Decoherence and the Measurement Problem

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- *Proceedings of the 2008 interdisciplinary conference on the interpretation of classical electromagnetism*

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- *The Mysterious Fossil: New Directions in the Interpretation of Dinosaurs*

The measurement problem

- In general, we “interpret” theories by taking them literally as describing / representing real features of the world’s structure
- This doesn’t seem possible for quantum mechanics, because
  - we can’t take the quantum state as a probability distribution over microscopic states of affairs because of interference phenomena
  - we can’t take the quantum state as a state of physical reality because it can exist in macroscopic superpositions and we don’t see them

Some ways to solve the problem

- “Change the physics” – replace, modify or augment the formalism of quantum theory so that it can be understood literally as a description of the world

(e.g. Dynamical collapse theories, hidden-variable theories)

- “Change the philosophy” – drop the strategy of interpreting theories by taking them literally, and come up with a new one

(e.g. operationalism, quantum logic, state as beliefs about measurement outcomes)

Everett's insight

- We're forced to try these strategies because it seems that we can't just take the theory literally on its own terms
- It seems that we can't do that because
  - the theory says that the world should be in a superposition of macroscopically distinct states
  - The world doesn't look as if it's in a superposition of macroscopically distinct states
- Everett: what would the world look like if it *did* look like it was in a superposition of macroscopically distinct states?

Multiplicity at the level of structure

- macrocopic superpositions are to be understood in terms of multiplicity
  - (**not** that we add multiplicity to the theory)
  - (**not** that the world doesn't really have multiplicity in it, it just looks that way)
- The physics problem: show that the world is *structured*, at the emergent, approximate, macro level, like a collection of non-interacting classical systems
- (The metaphysics problem: defend the claim that being structured that way is enough)

Dynamical autonomy

- We can't just take any old quantum system, decompose it in any old basis, and declare it to be a collection of parallel worlds
- Why not? – interference effects
- A quantum system is structured like a collection of autonomous systems if there's some basis with respect to which interference is negligible
- **Equivalently:** it's structured that way if there's branching but negligible recombination of branches
- **Equivalently:** it's structured that way if branch weights approximately obey the probability calculus

When is interference negligible?

- When we very carefully arrange for it to be negligible in some microscopic system

- When the system is massive and evolving under some non-chaotic classical-type Hamiltonian

- When the system is being decohered by an (internal or external) environment with a very large number of degrees of freedom

(The last of these has a statistical-mechanical character)

Metaphysics of Everett branches

- Branches are emergent, approximate, structural features of the world

  (like basically everything in the world)
- Branches don’t have a well-defined number (any given precisification of the decoherence basis will give such a number, but it’s an artifact of that precisification)
- Branches are local, and spread out at lightspeed or below

Do we have to believe in other worlds?

- The existence of the branches is straightforwardly entailed by quantum mechanics on a literal reading.
- There is no experimental way to test the many-worlds interpretation against ordinary quantum mechanics, because the many-worlds interpretation just is ordinary quantum mechanics taken literally
- Still, if you want to use quantum mechanics (and decoherence theory) without believing that branches are real, go ahead. It's a free country.

Do we have to believe in dinosaurs?

- The existence of dinosaurs is straightforwardly entailed by palaeontology on a literal reading
- There is no way to test the dinosaurs-are-real interpretation against ordinary palaeontology, because the dinosaurs-are-real interpretation just is ordinary palaeontology taken literally
- Still, if you want to use palaeontology without believing in dinosaurs, go ahead. It's a free country.

Clearly ontologically excessive