A DETERMINISTIC INTERPRETATION OF QUANTUM MECHANICS

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September 29, 2020

ABSTRACT

This paper offers a deterministic interpretation of quantum mechanics. It uses Bohm's explanation for the wave-particle duality and views entanglement as separate particles with states that were synchronized. The resulting theory uses the same mathematics as traditional interpretations, explains the double-slit and Bell test experiments, and resolves paradoxes such as Schrödinger's cat and Wigner's friend.

1 Introduction

Interpretations of quantum mechanics make the same real-world predictions but tell divergent stories about why and how things happen. These theories compete to explain particles with wave-like behavior, entangled particles whose measurements are correlated, and other results that are hard to explain with ideas developed before 1900[1].

Current interpretations have unintuitive consequences. For example:

- The Copenhagen interpretation says that particles are not in a definite state until a measurement occurs[2].
- The many-worlds interpretation argues that every measurement creates multiple universes, with one possible result occurring in each universe[3].
- The statistical interpretation says that it is impossible to predict the result of one measurement and that the only approach is to anticipate the distribution of results over a large number of trials[4].
- Bohm's interpretation suggests that a measurement can lead to the instantaneous transfer of information across any distance, which violates the theory of relativity[5].

This paper repairs the nonlocality in Bohm's interpretation.

2 Wave-Particle Duality

2.1 The Double-Slit Experiment

The double-slit experiment involves sending particles such as electrons toward two adjacent gaps in a barrier. A detector on the other side of the barrier records where each particle hits a backstop. The detector displays an interference pattern: bands with many arriving particles, separated by sections of no detections, spaced according to the wavelength of the particle used in that experiment. This pattern occurs even if the particles are sent through one by one[6].

The way in which particles appear as individual results at the detector but interfere with each other like waves is called the wave-particle duality[7]. Each interpretation of quantum mechanics explains this duality in a different way.

Bohm's interpretation says that particles have an associated quantum mechanical field, analogous to an electromagnetic field. The quantum mechanical field corresponds to Schrödinger's equation. In Bohm's interpretation, this field is a physical manifestation of the wave function. Bohm calls this the ψ-field[8].

In the double-slit experiment, a particle goes through one slit while its ψ-field goes through both slits. This wave-like field can interfere with other waves or, in this case, itself. A particle is drawn to where the interference is constructive and is less likely to go where the interference is destructive. Certain regions of the detector are thus more likely to receive particles, which leads to the interference pattern.

Bohm's interpretation says that the seeming randomness in quantum mechanics is due to incomplete information: each particle's path is deterministic and, given the complete state of the experimental setup, predictable. Slight variations in the state of particles can lead to different measurements, a case of sensitive dependence on initial conditions.

2.2 The Observer Effect

Attempts to determine the paths that particles take in the double-slit experiment have destroyed the interference pattern[9]. Measurements modify the physical state of an experiment; with enough information, such effects can be modeled and predicted.

All particles and measurement devices behave according to the standard equations of physics. Blocking one slit or inserting an extra detector changes how particles and their fields interact. This analysis also applies to quantum eraser experiments, another type of test to determine which path a particle takes[10].

In this paper's view, every particle in a double-slit experiment takes a single, definite path. It may be possible for an experiment to tell which slit a percentage of particles pass through, perhaps destroying the outer edges of the interference pattern while preserving the middle.

3 Entanglement

3.1 Background

Quantum entanglement describes interactions between particles that cause future measurements of those particles to be correlated. Two photons can be entangled so that their results at a polarizing filter will agree: either both will pass through or both will be blocked[11].

3.2 Action at a Distance

Some interpretations say that a quantum system is not in a single, definite state before a measurement occurs. This unresolved state is called a superposition. A measurement resolves a superposition to a particular value[12].

In the above view, two entangled particles can be in a superposition. An experiment can use entanglement to guarantee that a measurement of one particle will have the same result as an identical measurement of the second particle. If these particles are separated before one of them is measured, the superposition must resolve the same way at both locations.

This instant agreement between remote particles is the EPR paradox[13]. Bohm accepted the resulting nonlocality. This paper's interpretation uses a different approach to explain entanglement without instantaneous action at a distance.

3.3 Entanglement as Synchronization

The inability of distant particles to modify each other is known as the no-communication theorem[14].

The states of entangled particles remain correlated until they are measured or otherwise disrupted. One way to explain this agreement is as a form of synchronization or alignment. In this deterministic theory, two photons in identical states will have the same result when they reach a polarizing filter. An interaction that puts two particles into matching states can entangle them like this.

The correlation between entangled particles remains even once the particles are separated, unless other forces act on them to cause decoherence[15]. This paper's explanation of entanglement fits with the Bohm interpretation's claim that every particle has a defined position, momentum, and set of fields at all times. Sanctuary gave a similar explanation for entanglement from the perspective of the statistical interpretation[16].

In this paper's view, sending two entangled photons in a superposition to a polarizer is analogous to setting two coins into the exact same state and flipping them with a machine. The results of the flips should agree, though it may be difficult to predict heads or tails ahead of time.

3.4 Bell Test Experiments

Bell test experiments provide a benchmark for entanglement[17]. They show that 1) the measurements of entangled particles are correlated and 2) the probability that two entangled photons both pass through or are both blocked at polarizing filters is based on the cosine squared of the angle between the two polarizers[18].

The first point follows from the idea that, when two particles are entangled, the standard computations of quantum mechanics model them with a single wave function rather than as separate systems[19]. Bohm's interpretation uses the same approach, as does this paper.

The second point obeys Malus's law, developed in the early 1800s, which says that the intensity of light that passes through two polarizing filters depends on the cosine squared of the angle between them[20].

This paper's interpretation is consistent with both of these requirements and thus with the results of Bell test experiments.

4 Consciousness and Quantum Paradoxes

Researchers have debated how free will might influence Bell test experiments; a recent experiment showed that the correlated measurements of entangled particles do not depend on human choice[21].

Thought experiments such as Schrödinger's cat and Wigner's friend show that the idea of superposition leads to surprising results when applied to people.

Schrödinger's cat is alive or dead based on whether a radioactive atom has decayed. If the atom is in a superposition until a measurement occurs, so is the cat[22]. The idea is that the cat cannot be dead until an observation takes place.

Wigner argued that only consciousness can change the wave function[23]. If someone observes a quantum system, a superposition is resolved from their perspective; that superposition remains intact for another person until the first one tells them the result. A recent version of Wigner's friend paradox also grapples with the interface between humans and superposition[24].

In this paper's interpretation, the wave function describes a theoretician's lack of knowledge: a particle is always in one place. The positions of the atoms in a brain can be modeled by one or more wave functions; the particles inside a person follow the same laws as the particles outside of that person.

Schrödinger's cat dies as soon as the atom decays. In Wigner's example, a flash of light occurs whether or not either person sees it. Photons and electrons obey the same rules as macroscopic objects.

5 Conclusion

This paper explains quantum phenomena while maintaining local realism. The resulting interpretation highlights the common ground between quantum mechanics and classical physics[25].

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