Title: Mapping classical fields to quantum states

Date: Oct 01, 2009 04:00 PM

URL: http://pirsa.org/09100093

Abstract: Abstract: Efforts to extrapolate non-relativistic (NR) quantum mechanics to a covariant framework encounter well-known problems, implying that an alternate view of quantum states might be more compatible with relativity. This talk will reverse the usual extrapolation, and examine the NR limit of a real, classical scalar field. A complex scalar \psi that obeys the Schrodinger equation naturally falls out of the analysis. One can also replace the usual operator-based measurement theory with classical measurement theory on the scalar field, and examine the NR limit of this as well. In this limit, the local energy density of the field scales as |\psi|^2, adding credibility to this approach. With the added postulate that "all measurements correspond to boundary conditions that extremize the classical action" (see arXiv:0906.5409), additional quantitative comparisons emerge between this \psi and the standard quantum wavefunction. Uncertainty can then be introduced (along with a "collapse" due to Bayesian updating) by simply giving the classical scalar field two components instead of one, leading to an intriguing \psi-epistemic model.

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- Take flat-space, NR limits, search for links to NRQM

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- Euler-Lagrange equation in Minkowski spacetime is Klein-Gordon Equation (KGE);

$$\left(\hbar^2\frac{\partial^2}{\partial t^2} - \hbar^2c^2\nabla^2 + m^2c^4\right)\phi = 0$$

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Single particle Schr. Eqn: $\psi(\boldsymbol{x},t) = \int \left[\Psi(k)e^{i[\boldsymbol{k}\cdot\boldsymbol{x}-(\omega-\omega_0)t]}\right] d\boldsymbol{k}$

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- Adding scalar potential can be done without adding a new term; just adjust $g_{\mu\nu}$ in weak-field limit. (WKB solutions match S.E.'s in NR limit)

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Not quite the Born rule, but promising in ∞-particle limit.

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Lack of a conserved 4-current for the real KGE does not mean that it can't contain NRQM.

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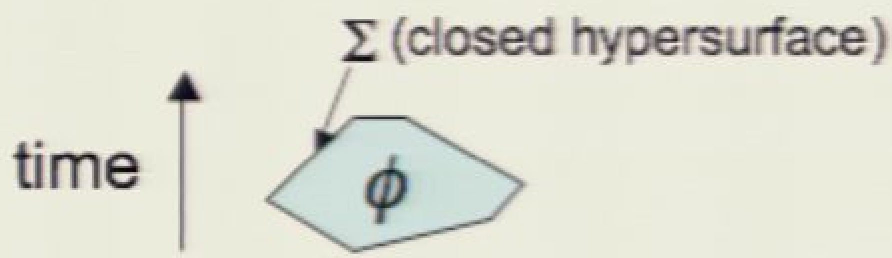

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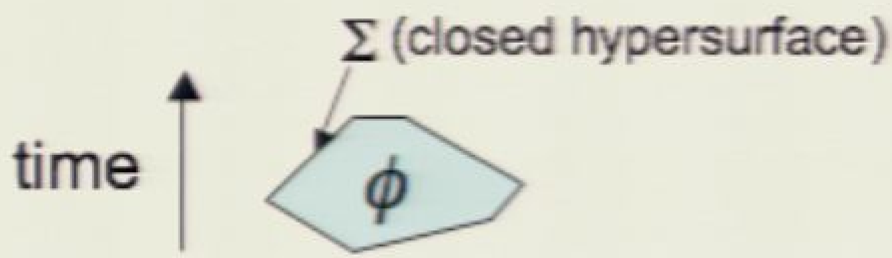

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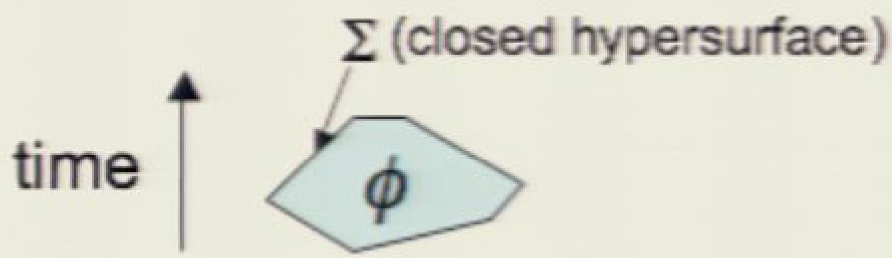

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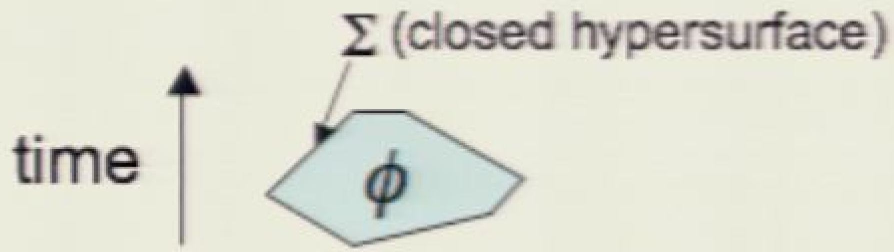

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Unlike QFT, constraints on ϕ can't be expressed via $\dot{\phi}$

Leads to a global constraint on most measurements.

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(for “non-relativistic” scalar fields)

Define “non-relativistic” field via stress energy tensor:

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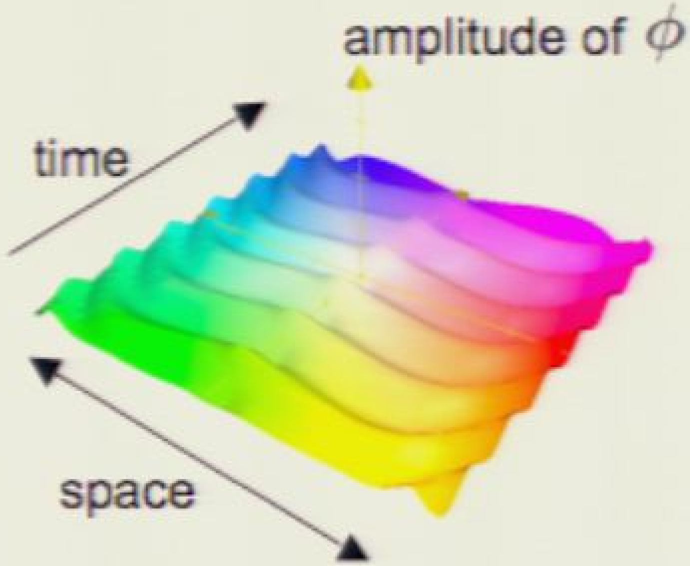

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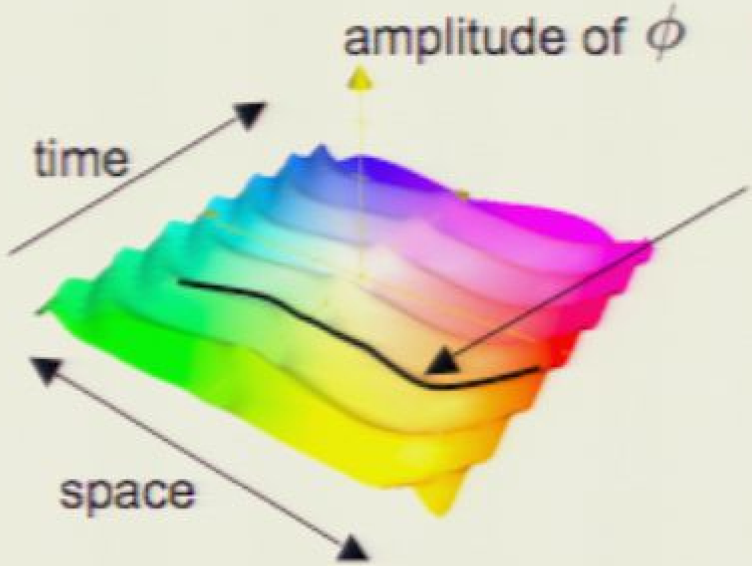

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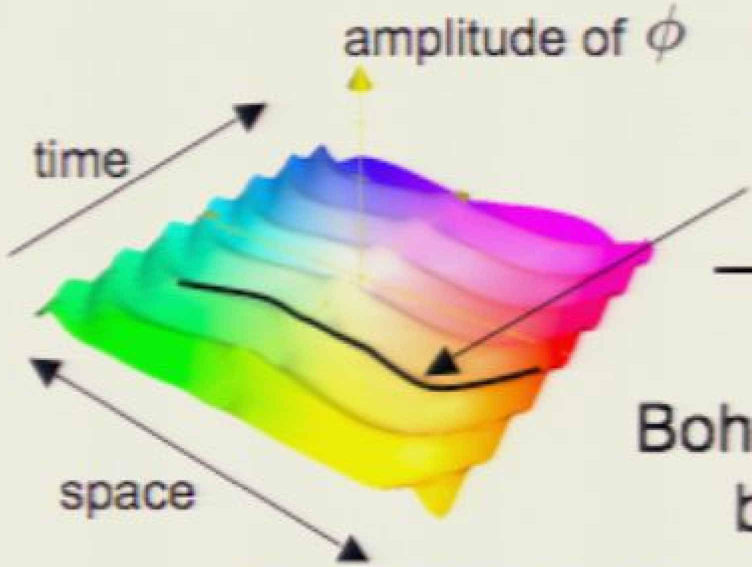

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$$m \oint v_g \cdot d\ell \approx nh$$

Bohr-Sommerfeld-like quantization, but only upon measurement.

arXiv:0906.5409 ; pirsa.org/09060031

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- Whence Probabilistic Measurement Outcomes?
  (not to mention apparent collapse, contextuality, Bell-inequality violations, etc., etc.)

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Due to nonlinearity, ψ_{meas} doesn't solve the S.E.!

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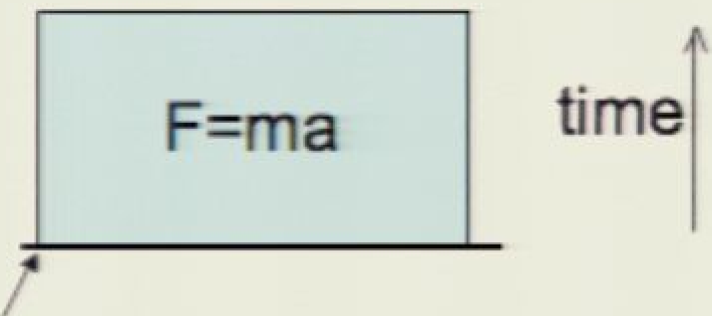

IBCs: $x(t_0), \dot{x}(t_0)$

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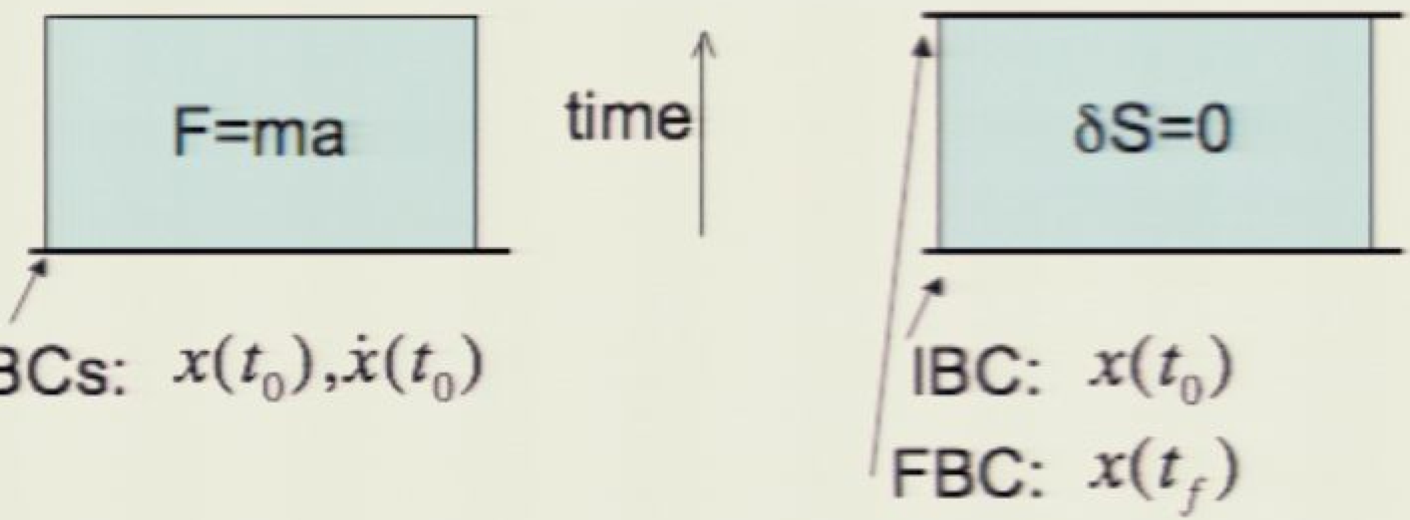

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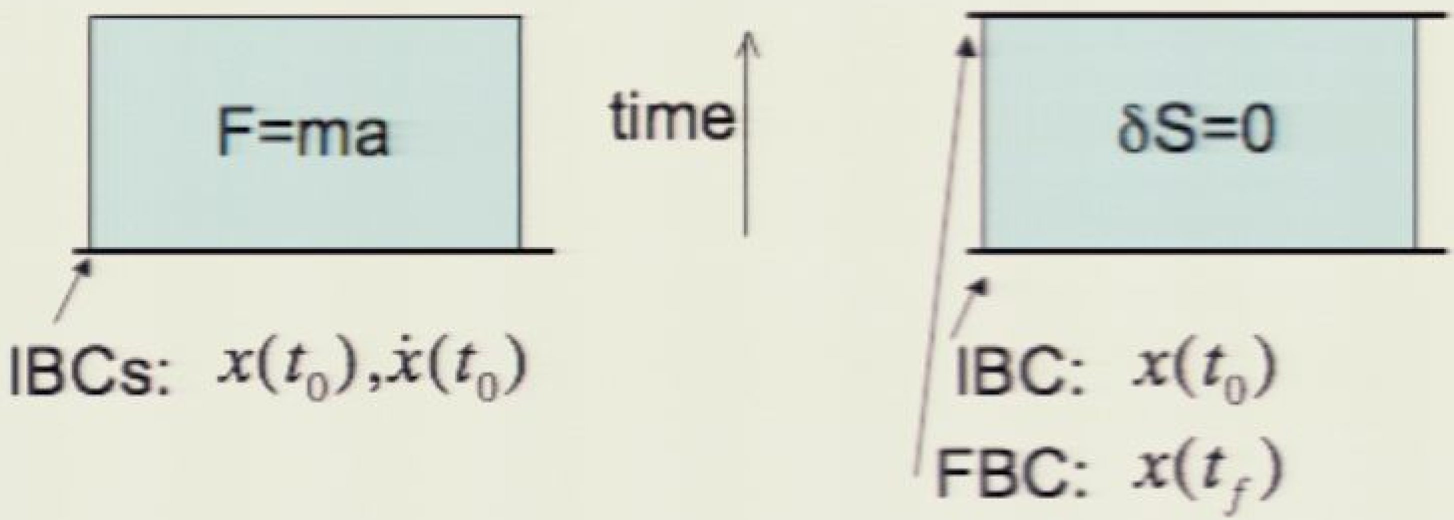

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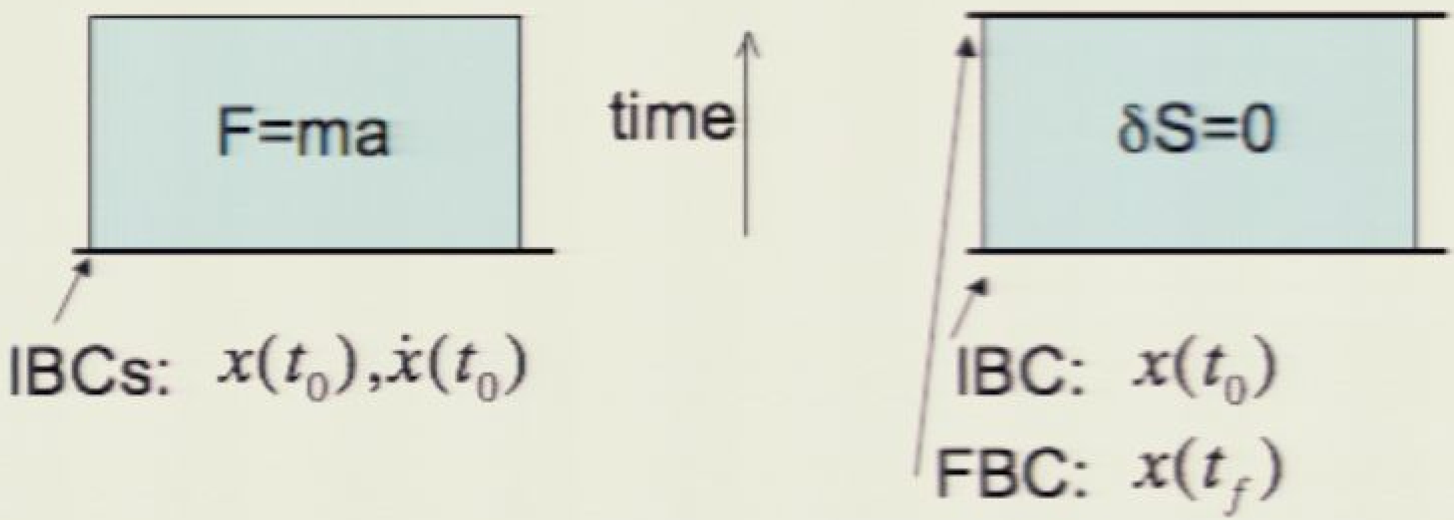

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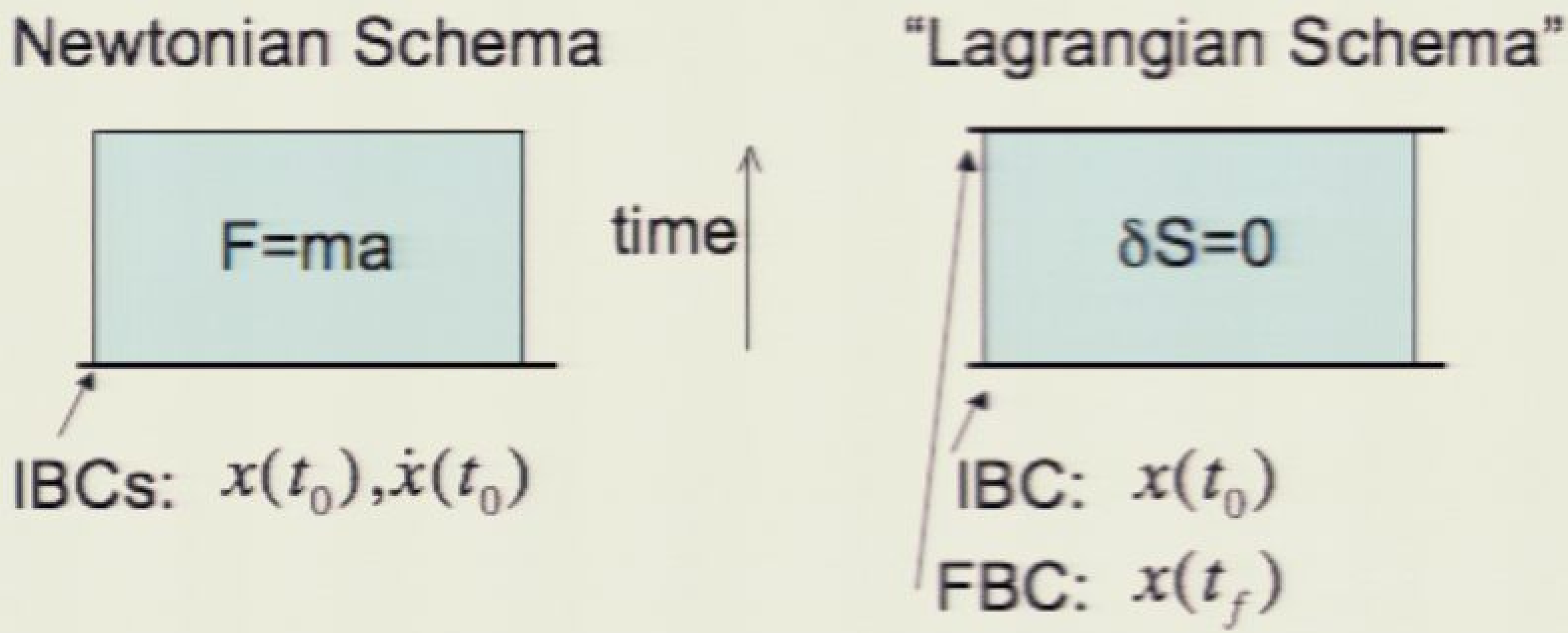

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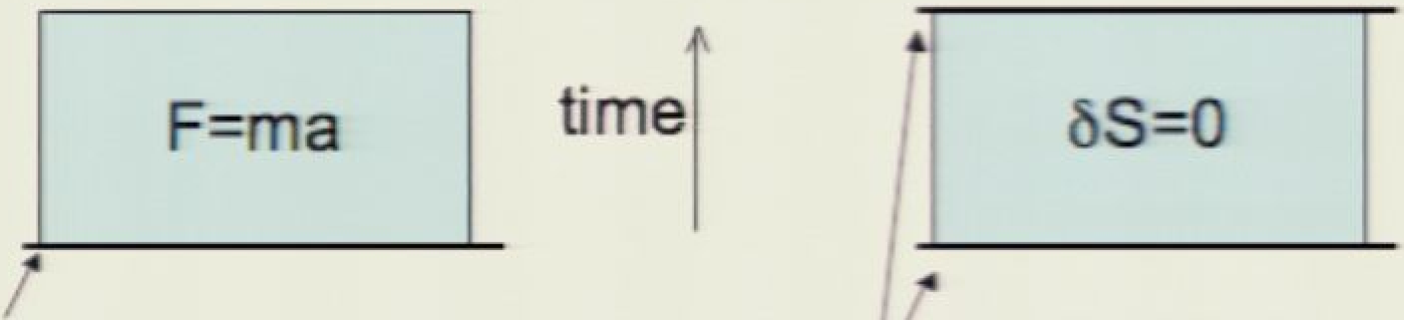

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FBC: $x(t_f)$

BCs are ontic!

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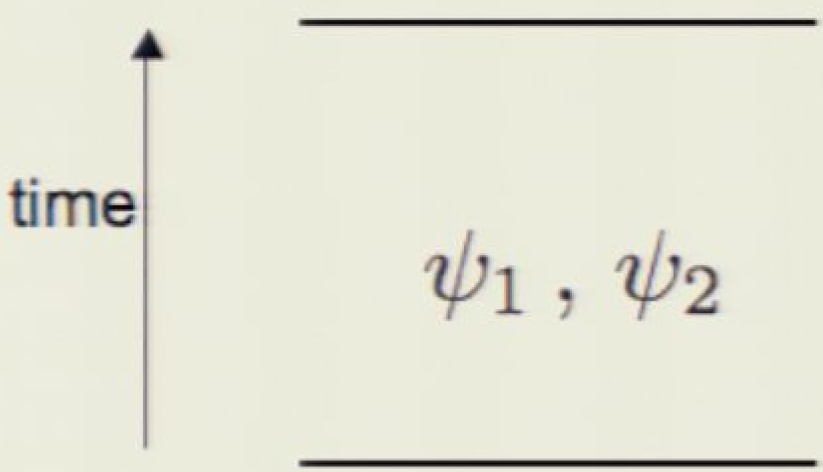
Boundary condition options for two-time-constrained fields (a very short history)



Boundary condition options for two-time-constrained fields (a very short history)

$$\psi_{meas} = \psi_2$$

time

$$\psi_1 \, , \, \psi_2$$

$$\psi_{meas} = \psi_1$$

1) Aharanov/Vaidman (1991)

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$$\psi_{meas} = \psi_1 - \psi_2$$

time

$$\psi_1 \, , \, \psi_2$$

$$\psi_{meas} = \psi_1 + \psi_2$$

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2) Wharton, *Found. Phys.* v37, p.159 (2007)

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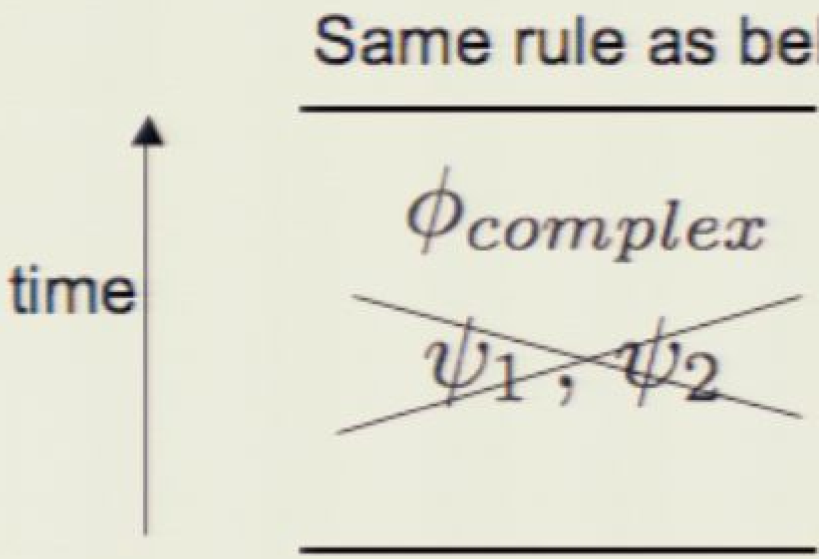

Time-even measurements:

$$\psi_{meas} = \phi_{complex}$$

Time-odd measurements:

$$\psi_{meas} \Leftrightarrow \dot{\phi}_{complex}$$

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3) Wharton, arXiv:0706.4075

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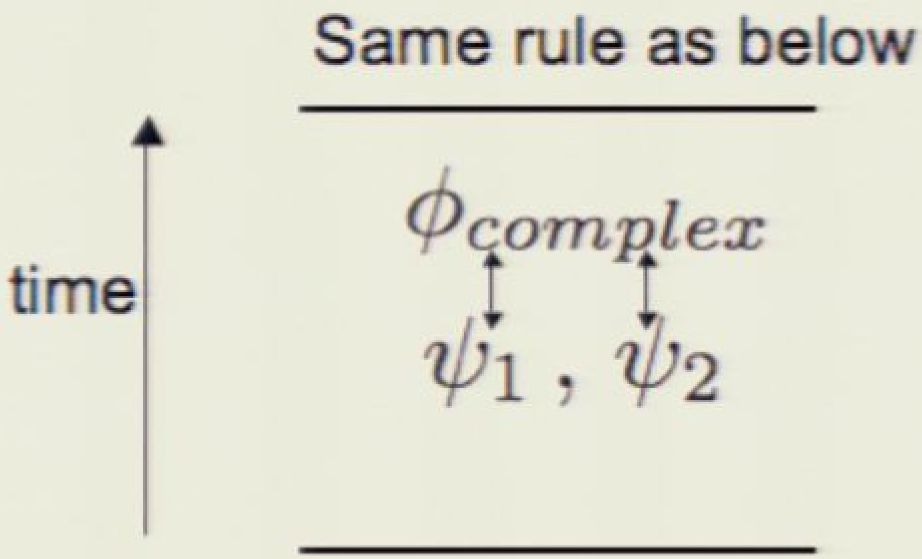

$$\rho_{meas} = \rho_1 + \rho_2$$

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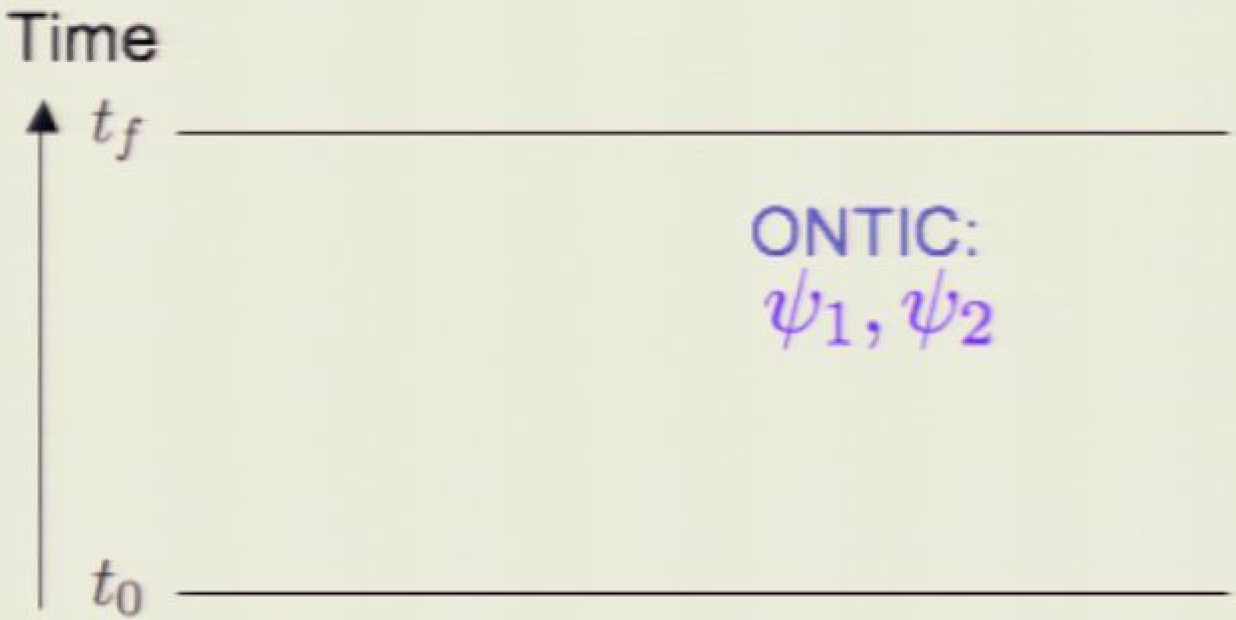
4) This Talk

Candidate Psi-Epistemic Theory
(Single particle wave mechanics)



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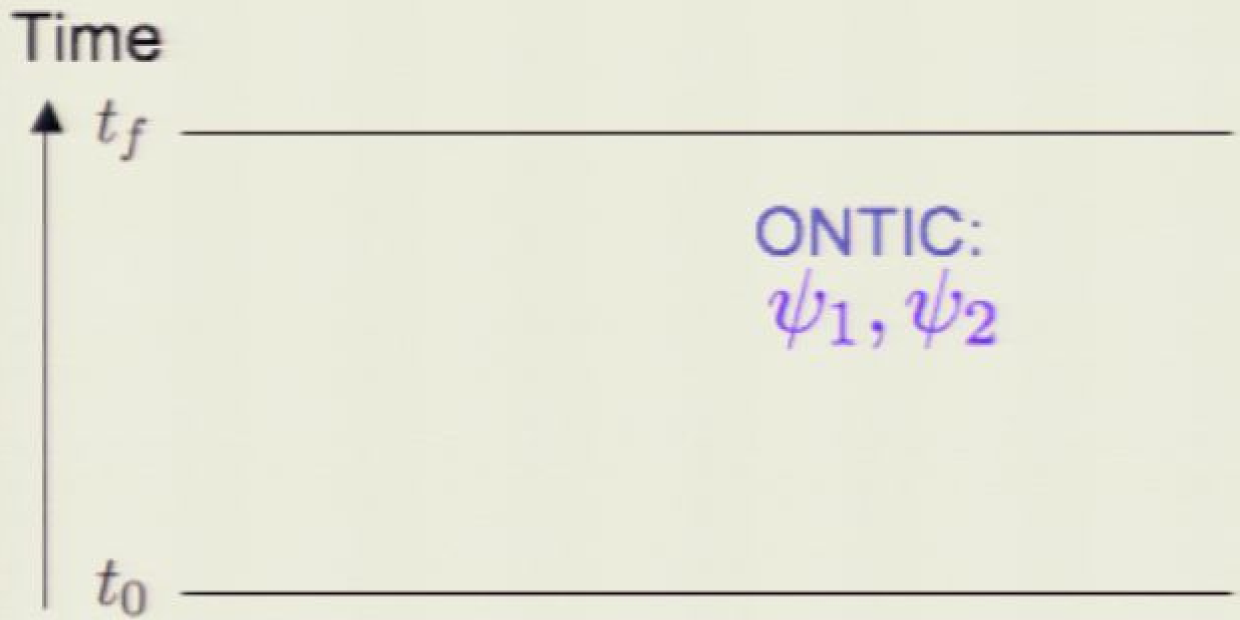

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$$J^i = Im(\psi \partial_i \psi^*)$$

Candidate Psi-Epistemic Theory
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t_f

ONTIC:
ψ_1, ψ_2

t_0

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Type of measurement at $t = t_f$ (and result) determine:
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Open question:

What algorithm can one use to reconstruct ψ_1, ψ_2 from $J^{\mu}_{meas}(t_0), J^{\mu}_{meas}(t_f)$?

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  - Should be joint probability distribution

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- Testable Experimental Consequences?
  - Key parameter: accurate time duration between preparation, measurement.

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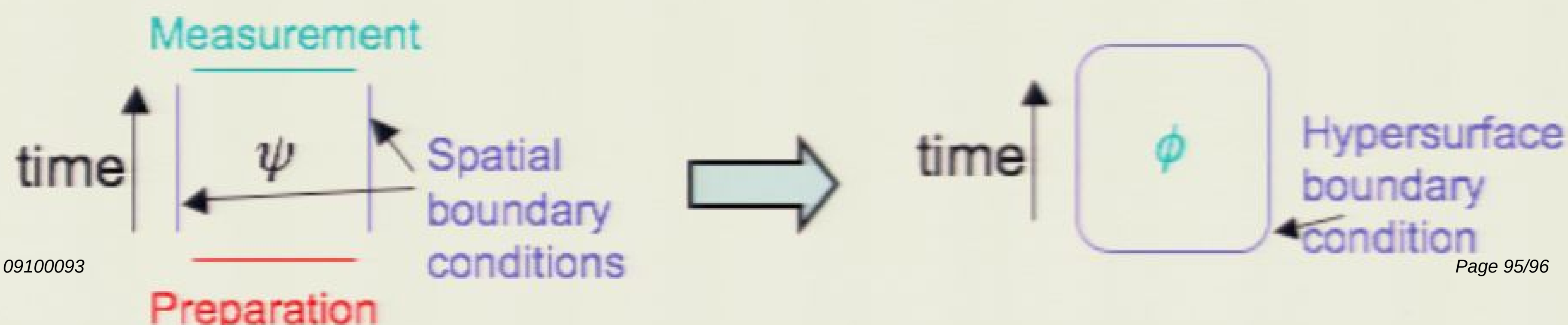

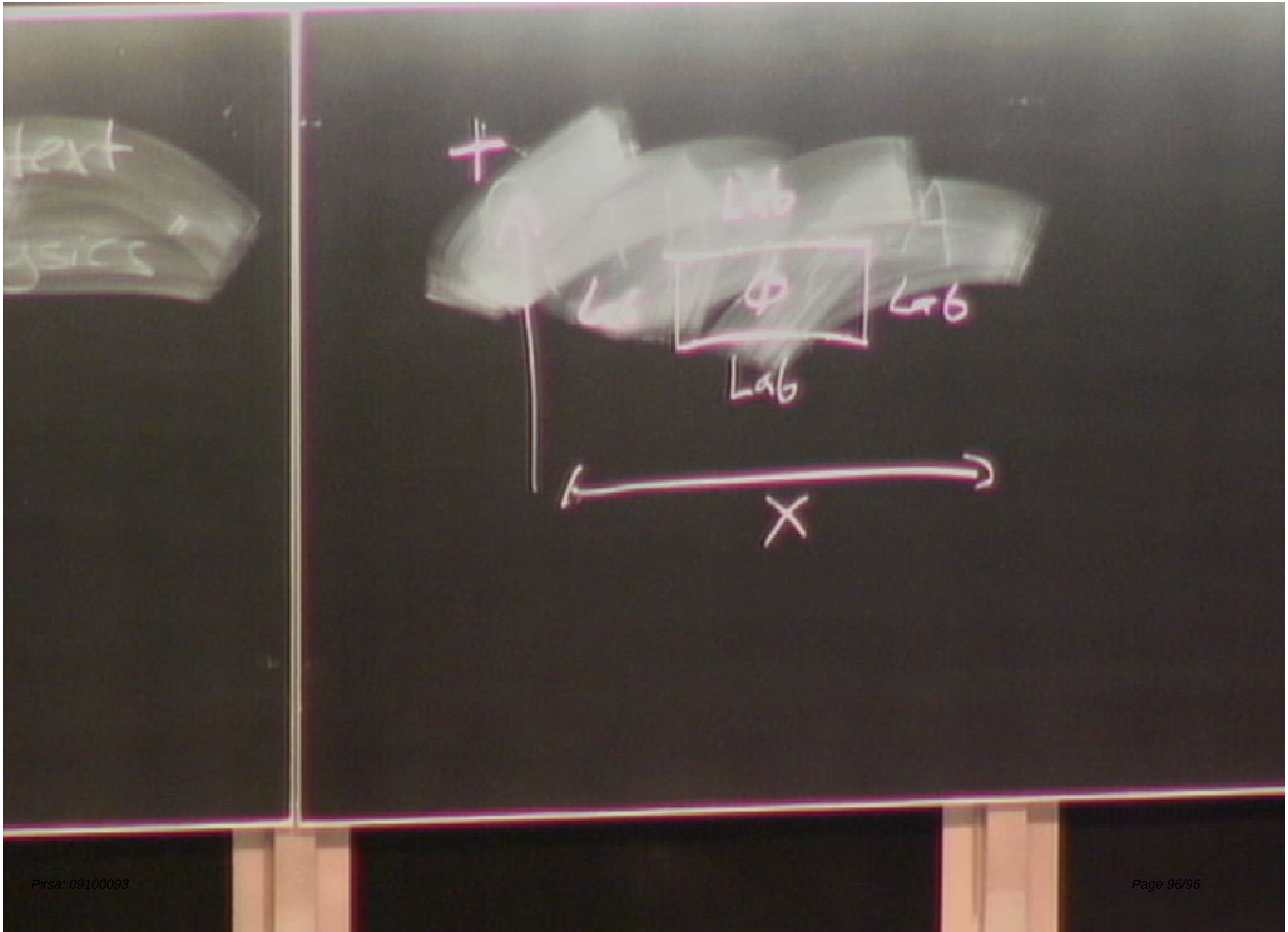
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