Title: Ontology of collapse theories

Date: May 28, 2013 11:00 AM

URL: http://pirsa.org/13050063

Abstract: The textbook collapse postulate says that, after a measurement, the quantum state of the system on which the measurement was performed , and becomes an eigenstate of the observable measured. Naively, this is what one would expect of dynamical collapse theories. What one gets, instead, is an approximation to such eigenstates. This leaves us with the question of how to interpret such theories as representing a macroscopically definite world. In this talk, I will review some approaches to the ontology of collapse theories, and raise the question: do these yield rival accounts of the nature of the physical world, or are they mere choices of how to hang talk about ordinary objects onto a theory whose physical import is already clear?

Ontology of Collapse Theories

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- Parameters are chosen so that:
  - A single isolated particle will undergo collapse very rarely
  - Superpositions involving macroscopic displacements of macroscopic numbers of particles are, with high probability, suppressed very quickly.

Interpreting Collapse theories

- **Naïve approach:**
  - Associate, in the usual way, physical observables with operators on the space of wave functions.
  - A system has a definite value of some observable if its wave function is an eigenfunction of the corresponding operator.
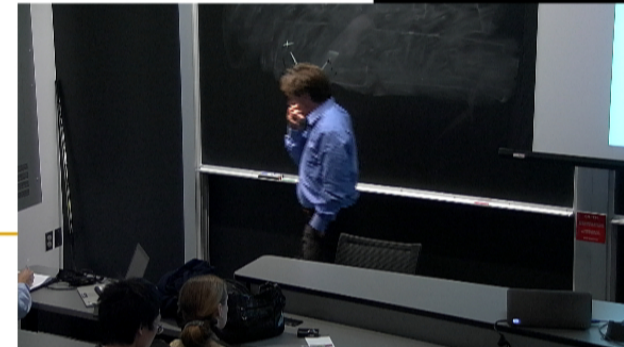 - Only if … ?
- **Problem of "tails"**

Finding the world in the wave function

- **Three proposals:**
  - Mass density (Ghirardi *et al.*)
  - Flash ontology (Bell)
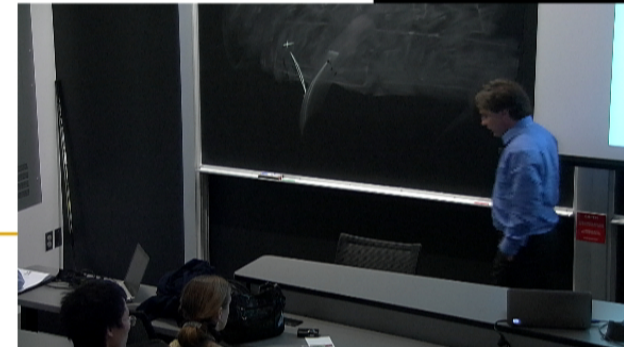
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- *"what the theory is fundamentally about"; "the stuff that things are made of."*

A comment

- We *always* need some interpretative postulate to make the mathematical apparatus into a physical theory (that is, a theory about the physical world)

Mass density

- Define mass density operator:

$$\widehat{M}(\boldsymbol{x}) = \textstyle\sum_k m_k \widehat{N}_k(\boldsymbol{x}) \, ,$$

where $\widehat{N}_k(\boldsymbol{x})$ is number density for *k*th particle type, and m_k is mass of *k*th particle type.

- Mass density:

$$M(\boldsymbol{x}, t) = \big\langle \psi(t) \big| \widehat{M}(\boldsymbol{x}) \big| \psi(t) \big\rangle$$

Mass density ontology

- Mass density is a field on 3-space.
- Ordinary objects are patterns in this density.

Flash ontology

- Bell:

the GRW jumps (which are part of the wave function, not something else) are well localized in ordinary space. Indeed each is centered on a particular spacetime point ($\mathbf{x}$, t). So we can propose these events as the basis of the 'local beables' of the theory. … A piece of matter then is a galaxy of such events.
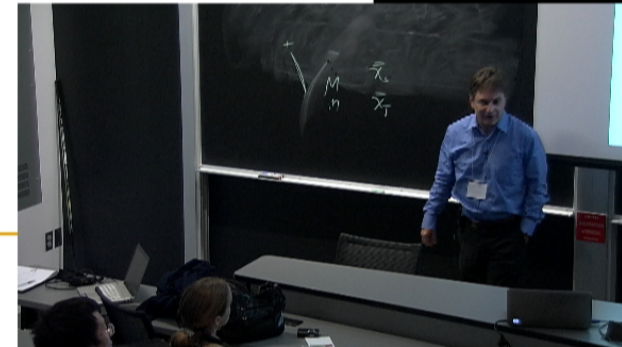
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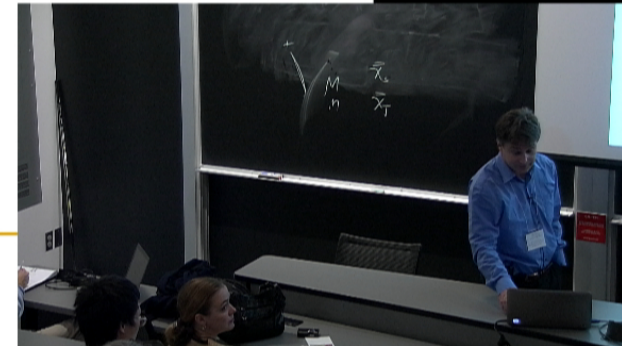
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The distinctness question

- Do these proposals offer:
  - Mutually exclusive accounts about the way the world is?
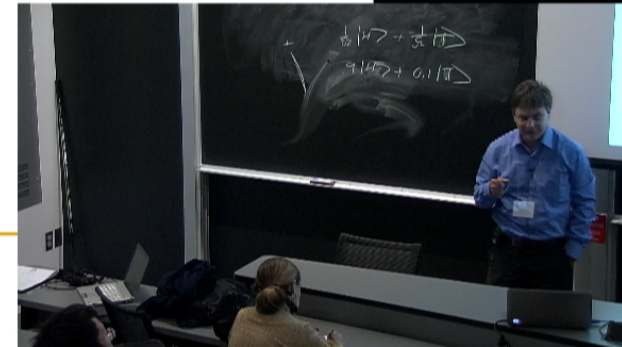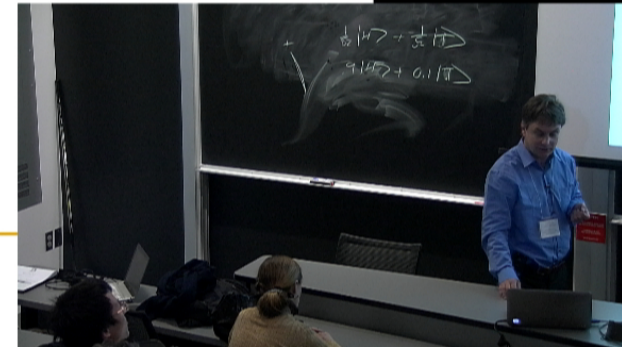
The distinctness question

- Do these proposals offer:
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    - Different proposals about how to hang talk of ordinary objects on one and the same physical theory?
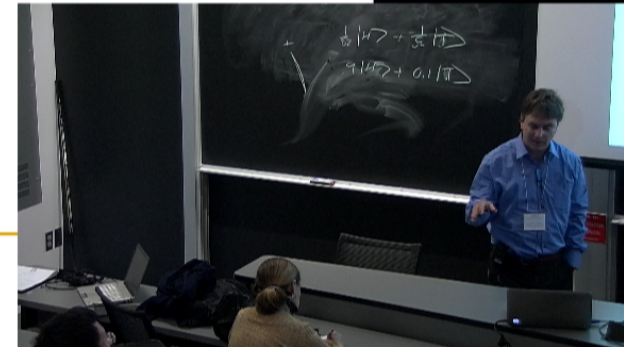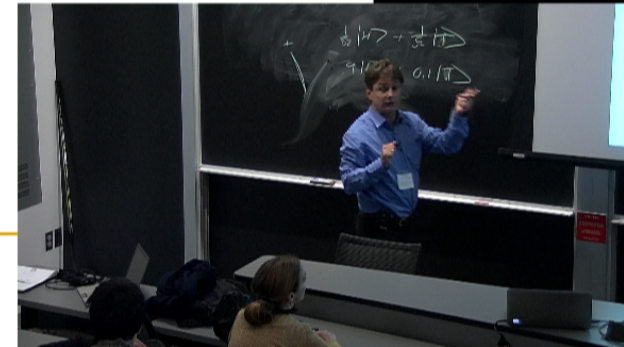
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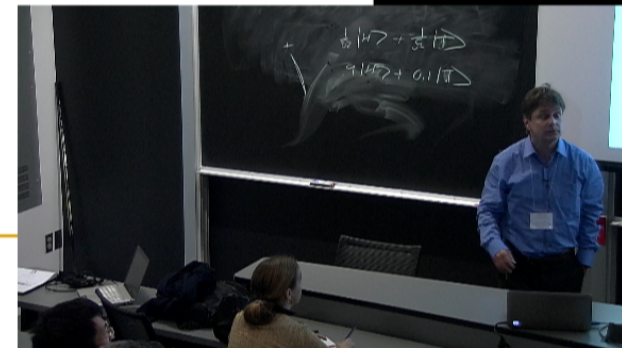 - Distinct physical theories

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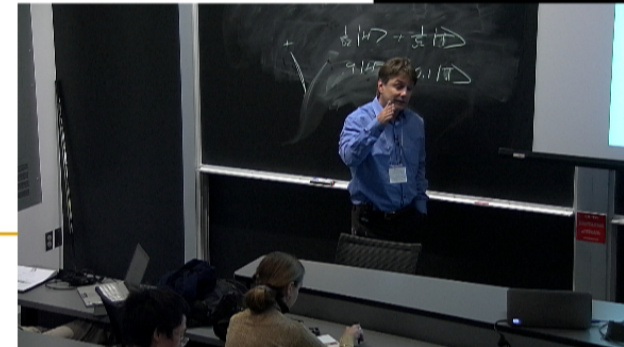 - Variant formulations of the same physical theory
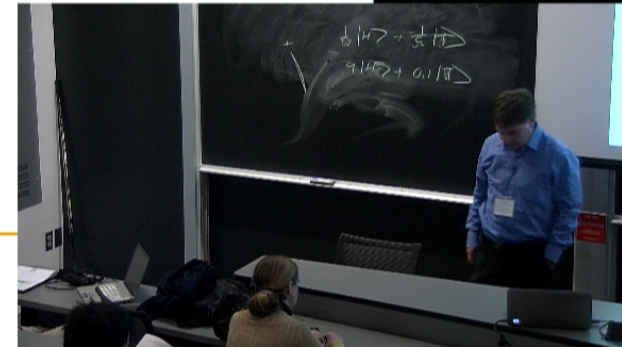
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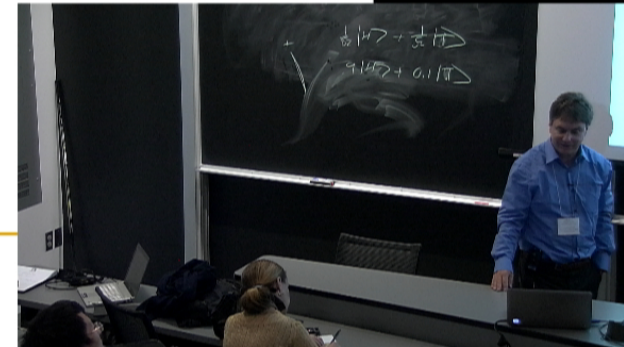- *Cf.* Peter Lewis (2006), "GRW: A Case Study in Quantum Ontology" *Philosophy Compass* **1/2**, 224-244.
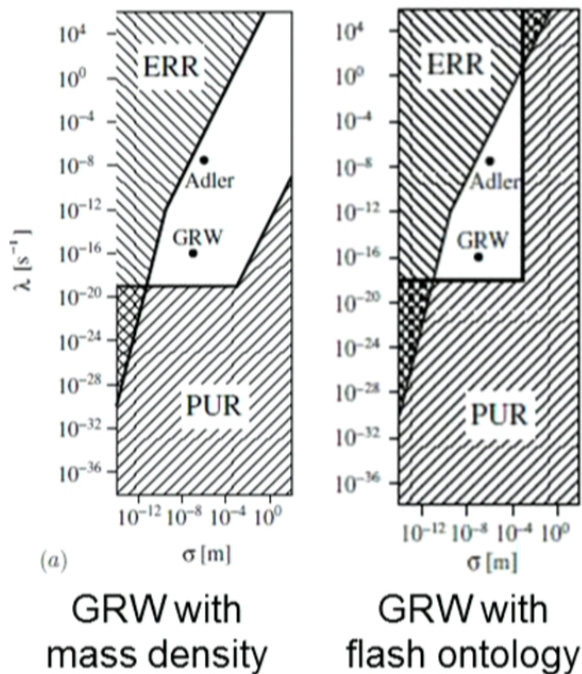
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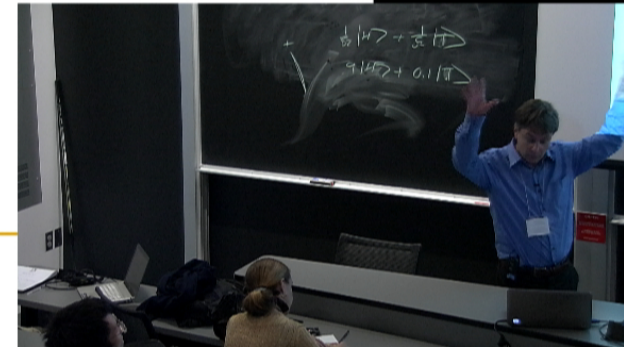
Is there a mass density, on the flash ontology?

- Yes.

- To make sense of dynamics of macroscopic objects, we need to invoke mass (which appears as parameter in the Schrödinger equation).
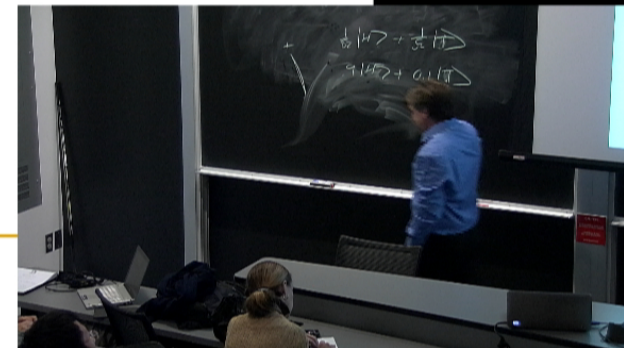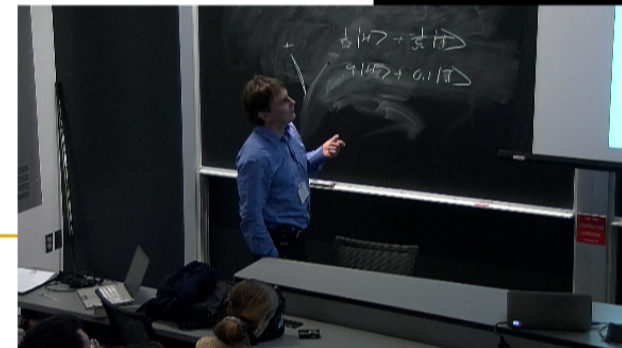
In favour of distinctness

Parameter diagrams

GRW with mass density

GRW with flash ontology

From Feldman and Tumulka , *J. Phys. A* **45** (2012) 065304.

PUR in GRWf

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