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Peer Review

Review of: "The Non-Reflexive Formulation of Quantum Mechanics: the Whys and the Hows"

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The manuscript by Prof. Krause is a useful summary of quasi-set theory and related matters. This fundamental approach was proposed to replace a more naive (and widespread) approach, where particles are first labeled and then given states that should respect their indistinguishability.

The epigraph "All physics is steeped in metaphysics" is suitable for this text. However, it is also known that modern ideas on logic, set theory, and (more generally) foundations of mathematics left surprisingly little influence on theoretical physics, particularly quantum mechanics. Before embarking on studying the details of the formalism presented by Prof. Krause, I would like to clarify several straightforward (but perhaps not so trivial) ideas.

-- In section 4, Prof. Krause discusses individuality versus non-individuality. In particular, he discusses two electrons in Lab 1 and Lab 2. Let me elaborate on this point. Assume that I approximately measured the coordinate of this electron at Lab 1. And after some time, I made another approximate coordinate measurement at Lab 1. Can I be sure that in the second measurement I measured the same electron as in the first experiment? In principle, yes. Such measurements exist. The most important thing I have to do is to isolate Lab 1 from other electrons, e.g., to ensure that they are sufficiently far away. I see only one way of making such experiments impossible in principle: to assume that electrons can move (and hence interchange) at a very large speed. This speed will have to correlate with the approximations involved in the notion of the approximate coordinate measurement. Is there any other more realistic way not to distinguish two far-away electrons?

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-- I understand that the distinguishability of two far-away electrons may not have experimental consequences [1]. However, the ontological differences are profound, especially in the context of works by Prof. Krause. The differences will become critical and lead to experimental consequences once the electrons approach each other [1].

-- Indistinguishability does not pertain to the quantum domain only. It holds as well for classical statistical mechanics, where it shows up as the famous 1/N! factor in the N-particle (classical) statistical sum. This is a real physical effect, i.e., it does have experimental consequences, which is related (among other things) to the Gibbs paradox. However, at the fundamental level, classical particles are distinguishable, e.g., because they have well-defined trajectories. This comes to hint that the actual indistinguishability is an emergent effect [1].

-- There is another explanation for the above classical effect: the quantum nature of particles survives the classical limit. But then one has to explain why the indistinguishability survives despite the existence of the trajectories. It will be useful to know the opinion of Prof. Krause on this matter.

-- An important practical question is whether the quasi-set theory + quantum mechanics leads to new (testable in principle) predictions compared with the old formalism.

[1] A. E. Allahverdyan, K. V. Hovhannisyan and D. Petrosyan, Dynamical symmetrization of the state of identical particles, Proceedings of the Royal Society A, 447, 20200911 (2021).

Declarations

Potential competing interests: No potential competing interests to declare.