Title: 12/13 PSI - Found Quantum Mechanics Lecture 1

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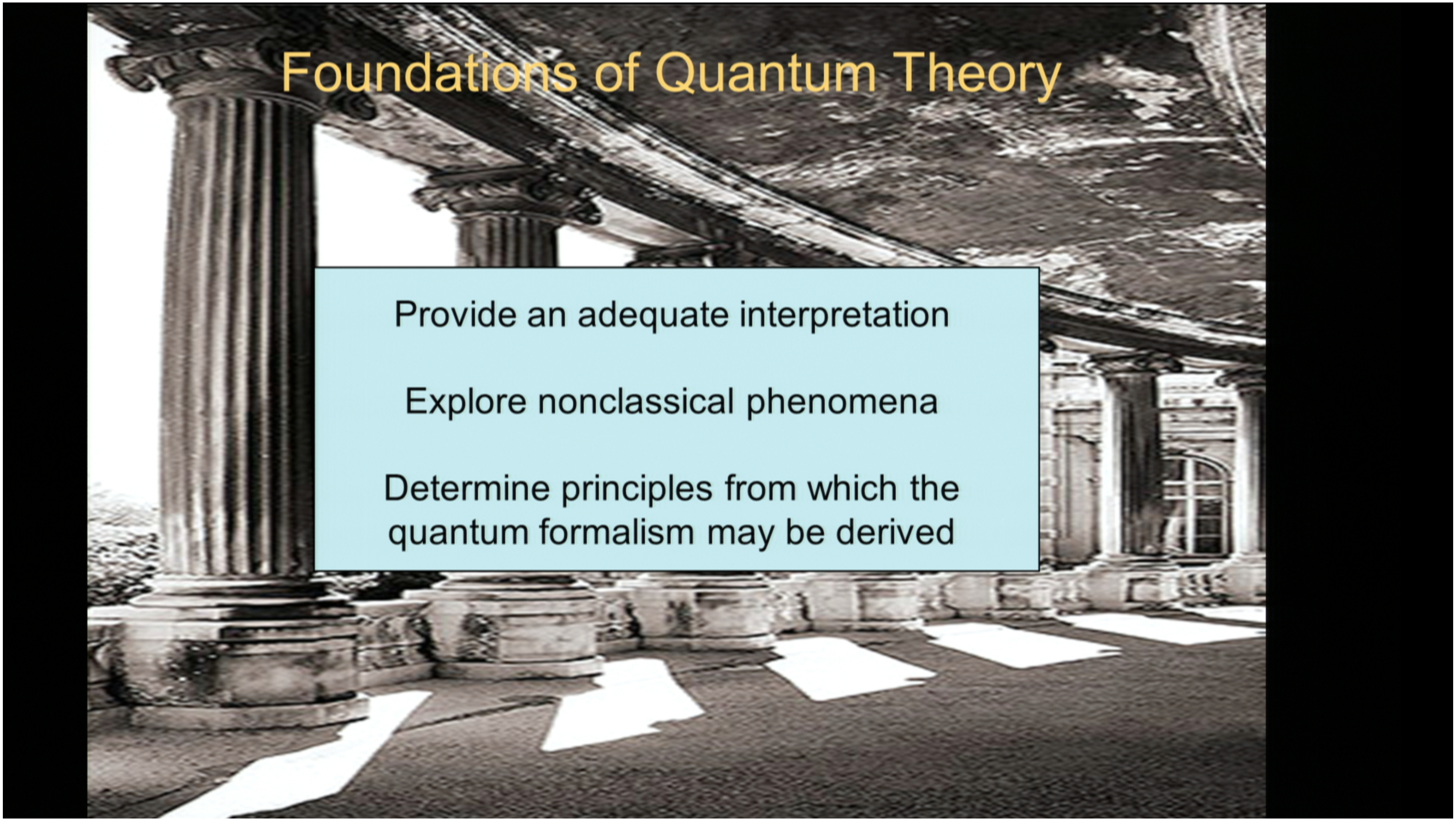
Abstract:


Foundations of Quantum Theory
Provide an adequate interpretation
Explore nonclassical phenomena
Determine principles from which the quantum formalism may be derived

Lorentz transformations

$\Uparrow$

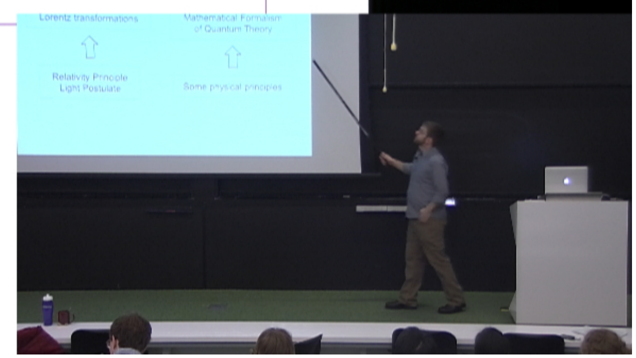
Relativity Principle
Light Postulate

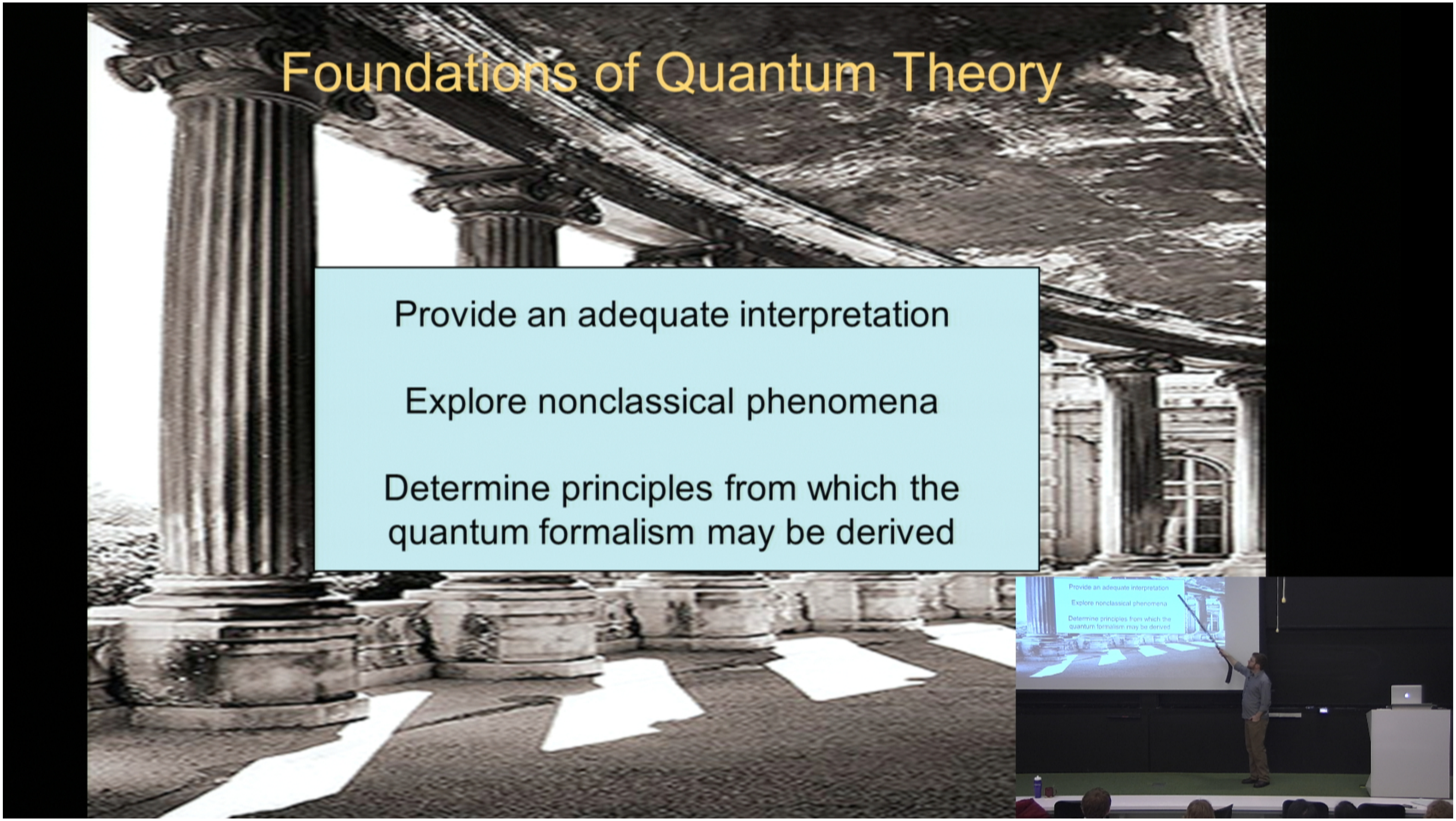
Lorentz transformations

Relativity Principle
Light Postulate

Mathematical Formalism of Quantum Theory

Some physical principles

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"Orthodox" postulates of quantum theory

Representational completeness of ψ. The rays of Hilbert space correspond one-to-one with the physical states of the system.

Measurement. If the Hermitian operator *A* with spectral projectors $\{P_k\}$ is measured, the probability of outcome *k* is $\langle\psi|P_k|\psi\rangle$. These probabilities are objective -- indeterminism.

Evolution of isolated systems. It is unitary, $|\psi\rangle \to U|\psi\rangle = e^{-\frac{i}{\hbar}Ht}|\psi\rangle$ therefore deterministic and continuous.

Evolution of systems undergoing measurement. If Hermitian operator *A* with spectral projectors $\{P_k\}$ is measured and outcome *k* is obtained, the physical state of the system changes discontinuously,

$$|\psi\rangle \to |\psi_k\rangle = \frac{P_k|\psi\rangle}{\sqrt{\langle\psi|P_k|\psi\rangle}}$$

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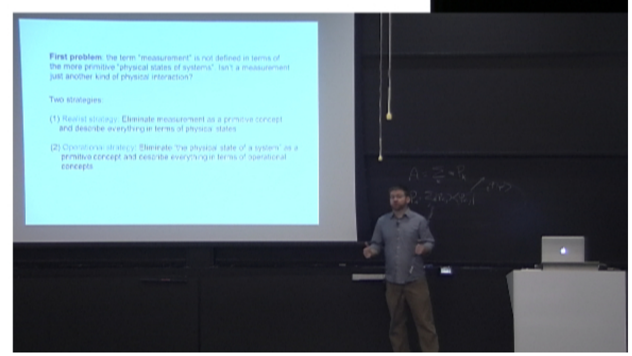
First problem: the term “measurement” is not defined in terms of the more primitive “physical states of systems”. Isn’t a measurement just another kind of physical interaction?

Two strategies:

(1) Realist strategy: Eliminate measurement as a primitive concept and describe everything in terms of physical states

(2) Operational strategy: Eliminate “the physical state of a system” as a primitive concept and describe everything in terms of operational concepts



“It would seem that the theory is exclusively concerned about "results of measurement", and has nothing to say about anything else. What exactly qualifies some physical systems to play the role of "measurer"? ”

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“In a strict sense, quantum theory is a set of rules allowing the computation of probabilities for the outcomes of tests which follow specified preparations.”

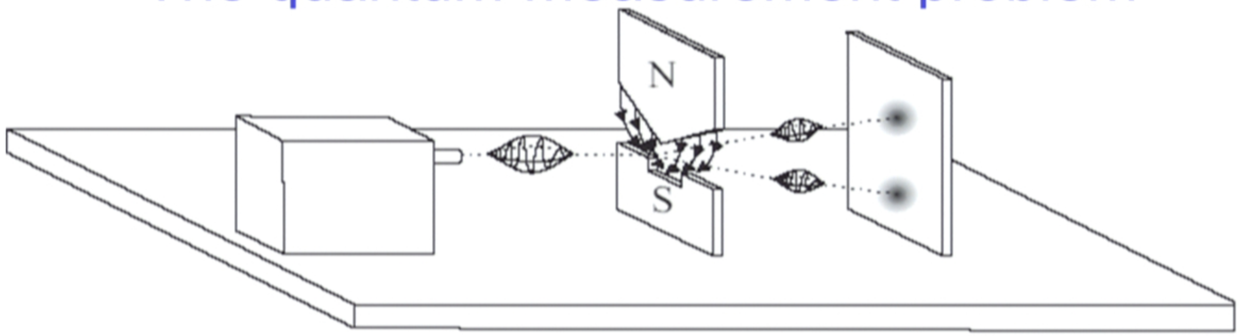
- Asher Peres

The realist strategy

Inconsistencies of the orthodox interpretation

By the collapse postulate (applied to the system)	By the unitary evolution postulate (applied to the isolated composite that includes the system and apparatus)
Indeterministic and discontinuous evolution	Deterministic and continuous evolution
Determinate properties	Indeterminate properties

The quantum measurement problem



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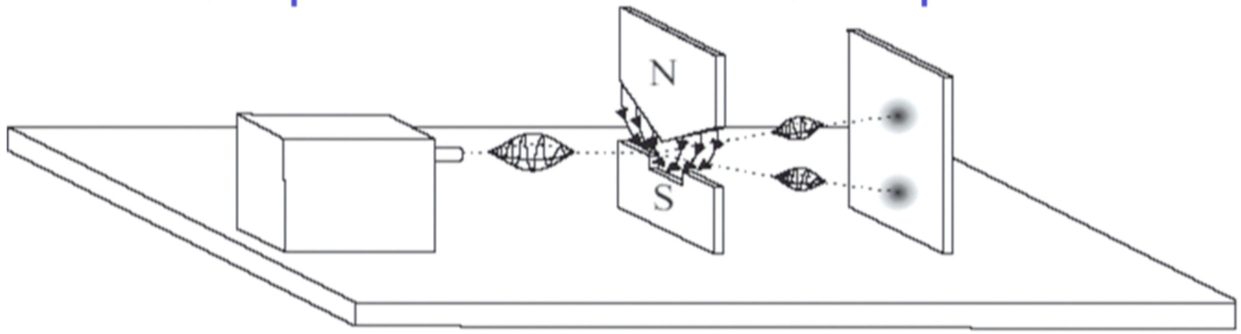

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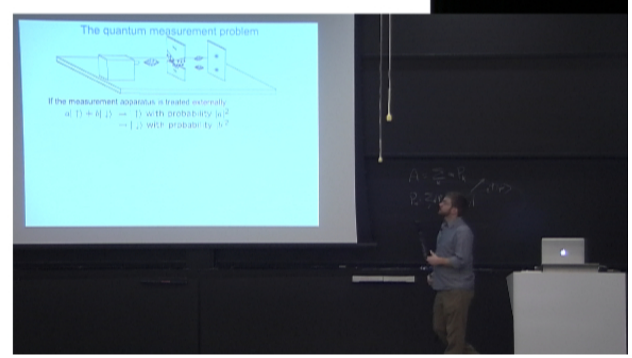
$$a|\uparrow\rangle + b|\downarrow\rangle \;\rightarrow |\uparrow\rangle \text{ with probability } |a|^2$$
$$\rightarrow |\downarrow\rangle \text{ with probability } |b|^2$$



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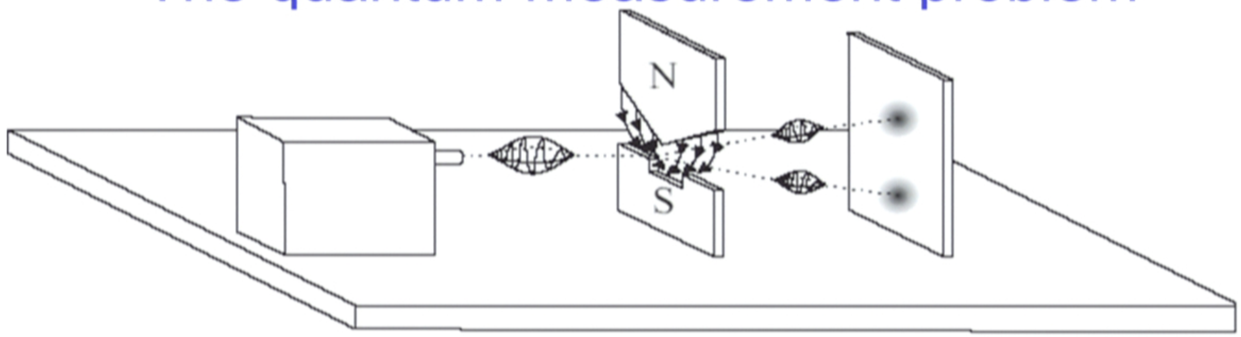

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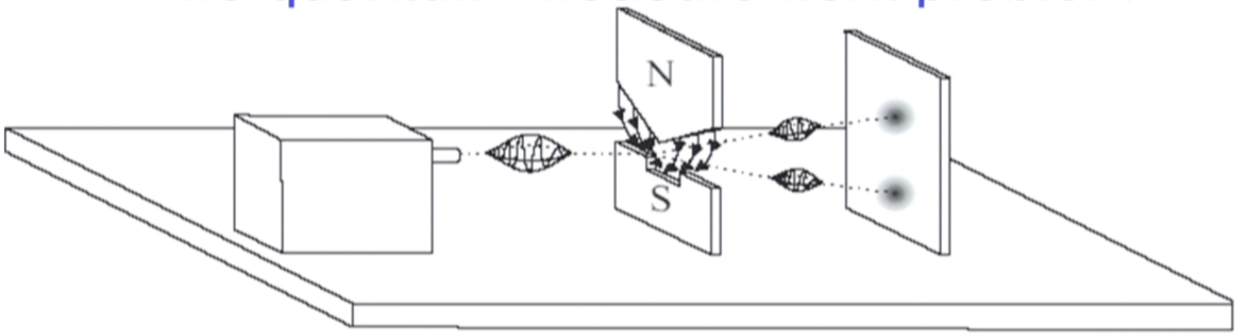

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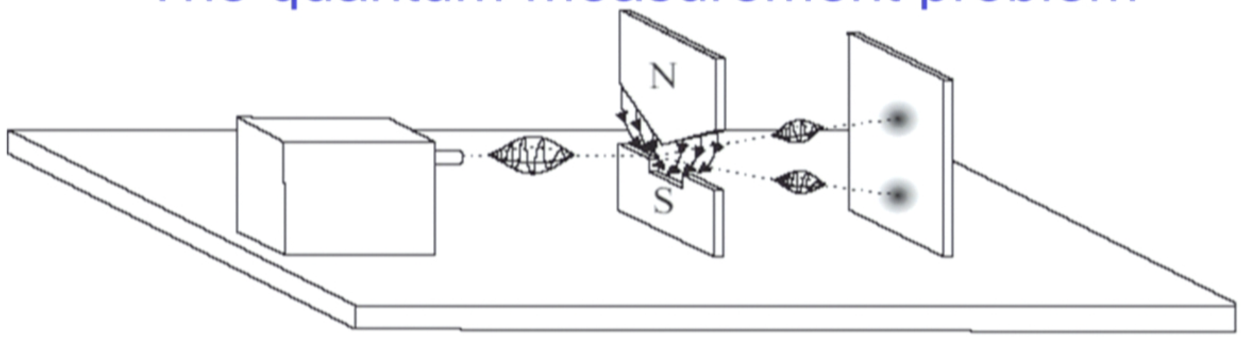

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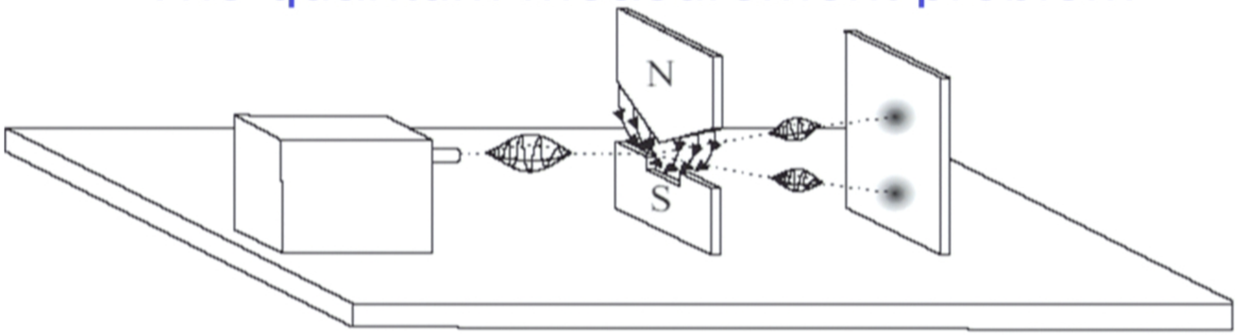

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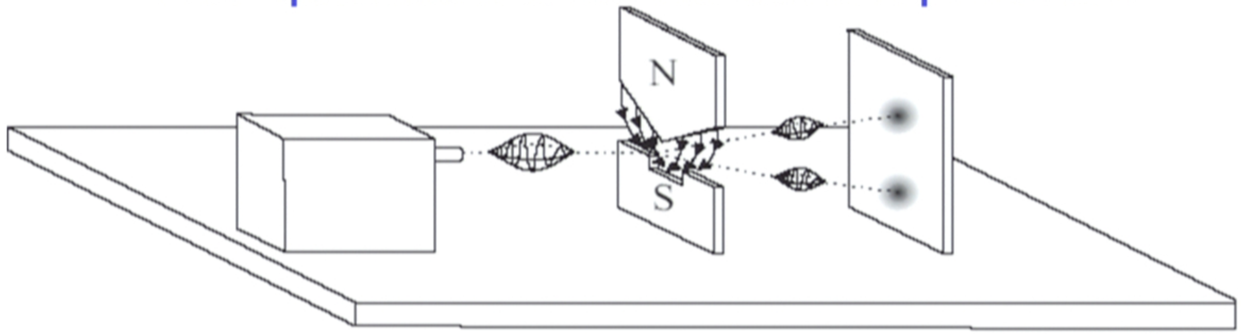

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$$(S_{\hat{z}} \otimes I)(a|\uparrow\rangle \otimes |\text{“up”}\rangle + b|\downarrow\rangle \otimes |\text{“down”}\rangle)$$

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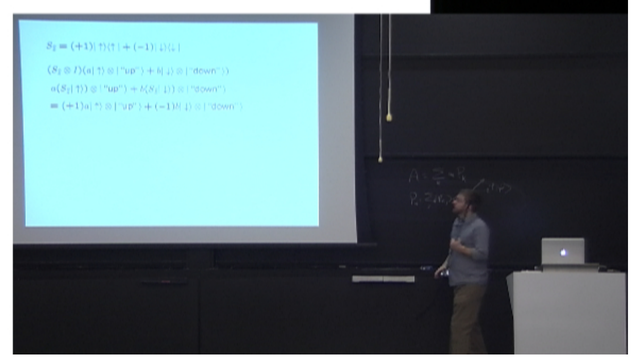

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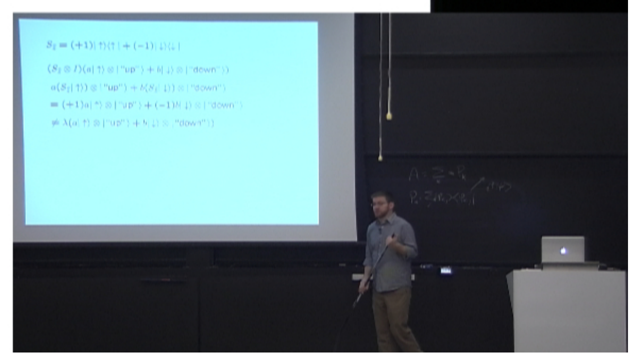
$$\neq \lambda(a|\uparrow\rangle \otimes |\text{“up”}\rangle + b|\downarrow\rangle \otimes |\text{“down”}\rangle)$$



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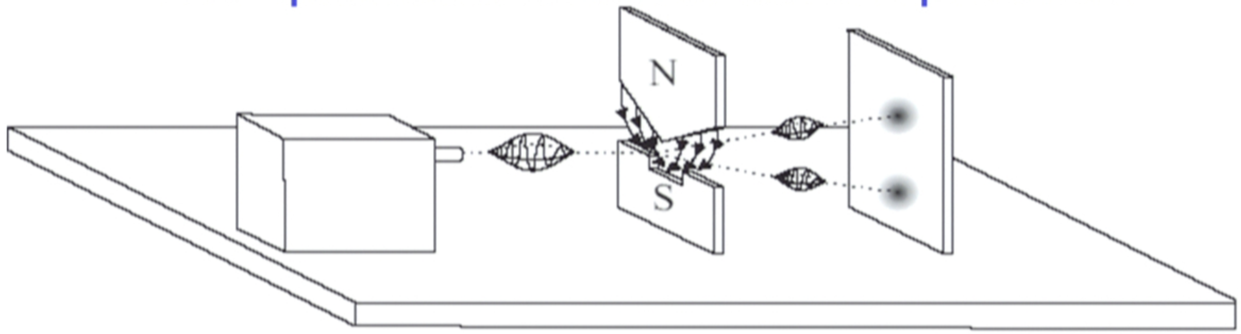

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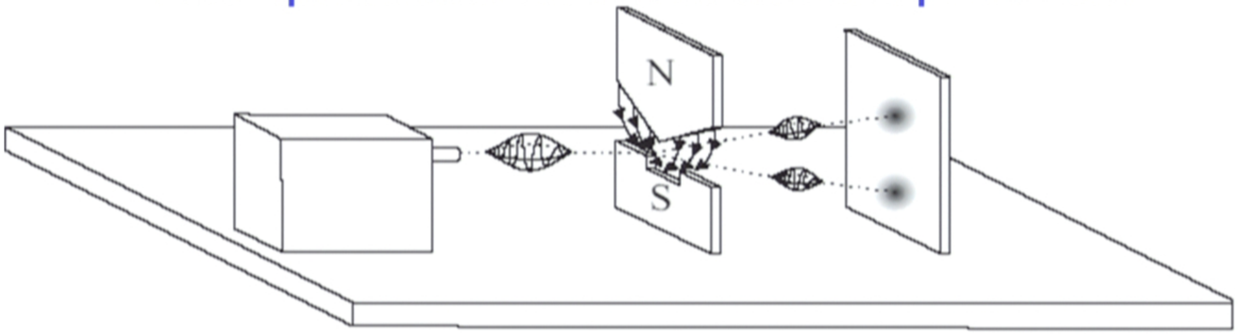

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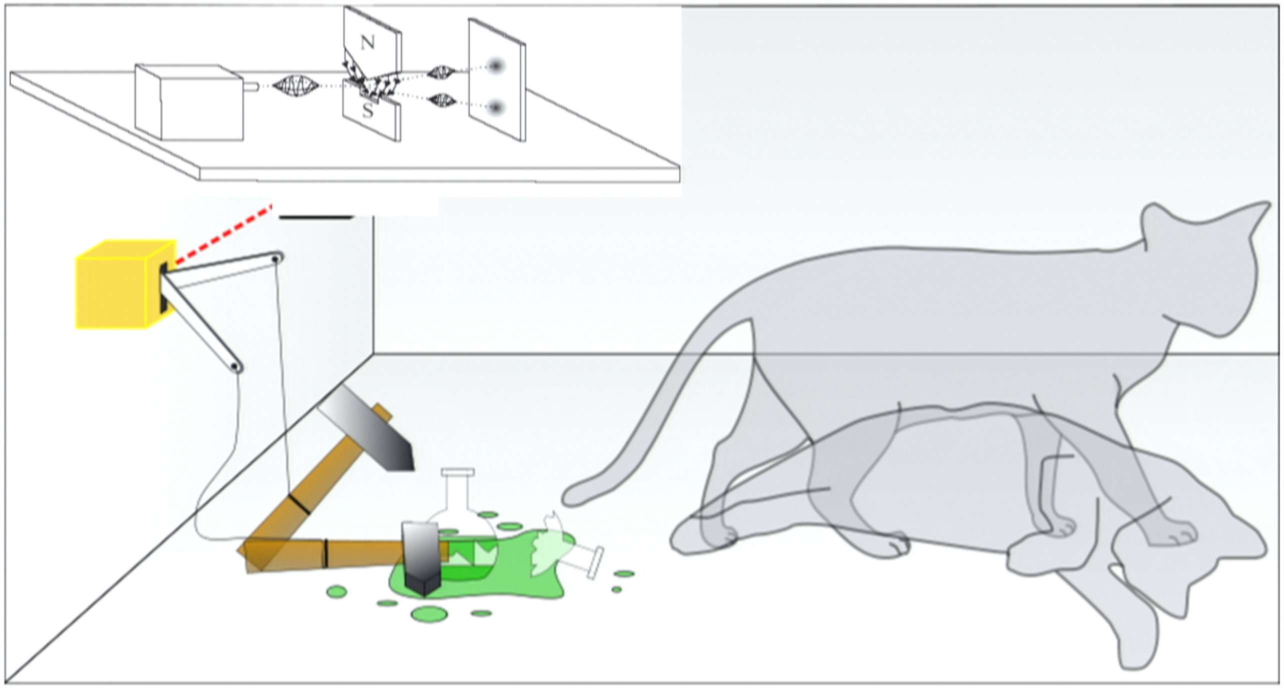
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False starts on the measurement problem

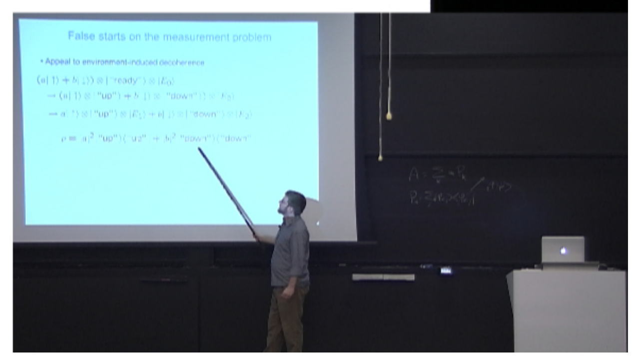
- Appeal to environment-induced decoherence

$$(a|\uparrow\rangle + b|\downarrow\rangle) \otimes |\text{“ready”}\rangle \otimes |E_0\rangle$$

$$\rightarrow (a|\uparrow\rangle \otimes |\text{“up”}\rangle + b|\downarrow\rangle \otimes |\text{“down”}\rangle) \otimes |E_0\rangle$$

$$\rightarrow a|\uparrow\rangle \otimes |\text{“up”}\rangle \otimes |E_1\rangle + b|\downarrow\rangle \otimes |\text{“down”}\rangle \otimes |E_2\rangle$$

$$\rho = |a|^2 |\text{“up”}\rangle\langle\text{“up”}| + |b|^2 |\text{“down”}\rangle\langle\text{“down”}|$$



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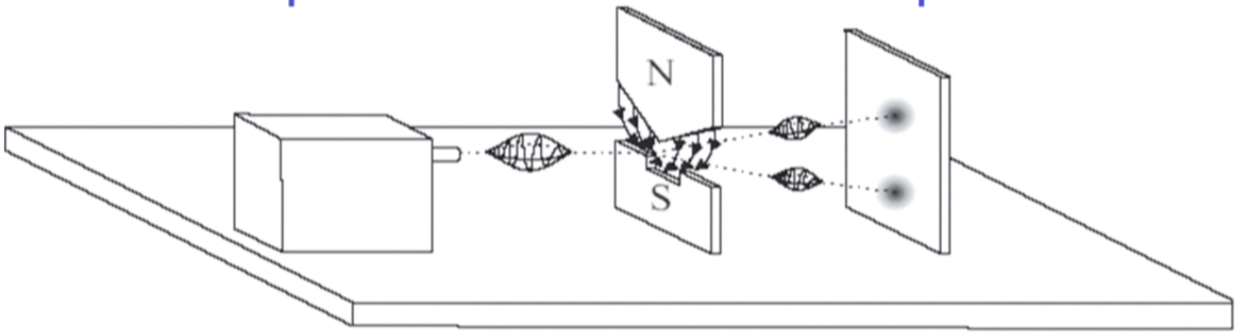

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    - Quantum-classical hybrid models
    - Collapse models

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5. Deny some other feature of the realist framework?