IV International Workshop on Quantum Mechanics and Quantum Information: Physical, Philosophical, and Logical Perspectives

ABSTRACTS

Group of Logic and Foundations of Science
Federal University of Santa Catarina
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ABSTRACTS

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Unscrambling the Quantum Omelette of Epistemic and Ontic Contextuality

In this paper we attempt to analyze the physical and philosophical meaning of quantum contextuality. We will argue that there exists a general confusion within the foundational literature arising from the improper "scrambling" of two different meanings of quantum contextuality. While the first one, introduced by Bohr, is related to an epistemic interpretation of contextuality which stresses the incompatibility (or complementarity) of certain measurement situations described in classical terms; the second meaning of contextuality is related to an ontic understanding of contextuality as exposed by the Kochen-Specker (KS) theorem which focuses instead on the constraints of the orthodox quantum formalism in order to interpret projection operators as preexistent or actual (definite valued) properties. We will show how these two notions have been scrambled together creating an "omelette of contextuality" which has been fully widespread through a popularized "epistemic explanation" of the KS theorem according to which: *The measurement outcome of the observable A when measured together with B or together with C will necessarily differ in case* $[A,B]=[A,C]=0$*, and* $[B,C]\neq 0$. We will show why this statement is not only improperly scrambling epistemic and ontic perspectives, but is also physically and philosophically meaningless. Finally, we analyze the consequences of such widespread epistemic reading of KS theorem as related to statistical statements of measurement outcomes.

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Do 'classical' space and time provide identity to quantum particles?

Non-relativistic quantum mechanics is grounded on 'classical' (Newtonian) space and time (NST). The mathematical description of these concepts entails that any two spatially separated objects are necessarily different, which implies that they are discernible (in classical logic, identity is defined by means of indiscernibility) — we say that the space is T2, or "Hausdorff". But quantum systems, in the most interesting cases, sometimes need to be taken as indiscernible, so that there is no way to tell which system is which, and this holds even in the case of fermions. But in the NST setting, it seems that

we can always give an identity to them, which seems to be contra the physical situation. In this paper we discuss this topic for a case study (that of two potentially infinite wells) and conclude that, taking into account the quantum case, that is, when physics enter the discussion, even NST cannot be used to say that the systems do have identity. This case study seems to be relevant for a more detailed discussion on the interplay between physical theories (such as quantum theory) and their underlying mathematics (and logic), in a way never considered before.

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Towards a Multi Target Quantum Computational Logic

Following the standard description of a quantum circuit, it is easy to realize that the actual carrier of information is given by the target bit, while the control bit remains unchanged under the application of a given quantum gate; furthermore, the set of the qubits that play the role of target can obviously change during the computation, in base on the gates that, time by time, are applied. On the other hand, despite its remarkable expressive power, the very preliminary notions of the Quantum Computational Logic QCL [see References] seem to do not take into suitable account this fact, assuming that the "useful" information is always stored by the last qubit only. Indeed, the assignment of the truth value of a given composition of qubits (a quregister) only depends on the last component. For this reason, all the gates that are involved in the language of the QCL are only one-target gates [see References]. This restriction is basically unnecessary and it could also seem to be a little far from the architecture of a real quantum circuit. For this reason, this talk will be devoted to introduce an extension of the QCL (that I will call Multi Target QCL, briefly MT-QCL) and to show some preliminary result. The immediate benefit of the MT-QCL with respect to the QCL is given by the fact that the MT-QCL can involve in the language also multi-target gates (such as the Swap gate, the square root of Swap gate Swap and the Fredkin gate F) without any lost of generality. Further, in this framework the standard QCL can be seen as a particular (one-target) case of the MT-QCL.

References

1 E. Beltrametti, M.L. Dalla Chiara, R. Giuntini, R. Leporini, G. Sergioli (2014). A quantum computational semantics for epistemic logical operators. Part I: epistemic structures. *International Journal of Theoretical Physics*, **53**, pp.3279-3292.

2 E. Beltrametti, M.L. Dalla Chiara, R. Giuntini, R. Leporini, G. Sergioli (2014). A quantum computational semantics for epistemic logical operators. Part II: semantics. *International Journal of Theoretical Physics*, **53**, pp.3293-3307.

3 E. Beltrametti, M.L. Dalla Chiara, R. Giuntini, R. Leporini, G. Sergioli (2012). Epistemic Quantum Computational Structures in a Hilbert-Space Environment, *Fundamenta Informaticae* **115**, pp. 1-14.

4 M.L. Dalla Chiara, R. Leporini, G. Sergioli (2015). Entanglement and quantum logical gates. Part II. *International Journal of Theoretical Physics*, **54-12**, pp.4530-4545.

5 H. Freytes, R. Giuntini, R. Leporini, G. Sergioli (2015). Entanglement and quantum logical gates. Part I. *International Journal of Theoretical Physics*, **54-12**, pp.4518-4529.

5 G. Gudder (2003). Quantum computational logics. *International Journal of Theoretical Physics* **42**, pp.39–47.

6 A. Ledda, G. Sergioli (2010). Towards Quantum Computational Logics. *International Journal of Theoretical Physics*, **49-12**.

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Modal Operators in the Von Neumann Approach to Quantum Mechanics

Quantum mechanics (QM) is recognized as one of the most successful physical theories but at the same time it is a common place to say that we do not know what the theory talks about. In the last years several approaches, using category theory, have been used to search for an adequate and rigorous language for quantum systems linking the von Neumann formalism for the QM to topos theory [1, 2, 3, 5]. In these approaches, the quantum analogue of classical phase space is captured by the notion of frame [4] providing an intuitionistic approach to QM. In this work we provide a representation of physical properties as modal operators in a Heyting structure and we analyze quantum and classical considerations of physical properties in terms of logical consequences.

References

1 G. Domenech and H. Freytes, "Contextual logic for quantum systems", J. Math. Phys. 46 (2005) 012102.

2 H. Freytes, C. de Ronde, G Domenech "Physical properties as modal operators in the intuitionistic approach to quantum mechanics" Foundations of Physics 44, Issue 12 (2014), pp 1357-1368.

3 C. Heunen, N. Landsman and B. Spitters, "A topos for algebraic quantum theory", Comm. Math. Phys. 291 (2009) 63-110.

4 C. Heunen, N. Landsman, B. Spitters and S. Wolters, "The Gelfand spectrum of a noncommutative CC-algebra: a topos theoretic approach", J. Australian Math. Soc. 90 (2011) 39-52.

5 C. Isham, "Topos methods in the foundations of physics", in Deep beauty: understanding the quantum world through mathematical innovation, H. Halvorson (Editor), Cambridge University Press, 2010, 187-206.

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On the nature of the quantum state vector

In the first part, I made a critical analysis of different proposals about the nature of the quantum state vector, starting with Bohr for whom $|\Psi\rangle$ is only an expedient for calculations and Heisenberg that proposes an interpretation in which $|\Psi\rangle$ represents ontological potentialities. I also analyze the general $|\Psi\rangle$-ontological interpretations and the proposal of Bohm that considers both $|\Psi\rangle$ and the particle as ontological. After the critical analysis, I present an interpretation in which the state vector does not have an ontology nature: it belongs to empirical reality and represents a *potentiality*. As its nature is not ontological, that potentiality is only *epistemic*, unlike that proposed by Heisenberg.

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Identity and mock individuality in quantum mechanics

The received view (RV) on quantum non-individuality is the view according to which quantum particles are not individuals. Typically, the RV is articulated in a rather radical way: non-individuals are entities for which the concept of identity does not apply. Now, the lack of the concept of identity introduces difficult challenges. Identity is employed for descripting the behavior of quantum entities in experiments, and it is also employed in theoretical situations. Accounting for those situations without identity seems possible, but it comes at the price of introducing awkward paraphrases of identity in terms of indiscernibility. We propose an alternative understanding of non-individuals that is compatible with the permanence of identity, so that the fact that identity is available does not entail individuality. This leaves us the conceptual resources brought by identity, without having to commit ourselves with the metaphysical demands of individuality. We argue that typical experimental and theoretical situations in quantum mechanics involve only this weaker (logical) notion of identity, but do not require the stronger (metaphysical) notion of individuality. This illustrates the use of what Toraldo di Francia called a “mock individuality”. The use of identity in the context of quantum mechanics does not commit us with anything more than this mock individuality, and we lose none of the useful resources of identity.

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Quantum Superpositions: A (different) modal logic approach

In the paper “A logical account of quantum superpositions”, Décio Krause and Jonas Arenhart (2016) offered a modal logic approach to deal with Quantum Superpositions.

However, their approach uses the standard *kripkean-style semantic* for modal logic. Some difficulties appears, such as the change of states when a measurement is made. In a moment, a system is in a superposed state and, all we have is the possibility of, after measurement, they collapse to some of its superposed states. Measurement done, they collapse to some of its superposed state, and the other(s) state(s) are not possible anymore. How can we deal, in modal logic, with the *evolution* (or *changes*) of the system? That is, in a moment, the system was in a superposition and have many possibilities; we apply the measurement, the system collapses to some of its superposed states, and lose some possibilities. In this presentation we want to provide a different modal logic, with a some kind of *annotated* syntax and *tense* modal semantics that allows us to deal with this kind of *change* (or *evolution*) of the system.

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Ontological models for scientific theories: problems of underdetermination

In brief, the underdetermination thesis may be formulated in two basic senses. The first stablishes that a set of physical phenomena can underdetermine more than one scientific theory, which describes them. The second one sets that a scientific theory can be committed with more than one ontology. In this work, the second underdetermination thesis will be conceived as a methodological principle for the ontological investigation acting like a metaontological principle. As I see it, the “traditional” conception of underdetermination has some problems, being the main one the difficulty of stablishing which ontological categories are compatible with the theories and which are not. If scientific theories can offer ontological models, then the ontological categories must be coherent with the theories. Another persistent problem is the almost exclusive attention paid to the categories whereas the categorical structures are neglect. Thus, an ontological filter is required to deal with the adaptability of the concept of underdetermination. However, there are many obstacles to construct such filter. The first one is the definition of what is a scientific theory. Certainly, a scientific theory is some kind of structure in a formal sense, but, despite the similarities, this is not a mathematical structure per se. So, if a scientific theory is a structure, it is a hybrid structure composed by first-order and higher-order mathematical structures. In this case, we have few approaches to that matter, but it would be adequate a model theory for scientific theories. Thus, if the notion of a “scientific structure” is vague, the notion of “ontological model” to such structure is even more. Thereby, we must clarify the notion of scientific structure and after that we will be able to initiate our investigation about ontological models.

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Understanding fictional explanations of quantum phenomena

It is argued that the absorption spectrum of Rydberg atoms is explained by classical orbits. This is a case of quantum chaos and (Bokulich, 2008; Bokulich, 2012; Bokulich,

2016) has provided a respectable philosophical account of it, with her model-structural explanation. The challenge is that the essential elements in the model are false entities that cannot be de-idealised by adding more information. In this paper I will critically engage with Bokulich's view by (i) analysing the classical orbits' fictitious status: in what sense are they fictions by difference with other more usual fictional models?; (ii) by specifying their explanatory role: how are they indispensable?; and by (iii) offering a novel view of the practice of physicists that recovers the causal element of Woodwardian explanation that Bokulich had left out.

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Remarks on Quantum Mechanics

We make some comments on the foundations of non-relativistic quantum theory. We discuss questions related to the concept of identity, the meaning of experience, and aspects of space-time.

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Non-Individuals: Metaphysical, Logical, and Mathematical Underdetermination

Non-individuals can be minimally conceived of as objects for which identity does not apply. They have been posited, as part of the development of certain interpretations of quantum mechanics, motivated, in particular, by the natural way in which quantum statistics emerges (for discussion and references, see French and Krause [7]). Should one thereby be ontologically committed to non-individuals? In this paper, I argue that one need not. Non-individuals involve underdetermination regarding their metaphysical, logical, and mathematical underpinnings. Their metaphysical nature is underdetermined; multiple logics can be used to formulate them, and a variety of different mathematical settings can be advanced to articulate such objects (see also French [5], Arenhart [1,2], and Krause and Arenhart [6]). As a result of this multi-layered underdetermination, anti-realist concerns emerge regarding any ontological commitment to such objects. This includes, I argue, ontological commitment to non-individuals at the level of structure. But the issue about the commitment to non-individuals is more extreme, since the applicability of the very notion of identity is challenged, and it is unclear that quantification can be successfully implemented in such a context (see Bueno [3,4]). Without quantification, how can the notion of ontological commitment be articulated for non-individuals? To answer this question, I provide a strategy to mimic quantification over non-individuals without requiring ontological commitment. In this way, talk of non-individuals can be maintained despite the concerns raised by their lack of identity.

References

1 Arenhart, J. [2017a]: "Does Weak Discernibility Determine Metaphysics?", Theoria 32, pp. 109-125.

2 Arenhart, J. [2017b]: "The Received View on Quantum Non-Individuality: Formal and Metaphysical Analysis", Synthese 194, pp. 1323-1347.

3 Bueno, O. [2014]: "Why Identity is Fundamental", American Philosophical Quarterly 51, pp. 325-332.

4 Bueno, O. [2017]: "Identity in Physics and Elsewhere", forthcoming in Cadernos de História e Filosofia da Ciência, 2017.

5 French, S. [2011]: "Metaphysical Underdetermination: Why Worry?", Synthese 180, pp. 205-22.

6 Krause, D., and Arenhart, J. [2017]: "Presenting Non-Reflexive Quantum Mechanics: Formalism and Metaphysics", forthcoming in Cadernos de História e Filosofia da Ciências.

7 French, S., and Krause, D. [2006]: Identity in Physics: A Historical, Philosophical, and Formal Analysis. Oxford: Clarendon Press.

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On physics, metaphysics, and metametaphysics

Non-relativistic quantum mechanics (QM) works perfectly well for all practical purposes. But once one admits that a successful scientific theory is supposed not only to make predictions, but also to tell us a story about the world in which we live in, a philosophical problem emerges: in the specific case of quantum mechanics, it is not possible to "extract" a unique scientific image of the world from the theory, but *several* images. This problem is tied with the measurement problem in QM; attempts to answer the problem amount (in general) to providing an *interpretation* of QM, and there are many of such interpretations, all of them incompatible among themselves. In this work, we distinguish between the ontological and the metaphysical dimensions of two interpretations of QM: the many worlds interpretation and the consciousness cause collapse interpretation. The fact that the theory may be compatible with distinct ontologies, and that those ontologies may themselves be plugged with a plurality of metaphysical approaches, gives rise to the problem of metaphysical underdetermination. To deal with this problem, we briefly investigate some of the objective criteria to theory choice in metaphysics, and check how well they fare in the case of interpreting QM. We conclude that the available metametaphysical criteria fail to grasp such objectivity in theory choice, and then we put forward our own criterion based on a tension between two methods of metaphysical inquiry: one closely related to science and another that is not. Some remarks about the place for metaphysics in science are made as well.