# Self-Locating Uncertainties in Many-Worlds

**Matthew Fox**
Perimeter Institute for Theoretical Physics
mfox2@pitp.ca

**Chaitanya Karamchedu**
Sandia National Laboratories
ckaramchedu@hmc.edu

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# Quantum Superpositions

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**What does this mean?**

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"Asking 'what is the spin of an electron in a spin superposition?' is like asking 'what is the marital status of the number 5?'."

– David Albert

# Bare-Naked Quantum Mechanics

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In our mind, a quantum theory obeys three postulates:

**Postulate I**

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Notable Implications:

- Quantum superpositions
- If the Universe is *just* a quantum system, then the Universe we experience must emerge from a Hilbert space structure

**Postulate II**

Two quantum systems $\mathcal{A}$ and $\mathcal{B}$, with Hilbert spaces $\mathscr{H}_{\mathcal{A}}$ and $\mathscr{H}_{\mathcal{B}}$, respectively, collectively form a composite quantum system, $\mathcal{A}+\mathcal{B}$, with a Hilbert space $\mathscr{H}_{\mathcal{A}+\mathcal{B}}$ equal to $\mathscr{H}_{\mathcal{A}} \otimes \mathscr{H}_{\mathcal{B}}$.

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Notable Implications:

- Quantum entanglement
- Anything reducible to quintessential quantum systems (quarks and electrons, say) is a quantum system

## Postulate III

If $|\psi\rangle \in \mathscr{H}$ is a state of a quantum system with Hilbert space $\mathscr{H}$, then $|\psi\rangle$ evolves in time according to the Schrödinger equation

$$\widehat{H}|\psi\rangle = i\hbar\,\partial_t|\psi\rangle,$$

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Notable Implications:

- Deterministic evolution
- Unitary (and hence linear) evolution

# The Quantum Measurement Problem

# The Everettian Resolution

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This entails:

- The universe has a Hilbert space $\mathscr{H}_U$ with a quantum state vector $|\psi\rangle$
- $|\psi\rangle$ evolves unitarily according to the Schrödinger equation
- Every other quantum system is related to $|\psi\rangle$ by the partial trace of $|\psi\rangle\langle\psi|$, e.g., you:

$$\rho_{\text{you}} = \text{tr}_{(U-\text{you})}|\psi\rangle\langle\psi|$$

# The DeWitt-Everett Dialogue

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Everett: I can plainly see that the earth doesn't really move because I don't experience its motion. But this doesn't falsify Newtonian mechanics, because Newtonian mechanics predicts that that is exactly what I should experience if the earth is in motion.

Everett: The same is true for my theory: it predicts that you would think you don't branch.

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Before measurement:

$$(\alpha|\uparrow\rangle + \beta|\downarrow\rangle) \otimes |\text{“ready”}\rangle \otimes |\text{see “ready”}\rangle \otimes |E_-\rangle$$

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After measurement:

$$\begin{aligned} |\psi\rangle \equiv \alpha|{\uparrow}\rangle \otimes |\text{“up”}\rangle \otimes |\text{see “up”}\rangle \otimes |E_\uparrow\rangle \\ + \beta|{\downarrow}\rangle \otimes |\text{“down”}\rangle \otimes |\text{see “down”}\rangle \otimes |E_\downarrow\rangle \end{aligned}$$

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$$
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\rho_{\text{you}} &= \text{tr}_{(U-\text{you})} |\psi\rangle\langle\psi| \\
&= \begin{pmatrix} |\alpha|^2 & \langle E_\uparrow | E_\downarrow \rangle \\ \langle E_\downarrow | E_\uparrow \rangle & |\beta|^2 \end{pmatrix}
\end{aligned}
$$

# Objections to Everett

# The Probability Puzzle and the Paths to Resolving it

# The Quantum Epistemic Separability Principle