The Quantum Handshake Explored

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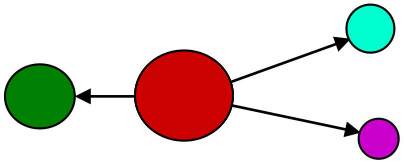
Outline of Talk

1. Quantum Entanglement and Nonlocality
2. The Transactional Interpretation of Quantum Mechanics
3. Applying the Transactional Interpretation to Quantum Paradoxes
4. The Process of Forming Transactions
5. Conclusions

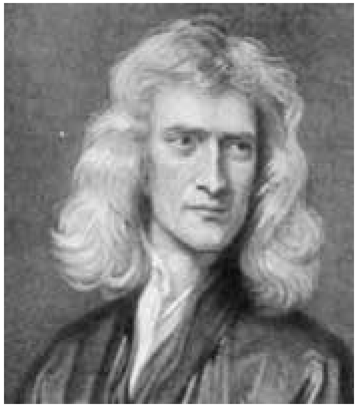
Part I
Quantum Entanglement and Nonlocality

Newtonian Mechanics vs. Quantum Mechanics

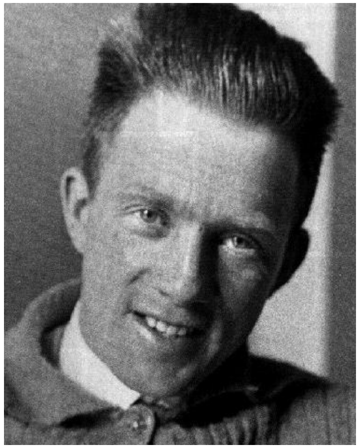


Newtonian Mechanics:

When a Newtonian system breaks up, each of its parts has a definite and well-defined energy, momentum, and angular momentum, parceled out at breakup by the system while respecting dynamics and conservation laws. After the component parts are separated, their properties are completely independent and ***do not depend on each other***.



Isaac Newton (1642 – 1726)



Werner Heisenberg (1901 – 1976)

Quantum Mechanics:

When a quantum system breaks up, its parts may have indefinite values for energy, momentum, and angular momentum, as described by Heisenberg's Uncertainty Principle. After the component parts are separated, their properties are ***not*** independent and ***may depend on each other***. This quantum property is called ***nonlocality,*** and the interdependent system parts are said to be ***entangled***.

Why Nonlocality?

Nonlocality comes from two seemingly conflicting and incompatible aspects of the quantum formalism:

(1) Energy, momentum, and angular momentum are ***conserved*** in all quantum systems. In the absence of external forces and torques, their net values must remain unchanged as the system evolves.

(2) In the wave functions describing emitted particles in a quantum system, Heisenberg's Uncertainty Principle allows energy, momentum, and angular momentum to be ***indefinite***, typically spanning a range of values. This non-specifity persists until a measurement collapses the wave function and fixes the measured quantities with specific values.

The EPR Paradox: How can the wave functions describing the separated members of a system of particles, ***which may be light-years apart***, have in-definite values for the conserved quantities, yet respect conservation laws when measurements are made?

Albert Einstein
(1879 - 1955)

Why Entanglement?

The conservation laws are respected because the quantum wave functions of particles are ***entangled***, a term coined by Schrödinger, meaning that even when the wave functions describe system parts that are far apart and out of light-speed contact, the separate wave functions ***continue to depend on each other*** and cannot be separately specified.

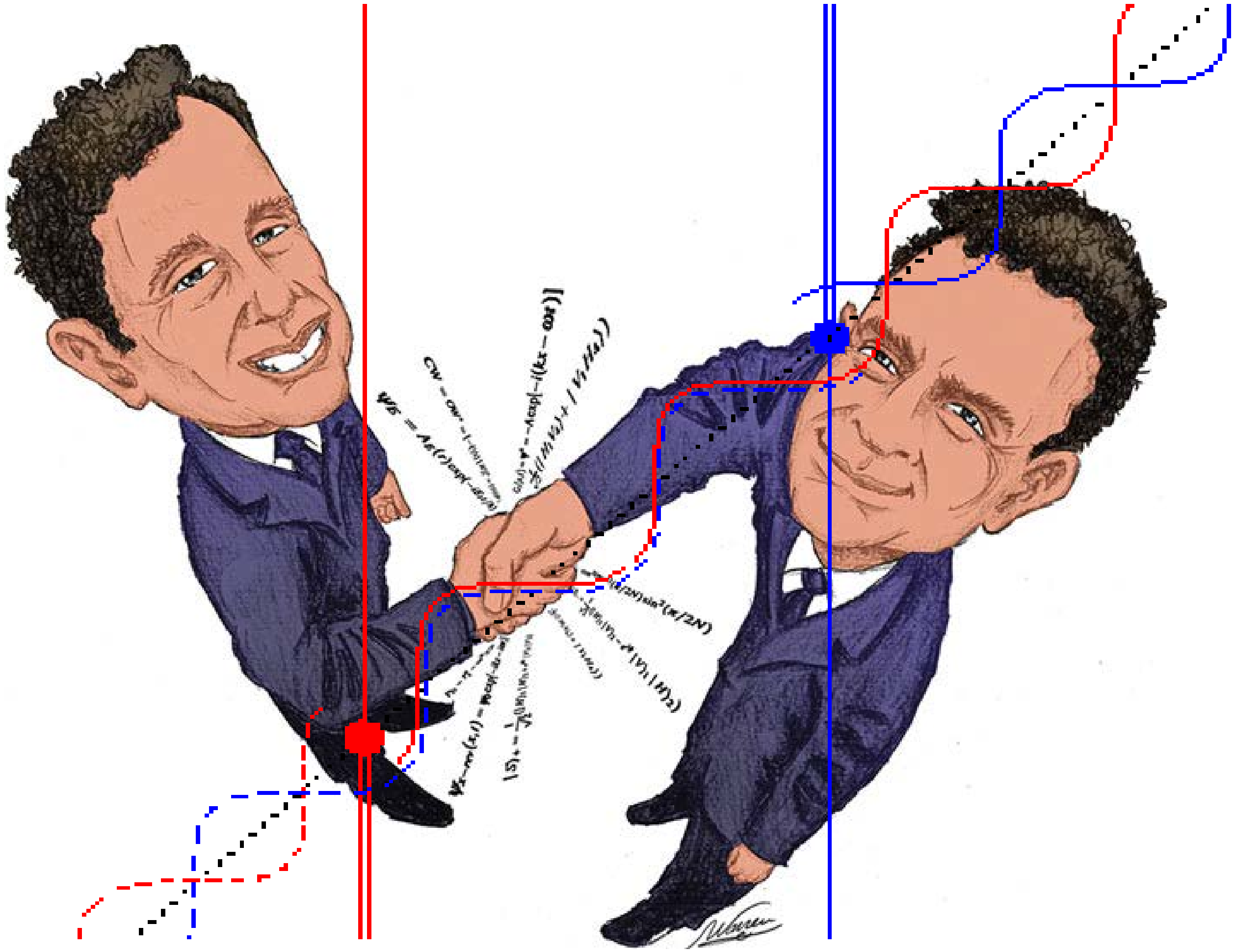
Erwin Schrödinger (1887 – 1961)

In particular, they depend on each other in such a way that conserved quantities in the parts must add up to the values possessed by the overall quantum system before it separated into parts. Einstein derisively called this nonlocal quantum behavior ***"spooky actions at a distance."***

How is this behavior possible? The TI provides an answer.

Part II
The Transactional Interpretation of Quantum Mechanics

The Wheeler-Feynman Handshake (1945)

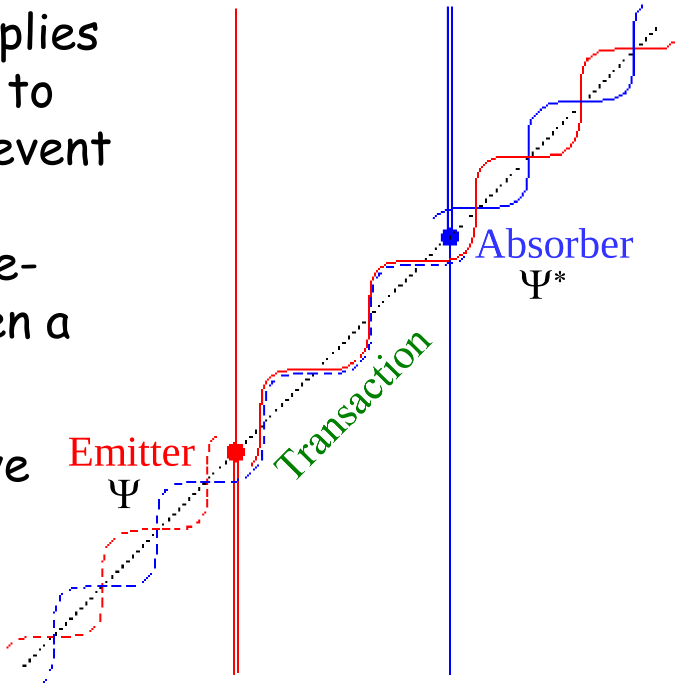


Transactional Interpretation of Quantum Mechanics

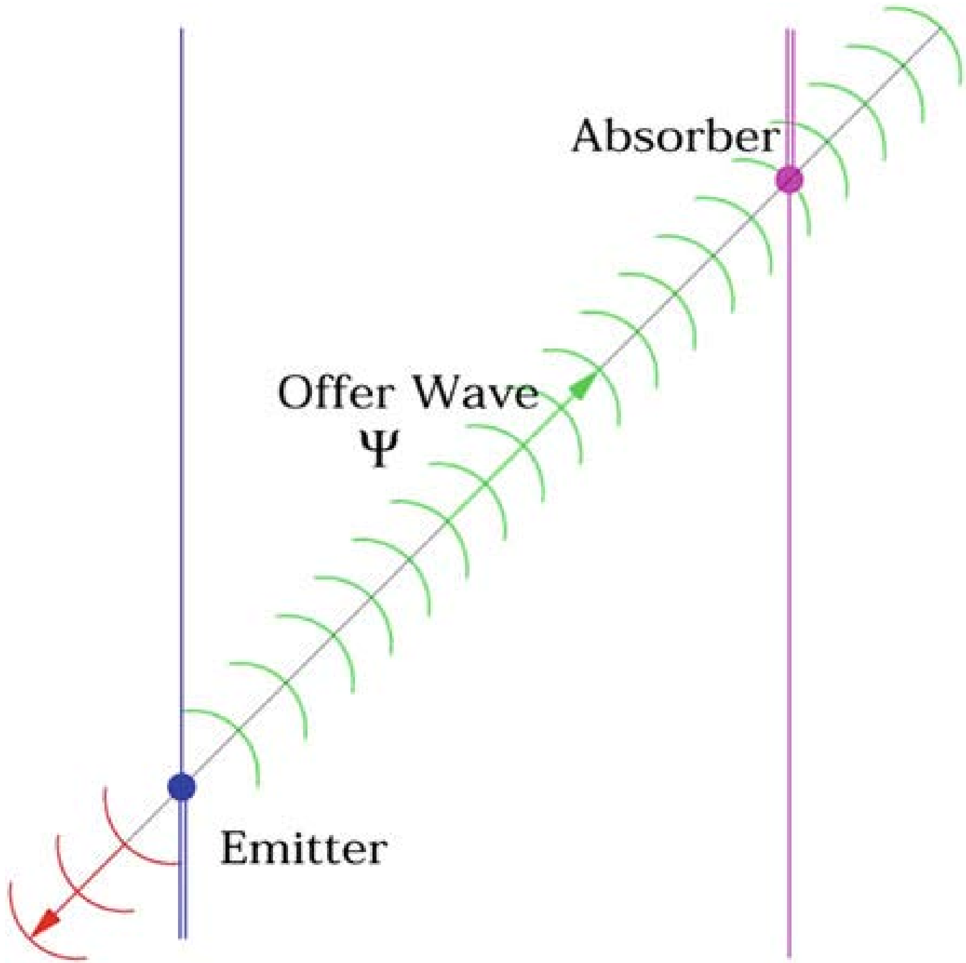
See https://www.amazon.com/dp/3319246402;
***The Quantum Handshake – Entanglement, Nonlocality and Transactions*, John G. Cramer, Springer (2016).**

Briefly, the Transactional Interpretation applies the logic of Wheeler-Feynman electrodynamics to quantum mechanics. It describes any quantum event as a "handshake" between an offer wave (Ψ) generated when a quantum is emitted and a time-reversed confirmation wave (Ψ^*) generated when a quantum is absorbed.

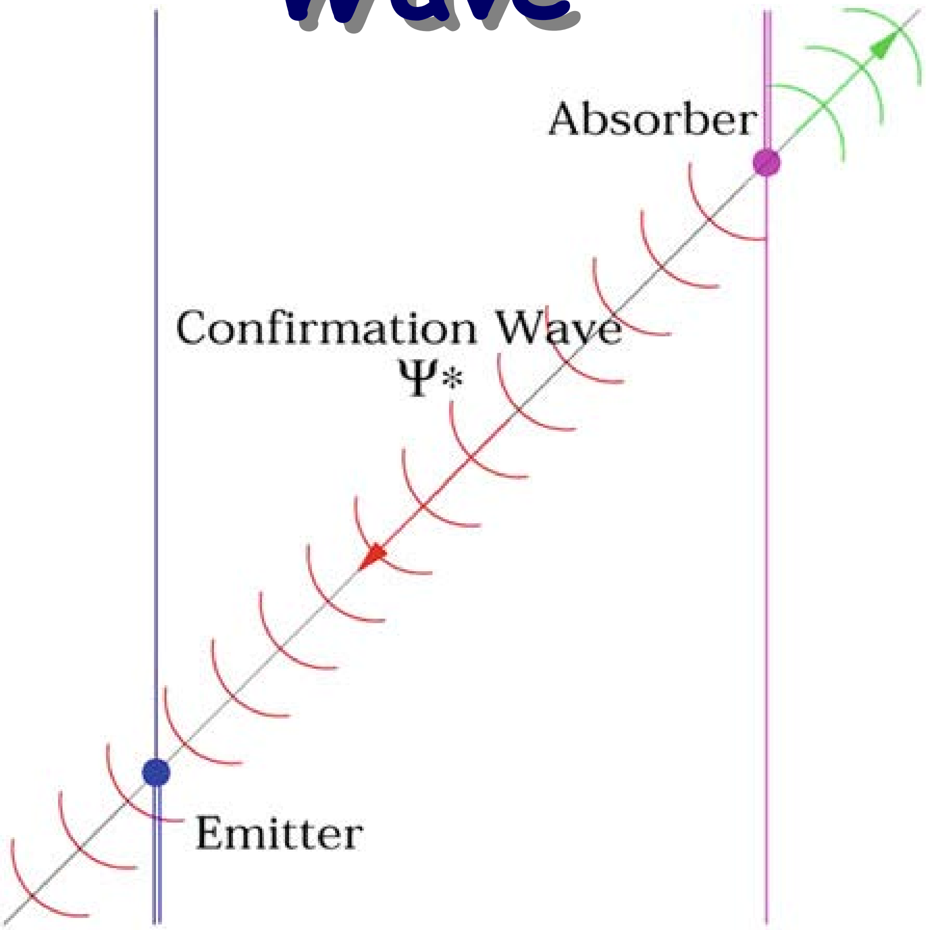
The transaction is essentially a standing wave that forms across space-time to transfer the energy, momentum, etc. of a particle from one location to another.



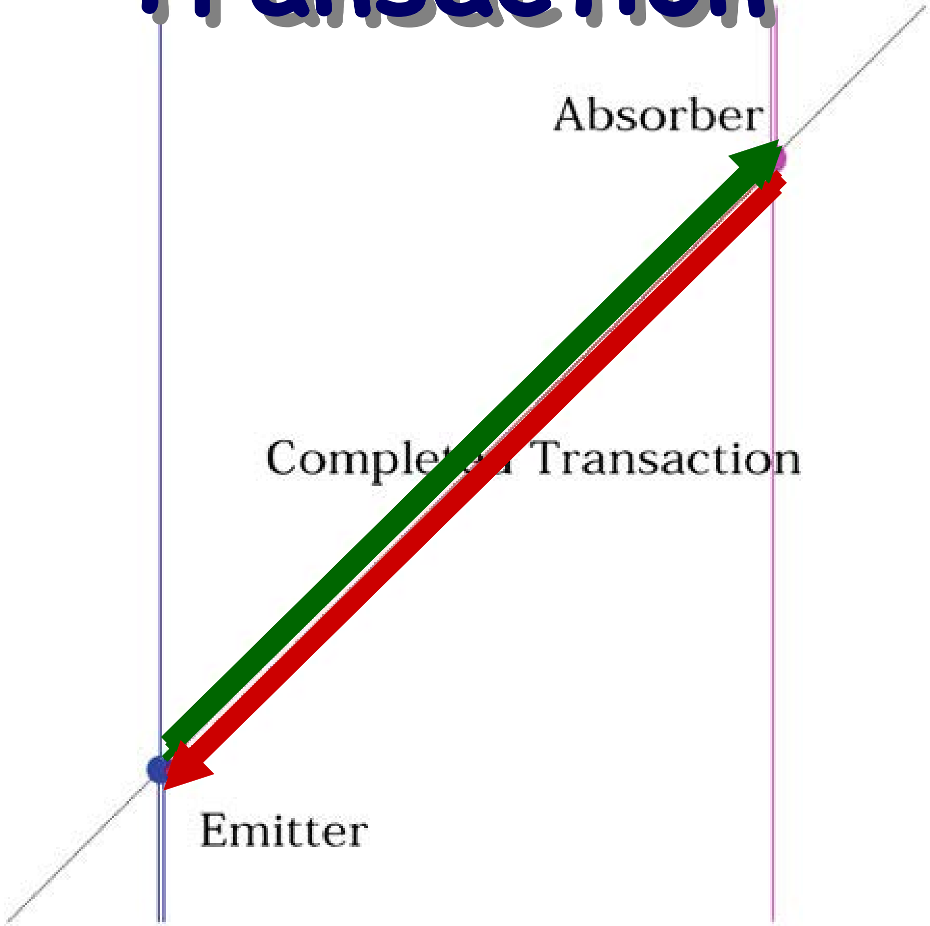
(Step 1) TI Offer Wave



(Step 2) TI Confirmation Wave

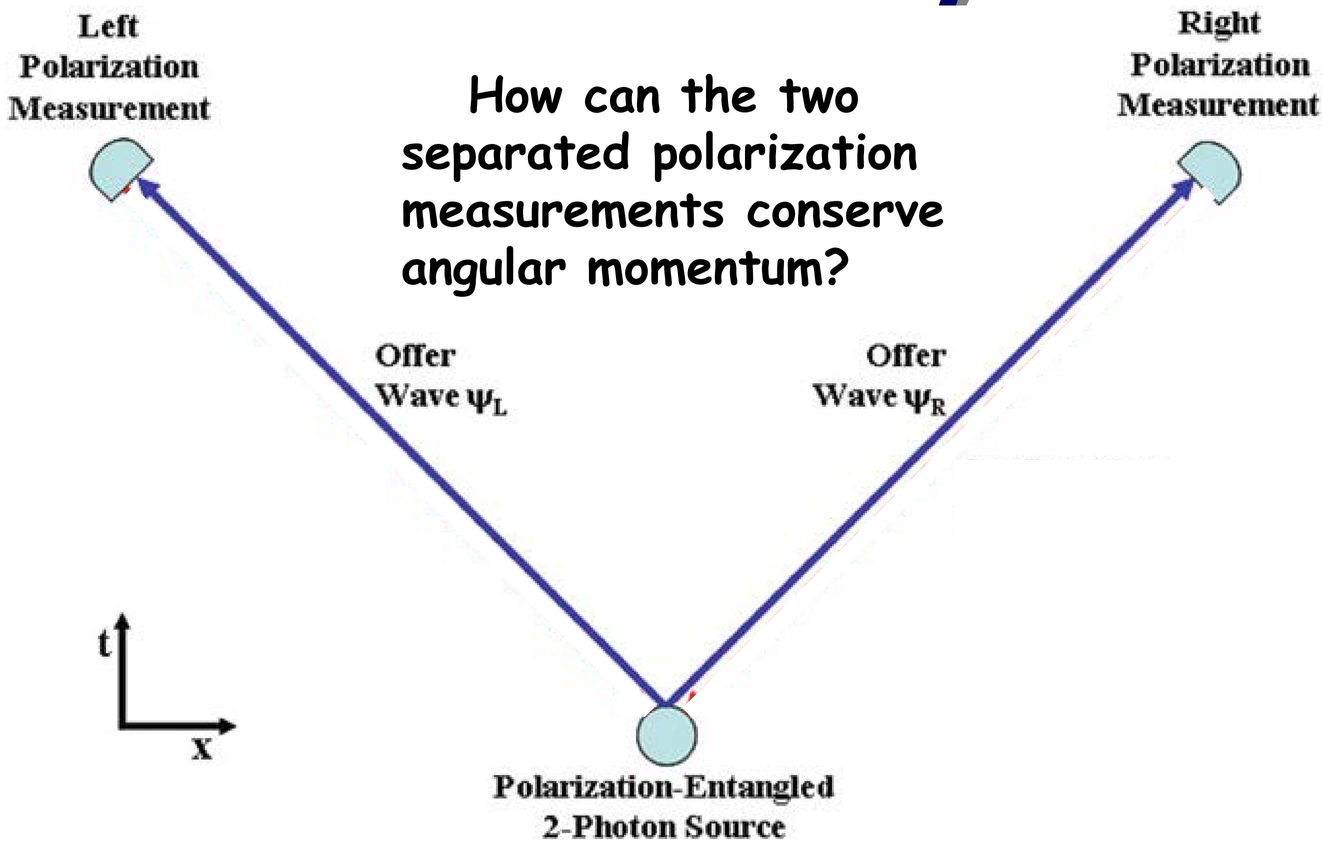


(Step 3) TI Completed Transaction



How the TI Explains Quantum Nonlocality in EPR

How can the two separated polarization measurements conserve angular momentum?



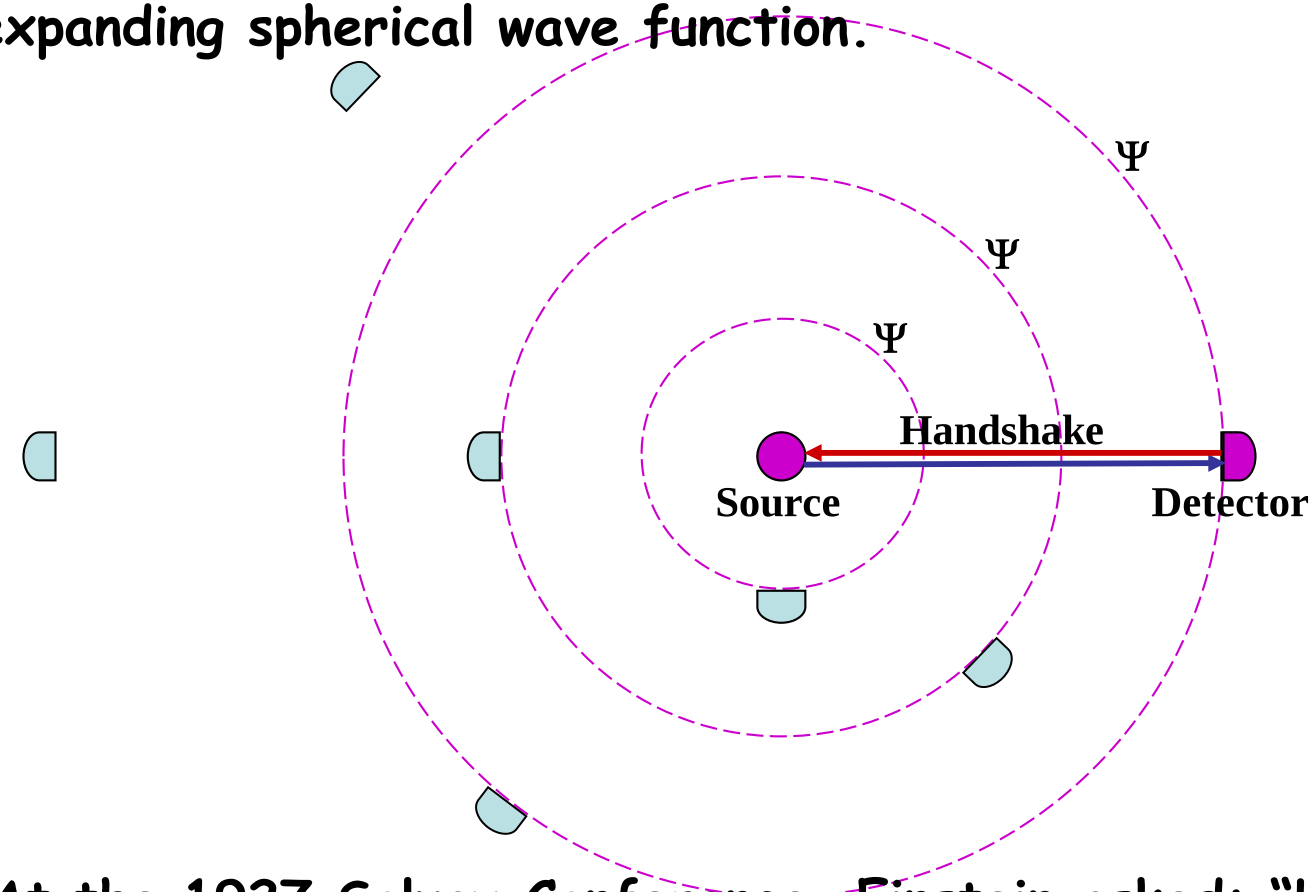
There is a double handshake between the source and the two detectors. This transaction *can only form* if the polarizations match, insuring that angular momentum conservation is enforced.

Part III

Applying the Transactional Interpretation to Quantum Paradoxes

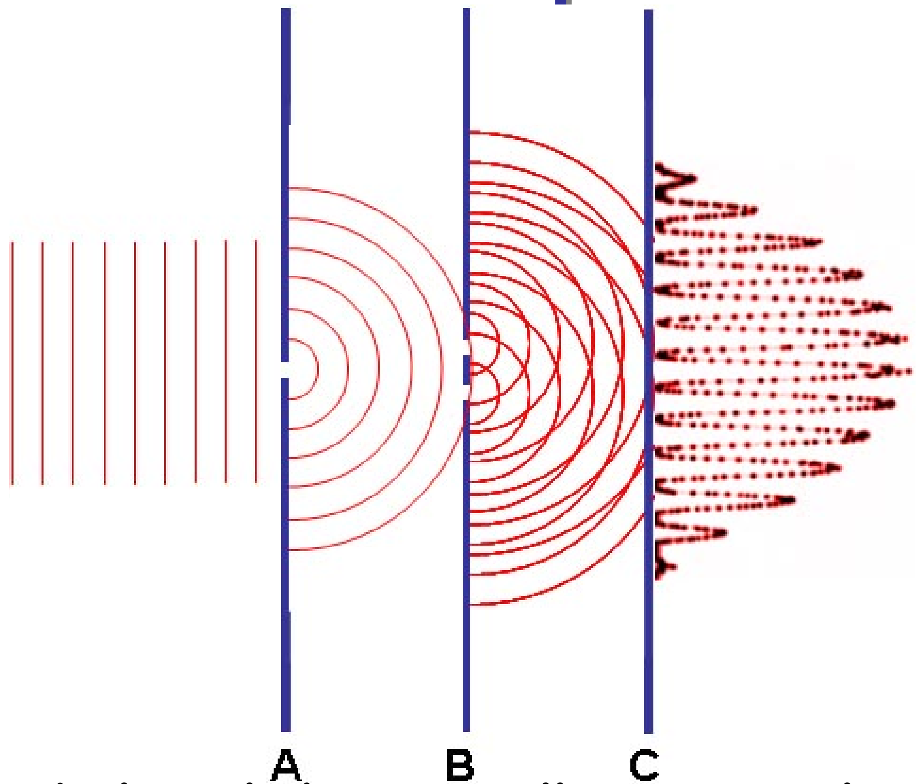
Einstein's Bubble (1927)

An isotropic light source emits a single photon as an expanding spherical wave function.



At the 1927 Solvay Conference, Einstein asked: "How do the remote parts of the photon's wave function 'know' that they should disappear when the photon is detected?"

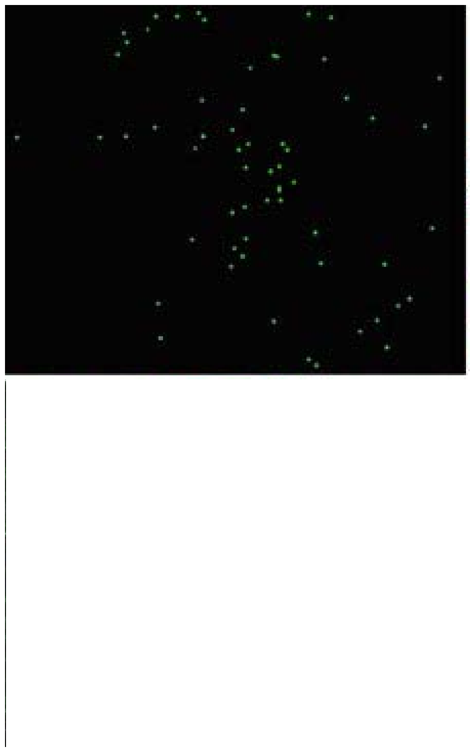
Young's 2-Slit Experiment (1803)



A polarized plane light wave illuminates slit A. The photon wave function passes through both slits at B and produces a 2-slit interference pattern (red) at C.

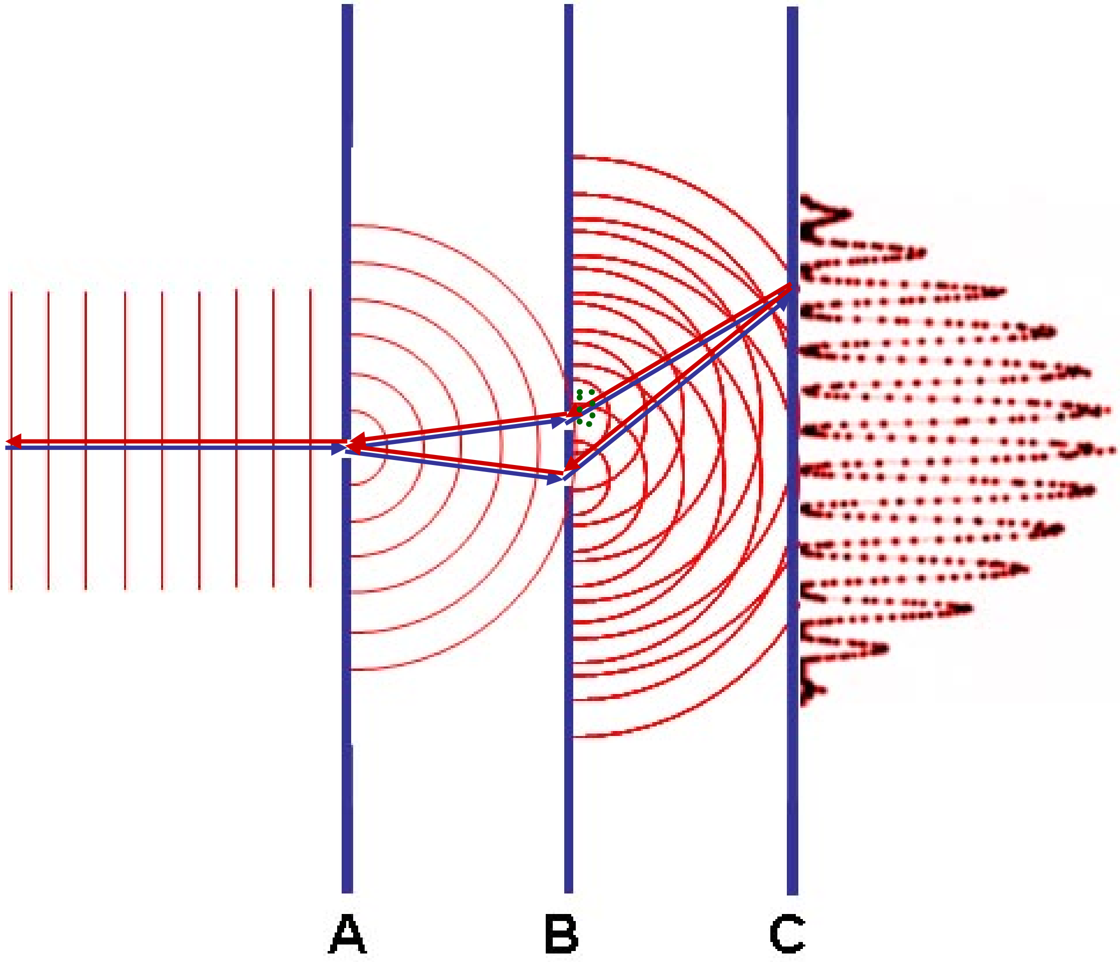
Placing a half-wave plate over one slit at B converts the 2-slit interference pattern to a 1-slit diffraction pattern (green).

The Interference Pattern Builds Up, Photon by Photon



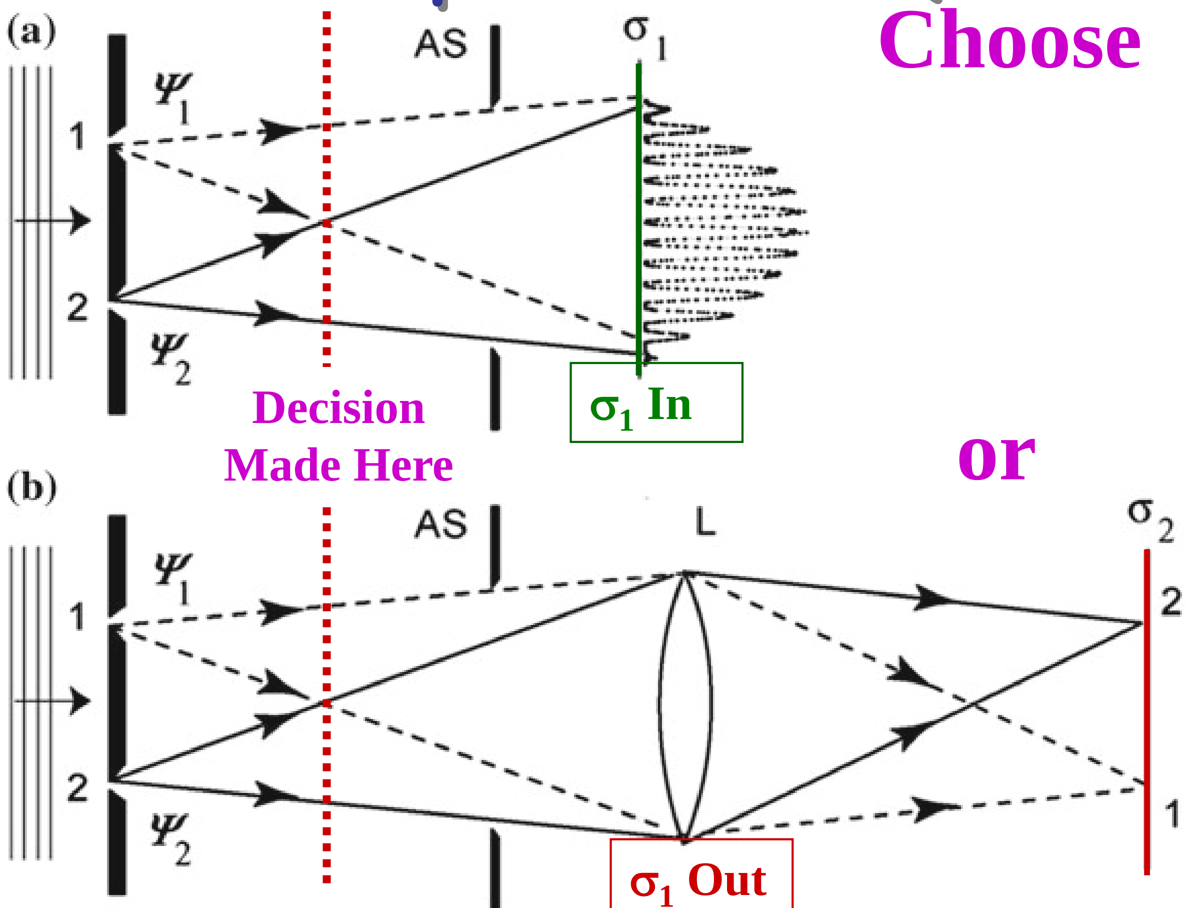
The wave interference pattern can be observed to build up, one photon at a time. Feynman called this behavior "the central mystery of quantum mechanics".

The TI & Young's 2-Slit Expt.



Wheeler's Delayed Choice Experiment (1978)

Choose



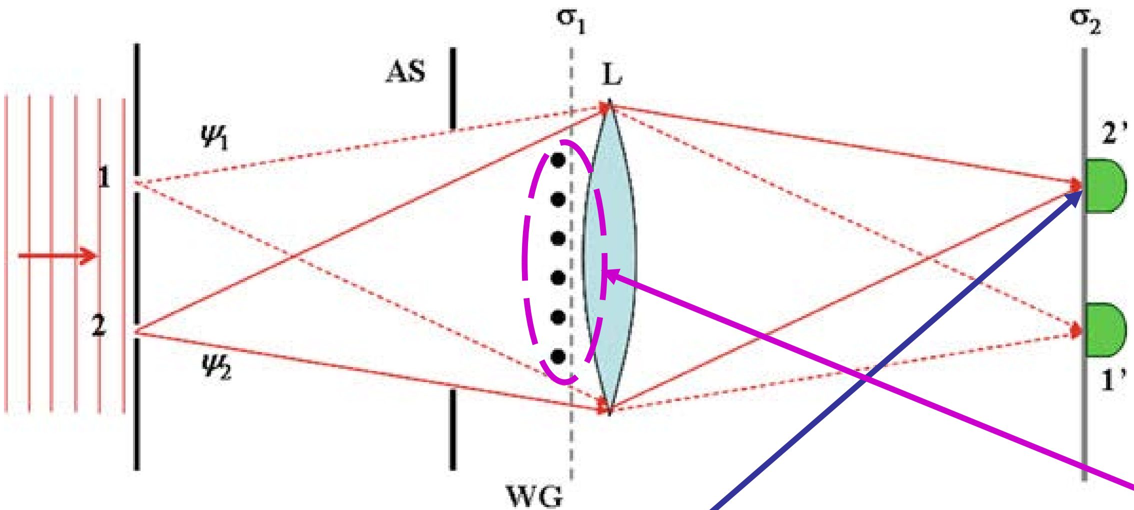
Wave-Like Interference Measurement (2 paths)

or

Particle-Like Which-Way Measurement (1 path)

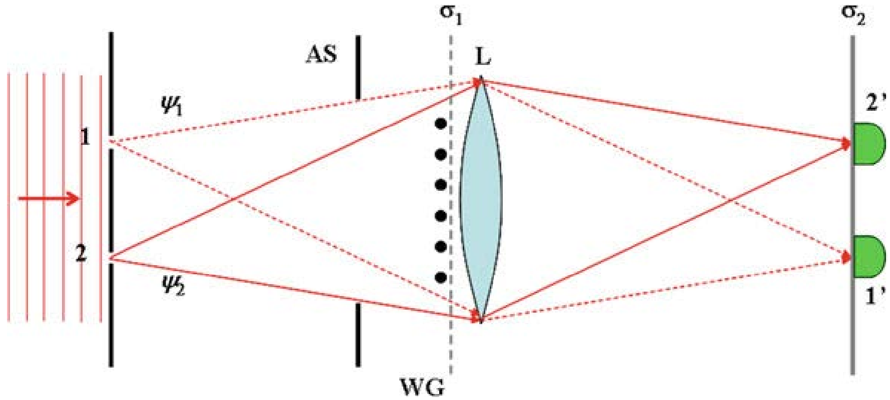
The observer decides which measurement to do *after* the photons have already passed through the slit system. Retrocausalitry?

Another Which-Way Experiment



- In a Which-Way setup, we place a set of wires with 6% opacity at the positions of the interference minima that were observed at σ_1;
- We place a detector at image focus 2′ on plane σ_2, and the experimenter observes and counts the particle flux passing through slit 2 to Det. 2′.

A Question for the Audience

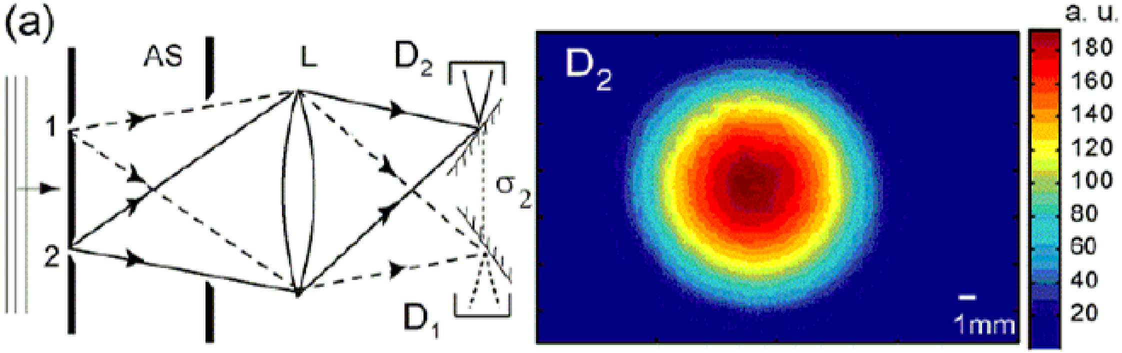


Q: Will interference be present or not? Which is true?

A. As Bohr taught us, when we do a particle-like Which-Way measurement, all wave properties are absent and no wave interference can be observed. Therefore, the wires will intercept **6% of the flux**.

B. Interference is still present. The wires have been placed at the interference minima, where wave cancellation occurs and wave amplitudes are zero. Therefore, the wires will intercept **almost no flux**.

Afshar Experiment Results



Grid Out & 2 Slits

No Loss

Grid In & 1 Slit

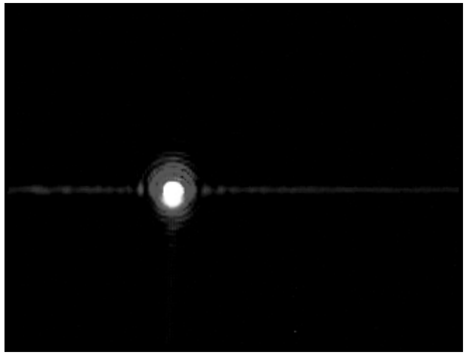
6% Loss

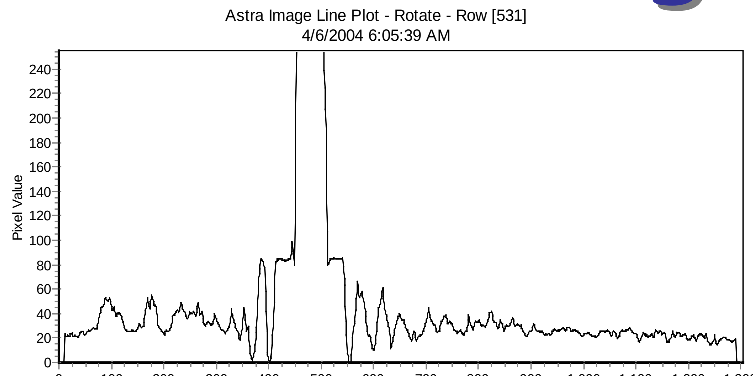
Grid In & 2 Slits

<0.1% Loss

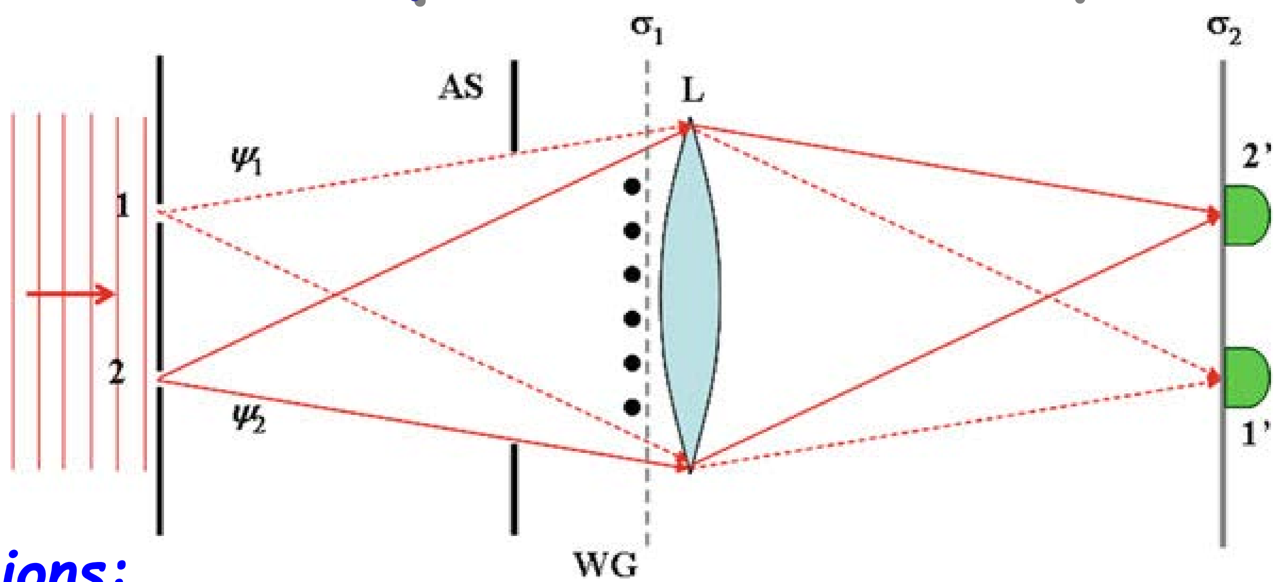
Afshar Experiment Images

One open
Wires In





Afshar Experiment Implications



Conclusions:

- Interference is ***still*** present, even when an unambiguous Which-Way experimental measurement is performed.

- Measuring particle-like behavior does ***not*** suppress wave-like behavior, if careful non-interactive wave measurements are made.

- It appears that ***simultaneously***, (1) waves pass both slits to create interference and (2) a photon passes through only one slit.

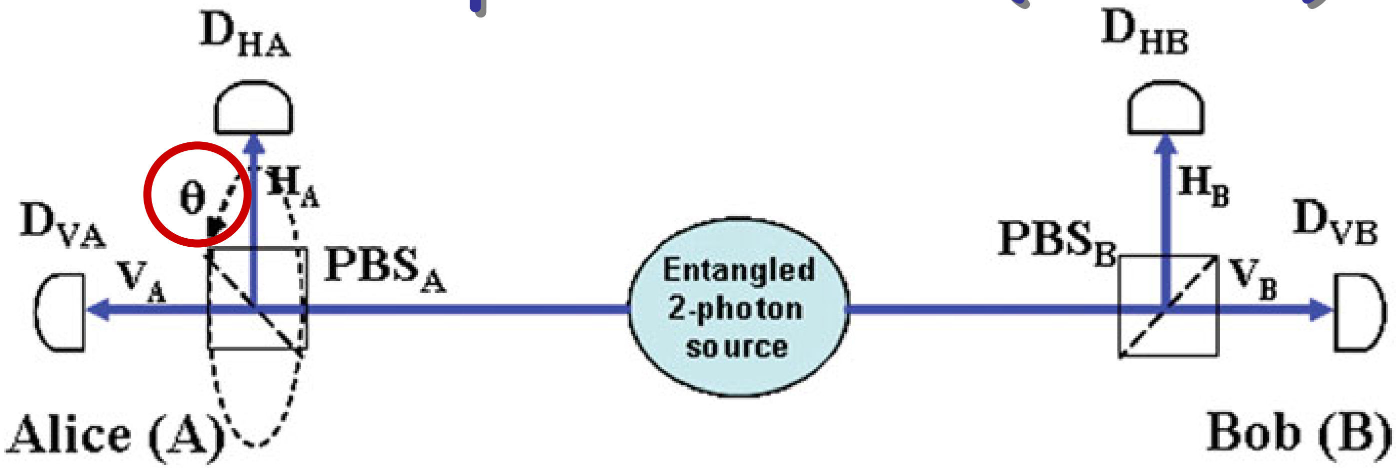
The Afshar Experiment and Quantum Interpretations

- ***The Copenhagen Interpretation*** asserts that quantum interference between waves only occurs when the waves are indistinguishable, and that when "Which-Way" measurements are performed, wave interference vanishes. The Afshar experiment ***falsifies*** this assertion.

- ***The Many Worlds Interpretation*** asserts that quantum interference between "worlds" cannot occur when the worlds are physically distinguishable. The Afshar experiment ***falsifies*** this assertion.

- ***The Transactional Interpretation*** explains the Afshar Expt. as the result of interference between initial offer waves from the two slits. Even in the Which-Way configuration with wires present, destructive offer-wave interference occurs. Therefore, transactions cannot form on the wires because the ***offer waves cancel there***. Consequently, the transmission must be nearly 100%, as observed.

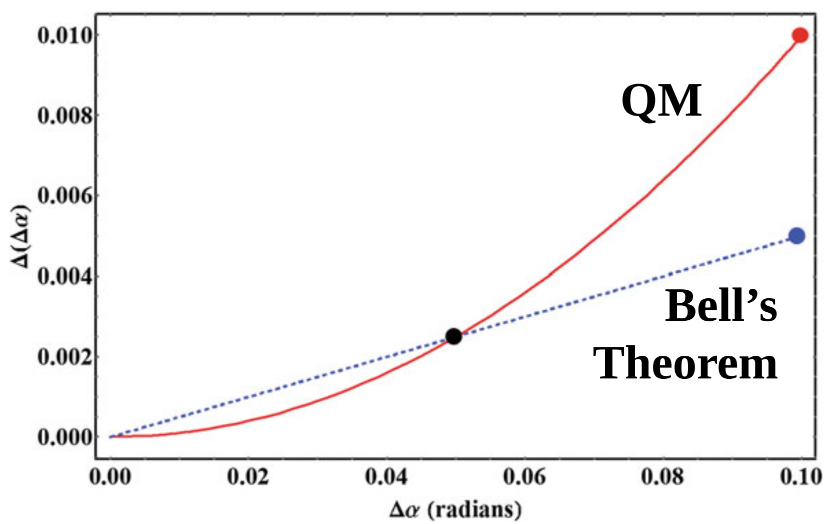
Freedman-Clauser Polarization EPR Experiment (1972)



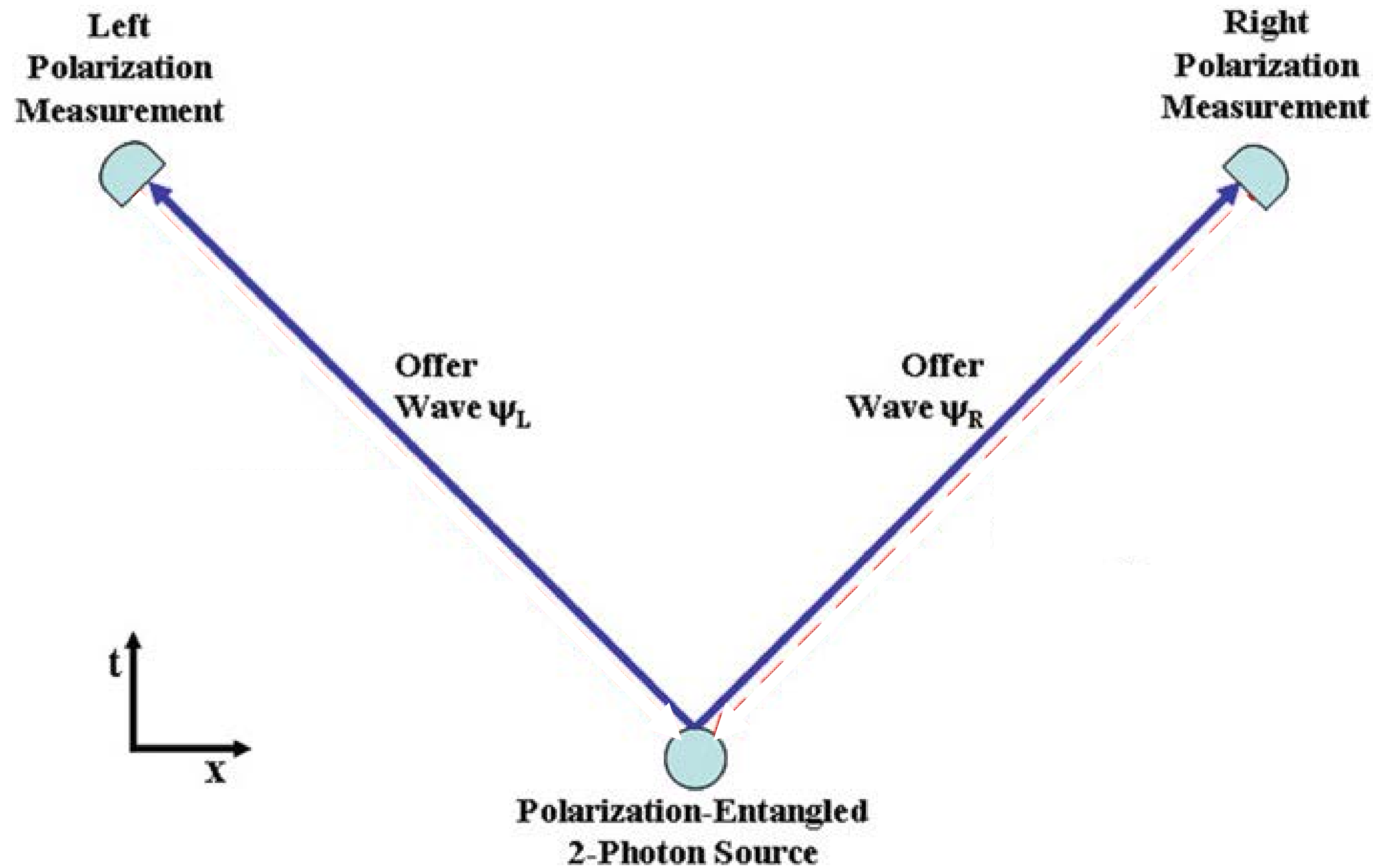
An EPR Experiment Testing QM vs. Bell's Theorem:

When polarimeters are aligned, only matching (H,H) or (V,V) coincidences are observed.

When polarimeter A is rotated, "noise" coincidences (H,V) and (V,H) grow initially as the square of rotation angle θ.



The TI's "V" Handshake Accounts for EPR Correlations



How can the measured polarizations match, no matter what polarization type is measured? How can the noise grow a θ^2?

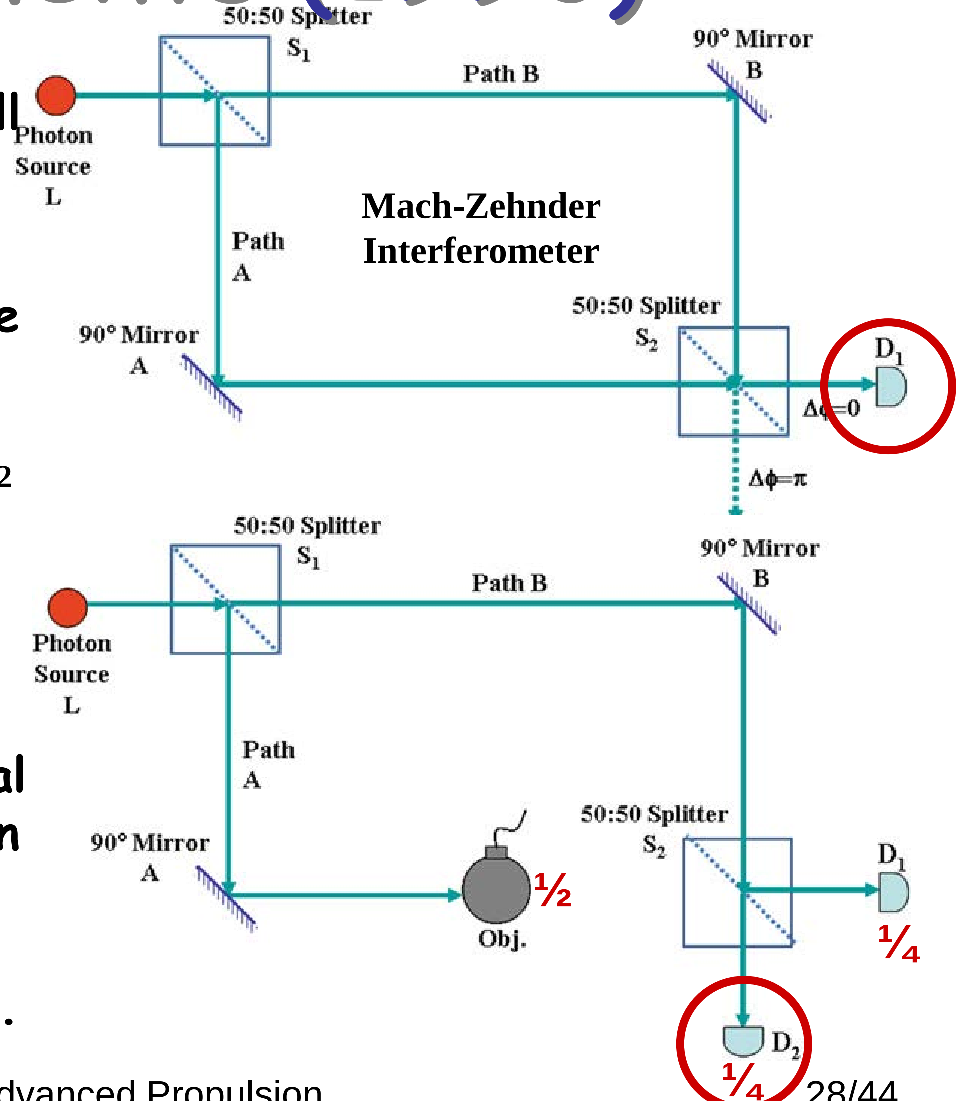
Interaction-Free Measurements (1993)

Interaction-Free Measurement:
With no object in lower beam, all of the photons go to D_1.

If an object is placed in the lower beam, photons go to D_2 one fourth of the time.

Thus, any photon detection at D_2 indicates the presence of an object in the beam, ***even though no photon has ever interacted with that object***.

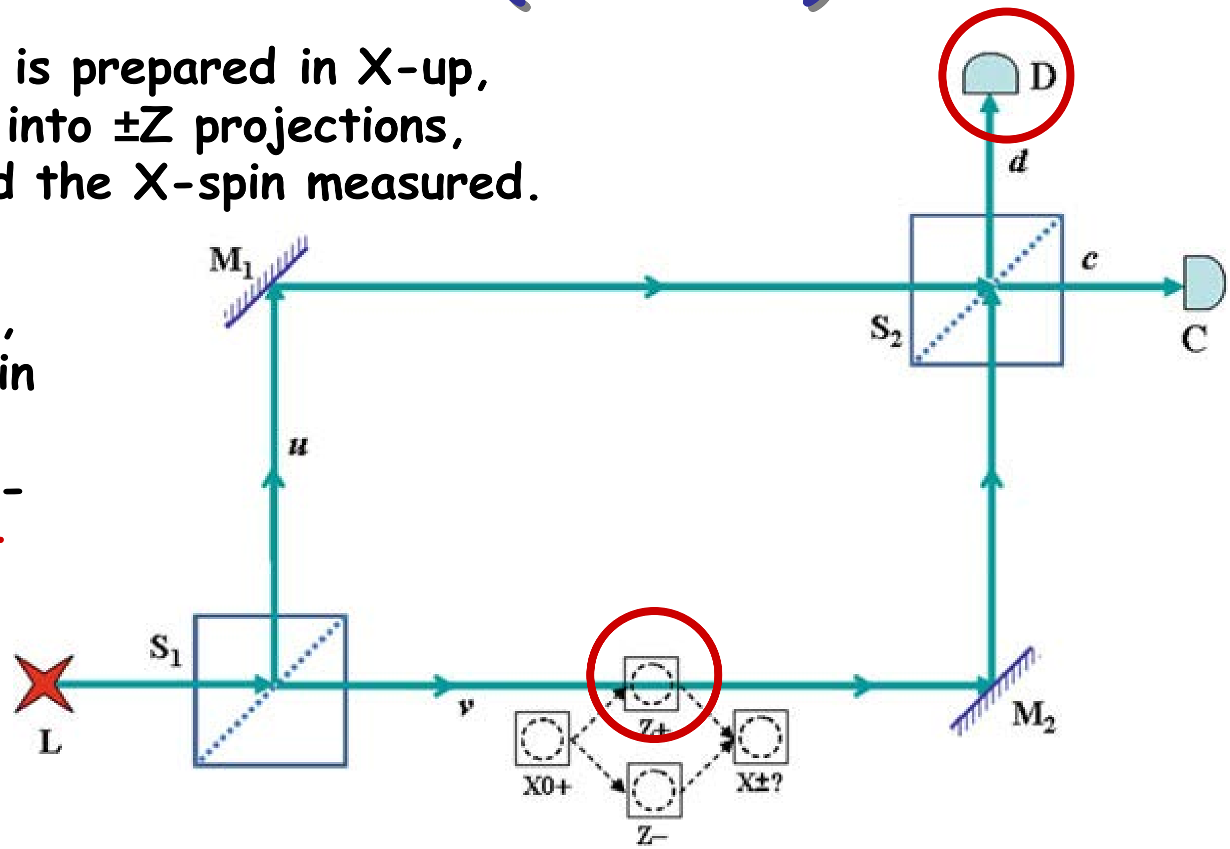
The TI explains this non-classical behavior as the suppression of an offer wave that would otherwise have canceled the upper-path wave at D_2, preventing detection.



The Hardy Boxed-Atom Experiment (1992)

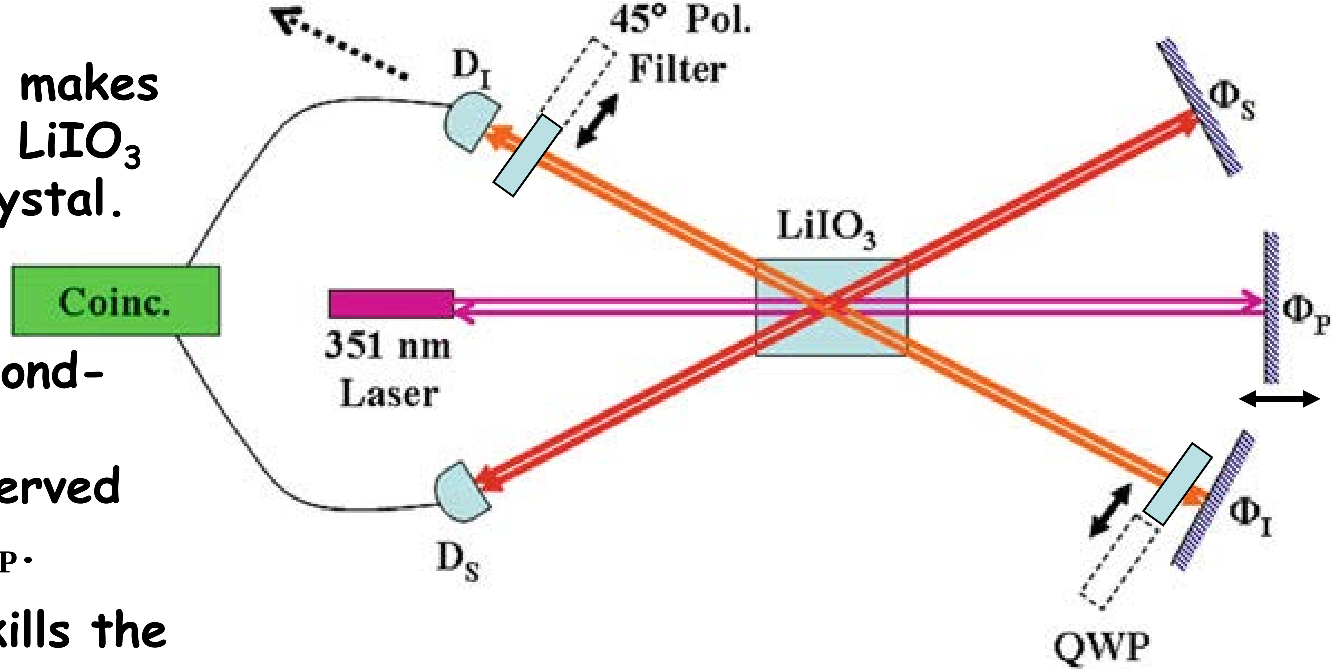
The spin ½ atom is prepared in X-up, Stern-Gerlach split into ±Z projections, then recombined and the X-spin measured.

For photons at D, the atom, prepared in X-up, has a 50% chance of being in X-down, even though it has never interacted with a photon.



The TI explains in the same way as the interaction-free measurement. Detection at D means the offer wave in the lower arm is blocked because the atom is in the Z+ state.

The Quantum Eraser Experiment (1995)



Pump laser beam makes two passes through $LiIO_3$ down-conversion crystal. First-pass photons are reflected to match paths of second-pass photons, and interference is observed by moving mirror Φ_P.

Inserting QWP kills the interference.

Inserting 45° filter near D_1 restores interference in D_1 and D_2, even if this happens far downstream.

The TI explains this behavior in terms of handshakes that include both passes, provided the paths are indistinguishable. Inserting QWP requires separate pass transactions. Inserting the 45° filter project out the same polarization in the two paths, *permitting a joint transaction*.

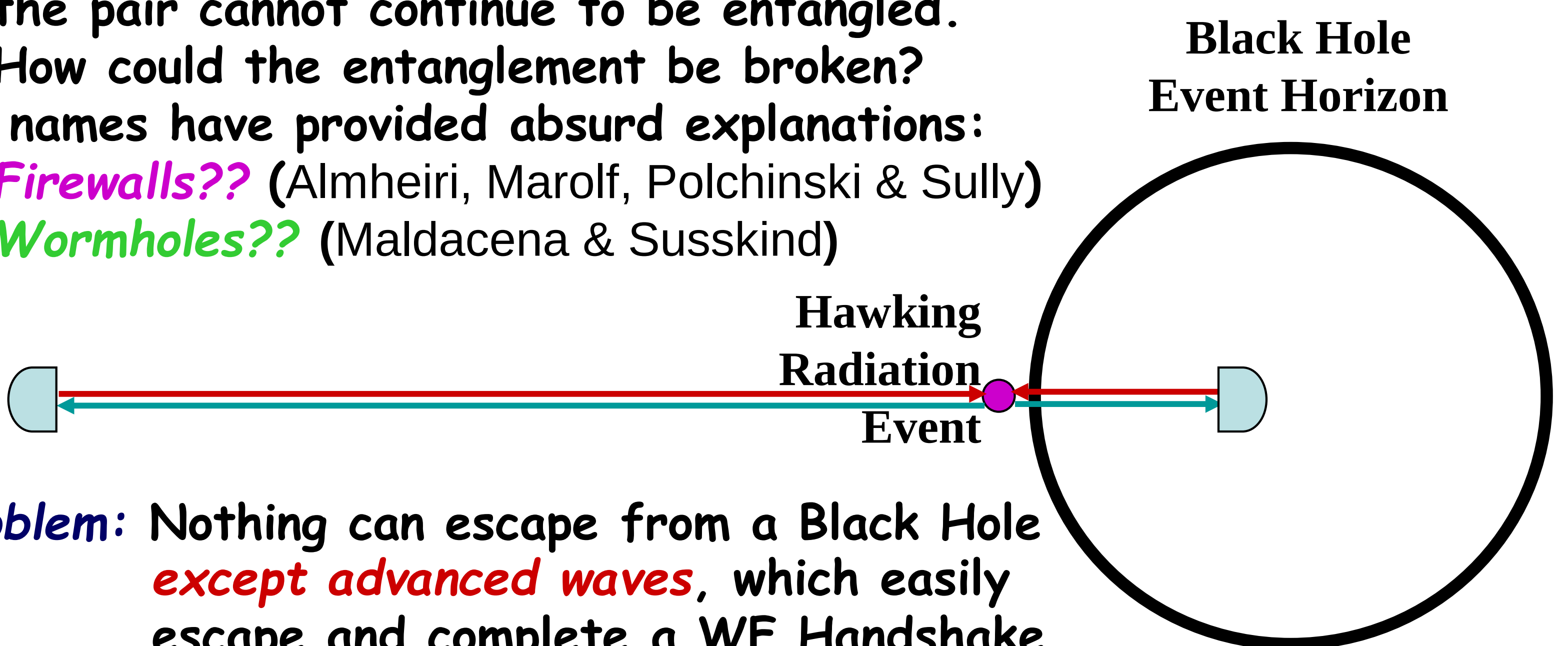
Handshakes and Black Holes

The Black Hole Information Paradox:

Hawking radiation makes pairs of entangled photons, one of which disappears behind the event horizon of a Black Hole. Therefore, it is argued, the pair cannot continue to be entangled. How could the entanglement be broken?

Big names have provided absurd explanations:

- ***Firewalls??*** **(**Almheiri, Marolf, Polchinski & Sully**)**
- ***Wormholes??*** **(**Maldacena & Susskind**)**



Problem: **Nothing can escape from a Black Hole *except advanced waves*, which easily escape and complete a WF Handshake, thereby preserving the entanglement. Therefore, the Black Hole Information Paradox goes away.**

Part IV
The Process of Forming Transactions

From Wheeler-Feynman to the Transactional Interpretation

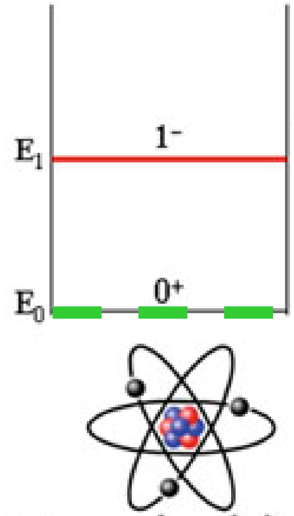
In classical Wheeler–Feynman electrodynamics, it is the advanced-wave responses from ***all*** of the absorbers in the future universe, arriving together back at the emitter that cause an emitting object to radiate, lose energy, and recoil during emission. Every future absorber is very slightly perturbed by the arriving retarded wave and generates an advanced-wave responses, which return to perturb the emitter.

In the quantum domain this scenario must be changed to reflect quantization and probabilistic quantum behavior. Due to the inverse-square law, any spherical wave function will become progressively weaker as it propagates for a significant distance before absorption, and cannot deliver a photon's worth of energy and momentum. Moreover, the absorber cannot accept less than a full quantum of energy, but it may be slightly perturbed by the arriving retarded wave.

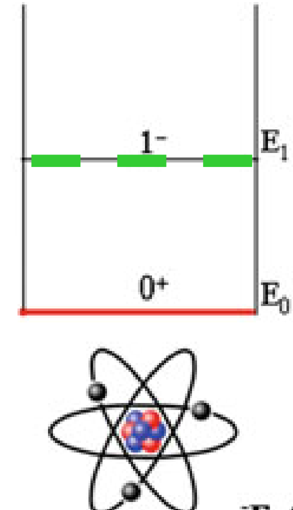
In the Transactional Interpretation, the Wheeler-Feynman process is only the initial "perturbative" phase of transaction formation.

A Two-Atom Transaction

Based on Sect. 5.4, *Collective Electrodynamics*, Carver Mead (2000)



$$\psi_E = A_E(r)\, e^{-iE_1 t/\hbar}$$

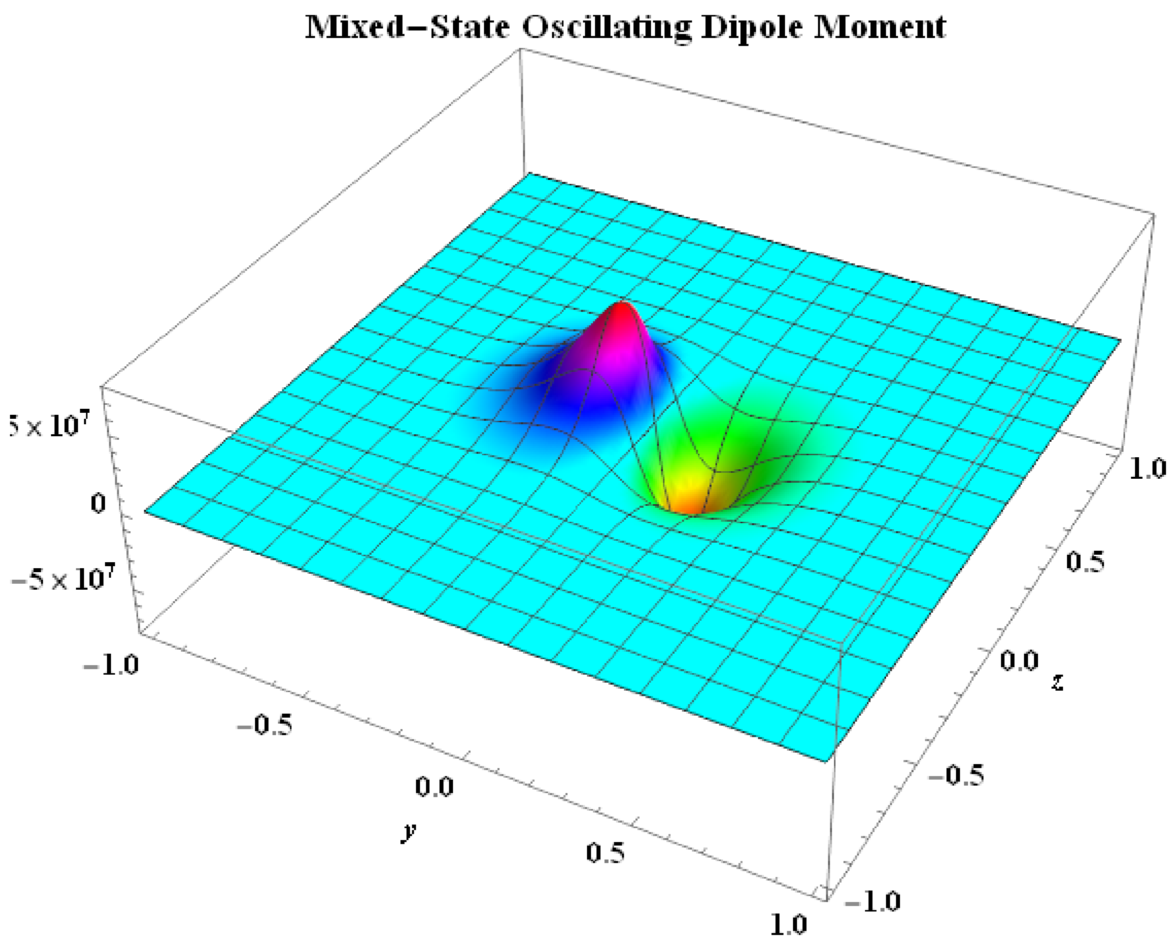


$$\psi_A = S_A(r)\, e^{-iE_0 t/\hbar}$$

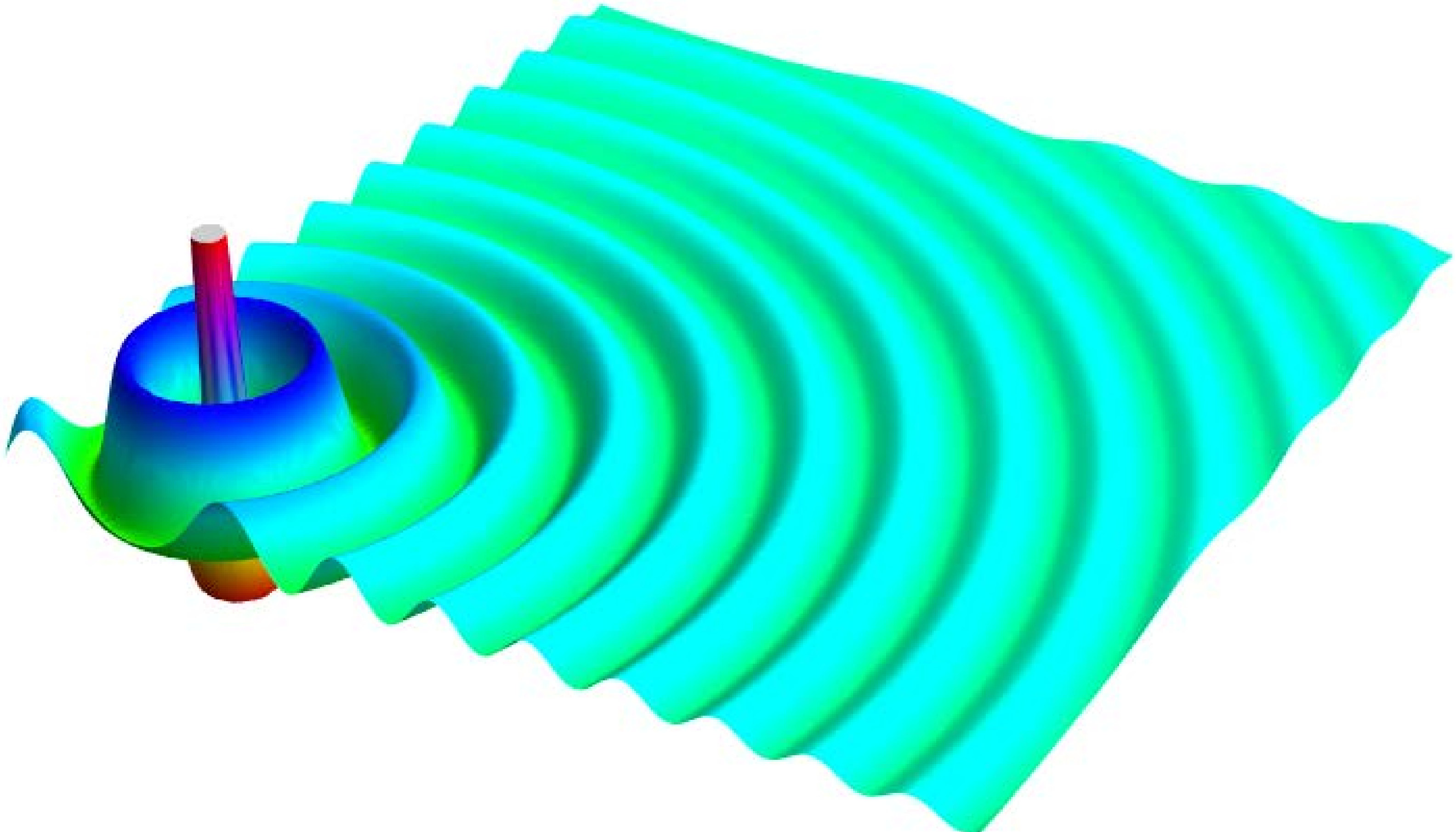
Emitter atom E is in its 1^- excited state and sends out a retarded "offer" wave ψ.

Absorber atom A is in its 0^+ ground state and responds with an advanced "confirmation" wave ψ^*. The result is that both atoms are very slightly perturbed by the arriving waves. Both become atoms in mixed states containing a small admixture (green) of an opposite-parity wave function.

Oscillating Dipole

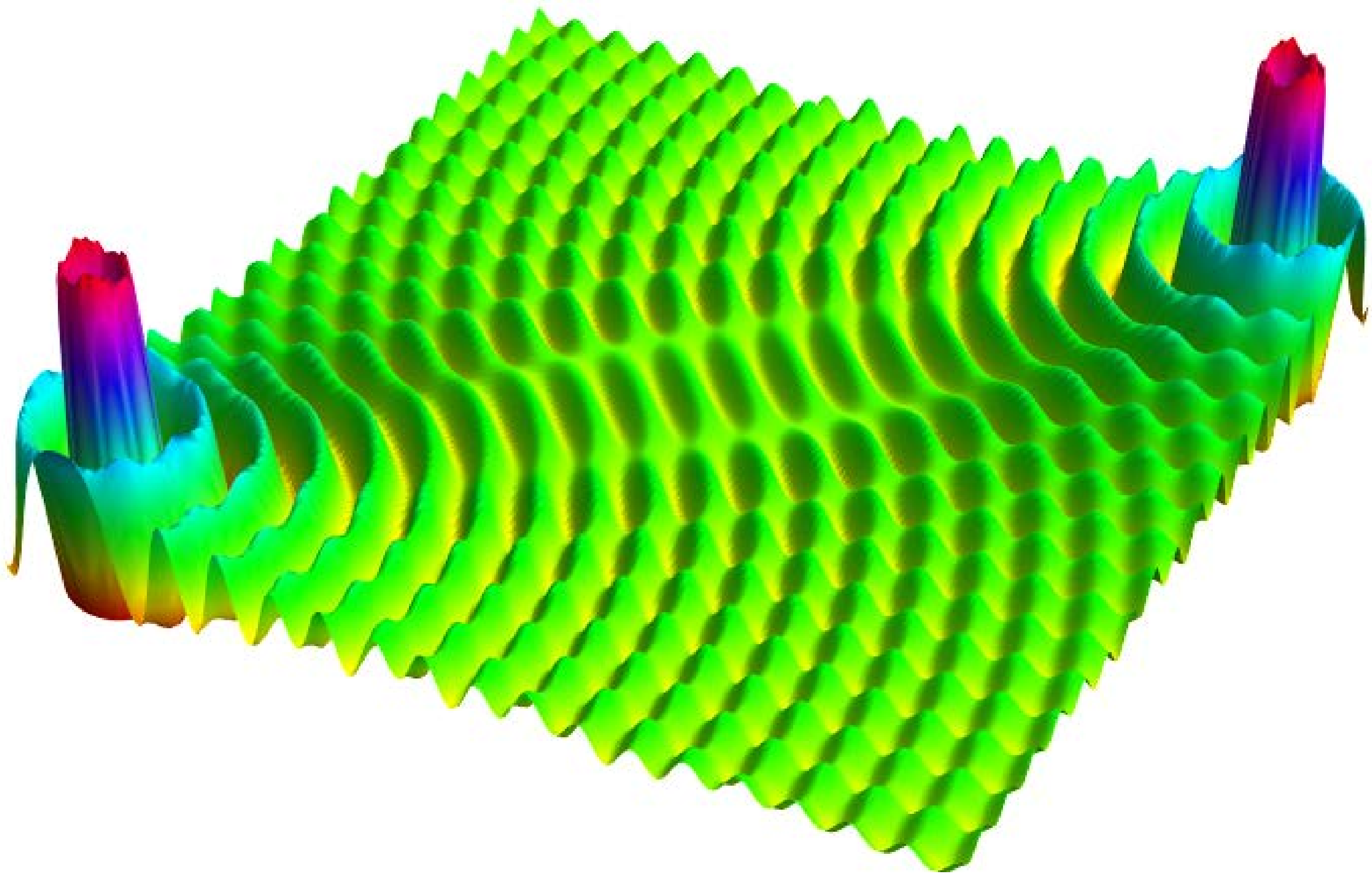


A Radiating Mixed-State Atom



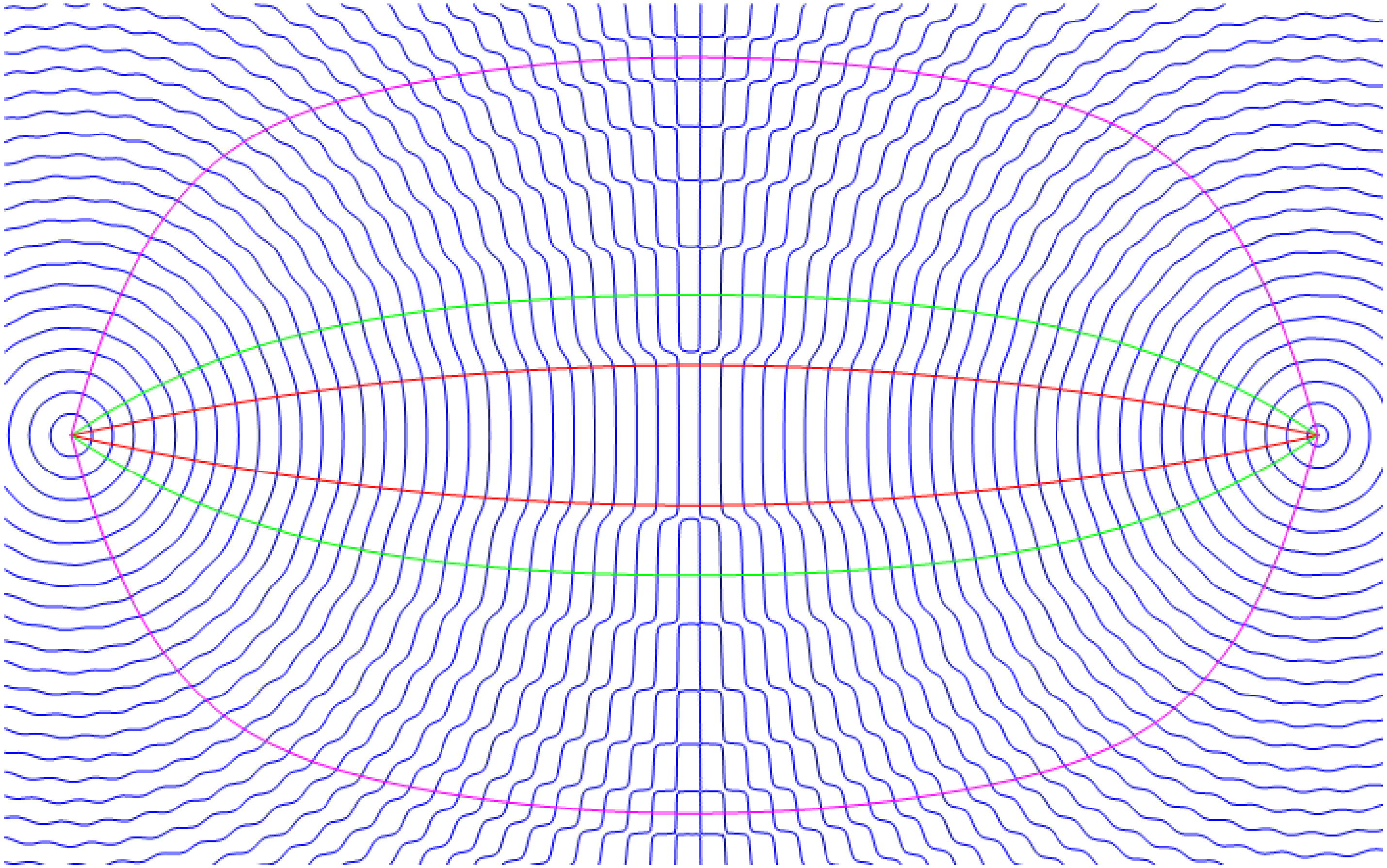
An atom in the ground state, but with a slight perturbation of an opposite-parity excited-state wave function, or *vice versa*, develops an oscillating dipole moment that radiates.

A Two-Atom Transaction



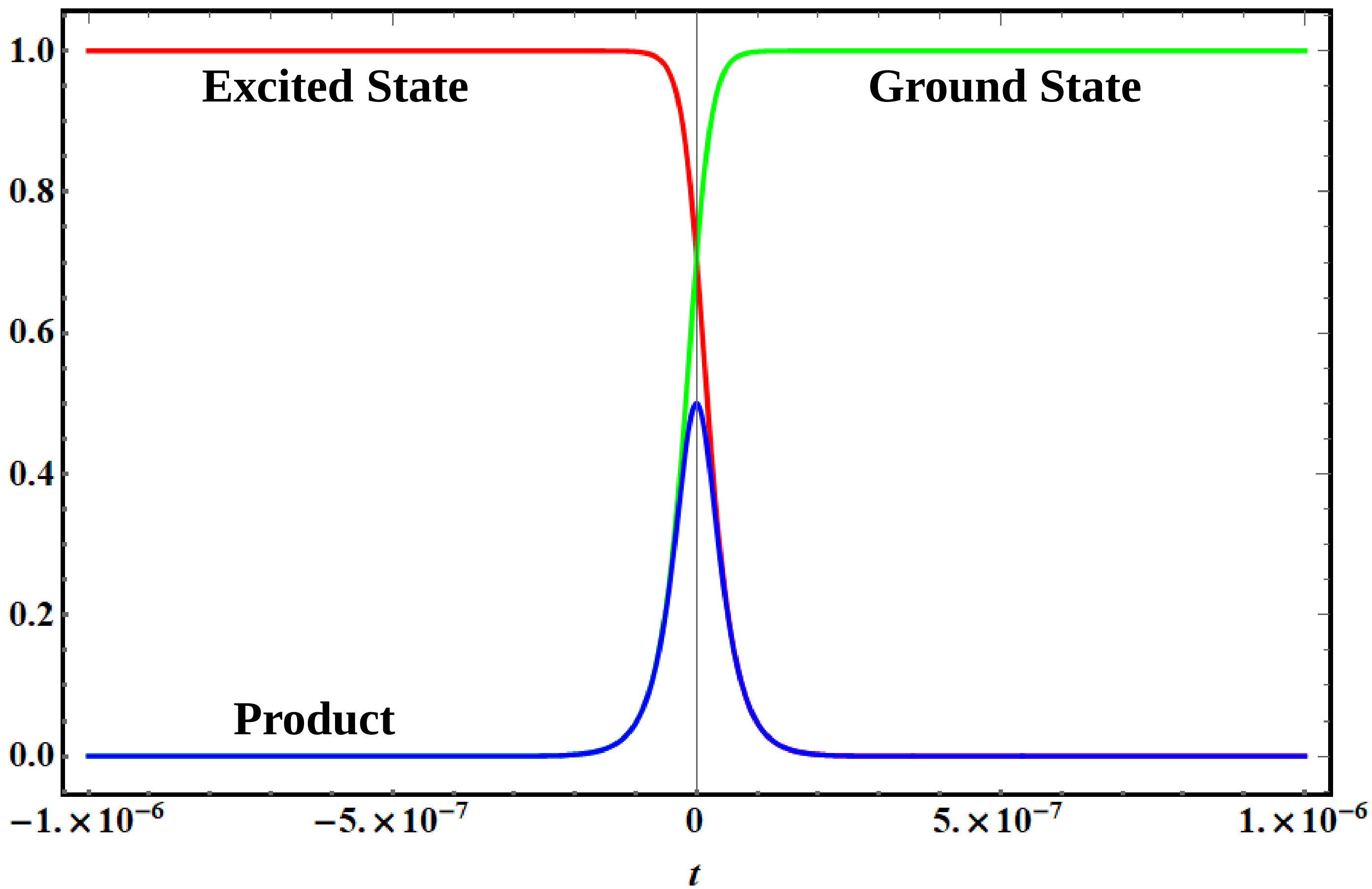
Two atomic dipoles oscillating with the same frequency and appropriate phasing dictated by their initial perturbations, transfer energy and momentum, thereby creating a transaction.

A Two-Atom Transaction



The zero crossings of the handshake vector potential at t = 0. Paths shown through high-amplitude regions have an even number of zero crossings. Thus the potentials traversing these paths all arrive *in phase*.

Wave Exchange Avalanches to Form a Transaction



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Part 5 - Conclusions

1. The Transactional Interpretation provides a rational way of visualizing and understanding the mechanisms behind entanglement, nonlocality, and wave function collapse.

2. The plethora of interpretational paradoxes and non-classical quantum-optics experimental results can ***all*** be understood by applying the Transactional Interpretation.

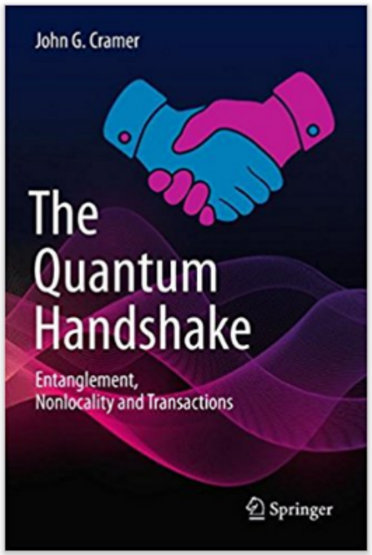
3. The process of transaction formation, at least in simple cases, emerges directly from the application of standard quantum mechanics to the advanced-retarded-wave handshake process as it builds and avalanches to completion.

4. As the the mattress commercial asks:
   Why buy your Quantum Interpretation anywhere else?

Reference

The Quantum Handshake: Entanglement, Nonlocality and Transactions 1st ed. 2016 Edition
by John G. Cramer (Author)
5 customer reviews

Look inside



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Any Questions?

Extra Slide:

Bohmian Trajectories of Photons in Slits & Crossing Beams

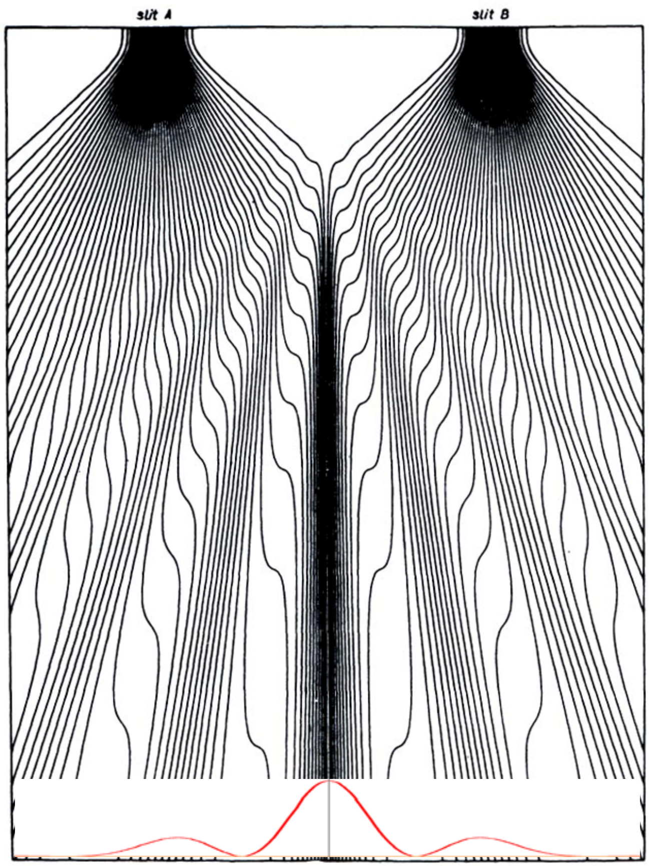
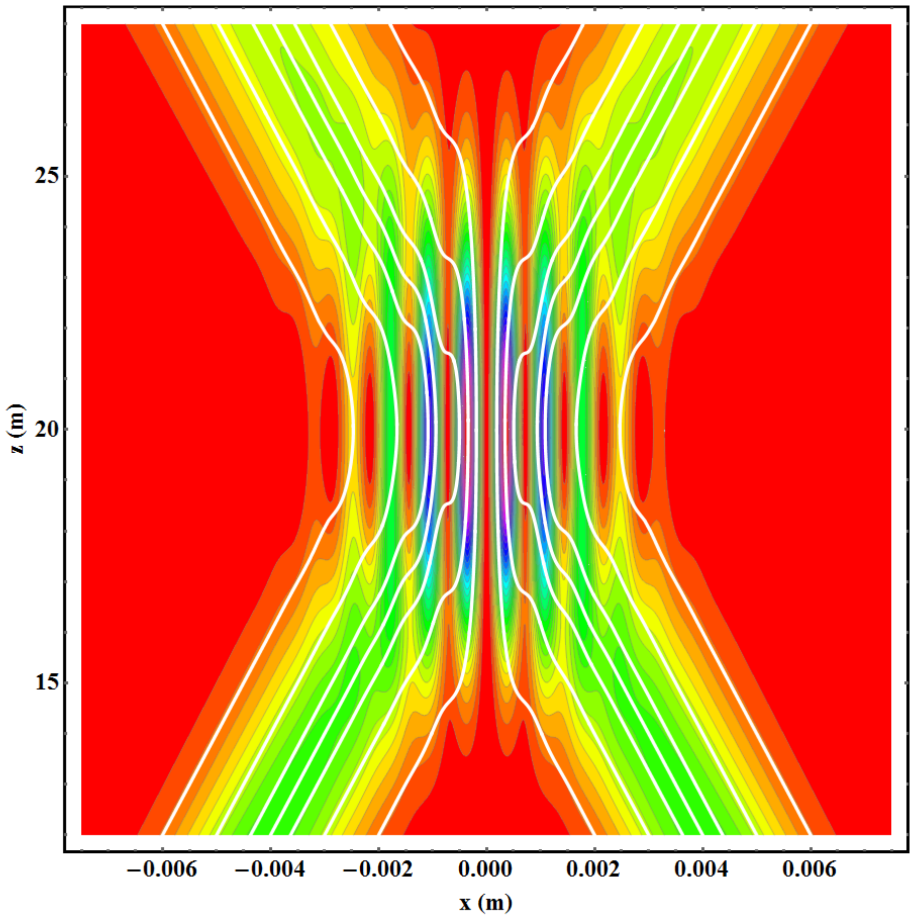


Figure 3.1: Trajectories for two Gaussian slit systems



Extra Slide:

A Gedanken Test of Bohmian Quantum Mechanics