Department of Philosophy Lakatos Award 2013 lectures

Developing the Scientific Image: The Quantum Darkroom
Professor Laura Ruetsche
Professor of Philosophy, University of Michigan

The Emergent Multiverse
Dr David Wallace
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Suggested hashtag for Twitter users: #LSELakatos
Quantum Theory and the Many-Worlds Interpretation

David Wallace (Balliol College, Oxford)
LSE, October 2014
Interpreting superpositions

$|\text{live cat}\rangle$ - represents system with a living cat in
Interpreting superpositions

\[
\text{\textcolor{blue}{|live cat\rangle}} \quad \text{- represents system with a living cat in}
\]

\[
\text{\textcolor{blue}{|dead cat\rangle}} \quad \text{- represents same system where the cat is dead}
\]
Interpreting superpositions

$|\text{live cat}\rangle$ - represents system with a living cat in

$|\text{dead cat}\rangle$ - represents same system where the cat is dead

$a|\text{live cat}\rangle + b|\text{dead cat}\rangle$ - represents ????????????????
Probabilities and amplitudes

Born rule:

When superpositions are measured, the mod-squared amplitude of a term in the superposition is the probability that the measurement outcome corresponds to that term.
Probabilities and amplitudes

Born rule:

When superpositions are measured, the mod-squared amplitude of a term in the superposition is the probability that the measurement outcome corresponds to that term.

Probability interpretation:

Superpositions represent systems in an unknown but definite state.
Problems for probabilistic interpretation
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- Interference
Problems for probabilistic interpretation

- Interference
- Kochen-Specker Theorem
- Gleason’s Theorem
- Pusey-Barrett-Rudolph theorem
The Measurement Problem
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- Microscopic quantum states cannot be interpreted probabilistically because of interference.
The Measurement Problem

- *Microscopic quantum states* cannot be interpreted probabilistically because of interference

- *Macroscopic quantum states* cannot be interpreted physically because of Schrödinger cat states
The Measurement Problem

• *Microscopic quantum states* cannot be interpreted probabilistically because of interference

• *Macroscopic quantum states* cannot be interpreted physically because of Schrodinger cat states

• *Actual physical practice* shifts inchoately between these interpretations
Change the philosophy?
Change the philosophy?

- Operationalism?
Change the philosophy?

- Operationalism?

- Complementarity?
Change the philosophy?

- Operationalism?
- Complementarity?
- Quantum logic?
Change the physics?
Change the physics?

- Collapse of the wavefunction
Change the physics?

- Collapse of the wavefunction?

- Hidden variables?
Change the physics?

- Collapse of the wavefunction?
- Hidden variables?
- Retrocausation?
The paradox of electromagnetism
The paradox of electromagnetism

\[ A(x,y,z,t) \] represents a pulse of radio waves going from Earth to Moon
The paradox of electromagnetism

\( A(x,y,z,t) \)- represents a pulse of radio waves going from Earth to Moon

\( B(x,y,z,t) \)- represents a pulse of radio waves going from Mars to Venus
The paradox of electromagnetism

\[ A(x,y,z,t) \] represents a pulse of radio waves going from Earth to Moon

\[ B(x,y,z,t) \] represents a pulse of radio waves going from Mars to Venus

\[ a \, A(x,y,z,t) + b \, B(x,y,z,t) \] represents ????????????
The Emergent Multiverse?
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- *Physics* (decoherence) tells us that the quantum state, at large scales, has the *structure* of a branching multiverse with the branches obeying quasiclassical dynamics.
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- *Physics* (decoherence) tells us that the quantum state, at large scales, has the *structure* of a branching multiverse with the branches obeying quasiclassical dynamics.

- *Philosophy* tells us (should tell us!) that higher-order ontology is a matter of autonomous higher-order structure and dynamics.
Two Problems of Probability
Two Problems of Probability

(1) What, if anything, is the categorical basis for probabilities?
Two Problems of Probability

(1) What, if anything, is the categorical basis for probabilities?

(2) Why does that categorical basis play the probability role?
   Lewis: Principal Principle?
   Papineau: Inferential & Decision-Theoretic Links
The “what” problem
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- Frequentism?
The “what” problem

- Frequentism?

- Best-systems analysis?
The “what” problem

- Frequentism?
- Best-systems analysis?
- Bare postulate?
The “what” problem

- Frequentism?

- Best-systems analysis?

- Bare postulate?

- Everett: probabilities are mod-squared amplitudes in regimes where decoherence guarantees they obey the probability calculus
The “Why” problem

“[I]s there any way that any Humean magnitude could fill the chance-role? Is there any way that an unHumean magnitude could? What I fear is that the answer is “no” both times! Yet how can I reject the very idea of chance, when I know full well that each tritium atom has a certain chance of decaying at any moment?”

(Lewis)
The “Why” problem, Everett-style
The “Why” problem, Everett-style

- Probability from locality
  (Zurek, Carroll/Sebens)
The “Why” problem, Everett-style

- Probability from locality
  (Zurek, Carroll/Sebens)
- Probability from decision theory
  (Deutsch, Greaves, Myrvold, DW)
The “Why” problem, Everett-style

- Probability from locality
  (Zurek, Carroll/Sebens)
- Probability from decision theory
  (Deutsch, Greaves, Myrvold, DW)

The Everettian Epistemic Theorem (EM 218-223)
(roughly) “An agent who obeys normal decision-theoretic axioms, and who considers Everettian QM as a live epistemic probability, will treat mod-squared amplitudes in that theory as probabilities”
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