A possible articulation between the Modal-Hamiltonian Interpretation and topos approach in quantum mechanics

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Within the multiple facets of the problem of the interpretation of quantum mechanics, the ontological dimension has acquired a central character in the recent philosophical debate, where realistic interpretations of quantum formalism have taken a preponderant role. Of all the realistic alternatives in the recent literature, the Modal-Hamiltonian Interpretation (IM-H), originally proposed by Lombardi and Castagnino (2008), advances an ontology where physical systems correspond to bundles of properties, which would allow us to account for some of the specificities of the physical world described by quantum mechanics: the indistinguishability of quantum systems, which defies the traditional notion of object (non-individuality of quantum particles); contextuality, which prevents assigning determined values simultaneously to all the properties of a quantum system (Kochen-Specker theorem); non-separability, which aims to challenge the idea of the existence of systems independent of each other (quantum entanglement), among others.

The IM-H intends to articulate a realistic interpretation that seeks to describe what the world would be like if quantum mechanics were true. Likewise, it adopts algebraic formalism, and not the traditional one in terms of Hilbert's space, but it is based on the standard formalism of quantum mechanics, that is, it does not introduce modifications or extra elements to the formalism originally postulated for the theory. However, a central aspect of IM-H is that in this interpretation a quantum measurement is a common physical interaction, just like the rest of the interactions, where measurement results constitute actual properties of the measuring devices: in this sense, there is no 'collapse' of the wave

function. For IM-H, the quantum state describes possible properties of the systems, with their corresponding probabilities that evolve unitarily according to the Schrödinger equation, so the quantum state refers to singular systems and not a set of systems.

In this way, the IM-H introduces a distinction between the actual and the possible, between the quantum state of a system (referred to as [type-properties]) and actual properties [case-properties], which due to contextuality of the quantum world it is not possible to ascribe determined values simultaneously, so the preferred context of actualization is defined by means of a specific rule. This actualization rule determines the central role assigned to the Hamiltonian as observable in this interpretation: within an experimental context, only observable values compatible with the Hamiltonian will be actualized and have defined values [case-properties], which is expressed through the commutations conditions.

The aim of this work is, first of all, to examine if the 'topos approach' formulated by Isham & Butterfield (1998; 1999; 2002) and Isham & Döering (2008) could provide the tools that Costa, Lombardi and Lastiri demands. One of the reasons would be that both perspectives fully assume the consequences of the Kochen-Specker theorem (1967), according to which it is impossible to assign precise values to all observables of a quantum system simultaneously. Along with the above, some of the logical and ontological consequences of the application of topos theory will be examined, which would imply adopting an intuitionist logic for quantum mechanics, where truth values ascribed to the propositions should be contextualized and multi- valued, represented by an Heyting algebra. Besides that, it will be analyzed if the process called 'Daseinization' (in direct allusion to Heidegger's philosophy) could imply a serious obstacle in the attempt to articulate a modal interpretation such as IM-H with the neo-realistic stance that inspires the original topos approach to quantum mechanics.

References

DA COSTA, N., LOMBARDI, O. & LASTIRI, M. (2013) "A modal ontology of properties for quantum mechanics", *Synthese* 190: 3671-3693.

FLORI, C. (2013) *A First Course in Topos Quantum Theory*, Berlín-Heidelberg: Springer-Verlag.

ISHAM, C. & BUTTERFIELD, J. (1998) "A topos perspective on the Kochen–Specker theorem: I. Quantum states as generalized valuations" *International Journal of Theoretical Physics* 37: 2669–2733.

ISHAM, C. & BUTTERFIELD, J. (1999) "A topos perspective on the Kochen-Specker theorem: II. Conceptual Aspects, and Classical Analogues" *International Journal of Theoretical Physics* 38: 827-859.

ISHAM, C., BUTTERFIELD, J. & HAMILTON, J. (1999) "A Topos Perspective on the Kochen-Specker Theorem: III. Von Neumann Algebras as the Base Category" *International Journal of Theoretical Physics* 39(6): 1413-1436.

ISHAM, C. & BUTTERFIELD, J. (2002) "A Topos Perspective on the Kochen-Specker Theorem: IV. Interval Valuations" *International Journal of Theoretical Physics* 41: 613-639.

LOMBARDI, O. & CASTAGNINO, M. (2008) "A modal-Hamiltonian interpretation of quantum mechanics", *Studies in History and Philosophy of Modern Physics*, 39: 380-443.