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METAPHYSICAL ISSUES IN THE PHILOSOPHICAL FOUNDATION OF QUANTUM MECHANICS

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1 Introduction to the Current Volume

The advent of quantum mechanics in physics was concomitant with the arrival of logical empiricism on the philosophical scene. While quantum mechanics quickly lead to philosophical speculation among physicists (which many scholars felt was metaphysical), logical positivism was a frontal assault on the deep seated tendency towards metaphysics in Western philosophical thought. However, the philosophical movement that grew out of Logical Empiricism – sometimes going by the name Anglo-Saxon philosophy but better know as analytic philosophy – "was subverted by reactionary forces. [...] And lo, even before mid-century, some of its ablest adherents began to make the world safe for metaphysics again" (van Fraassen, 2002, p. xviii). Thus, the possibility or impossibility of a metaphysical development of physics – a discussion which has taken place mainly within the analytic domain – remains at stake at the beginning of the 21st century. Contrary to that other revolution in physics, relativity theory, quantum mechanics was ambiguous with respect to metaphysics from the start. So even though metaphysics is again relevant in any domain of physics, including

relativity theory, quantum mechanics – exactly because of its recalcitrant nature with respect to any kind of interpretation – remains an even more interesting locus for philosophical research into the nature of a contemporary metaphysics of science than relativity theory. From very different perspectives, this special issue is an attempt to address the metaphysical and anti-metaphysical stances of very different proposals regarding the interpretation of quantum mechanics.

The question of metaphysics in the context of quantum mechanics has – implicitly or explicitly – raised many questions and problems. In particular, the debate which took place between Einstein and Bohr regarding the interpretation of quantum mechanics reveals the tension present not only in the 20th century physics but also philosophy between two contrary stances. On the one hand, Einstein analyzed the conditions of possibility for physical experience and worried about the problem of reality, on the other, Bohr conceived a pragmatic scheme based on language and communicability. Einstein and Bohr took different stances in the analysis of the meaning of quantum mechanics and physics itself. These discussions, as exposed in the current volume, have not only continued but are still an important aspect of our present day analysis of quantum theory.

In the volume at hand we have the honour to bring together some of the most distinguished physicists and philosophers which have contributed to the foundational understanding of quantum theory in the last decades. Diederik Aerts, a disciple of Josef-Maria Jauch and Constantin Piron, has continued with renovated strength the quantum logical developments of the Geneva School. Already in his Doctoral dissertation Aerts provided a new understanding of the meaning of separability in quantum systems (Aerts, 2002). The importance of his research is stressed by Bas van Fraassen in his book *Quantum Mechanics: An Empiricist View*: "The three main issues in the philosophical foundation of quantum mechanics are measurement, the 'paradoxes' and the problem of identical particles. Each of these concerns

the composition of several systems – sometimes interacting and sometimes not – which is a subtle matter in quantum mechanics. Dirk Aerts very aptly sums up these issues as the problem of the One and the Many, which has here taken on a new form of life." Michel Bitbol is one of the most important proponents of the neo-Kantian approach to quantum mechanics and continues a long tradition which goes back to Carl Friedrich von Weizsäcker, Pieter Mittelstaedt and Bernard D'Espagnat. Through his many publications and books – *Mechanique Quantique, une introduction philosophique* and *L'auveglante Proximite du Reel* – Bitbol has been able to build a complex and interesting bridge between the ideas of Niels Bohr and Ludwig Wittgenstein, ideas which point in the direction of a new understanding of quantum mechanics in particular and of science in general. Dennis Dieks has been one of the leading figures together with Bas van Fraassen, Simon Kochen and Jeffrey Bub regarding the development of modal interpretations, maybe one of the most interesting and fruitful developments regarding the interpretation of quantum mechanics in the last decades. Alexei Grinbaum, has published important contributions in the logical development of quantum information and the epistemological understanding of quantum theory. He is also actively involved in the organization of many conferences and seminars in Continental Europe.

2 The Contributed Papers

Diederik Aerts advances in his paper beyond the Aristotelian based interpretation of Constantin Piron (1973; 1983) and into his own original metaphysical scheme for interpreting quantum mechanics. This attempt provides an interpretation based on the notion of *potentiality* and *conceptuality*. "The main hypothesis of this new interpretation is that quantum particles are entities interacting with matter conceptually, which means that pieces of matter function as interfaces for the conceptual content carried by the quantum particles." Aerts also provides his own

interpretation of potentiality which is explained in terms of his well known example of "the vessels of water experiment" (Aerts, 1982; see also Christiaens *et al.*, 2010). In this paper Aerts goes deeper into his own attempts (Aerts, 1983; 1985; 1993; 1998) to provide a metaphyscal account of physical reality based on a non-space like description of the quantum realm. This realistic interpretation is based on the notions of *abstract* concepts and *concrete* particles, giving rise to a new twist to the possible understanding of the relation between classical and quantum physics. Aerts provides an original interpretation turning upsideown the problem exposed through the linguistic turn, putting forward an ontological scheme for concepts and language itself. This scheme allows him to account for certain paradigmatic problems such as 'measurement', Schrödinger's cat and 'individuality' of quantum particles. Aerts argues that: "There are various reasons why we believe we should try and look for new interpretations of quantum mechanics with the aim of finding explanations, including for such fundamental questions as 'What is a quantum particle?' " And stresses the fact that: "young physicists and philosophers should be encouraged to do so." In this sense Aerts continues a long tradition which goes back to Wolfgang Pauli, who considered "the most important and extremely difficult task of our time to work on the elaboration of a new idea of reality."

Michel Bitbol presents in his paper "Reflective Metaphysics: Understanding Quantum Mechanics from a Kantian Standpoint" an attempt to engage the question of metaphysics within the neo-Kantian scheme. Already in the introduction we find the very interesting remark which shows the, sometimes unaknowledged, importance of metaphysics for the Kantian architectonic. Bitbol stresses that, according to Kant, metaphysics is the discipline of the boundaries of human knowledge and, although was clearly against *dogmatic* metaphysics, – which attempts to provide access to some suprasensible realm and finds its best exposure in the philosophy of Leibniz and Wolff – he was able to recognize at the same time the *function* of the metaphysical quest *within* human

knowledge itself – and the *regulative* aspect of metaphysical notions. From this standpoint, in which metaphysics is understood as "reflective", Bitbol discusses in this paper the possibility that "quantum mechanics might well require from us a complete redefinition of the nature and task of metaphysics". Another interesting point addressed by Bitbol regards the clarification of "why it looks culturally so difficult to accept a reflective and non-ontological standpoint on physical theories." Already in the introduction Bitbol presents a critical position towards the "necessity" of an ontological scheme for understanding quantum theory, and characterizes "the current state of philosophical research about quantum mechanics [as] a combination of (i) urgent need for pictures of what is allegedly 'beyond' the empirical domain, and (ii) persistent failure to gain general agreement about any such picture." The strategy proposed by Bitbol is then to recall on Kant's understanding of reflective metaphysics, in order to advance towrds the nature and task of quantum metaphysics itself and at the same time "dispel some alleged 'paradoxes' of quantum mechanics". At this point Bitbol goes beyond Kant and adopts a pragmatic redefinition of the *a priori* – instead of the "purely intelectual" notion used by Kant in his *Critique of Pure Reason*. With these tools at hand Bitbol goes back to quantum mechanics and provides an analysis of some of the main interpretations together with their problems.

The study of the modal character of quantum mechanics was explicitly formalized in the seventies and eighties by a group of physicists and philosophers of science. Bas van Fraassen was the first one to formally include the reasoning of modal logic in quantum mechanics. He presented a modal interpretation of quantum logic in terms of its semantic analysis (1973). Dennis Dieks was one of the leading reserachers in this field and provided a general scheme based on the bi-orthogonal (also called Schmidt) decomposition (Dieks, 1988a; 1988b; 1989). Regarless of its long history of now several decades, the meaning of *possibility* remains a controversial issue within the different proposals of the modal

interpretation (de Ronde, 2010). In this paper Dieks analyzes different metaphysical and anti-metaphysical possitions regarding the interpretation of modality. Although Dieks does not close completely the door to the development of a coherent metaphysical scheme which would allow us to understand possibility in "intuitive terms", – as some kind of propensity or objective chance – he argues that "quantum mechanics gives us no special reason to believe in the actual existence of modalities". Instead of an ontological interpretation of possibility, in this paper Dieks develops arguments in favor of a Humean interpretation of quantum mechanics which, he argues, has many advantages over metaphysically based schemes; e.g. propensity interpretations and modal realism. In particular, Dieks analyzes the physical interpretation of *quantum superpositions* and shows how a Humean scheme can also provide a coherent account of the quantum mechanical formalism. Dieks concludes that "The Humean view is a sober one: it recognizes only one world, namely our actual one. According to this view laws are descriptions of regularities exhibited by the events in the actual history of our universe." And continues: "Modalities, like possibility and necessity, and counterfactual statements, are accordingly introduced *a posteriori*, as conceptual tools that enable us to deal theoretically with the actual world; they do not have an independent life of their own."

In his paper entitled *On epistemological modesty*, Alexei Grinbaum argues "against the claims that physical theories, e.g. quantum mechanics, favor any ontological statements on the nature of reality." The methodological precept which guides this anti-ontological scheme in the reconstruction of physical theories from axioms runs as follows: "If the theory itself does not tell you that the states of the system (or any other variables) are ontic, then do not take them to be ontic." In other words: "Epistemological modesty requires that one brackets his or her personal motives for the choice of first principles, which merely become axiomatic statements in the reconstruction of a given theory." Grinbaum then advances into the discussion of the structural relationship between

physical entities and the *theoretical assumptions* involved within a physical theory. Recalling on the epistemological lesson of quantum mechanics regarding the necessity of the cut between the observer and the observed he provides a loop scheme in which "any particular theory is represented by cutting the loop at some point and thus separating the target object of the theory from the theory's presuppositions. Due to the necessity of the cut, it is impossible to give a theoretical description of the loop as a whole. Now, when the position of the cut is fixed, some elements of the loop are treated as objects of the theory, while other elements fall into the domain of meta-theory." In this way Grinbaum is able to account for the relation between physical theories. "Different theories do not form a pyramid which is reduced to yet more and more fundamental theories with 'stronger postulates'; on the contrary, for the purposes of each theory, a part of the loop must be taken as a given, and the relation between theories is the one of mutual illumination rather than that of reduction." Einstein's plea for "stronger postulates" becomes then a mere epistemological illusion.

The number of interpretations of quantum mechanics has kept growing in the last decades with many different attempts to "make sense" of the theory. In such schemes the questions related to the possibility of providing a "metaphysically tenable interpretation" have been extensively discussed. In the realm of the quantum, we could summarize this discussion in two main groups of interpretations, those which begin "right from the start" from metaphysical presuppositions and those which tend to begin "right from the start" with the analysis of the orthodox quantum formalism itself, its symmetries and invariances. Also, within the modal interpretation, this question has been addressed on many occasions and while some versions take metaphysical presuppositions as the very starting point of departure of their analysis others present a much more agnostic position regarding metaphysical principles (Dieks, 1988b; van Fraassen, 1991; Bub, 1992; Clifton, 1996; Bacciagaluppi and Dickson, 1997; Vermaas, 1999). In my own contribution to this volume I discuss

and analyze some of these positions within the modal interpretation and provide arguments for a stance regarding the metaphysical possibilities of the modal interpretation.

We hope that this volume contributes to the ongoing discussion regarding the interpretation of quantum mechanics and its relation to metaphysics.

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Presentation on theme: "Philosophical Issues in Quantum Physics and Metaphysical Implications."â€” Presentation transcript: 1 Philosophical Issues in Quantum Physics and Metaphysical Implications.Â 5 Recap: The Strange Quantum World Wave Particle Duality How to describe systems? Wave Function describes the state of a system in a probabilistic sense Systems exist a superposition of states Observation collapses to a particular state. 6 Recap : Two Views Complementarity (Critical Realism?) â€“Must consider interaction between subject and object in an experiment â€“Conceptual limitation of understanding Realism â€“Theories are description of nature in itself â€“Hidden Variables to explain away apparent indeterminacy? While quantum mechanics quickly lead to philosophical speculation among physicists (which many scholars felt was metaphysical), logical positivism was a frontal assault on the deep seated tendency towards metaphysics in Western philosophical thought. However, the philosophical movement that grew out of Logical Empiricism â€“ sometimes going by the name Anglo-Saxon philosophy but better know as analytic philosophy â€“ â€œwas subverted by reactionary forces. [...] And lo, even before mid-century, some of its ablest adherents began to make the world safe for metaphysics againâ€ (van Fraassen, 2002, p. x...Â The question of metaphysics in the context of quantum mechanics has â€“ implicitly or explicitly â€“ raised many questions and problems. Part of a series of articles about. Quantum mechanics. SchrÃ¶dinger equation. Introduction. Glossary. History. v. t. e. An interpretation of quantum mechanics is an attempt to explain how the mathematical theory of quantum mechanics "corresponds" to reality. Although quantum mechanics has held up to rigorous and extremely precise tests in an extraordinarily broad range of experiments (not one prediction from quantum mechanics has been found to be contradicted by experiments), there exist a number of... Quantum Ontology is an outstanding guide to contemporary philosophy of quantum mechanics. The book's intended audience is philosophers who are knowledgeable about metaphysics and curious about the relevance of quantum mechanics to metaphysical debates. For this audience, the book is ideal. Lewis relentlessly avoids overly technical presentations of the physics, using simple examples and helpful visualizations to get to the heart of the matter at hand.Â In the final chapter Lewis emphasizes that the way our classical metaphysics must be revised in light of quantum mechanics depends on which version of the theory is correct. At the moment, "very little can be concluded unconditionally on the basis of quantum mechanics . . .