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Qeios

Peer Review

Review of: "Fundamental Issues and Measurement Problem in Quantum Mechanics"

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1. Summary of the Manuscript

The author proposes a conceptual reorganization of quantum mechanics (QM) aimed at dissolving the measurement problem (MP). The central move is a strict distinction between:

- **Type A quantities:** real, observable dynamical variables (Hermitian operators) whose eigenvalues (EVs) are selected in a single measurement and persist through amplification.
- **Type B quantities:** theoretical constructs (wave functions, state vectors, probability distributions) used solely to compute ensemble-level probabilities.

The author argues:

- Wave functions never collapse.
- Eigenstates do not persist after measurement.
- Measurement is a physical process involving a microscopic quantum jump (MIJ) followed by amplification.
- Classicality emerges from large bosonic occupation numbers.
- Many-particle systems (especially bosonic condensates and photon fields) allow a single measurement to reveal a real ensemble.

The paper revisits standard experiments (double-slit detection, CCDs, cloud chambers) and many-body systems (photons, BECs, superconductors) to illustrate the framework. It also briefly discusses the possible “reality” of the wave function in the context of relativistic quantum field theory (RQFT).

2. General Assessment

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The manuscript is ambitious and clearly motivated by a desire to clarify the conceptual foundations of QM using operational language grounded in detector physics. The author's insistence on distinguishing theoretical constructs from observables is philosophically valuable and resonates with long-standing concerns about reifying mathematical structures.

However, the paper's conceptual architecture is uneven. Some distinctions are insightful, but others are asserted rather than justified. The proposed framework sits somewhere between an operationalist interpretation and a realist interpretation of observables, yet the manuscript does not fully articulate its philosophical commitments. As a result, the conceptual coherence is not always stable.

The paper is strongest when discussing detector physics and weakest when making broad interpretive claims about the ontology of quantum states.

3. Strengths

3.1. Clear operational grounding

The analysis of measurement devices (MCPs, CCDs, cloud chambers) is concrete and physically accurate. The emphasis on MIJs and amplification is a welcome antidote to overly abstract discussions of measurement.

3.2. Useful distinction between single-event and ensemble-level quantities

The Type A / Type B distinction is pedagogically helpful and aligns with the idea that probabilities are inherently ensemble-level constructs.

3.3. Insightful treatment of many-boson systems

The discussion of how large occupation numbers yield classical behavior is consistent with standard many-body physics and helps bridge the quantum–classical divide without invoking collapse.

3.4. Reinterpretation of the Mott problem

The author's explanation of radial tracks in cloud chambers is physically correct and avoids unnecessary metaphysical commitments.

4. Conceptual Weaknesses and Points Requiring Clarification

4.1. The status of eigenstates is underdeveloped

The author asserts that eigenstates "do not exist in reality" after a quantum jump. But:

- What does "exist" mean here?

- Are eigenstates merely computational tools?
- If so, why treat operators as real but not their eigenvectors?

This asymmetry is philosophically delicate. In standard QM, operators and eigenstates are part of the same mathematical structure; privileging one over the other requires justification.

4.2. The rejection of wave function collapse is not new

The author's claim that wave functions never collapse aligns with:

- Everettian interpretations
- Statistical (ensemble) interpretations
- Many operationalist approaches
- Decoherence-based accounts

However, the manuscript does not engage with these existing frameworks, making the contribution appear less novel than it could be.

4.3. The MIJ framework resembles decoherence without acknowledging it

Although the author explicitly rejects decoherence, the MIJ + amplification picture is structurally similar:

- A microscopic interaction entangles system and apparatus.
- Amplification leads to effectively classical outcomes.
- The wave function remains globally uncollapsed.

The author should clarify how MIJ differs from decoherence beyond the rejection of the "classical apparatus" assumption.

4.4. The Type A / Type B distinction risks circularity

The author defines:

- Type A = what is observed in a single measurement
- Type B = what is not observed

But this is close to defining reality by observability, which is a philosophical stance (operationalism) that the author does not explicitly defend. Moreover, the distinction becomes blurry in many-body systems where ensemble-level quantities emerge from a single measurement.

4.5. The discussion of RQFT and the "reality" of the wave function is speculative

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The suggestion that wave functions might be “real” because they arise from matrix elements of field operators is intriguing but underdeveloped. The manuscript does not address:

- Haag’s theorem
- The nonexistence of a single-particle Hilbert space in interacting QFT
- The role of antiparticles
- The fact that field operators themselves are not directly observable

Without engaging these issues, the argument remains tentative.

5. Comparison with Major Interpretations

5.1. Copenhagen

Nakajima’s view resembles a sharpened Copenhagen stance but rejects collapse and the classical–quantum divide. The emphasis on operational language is similar, but the ontology of observables is more realist.

5.2. Decoherence

The MIJ + amplification picture is functionally similar to decoherence, but the author rejects decoherence for relying on classical apparatus assumptions. This critique is not fully convincing, as modern decoherence theory does not require classicality at the outset.

5.3. Everett (Many-Worlds)

The author agrees with Everett that wave functions never collapse, but rejects the ontological commitment to branching worlds. The Type A / Type B distinction is incompatible with Everett’s universal wave function realism.

5.4. Bohmian Mechanics

The author’s framework is incompatible with Bohmian mechanics, which treats the wave function as ontic and guiding particle trajectories. Nakajima’s insistence that wave functions are purely theoretical (Type B) contradicts Bohmian ontology.

5.5. QBism / Information-Theoretic Interpretations

Nakajima’s view is more realist about observables and less subjective about probabilities than QBism. However, the emphasis on the wave function as a tool rather than a physical object is QBist-adjacent.

5.6. Statistical (Ensemble) Interpretation

The closest match. Both views treat the wave function as describing ensembles, not individual systems. Nakajima adds the MIJ mechanism and the many-boson analysis, but the core idea is similar.

6. Recommendations for Improvement

1. **Clarify the ontological commitments**

   What is the metaphysical status of operators, eigenvalues, and eigenstates?

2. **Engage more deeply with existing interpretations**

   Especially decoherence, ensemble interpretations, and Everett.

3. **Strengthen the argument against collapse**

   Currently, it is asserted rather than derived.

4. **Develop the RQFT discussion**

   Address known obstacles to deriving NRQM from RQFT.

5. **Explain the novelty**

   The MIJ framework is interesting, but its relation to existing theories should be articulated.

Declarations

Potential competing interests: No potential competing interests to declare.