovative insight in quantum mechanics and its possible philosophical implications.

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