Quantum Mechanics - Ontology Meets Epistemology

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At issue: the nature of reality (ontology) and

the pursuit of knowledge (epistemology).

At quantum scale, ontology meets epistemology. What is proposed in this paper is an alternative interpretation of quantum behavior.

A starting point different than the historical demystify certain concepts in QM.

Part 1 Some philosophical and historical salient points

We are asked to tackle the very nature of reality. And sometimes, a little of philosophy and history can shed some crucial light on the thorniest of problem.

Some statements from P. Ball[1]:

1. *Bohr had electrified the scientific world in 1913 with his bold theory of how atoms are constituted. Drawing on an idea proposed in 1900 by the German physicist Max Planck, he said that the electrons that orbit the dense central nucleus are constrained to specific orbits, able to jump between them only by emitting or absorbing light in discrete packets of energy called quanta. …. Bohr craved an explanation that got to the root of why atoms seemed to behave in this peculiar way.*

False start: The initial concern was about the energy of the atom when it should have been about what happens to a single isolated particle such as an electron at exceedingly small distance, that is, at the quantum scale.

2. *Heisenberg was determined to work only from what experiments had revealed, with no assumptions about the underlying reality it described.*

Second false start: the cost would be a dive into fantastical ideas, reminiscent of fairy tales.(Example: particle existing simultaneously at two different places)

3. *Schrödinger announced a rival form of quantum mechanics to Heisenberg's, based on the idea that quantum particles could be described as waves.*

Although this explanation was a first attempt at trying to fit QM with physical reality, it had the misfortune to interpret the so-called 'wave function" as a real wave when in fact, it's a mathematical object more apt to calculate probability outcomes[2].

4. *Quantum mechanics, they said, demanded we throw away the old reality and replace it with something fuzzier, indistinct, and disturbingly subjective.*

Misunderstanding between what is objective versus subjective. A proposition or state of affairs is *objective* if its truth-value or existence does not depend on any individual's perception, belief, or experience. Quantum mechanics doesn't make reality itself subjective in the sense of "dependent on personal opinion or consciousness." Rather, it shows that our knowledge and descriptions of physical systems are probabilistic and observer-dependent. If anything, quantum mechanics replaces the *illusion* of classical objectivity with a new kind of objectivity: one that acknowledges that measurement outcomes depend on the conditions under which observation occurs, not on who performs the observation.

Part 2 Single isolated particle

Absolute, full-scale determinism leads to no determinism. At quantum scale, that is randomness.

Consider a single electron, and a tiny net force acting on it, (F=ma), for a nanosecond. This is the traditional determinism known since Newton.

The next nanosecond, the force changes direction due to the motions of all the other particles, near and far[3].

The next, next nanosecond, the same will happen.

The net result, say in one second, is a billion steps in which the electron will have performed a sort of dancing, wiggling and jingling – which for all purposes maybe called randomness – also known as the particle/wave duality.

Is this randomness due to our lack of knowledge (epistemology) or the very nature of the universe (ontology)?

What else is there but to try and find out.

So we shoot photons at the electron. Chance are that we get one photon that will hit the electron and bounce back to our detector, revealing its position. But we are out of luck as the electron is knocked off in an unpredictable direction (the Heisenberg Uncertainty Principle, HUP).

There's an old saying: too much freedom leads to no freedom (democracy descending into anarchy). By analogy, too much determinism (F=ma) leads to no determinism (randomness). Some predictability is lost (the need of probability). QM has all of these features (a probability theory with wave/particle duality, HUP)[4].

Note: a probability theory demands that you must take all of the outcomes in consideration. It's not that the particle "exists" in all those superposition states. And when the calculation is done, one outcome comes out, and the theory lives or dies on its ability to predict that outcome. However, to label that as the "collapse of the wave" is a mistake and indicative of a fundamental misunderstanding of QM.

Part 3 Ontology meets epistemology

Step 1: Ontology vs. Epistemology

- Ontology → *what reality is like in itself.* (What is real versus what is fiction. Does the world contain randomness? Is it deterministic?)
- Epistemology → *what we can know about reality.* (What is the limit of our knowledge? Even if the world is deterministic, can we predict outcomes?)

Step 2: Randomness

- Ontological randomness = randomness is *built into* reality itself (e.g., Copenhagen quantum mechanics).
- Epistemological randomness = randomness is just a *measure of our ignorance* (e.g., coin tosses, chaotic systems).

If randomness is a basic property of the universe → it's an ontology problem.

On the other hand, if randomness is just due to incomplete knowledge → it's an epistemology problem.

Step 3: Determinism vs. Predictability

- Determinism (ontological) → The future is completely fixed by the past and the laws of nature.

Example: In Newtonian mechanics, if you know all initial conditions, the future state is uniquely determined.

This is the old saying: The universe "runs like a clock."

- Predictability (epistemological) → Whether *we humans (or any finite knower)* can actually calculate or foresee the outcome.

Example: Weather systems are deterministic in principle but so chaotic that we can't predict them beyond a short window.

Ontology decides if the world is deterministic or indeterministic

Epistemology decides if we (or any rational agent) can predict outcomes.

Epistemology: Our knowledge and computational limits constrain predictability.

Randomness straddles the line: it can be ontological (built into reality) or epistemological (just ignorance).

Randomness can be either, depending on whether it's real or just apparent.

We can rephrase as the following: because in our attempt to find out what is the state of a particle, that is, our intervention changes that state – the result of which is that the prior state is unavailable to us – this leaves us to speculate what is the nature of reality.

At quantum scales, ontology meets epistemology. Often the question is: in QM is the basic problem ontic or epistemic?[5] The answer is both. Ontic because we have a deterministic universe that produces a dancing electron that re-creates randomness (the wave/particle duality): Epistemic because any attempt on our part to know about its position and momentum is thwarted by our observation (the HUP). So at quantum scale, our theory must be a probability, otherwise, the universe would be weird – akin to a mathematical point being real (fiction is fact).

[1] *Phillip Ball, When Reality Came Undone, b Nautilus, August 28, 2024)*

[2] *Joseph Palazzo, The Collapse of the Wave Function, https://vixra.org/abs/1608.0350, August 25, 2016*

[3] *Joseph Palazzo, Everything is matter moving through space, Authorhouse, 2020*

[4] *Joseph Palazzo, Why QM Must Be a ProbabilityTheory, https://vixra.org/abs/2310.0008, October 2, 2023*

[5] *B Rifai, MF Rosyid, The Ontic Necessity of the Quantum Wavefunction: Why Epistemic Views Struggle with the Uncertainty Principle, https://arxiv.org/html/2507.09944v2, July 20, 2025.*