Bohmian Interpretation of Quantum Measurement Theory

DRP - Physics Department
Rylee Ross Avik Roy

Introduction

Copenhagen Interpretation of Quantum Mechanics

Bohmian Interpretation

Double Slit Experiment

The Measurement Problem

Copenhagen Interpretation

- The wave function Ψ represents everything that can be known about the state, it holds no additional hidden parameters and expresses the wave-particle duality. Ψ is not physical significance
- According to the Born rule, $|\Psi|^2$ describes the probability density of finding the particle at the position q at time t.
- Random by nature cannot be removed
- The wave function evolves according the Schrodinger's wave equation;

$$i\hbar\frac{d}{dt}\psi = -\left(\frac{\hbar^2}{2m}\right)\nabla\psi + V(x)\psi$$

Bohmian Mechanics

$$j := \frac{\hbar}{m} Im(\psi * \nabla \psi)$$

$$\frac{d}{dt}Q(t) = \frac{j}{|\psi|^2}(Q(t), t)$$

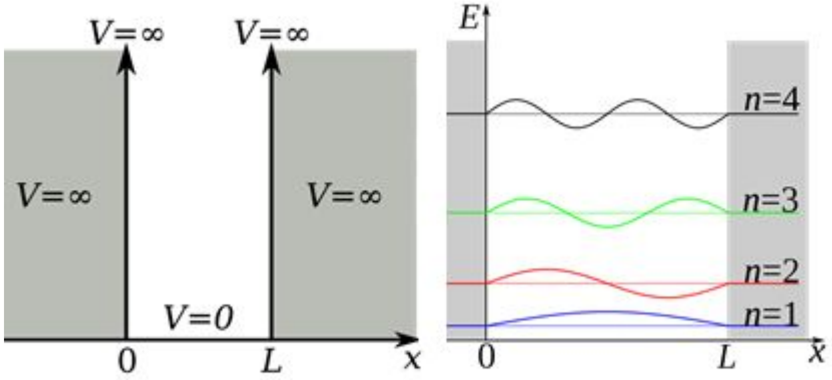
- Compensates SWE with the guiding egn.
- Particles, a point in physical space, always have an objective position $Q \in R^3$ and definite outcome at any time.
- Probability current: wfn tells us that the guiding equation is probability current over probability, similar to flux
- Particle move along trajectories that evolve in time according to swe. Variable of q, predict Q(t) and v(q,t)
- Randomness in initial conditions
- Nonlocal, the outcome is directly influenced by not only the immediate surroundings.
- $|\Psi|^2$ gives probability density for the actual position Q(t) to be at the location q at time t.

1D Particle In Box

Time independent swe sln is real.

Position of particle does not change, it must follow the trajectory set about for it by the guiding eqn forced by the quantum potential.

Both interpretations show the expected energies.

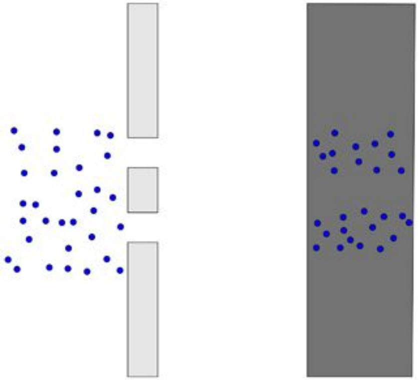


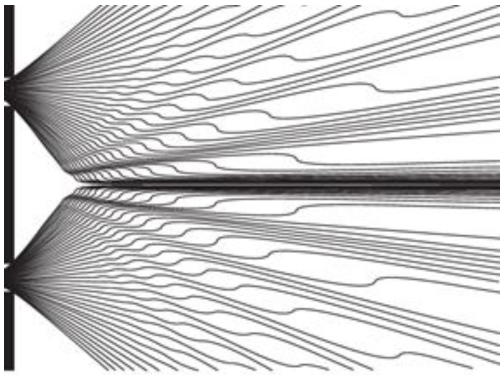
$$\psi(x) = \sqrt{\frac{2}{L}} \sin\left(\frac{n\pi x}{L}\right)$$

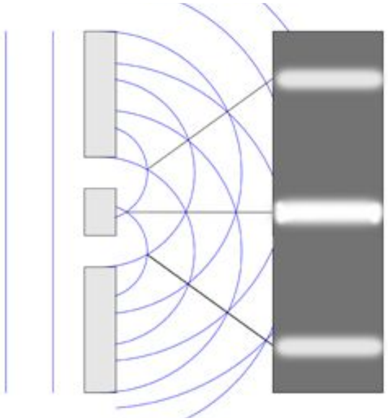
Double Slit Experiment

Bohmian trajectories, showcasing how the particles always have a determined location, rather than in the the standard interpretation of the wave diffraction pattern.

However, When minimally invasive measurement present in the slits this interference pattern disappears and all that remains is the expected particle pattern.



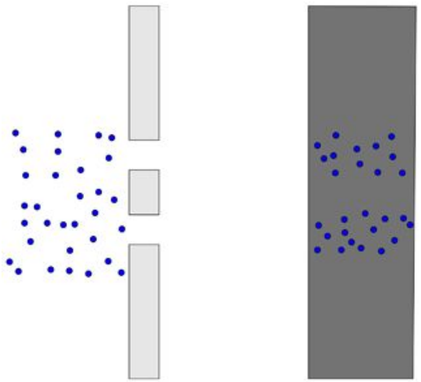


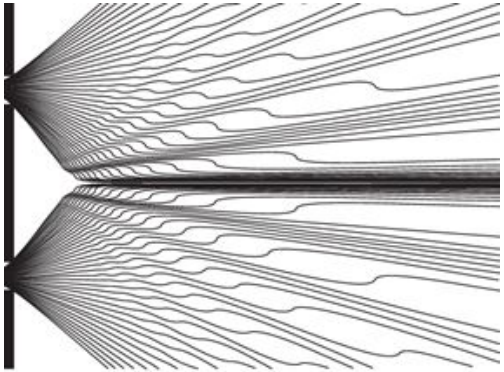


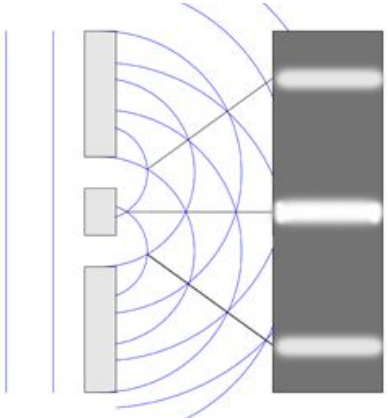
Double Slit Experiment

Bohmian mechanics is able to explain both of these outcomes.

When the slit is measured the wfn is determined to has a specific trajectory, and in bohmian mechanics the particles will not jump to other disjoint branches.







Measurement problem

- A common issue amongst and between QM theories is the definition of measurement.
- Measurement as the finite interaction between two QM systems, the measured system and the measuring apparatus which has several macroscopically distinguishable configurations.
- Prior to the measurement the ready state of the apparatus is known.
- The apparatus reacts to certain systems in definite way, without superpositions, however the time evolution of the initial state of the system yields a superposition a consequence of the linearity of swe.

Wigner's Friend

$$|1\rangle_c + |0\rangle_c \qquad\qquad |1\rangle_c \otimes |1\rangle_f + |0\rangle_c \otimes |0\rangle_f$$

Wigner's friend looks at Schrodinger's cat. The system becomes him and the cat.

The contents of the box will forever be in a superposition along with observer.

The proper wfn after interaction is one of these terms not a linear combination.

Observers collapse superposition. But are also a part of the superposition.

Measurement Problem

- Does the Schrodinger dynamics breaks down? in this case wfn follows a different dynamic that collapses to a single solution.
- If collapse only happens in connection with measurement atoms should then follow swe always.
- Distinguishable macro-states that evolve after measurement to be a sum of the initial states.
- Some argue that due to decoherence the system is macroscopically distinguishable, and the initial states are brought to a state with a continuous structure.

Bohmian Mechanics: Measurement Problem

- From initial configuration, the wfn allows a unique sln for definite position Q(t) for all t that is guided by the pilot wave moving only where the wfn is nonzeo, it follows distinct branches.
- After the interaction, the configuration will be in support of a single term due to a unique determination of the initial conditions.
- Effective wfn collapse and that is one reason why Bohmian mechanics is once again gaining attention.

Conclusion

Copenhagen handles many situations in QM extremely well.

Bohmian mechanics is able to follow up on the problems that arise due to Copenhagen.

Quantum Information Theory

Acknowledgement

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Questions?

Works Cited

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Realism

Local and Real einstein pg 110 local

Naive realism

Anti-realism nonlocality

Probability

Bell's theorem nonlocality qm incompatible with hidden variable theorem

-Proper topics?

-Any topic I left out

Any topic too long

More math

    Derive Quantum potential

    Bohmian measurement collapse

    Bells thing

Pilot Wave

Sln to the guiding equation define trajectories of the particles at any time as solutions to the pilot wave equation.

From SWE we can derive a continuity equation that shows the wfn is never created or destroyed, conserved probability of state at all time . only moving around by velocity J/ where j is the quantum current

$$\frac{d}{dt}|\psi|^2 = -\nabla \cdot \mathbf{j}$$