Quantum Theory: A Philosopher's Overview
SALVATOR CANNAVO
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Given its general motivation, “Quantum Theory: a Philosopher's Overview” by Salvator Cannavo is a very interesting book. The fundamental question is: Can quantum mechanics be an explanatory theory? In a nutshell, his answer is: “No”. I respectfully disagree. Before we enter into the merits of his case, let me describe the book.

In Chapter 1 the author nicely reviews quantum theory. On the one hand, quantum mechanics (in the text “QT”) has had an unprecedented and overwhelming experimental success. On the other hand, however, quantum mechanics raises profound conceptual problems which are equally unprecedented. Since its discovery, the theory has generated a large philosophical debate about its ultimate intelligibility and its metaphysical implications. As Cannavo points out, “nothing of this glorious classical history, however, has been quite as stunning as the success of quantum theory – a success that has seemed utterly magical. [...] What quantum mechanics has not yet found itself is a universally accepted interpretation [...].” (p.3). As the author discusses in Chapters 2 and 3, quantum physics presents most puzzling features, among which are the wave-like behavior of particles and *vice versa*, the macroscopic superpositions, the active role of a conscious observer, and nonlocality. “The natural response to the baffling aspects of quantum physics is the demand for an interpretation for QT” (p.39). In Chapter 4 Cannavo presents the Copenhagen interpretation and Bohm's hidden variable theory, while in Chapter 5 he discusses the many-worlds interpretations, the many-minds interpretations, decoherence theory, GRW theory, and quantum logic. The conclusion is that the situation is hopeless: all these interpretations are inadequate, for they all fall short of providing the sort of explanation an interpretation should give. After describing the distinction between explanatory and algorithmic theories (the former being able to make predictions and explanation, the latter just predictions), Cannavo shows in Chapter 6 how quantum theory has always been ultimately and irreducibly algorithmic, so that “[…] the very long history of failed efforts at formulating a generally acceptable interpretation strongly suggests that the interpretational program is deeply impractical, if not utterly futile […]” (p. xii). We should recognize, Cannavo claims, that it is in the nature of quantum mechanics of not being able to explain phenomena. Physicists have developed new theories, like quantum electrodynamics, quantum field theory and string theory (to which Cannavo refers as “quantumized theories” (p. 105)), which start off assuming quantum theory, and hoping these new theories will be explanatory. Chapter 7 and 8 explore this possibility. The conclusion is that they all are unexplanatory, for they fundamentally lack unity and leave the foundational problems unresolved. Therefore, in Chapter 9 the author argues that, in order to solve both the difficulties of quantum mechanics and have an explanatory theory, we should look for “a deeper incorporation of” quantum mechanics (p.119). That is, physicists should search for an entirely novel theory, “a theory of nature that would make for a fuller mathematical integration of contemporary physics by recovering -*through explanation*- the predictions of present-day quantum and quantumized theory together with all that classical theory (relativity included) can tell us about the macroworld” (p. 130). This theory, H, will most likely contain hidden variables, like Bohm's theory does. But in this context they will be acceptable, because H “does not have to be a deepened or extended QT. That is, the formalism of H does not have to implicitly ``include" (i.e. entail) any part or aspect of QT so as to render that part or aspect mathematically derivable from H and, in this sense, ``explainable" *by* (perhaps better *within*) H. Such a requirement would only take us back to the burdens of the HVI [hidden variable interpretation]” (p.100).

I think Cannavo's conclusion is too hasty, for the following reasons. I agree that a theory, to be satisfactory, should provide more than just the ability of making predictions. I also agree that the quantumized theories do not solve the puzzles and paradoxes of quantum mechanics. But our agreement ends here: Cannavo's arguments that all interpretations fail are flawed.

Most discussions in the book (e.g. the EPR experiment and Bell's inequality) are complete, correct, clear and straightforward, developed in a nontechnical language understandable also by the nonspecialist reader. But when we arrive at the interpretations, the analysis is unfortunately incomplete, extremely poor, and based on fundamental misunderstandings.

First of all, the presentation of Bohm's theory is incorrect, clumsy and unclear. For example, the statement: "Bohm tried to relate the quantum state vector |Ψ>, representing the quantum system to his posited hidden variable |λ > and to do this, he introduced a nonlinear term in the Schrödinger formalism" is strictly speaking false or *at best* misleading. Also, Cannavo only makes reference to Bohm's original 1952 formulation in terms of the quantum potential. It has been shown (see Dürr, Goldstein and Zanghì 1992) that this presentation obscures what Bohm's theory really is: a deterministic theory of particles whose motion is governed by the wave function that evolves according to Schrödinger's equation. The theory (now commonly called Bohmian mechanics, BM) has been developed by many since 1952, but any reference to the recent literature on BM is entirely absent in Cannavo's book. And this is unacceptable for a book that claims we should abandon the "interpretational program" (p. xii). In fact, Cannavo does not do justice to BM, and makes it difficult to assess its theoretical vices and virtues, such as its ontological clarity, its simplicity and explanatory power.

Not only BM is poorly presented, but also the main objection put forward against it is unsound. In fact, it is based on "the findings of various investigators [...]" that "pose logical impasses (so-called ``no-go theorems'') to defining physical states in terms of hidden variables [...]" (p.124). But this rests on a profound misunderstanding (see Dürr, Goldstein and Zanghì 2004). These theorems assume that BM supplies a map from operators to random variables (representing measurement results), while this is not correct: it presupposes that BM uncritically assumes the quantum formalism of operators as observables, while it does not. So, the objection just dissolves like snow in the sun. Indeed, Cannavo's lack of appreciation of BM makes him judge as unacceptable (*qua* non-explanatory) the use of hidden variables in this theory, while the opposite is actually the case. For, it is exactly the introduction of the particle positions (the hidden variables) that allows BM to explain all the quantum features (see Dürr, Goldstein and Zanghì 1992).

Also, the discussion of the many-worlds interpretation is not fair, given that it is not entirely up-to-date: the theory presented is mainly the one due to Hugh Everett III in 1957. In the bibliography one can find more recent authors (especially David Wallace) but in the text there is no mention of their position, mostly aimed at solving the problems raised by Cannavo against the theory, like the preferred basis problem, and the problem of recovering quantum probabilities (in addition to Wallace, see also e.g. Saunders 1994; Deutsch 1999; Greaves 2007; Baker 2007). In addition, the discussion of the many-minds interpretation seems to be without proportion, considering that even some of its proponents regard it more as a thought experiment than a serious interpretation.

The presentation of GRW is instead much clearer and accurate. The main objection to it presented in the book is that "GRW raises a serious question of intelligibility. Its account pivots on the mysterious notion of a physical state ``interacting'' with an abstract wave function whose physical significance defies all definition" (p. 128). Proposals have been made in the literature about the role of the wave function in GRW to account for this (see e.g. Ghirardi, Benatti, Grassi 1995; Albert 1996; Allori, Tumulka, Goldstein and Zanghì 2008), but their arguments are not addressed in the book. Once again, the conclusion that the theory is unacceptable is unwarranted.

To sum up, while I greatly sympathize with Cannavo's search for an explanatory quantum theory, I believe he should have given a closer look to the recent work in the literature in the interpretational program before coming to the conclusion that QT cannot be turned into such a theory. Indeed, Cannavo wants a novel theory "to provide a coherent, causal-mechanics architecture for explaining quantum phenomena [...]" (p.101). He is not scared of hidden variable *per se*, since he recognizes that physical theories use and have always used hidden variables, but he finds Bohm's attempt to be misguided. I would be extremely surprised if, with a better knowledge of what BM really is, Cannavo would not find BM exactly what he is looking for.

References:

ALBERT, D.Z. 1996. Elementary Quantum Metaphysics. In J. CUSHING, A. FINE, S. GOLDSTEIN (Eds.) *Bohmian Mechanics and Quantum Theory: an Appraisal* (New York, Springer).

ALLORI,V.; GOLDSTEIN, S. ; TUMULKA, R., ZANGHÌ, N. 2008. On the Common Structure of Bohmian Mechanics and the Ghirardi-Rimini-Weber Theory. *The British Journal for the Philosophy of Science* 59: pp. 353-389.

BAKER, D. 2007. Measurement Outcomes and Probability in Erverettian Quantum Mechanics. *Studies in the History and Philosophy of Modern Physics 38*: pp. 153-169.

DEUTSCH, D. 1999. Quantum Theory of Probability and Decisions. *Proceedings of the Royal Society of London* A455: pp. 3129–3137.

DÜRR, D; GOLDSTEIN, S.; ZANGHÌ, N. 1992. Quantum Equilibrium and the Origin of Absolute Uncertainty. *Journal of Statistical Physics* 67: pp. 843-907.

DÜRR, D; GOLDSTEIN, S.; ZANGHÌ, N. 2004. Quantum Equilibrium and the Role of Operators as Observables in Quantum Theory. *Journal of Statistical Physics* 116: pp. 959-1055.

GHIRARDI, G.C.; BENATTI, F.; GRASSI, R. 1995. Describing the Macroscopic World — Closing the Circle within the Dynamical Reduction Program. *Foundations of Physics* 25: pp. 5-38.

GREAVES, H. 2007. Probability in the Everett Interpretation. *Philosophy Compass* 2(1): pp.109-128.

SAUNDERS, S. 1994. Decoherence and Evolutionary Adaptation. *Physics Letters A* 184: pp.1-5.

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