BOOK REVIEW:
Physical Theory and its Interpretation – Essays in Honor of Jeffrey Bub
Edited by William Demopoulos and Itamar Pitowsky
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This book is an hommage to Jeffrey Bub, with twelve contributions from colleagues and friends – philosophers, physicists and mathematicians – working in the foundations and philosophy of modern physics. The range of topics covered reflects the scope of Bub's broad interests and life work in this field, and each article is a tribute to his commitment to conceptual and mathematical rigor. Some of the contributions are more didactic in nature, giving an accessible introduction to or survey of their subject. Others are reviews of a larger research program or critical assessments of the status of a problem of current interest, while some authors chose to report their recent research results.

True to the characterization given of Jeff Bub in the preface as "untiring in his determination to understand the nature of the reality quantum mechanics seeks to describe", the unifying theme that runs through the book as a red thread is in fact quite generally the investigation of the nature of physical reality as it is encoded in our modern theories of physics. Taken as a whole, the book thus provides interesting insights into this problem from a variety of angles.

The contributions are arranged in chapters, not in a systematic manner according to subjects but in alphabetic order of the first authors' (last) names. Here I briefly survey the contributions, following roughly the order of increasing specialization.

Richard Healey investigates the scope of scientific realism in view of "symmetry", understood in the abstract sense of the existence of distinct models of a physical theory with the same empirical content. Two questions are addressed, one semantic, the other epistemological: how does a term referring to structures without direct empirical significance acquire its meaning (if any); and what justification is there for the belief that such term has a referent in the physical domain? An approach proposed by David Lewis to answer the first question is used as a diagnostic tool for exhibiting surplus theoretical structure in the presence of symmetry, and such surplus features are taken to indicate an epistemological defect of the theory that one usually aims at eliminating by way of an appropriate reformulation. The negative answer to the second question is illustrated with reference to Newton's absolute space and electromagnetic gauge invariance. This contribution concludes with just a hint at the problem of interpreting quantum mechanics, and it would be very interesting to see the present consideration extended to this case in some detail.

The second contribution of a more general character is that of Harvey Brown and Christopher Timpson, and it addresses a methodological issue. These authors explain "why special relativity should not be a template for a fundamental reformulation of quantum mechanics". Pointing out that special relativity was designed by Einstein as a *principle theory* only because at the time formulation as a *constructive theory* was not within reach, these authors argue that an analogous derivation of quantum theory from empirical postulates cannot help to "reveal the fundamental form of the theory". The recent reconstruction of quantum mechanics from information theoretical principles given by Clifton, Bub and Halvorson [1] is considered as a specific instance, and Bub's own assessment of the impact of such an exercise is briefly commented upon. The paper ends with an interesting conundrum: While Einstein's quest for an atomic theory of moving rods and clocks appears to have been motivated conceptually by a desire for a more fundamental explanation, Bub's conclusion is that a mechanical theory capable of giving an account of quantum mechanical measuring instruments must violate the information theoretic principles that are inherently satisfied by quantum mechanics. The resolution may lie in the observation that Brown and Timpson's reference to the "crude instrumentalistic nature" of Bohr's interpretation of quantum mechanics does not do justice to Bohr's rather more sophisticated Kantian outlook and approach. If the latter is bourne in mind, then it would seem conceivable that operational reconstructions of quantum mechanics such as that of Clifton-Bub-Halvorson do have a bearing on the fundamental form of the theory, after all: specifying the conditions of the possibility of experience in the form of empirical constraints may well enable us to envisage elements of the fundamental theory in which they are encoded.

The next four contributions are concerned with the logic of quantum mechanics in different ways. William Demopoulos discusses the general question, raised by Einstein with reference to quantum mechanics, of whether and how a physical theory can be considered complete if one of its “principal consequences is that our knowledge of the objects with which it deals is necessarily incomplete”. His investigation is quantum logical in spirit and leads to a characterization of “inherent incompleteness”; however, the conclusion, that physical theories such as quantum mechanics do entail the impossibility of universal truth value assignments is, perhaps surprisingly to some, at odds with the original intentions of the quantum logic approach, which was thought to make room for such assignments in a consistent way.

Allen Stairs revisits memories of a talk of Saul Kripke of some thirty years ago. In this lecture, Kripke put forth criticisms of Putnam’s view that empirical discoveries may rightly lead to a revision of logic and of the thesis that all quantum mechanical propositions have definite truth values, which are revealed by measurements. To avoid being accused of putting words into their mouths, Stairs draws up his story, quite amusingly, by introducing fictitious characters of the names Krispe and Tupman. His focus is on the validity of the distributive law: reasoning that is based on the assumption that all propositions have definite truth values appears to render distributivity as a law of thought that is not open to adoption or rejection. But if it is the case that “the classical logician has overlooked the possibility that propositions can be incommensurable”, then the self-evidence of distributivity is lost and there is scope for a revision of logic. Stairs concludes with a consideration of issues (probability, Schrödinger’s cat, nonlocality) as they would arise in a quantum logical world.

Itamar Pitowsky offers an impressive account of “quantum mechanics as a theory of probability”. He reviews the quantum logical derivation of Hilbert space quantum mechanics, including a discussion of the role of Solèr’s axiom (the famous, long-sought missing link) for which he offers a probabilistic reading. In a discussion of Bell iinequalities and the associated correlation polytopes, he reminds us of the fact that such inequality constraints for probabilities were already conceived by George Boole in the nineteenth century, as *conditions of possible experience* [2, 3]. An information-theoretic conjecture is made precise which, if true, would offer an explanation (independent of decoherence) of the effective impossibility (or rather difficulty) of observing entanglement in macroscopic systems.

The issue of quantum logical value-definiteness is taken up once more by Christopher Isham who has developed a novel form of multi-valued, contextual truth values. This contribution is a reprint of a review written for physicists which appeared originally in the journal *Contemporary Physics*. Starting with a formalization of quantum mechanical coarse-graining in order to capture the idea of approximate truth, the paper develops an accessible, intuitive introduction of the *presheaf* of local, contextual truth values. Presheaf theory is a special instance of topos theory. Isham’s aim is to apply the resulting new structure and notion of quantum reality in the context of quantum cosmology.

The subject of the next group of papers are interpretational and formal aspects of quantum theory. The contributions of Clark Glymour and Miklós Rédei are concerned with different aspects of quantum correlations and entanglement. Glymour revisits Aspect’s experiments in a simplified variant due to David Mermin (whose name becomes conspicuously transformed into Mirmin after the first and before the last occurrence – the perhaps most irritating occurrence of typos which otherwise are pleasantly rare in this book), to highlight possible hidden assumptions in the known proofs of the impossibility of local hidden variables. He concludes that the correlations exhibited in Bell experiments “have no causal explanation consistent with the Markov Assumption [which is Reichenbach’s screening assumption], and the Markov assumption must be applied, implicitly or explicitly, to obtain this conclusion.” This raises once more the question why the Markov assumption does work in the macroscopic domain, for which some tentative suggestions are offered.

Rédei focuses on the issue of a possible violation of local causality in the presence of entanglement between separated subsystems. He starts by providing some interesting historical background on von Neumann’s exchange with Einstein and Schrödinger on the latter’s seminal papers of 1935 and 1936. He then goes on to show that von Neumann’s response amounts to the following alternative: either probabilities are understood as expressions of ignorance, or there has to be a common cause for such distant correlations. Putting aside the first option, Rédei proceeds to review investigations of forms of *common cause principles* that do hold true for correlations in relativistic quantum field theories.

The possible conflict between quantum theory and special relativity is also prominent in the article by Joseph Berkovitz and Meir Hemmo, who propose a "new modal interpretation of quantum mechanics in terms of relational properties". This appears to be a rather recent idea, which amounts to assuming an (additional) element of contextuality with reference to system decompositions. In this way, it can be argued that joint probabilities exist only in a restricted sense, and this allows the authors to circumvent the known objections to modal interpretations, to propose resolutions of the measurement problem and offer explanations of the quasi-classical behavior of macroscopic systems. It seems that the formalization of the definitions and postulates presented in this paper is somewhat lacking in precision so that it is difficult to assess the viability of this new proposal.

As the last author in this group, Stan Gudder gives a very nice didactic exposition of quantum entropy and its properties, with proofs, for the case of finite-dimensional Hilbert spaces.

The last two papers are devoted to physical theories other than quantum mechanics. Jeremy Butterfield gives a very beautiful and thorough (and extensive) account of "symmetry and conserved quantities in classical mechanics". He develops formulations of Noether's theorem in Lagrangian and Hamiltonian mechanics using the modern geometric language, and proceeds to provide a clear explanation of the roles, logical connections, scope and relative merits of these two formulations of classical mechanics. It is likely that such exemplary conceptual and logical analysis of classical mechanics will turn out invaluable for a deeper understanding of the quantum-classical contrast, considering that quantum mechanics possesses the structure of an (infinite dimensional) symplectic manifold itself (the projective Hilbert space with its natural symplectic form induced by the inner product).

Finally, Herbert Korte revisits "Einstein's hole argument and Weyl's field-body relationalism". In addressing the hole argument – Einstein's worry about a possible conflict between causality and general diffeomorphism invariance – he introduces clear distinctions between formal, theoretic and physical coordinates and associated symmetry transformations and considers the consequences of the equivalence of active and passive transformations. The main thesis is that of the necessity of adopting the ontological position of a field-body relationalism, as had been argued by Hermann Weyl. This position is exemplified with an explicit construction of Newtonian spacetime and Newton's laws based on the existence of a guiding field, as postulated by Weyl. The paper is rather technical, drawing on the author's work of the 1980s (which some readers may find helpful to consult).

The book concludes with a bibliography of Jeffrey Bub's publications to 2006.

As this brief summary shows, this book holds something of interest for philosophers and physicists alike who are interested in the philosophical problems of modern physics. The expositions are generally of high quality, and the book makes for very interesting and, in places even entertaining, reading. A good degree of historical perspective is provided alongside the exposition of a range of problems of current interest in the foundations of quantum physics and beyond, demonstrating the breadth and vitality of this area and the high standard of intellectual rigor of the research carried out in it.

References

[1] R. Clifton, J. Bub and H. Halvorson, *Characterizing quantum theory in terms of information theoretic constraints*, Found. Phys. **33** (2003) 1561.

[2] G. Boole, *On the theory of probabilities*, Phil. Transact. Roy. Soc. London **152** (1864) 225; *The Laws of Thought*, Dover, New York, 1958 (first published 1854).

[3] I. Pitowsky, *George Boole's "conditions of possible experience" and the quantum puzzle*, Brit. J. Phil. Sci. **45** (1994) 95.