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Quantum epistemology from subquantum ontology: Quantum mechanics from theory of classical random fields

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HIGHLIGHTS

- The problem of interpretation of the wave function is analyzed in the ontic/epistemic framework.
- The concrete ontic model, random field model is presented and compared with the psi-ontic/epistemic models.
- The notions of superposition of pure quantum states are clarified by using the ontic model.

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ABSTRACT

The scientific methodology based on two descriptive levels, ontic (reality as it is) and epistemic (observational), is briefly presented. Following Schrödinger, we point to the possible gap between these two descriptions. Our main aim is to show that, although ontic entities may be unaccessible for observations, they can be useful for clarification of the physical nature of operational epistemic entities. We illustrate this thesis by the concrete example: starting with the concrete ontic model preceding quantum mechanics (the latter is treated as an epistemic model), namely, prequantum classical statistical field theory (PCSFT), we propose the natural physical interpretation for the basic quantum mechanical entity—the quantum state ("wave function"). The correspondence PCSFT $\mapsto$ QM is not straightforward, it couples the covariance operators of classical (prequantum) random fields with the quantum density operators. We use this correspondence to clarify the physical meaning of the pure quantum state and the superposition principle—by using the formalism of classical field correlations.

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1. Introduction

Recently I presented [1] an analysis of the consequences of the final loophole free Bell's tests [2–4] based on the ontic–epistemic approach to physical theories stimulated by a series of works of Atmanspacher et al. [5–7]. This approach[1] prevents us from mixing two descriptive levels: ontic, "reality as it is", and epistemic, representing results of observations.[2]

Moreover, in [1] I was very sympathetic to Schrödinger's viewpoint [11] that *theory and observations are not necessarily related in a term-to-term correspondence and a certain degree of independence exists between them*. In this paper I want to illustrate this Schrödinger's statement by the concrete example, the correspondence between the concrete ontic model, *prequantum classical statistical field theory* (PCSFT), e.g., [12–17], and quantum mechanics (QM).

We remark that recently a group of authors started to develop the ψ-ontic/epistemic approach to quantum mechanics, see [18–23]. This approach differs essentially from one presented in this paper and in general in works of Atmanspacher et al. [5–7]. We shall briefly present the scheme of ψ-ontic/epistemic modeling and compare it with one of the present paper (Section 8); we shall follow the work of Ballentine [23] in which the reader can find very clear and compact presentation and analysis of the basics of the ψ-ontic/epistemic modeling. We remark that this modeling led to controversial conclusions. This controversy is resolved in this work of Ballentine. We also point to other approaches to ontology of quantum mechanics: the consistent histories approach, see Griffiths [24] for the recent review, and the recent attempt of Grangier et al. [25–27] to recover realism in quantum mechanics by developing a novel contextual viewpoint on quantum measurements. These approaches differ essentially from the PCSFT-approach. They are closer to the recent ψ-ontic/epistemic modeling.

As respond to [1], I received a few messages stating that it is meaningless to consider "fuzzy correspondence rules" between subquantum and quantum models, since such considerations have no value for physics. I disagree with such claims. By the example of the PCSFT $\mapsto$ QM correspondence it will be shown that a hidden ontic structure can clarify the real physical meaning of formal operational entities of the quantum formalism. Thus ontology can clarify the physical meaning of the basic epistemological structures.

In QM a quantum state ψ is one of such main structures and its interpretation is characterized by huge diversity which is definitely a sign of theory's crises. The main message of PCSFT (the ontic model under consideration) to QM is that a quantum state is simply a normalized covariance operator of a "*prequantum*" *random field*, a physical random field propagating causally in space–time [17]. Thus, in particular, ψ encodes not waves, neither physical a la de Broglie [28,29], Schrödinger [30], Einstein and Infeld [31] nor probabilistic a la Born (see von Neumann [32] for detailed presentation), but correlations inside a random signal sent by a source of a prequantum random field (a source of quantum systems in the epistemic terminology).

We stress that random fields (elements of the ontic model) represented by quantum pure states (elements of the epistemic model) are very special—they are concentrated in one dimensional subspaces of the L_2-space. (Quantum mixed states given by density operators represent random fields smashed over L_2-space.)

We also analyze the ontic structure behind the quantum notion of *superposition of pure states*. From the ontic viewpoint, creation of a superposition corresponds to fine tuning of signals represented by components of the superposition. Such turning has to generate from one dimensional components a new one dimensional field. We shall prove that in the probabilistic terms this is equivalent to *maximal correlation between components of the* "*superposition random field*".

[1] It has its roots in the old Bild conception elaborated by Hertz, Boltzmann, Einstein, Schrödinger, see, e.g., D'Agostino [8] for a good introduction.

[2] In particular, in [1] Bell's argument [9,10] was presented as the conjecture about *identification of the ontic states with the epistemic states*. From this ontic–epistemic viewpoint, the final loophole free test means that this conjecture about ontic–epistemic identification has to be rejected and the correspondence between the ontic and epistemic descriptions is not so straightforward as it was assumed in the "Bell theorem".

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