The many-worlds theory

Hugh Everett III (1955, 1957)

Everett's theory = GRW∅ with $\lambda = 0$

Schrödinger's (1926) theory = GRW(m) with $\lambda = 0$

Bell's theory

$$\Psi(t_2) = \sum_\alpha c_\alpha \Psi_\alpha$$

Schr's many-worlds theory : Sm

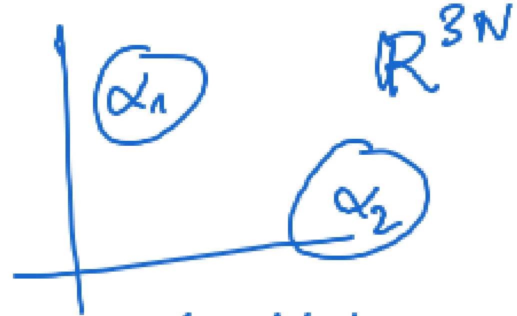
1) matter is cont'ly distributed with density

$$\underline{m}(\underline{x},t) = \sum_{i=1}^{N} m_i \int_{\mathbb{R}^{3N}} d^3\underline{x}_1 \cdots d^3\underline{x}_N \, \delta^3(\underline{x}-\underline{x}_i) \, |\underline{\psi}_t(\underline{x}_1,\dots,\underline{x}_N)|^2$$

2) ψ_t evolves acc. to the Schr eq.

Ex 2-slit

$$\underline{\Psi}(t_2) = \sum c_\alpha \underline{\Psi}_\alpha$$



$\forall q \in \mathbb{R}^{3N}$:

$$|\underline{\Psi}(q)|^2 = |c_\alpha|^2 |\underline{\Psi}_\alpha(q)|^2$$ for some (suitable) α

Set $m_\alpha := m^{\underline{\Psi}_\alpha}$. Then

$$m(\underline{x}) = \sum_\alpha |c_\alpha|^2 \, m_\alpha(\underline{x})$$

Everett's many-worlds theory: SØ

- idea: retain parallel worlds, dispense with m
- illusion of necessity
- preferred basis problem: $\Psi \in \mathcal{H}$

$$\Psi = \frac{1}{\sqrt{2}}|\text{alive}\rangle + \frac{1}{\sqrt{2}}|\text{dead}\rangle = \frac{e^{i\pi/4}}{\sqrt{2}}|+\rangle + \frac{e^{-i\pi/4}}{\sqrt{2}}|-\rangle$$

$$|+\rangle = \frac{1}{\sqrt{2}}|\text{alive}\rangle + \frac{i}{\sqrt{2}}|\text{dead}\rangle$$

$$|-\rangle = \frac{1}{\sqrt{2}}|\text{alive}\rangle - \frac{i}{\sqrt{2}}|\text{dead}\rangle$$

In Sm, the position basis in $\mathcal{H}$ is preferred.

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tree-like structure of $\Psi(t)$

branches Ψ_α

- Some people object that one cannot observe the other worlds.

Bell's first many-worlds theory

at t, $\Psi(t)$ (evolves acc to Schr. eq)

N material points at $Q = (\underline{Q}_1, \ldots, \underline{Q}_N)$

in 1 universe

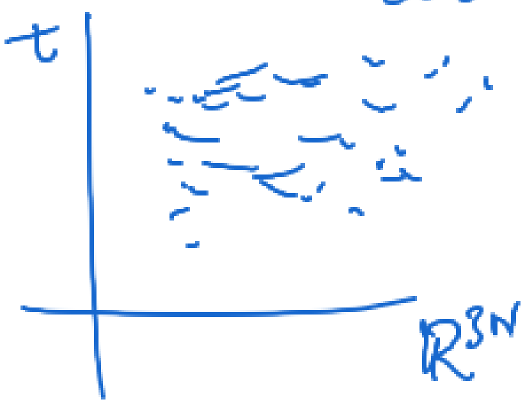
now ∞ many universe, $Q \sim |\Psi_t|^2$

no relation between worlds at t_1 and t_2

Bell's second many-worlds theory

Ψ_t evolves according to the Schr eq.

at t: 1 world, pick $Q \sim |\Psi_t|^2$ randomly and independently of $t_2 \neq t$.



Probabilities in many-worlds theories

nothing random: prob of what?

Here is what prob could mean in Sm: counting worlds.

1000 SG exp., $|c_{up}|^2 = \frac{1}{2} = |c_{down}|^2$

2^{1000} branches, in each $\uparrow\downarrow\downarrow\uparrow\uparrow\downarrow\uparrow\downarrow\downarrow\downarrow\uparrow\downarrow\downarrow$ ---

2^{1000} sequences

$f :=$ fraction of $\uparrow$ $\in [47\%, 53\%]$ in most sequences

In the overwhelming majority of worlds, $f \in [47\%, 53\%]$.

Problem: $|c_{up}|^2 = \frac{1}{3}$, $|c_{down}|^2 = \frac{2}{3}$