Self-Locating Uncertainties in Many-Worlds

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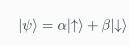
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Quantum Superpositions



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What does this mean?

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Exhaust logical possibilities!

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Exhaust logical possibilities!

"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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What do we mean by the qualifier "quantum" when we say a

theory is a *quantum* theory?

In our mind, a quantum theory obeys three postulates:

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

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

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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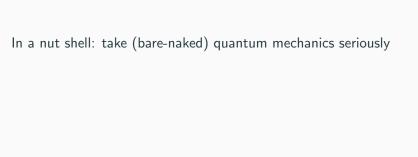
Notable Implications:

- · Deterministic evolution
- · Unitary (and hence linear) evolution

The Quantum Measurement

Problem

The Everettian Resolution



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In a nut shell: take (bare-naked) quantum mechanics seriously

This entails:

- . The universe has a Hilbert space \mathscr{H}_U with a quantum state vector $|\psi\rangle$
- $\cdot |\psi\rangle$ 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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Newtonian mechanics, because Newtonian mechanics predicts that that is exactly what I should experience if the earth is in motion.

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

electron
$$\longleftrightarrow |\!\!\uparrow\rangle, |\!\!\downarrow\rangle$$

$$\begin{array}{c} \text{electron} \longleftrightarrow |\!\!\uparrow\rangle, |\!\!\downarrow\rangle \\ \\ \text{measuring device} \longleftrightarrow |\!\!\text{"ready"}\rangle, |\!\!\text{"up"}\rangle, |\!\!\text{"down"}\rangle \end{array}$$

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Before measurement:

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

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Before measurement:

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After measurement:

$$\begin{split} |\psi\rangle &\equiv \alpha |\!\!\uparrow\rangle \otimes |\!\!\text{ "up"}\!\!\rangle \otimes |\!\!\text{see "up"}\!\!\rangle \otimes |E_\uparrow\rangle \\ &+ \beta |\!\!\downarrow\rangle \otimes |\!\!\text{ "down"}\!\!\rangle \otimes |\!\!\text{see "down"}\!\!\rangle \otimes |E_\downarrow\rangle \end{split}$$

$$ho_{
m you} = {
m tr}_{(U-{
m you})} |\psi
angle \!\langle \psi|$$

$$ho_{\mathsf{you}} = \mathsf{tr}_{(U-\mathsf{you})} |\psi
angle \langle \psi|$$

 $= \begin{pmatrix} |\alpha|^2 & \langle E_{\uparrow} | E_{\downarrow} \rangle \\ \langle E_{\downarrow} | E_{\uparrow} \rangle & |\beta|^2 \end{pmatrix}$

Objections to Everett

The Probability Puzzle and the

Paths to Resolving it

The Quantum Epistemic

Separability Principle