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Article

Quantum Logic versus Alternative Approaches

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Abstract: In the present paper we will discuss the following problem: Is the external reality primarily a quantum world such that in macroscopic dimensions classical properties evolve by decoherence and emergency? – Or is there only a classical, macroscopic world of apparatuses and observers, and what we can say about the quantum world is nothing but a consistent way of speaking which illustrates without any ontological commitments merely the formalism of quantum mechanics?

Keywords: Quantum physics, classical physics, quantum logic, decoherence

1 The quantum logic approach

The main goal of the quantum logic approach is the bottom-top reconstruction of Hilbert lattices and of quantum mechanics in Hilbert space – and that without any reference to the actual historical development of this theory. Starting from a weak quantum ontology O(Q), that can be obtained from classical ontology O(C) by eliminating some metaphysical hypotheses (Mittelstaedt 2005), we can construct a formal language $\mathcal{S}_Q$ of quantum physics whose syntax leads in some formal steps to the calculus $\mathcal{L}_Q$ of quantum logic. The Lindenbaum-Tarski algebra of $\mathcal{S}_Q$ turns out to be a complete, orthomodular lattice L_Q. If the language refers to a single system, the lattice is atomic and fulfills the covering law. It will be denoted here by L_Q^*. Using the Piron-McLaren theorem and the angle-bisecting condition of Solèr, we arrive at the Hilbert lattice L_H, the classical Hilbert spaces and the well-known quantum mechanics in Hilbert space. It should be mentioned, that within this approach a realistic interpretation of quantum mechanics must refer to the presupposed weak quantum ontology O(Q).
In Hilbert space quantum mechanics the most general observables are given by POV-measures (Busch/Lahti/Mittelstaedt 1996), which correspond to unsharp properties. Hence in order to make the result of the quantum logic approach

compatible with the underlying ontology we should replace the quantum ontology O(Q) by a more general ontology O(Q^u) of unsharp properties. In this ontology, two unsharp properties can be attributed jointly to a system, provided the conveniently defined degrees of unsharpness satisfy the uncertainty relation. Hence the quantum ontology O(Q^u) which replaces the strict complementarity requirement by the more relaxed uncertainty principle is somewhat stronger than the original ontology O(Q), but still weaker than the classical ontology O(C). More details about this way of reasoning can be found in the literature (Mittelstaedt 2005).
There is still another point to be mentioned. If quantum mechanics is considered to be universally valid, it is applicable to macroscopic as well as to microscopic systems and in particular to the measurement apparatuses. It is well known, that within the framework of quantum mechanics it is not possible after a unitary premeasurement to attribute sharp or unsharp values to the pointer observable (Busch/Lahti/Mittelstaedt 1996; Mittelstaedt 1998 and Busch 1998). Even if merely unsharp values are attributed to the pointer, these values turn out to be not strictly reliable.[1] For macroscopic quantities, however, this unreliability is practically negligible, and hence it was never observed. On the other side, we should keep in mind that in quantum physics the requirement of objective and reliable pointer values – the pointer objectification postulate – is merely a reminiscence to classical physics. However, classical physics is based – at least partially – on ontological hypotheses without any rational or empirical justification. Hence, there is in principle no reason to maintain the requirement of objectification.

2 A new alternative approach to quantum mechanics

The alternative approach to quantum mechanics that we will briefly discuss here, was considered by its authors as a means to remove many conceptual problems of quantum mechanics. We mention here in particular the work of Aage Bohr, Mottelson, and Ulfbeck (Ulfbeck/Bohr 2001; Bohr/Mottelson/Ulfbeck 2004a and Bohr/Mottelson/Ulfbeck 2004b) and several papers that are concerned with the probability interpretation (e. g., Appleby 2005). Also the comment by Mermin (2004) contains interesting information. The starting point of the new approach is the almost trivial observation that we can perceive merely clicks in a detector and that an individual click can in general not be determined by any law. Furthermore, it is assumed that these entirely uncaused clicks are objective events in space and time. Moreover, since we observe merely these undetermined click events, there is no objective causality law that connects in an experimental set-up the preparation with the registration. In addition, particles as carriers of properties are merely imaginations and do not exist as real entities.
There is, however, still another point that must be contained in any new interpretation of quantum mechanics. In addition to, and in spite of the objective

[1] This means that "... one cannot claim with certainty that the reading one means to have taken is reproducible on a second look at the pointer" (Busch 1998, p. 246).

indeterminacy of single events, a large number of identically prepared and registered events fulfill the well known statistical laws of quantum mechanics. The protagonists of the new approach argue that "the clicks do not occur in pure emptiness but in the context of counters and apparatuses, which provide the classical background for the exploration of the click". It is then shown, that from these weak premises together with some invariance requirements (e.g. Galileo invariance), the statistical laws of quantum mechanics can be derived.
Summarizing the main results of this approach, Bohr/Mottelson/Ulfbeck (2004a) emphasize the new principle of "genuine fortuitousness" which means that a single click is entirely uncaused. There is no need to consider a click in the detector as caused by a particle. The click has no cause and is recognized merely as a macroscopic discontinuity. Hence, particles are completely eliminated.

3 Critical remarks

3.1 The constitution of objects

From a philosophical point of view the restriction of our knowledge to observed qualities can be traced back to the writings of David Hume. In his *Treatise of Human Nature* of 1739 Hume emphasized that we never observe objects directly but only qualities and that it is nothing but imagination if we regard the observed qualities as properties of an object. Consequently, within Hume's scepticism against induction there is no reason to assume that objects – as fictitious entities obey some causal laws. However, on account of the same scepticism, Hume never denied the existence of objects and of laws of nature. Only within the positivism of the 19^{th} century, Ernst Mach argued in a more antirealistic way and denied explicitly the existence of atoms, since – at this time – atoms could not directly be observed.
In contrast to Hume, Kant emphasized in the *Critique of Pure Reason* that objects of experience are not arbitrary imaginations but entities that were constituted from our observations by means of some conceptual prescriptions, the categories of substance and causality. Kant formulated necessary conditions, which must be fulfilled by the observed qualities if these qualities are considered as properties of an object. We will not go into detail here, since the same way of reasoning was also applied in physics during the last 50 years.
In classical mechanics in phase space as well as in quantum mechanics in Hilbert space, we describe measurable quantities, observable properties and their temporal development, but not objects as carriers of properties that persist in time. In both fields, classical physics and quantum physics, objects must be constituted by formal methods, which might be considered as a reconstruction of the Kantian way of reasoning. In quantum mechanics, we can argue as follows. If we are given a convenient invariance group G, e.g. the Galileo group, a pointer observable Z of the apparatus, and a pointer function f that connects pointer values Z_i with values $f^{-1}(Z_i)$ of the measured observable (POV-measure), then we arrive at the following result:

Whenever the triple (G; Z; f) fulfills the requirements of a system of imprimitivity, then objects as persistent carriers of properties are given by convenient representations of the symmetry group G (cf. Mackey 1963; Piron 1976; Mittelstaedt 1995 and Mittelstaedt/Weingartner 2005, Ch. 10).

More explicitly this means, that the object values $f^{-1}(\mathrm{G}[Z_i])$ of the G-transformed pointer values Z_i must agree with the G-transformed object-values $\mathrm{G}[f^{-1}(Z_i)]$ of the pointer values Z_i, i.e.

$$f^{-1}(G[Z_i]) = G[f^{-1}(Z_i)].$$

Since in the new alternative approach to quantum mechanics these possibilities to constitute objects in an empiricist framework, are not considered at all, neither in the sense of Kant's philosophy, nor in the sense of systems of imprimitivity, the supposed new interpretation represents nothing but a crude antirealism in the foundations of quantum mechanics.

3.2 Probability laws

The possibility, on the basis of completely undetermined single events, to derive the quantum mechanical probability laws is neither new nor a merit of the antirealist approach mentioned. Originally, a result of this kind was obtained within the framework of the many worlds interpretation by Everett (1957), Graham (1973) and DeWitt (1971), within the context of quantum logic by Finkelstein (1962), and within quantum cosmology by Hartle (1968). Within the framework of contemporary quantum theory of measurement, various probability theorems were proved, the most simple one reads:

Let φ be the preparation of a system, and $\mathrm{A} = \Sigma \mathrm{A}_i\ \mathrm{P}(\mathrm{A}_i)$ the measured observable with eigenvalues A_i and projection operators $\mathrm{P}(\mathrm{A}_i)$. If a unitary premeasurement fulfills the calibration postulate, then the relative frequency $\mathrm{f}(\mathrm{A}_i)$ of outcomes A_i is given in the limit of infinitely many measurements of A by the probability distribution $\mathrm{p}(\varphi, \mathrm{A}_i) = (\varphi, \mathrm{P}(\mathrm{A}_i)\varphi)$, which depends on the preparation and the measures observable (Mittelstaedt 1991; Busch/Lahti/Mittelstaedt 1996; Gutmann 1995; Mittelstaedt 1998 and Mittelstaedt/Weingartner 2005).

It must be emphasized that this result holds if and only if the single measurement outcomes are completely undetermined and do not depend on hidden individual properties like a *potentia* (Heisenberg) or *propensity* (Popper). This means that the quantum mechanical probability law $\mathrm{p}(\varphi, \mathrm{A}_i) = (\varphi, \mathrm{P}(\mathrm{A}_i)\varphi)$ just reflects that the individual events are not determined by any law. Hence, it is neither new nor surprising that in the antirealist approach a probability law can be derived for completely uncaused events. Obviously, this result has nothing to do with the strange and antirealist philosophy of this approach.

4 Conclusion

The arguments of the present paper lead to a two-fold result. On the one hand, if we were starting from the ontology of the quantum world and proceed according to the quantum logical way of reasoning, then we would arrive at quantum mechanics in Hilbert space. However, since this way does not lead to decoherence, the classical world cannot be achieved or reconstructed in this way. On the other hand, if we were starting from the classical world of apparatuses and observers, we would not obtain causality of single events and hence no particles as bearers of causally connected properties. What we obtain is an abstract scheme, a formalism for calculating probabilities, but not objects of a quantum world.

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