Spontaneous Wave Function Collapse with Frame Dragging

Lajos Diósi

Wigner Center, Budapest

25 Sept 2019, Frascati

Supported by
Foundational Questions Institute & Fetzer Franklin Fund National Research Development and Innovation Office of Hungary

Grant number K12435

Spontaneous Collapse (SC) of Wave Functions

50 yy: Károlyházi, Pearle, GRW , Penrose, Gisin, D, Bassi, Adler, ...

SC:

1 a hypothesis beyond standard quantum theory
2 similar to standard Collapse, but without measurement devices
3 happens universally and spontaneously every where and time
4 explains spontaneous emergence of classical data from $|\psi\rangle$
5 retains the Born probabilities $|\langle\phi|\psi\rangle|^2$
6 keeps massive degrees of freedom well localized
6 Schrödinger Cats are cruelly persecuted, they never come to existence, if you create one in your lab, she will die at birth.

Stochastic Schrödinger Equation (SSE)

SC yields randomness, Schrödinger equation is replaced by SSE:

$$\frac{d|\psi\rangle}{dt} = \text{standard term} + \text{nonlinear term} + \text{stochastic term}$$

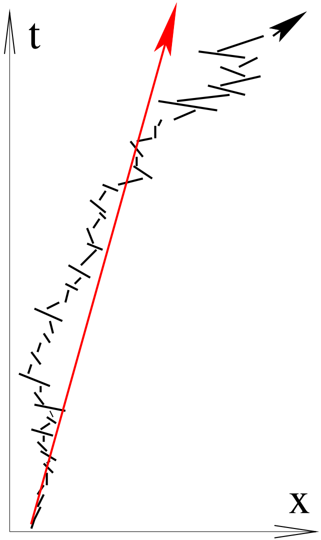
SSE tinily violates conservation of energy, momentum, continuity

not detected so far - efforts could start just 10-15 yy ago

$$\frac{d\langle\hat{H}\rangle}{dt} \neq 0, \quad \frac{d\langle\hat{p}\rangle}{dt} \neq -\langle\nabla V(\hat{x})\rangle, \quad \frac{d\langle\hat{\varrho}\rangle}{dt} + \langle\nabla\hat{\mathbf{J}}\rangle \neq 0$$

$$\left\langle \nabla_{\mathbf{b}} \hat{\mathbf{T}}_{\mathbf{a}}^{\mathbf{b}} \right\rangle \neq \mathbf{0}$$

Inertial motion: Newton vs SC



Newton's definition of inertial frame:
Free motion is rectilinear at constant speed.

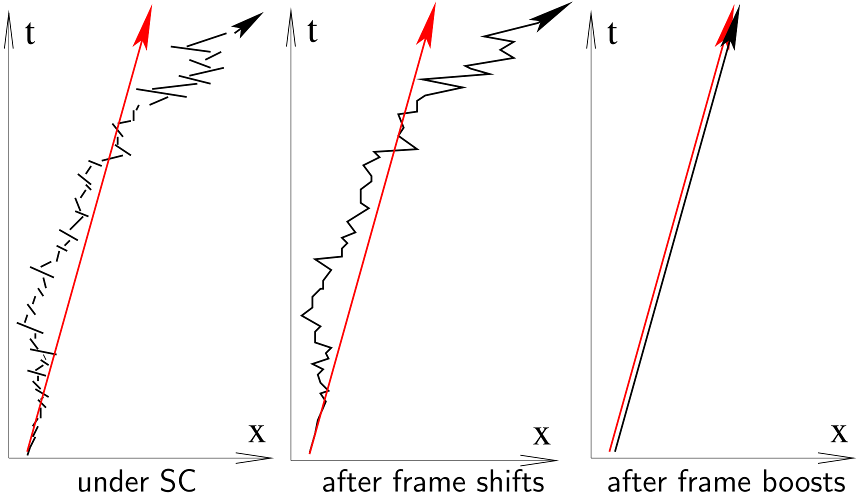
If it is not: we are in the wrong frame with non-Cartesian coordinates.

We have to redefine x, y, z (maybe t, too)!

Let free masses drag their local inertial frames with themselves!

Schematics of frame dragging

Free motions



Mathematics of SC with frame dragging

$\hat{x}_c = \hat{x} - \langle\hat{x}\rangle$; $\hat{p}_c = \hat{p} - \langle\hat{p}\rangle$; $\sigma^2 = \langle\hat{x}_c^2\rangle$; $R = \hbar^{-1}\mathrm{Re}\langle\hat{x}_c\hat{p}_c\rangle$; W=Wiener noise.
SSE of SC:

$$d|\psi\rangle = -\frac{i}{\hbar}\frac{\hat{p}^2}{2M}|\psi\rangle dt - \frac{D}{\hbar^2}\hat{x}_c^2|\psi\rangle dt + \frac{\sqrt{2D}}{\hbar}\hat{x}_c|\psi\rangle dW.$$

LISA pathfinder's data: $D/(2kg)^2 \leq 10^{-22} cm^2/s^3$ (Helou et al 2017).

C.o.m. "diffusive" trajectory:

$$d\langle\hat{x}\rangle = \frac{\langle\hat{p}\rangle}{M}dt + \frac{\sigma^2}{\hbar}\sqrt{8D}dW; \qquad d\langle\hat{p}\rangle = R\sqrt{8D}dW,$$

Frame draggings ("diffusive" ones), shift du and boost dv:

$$du = vdt + \frac{\sigma^2}{\hbar}\sqrt{8D}dW; \qquad dv = \frac{1}{M}R\sqrt{8D}dW$$

C.o.m. trajectory becomes inertial:

$$d\langle\hat{x}\rangle = \frac{\langle\hat{p}\rangle}{M}dt; \qquad d\langle\hat{p}\rangle = 0$$

New SSE, with frame dragging

$\hat{x}_c = \hat{x} - \langle\hat{x}\rangle$; $\hat{p}_c = \hat{x} - \langle\hat{x}\rangle$; $\sigma^2 = \langle\hat{x}_c^2\rangle$; $R = \hbar^{-1}\mathrm{Re}\langle\hat{x}_c\hat{p}_c\rangle$; W=Wiener noise.

SSE of "old" SC:

$$d|\psi\rangle = -\frac{i}{\hbar}\frac{\hat{p}^2}{2M}|\psi\rangle dt - \frac{D}{\hbar^2}\hat{x}_c^2|\psi\rangle dt + \frac{\sqrt{2D}}{\hbar}\hat{x}_c|\psi\rangle dW.$$

New SSE of SC with frame dragging:

$$d|\psi\rangle = -\frac{i}{\hbar}\left(\frac{\hat{p}^2}{2M} + \hat{H}_\psi\right)|\psi\rangle dt - \frac{D}{\hbar^2}\hat{A}_c^\dagger\hat{A}_c|\psi\rangle dt + \frac{\sqrt{2D}}{\hbar}\hat{A}_c|\psi\rangle dW$$

$\hat{H}_\psi = \frac{4D}{\hbar}(R\hat{x}_c^2 - \sigma^2\hat{R})$ drag-induced nonlin Hamiltonian, $\hat{R} = \frac{\mathrm{Herm}\hat{x}_c\hat{p}_c}{\hbar}$

$\hat{A}_c = \hat{x}_c - 2i[R\hat{x}_c - \hbar^{-1}\sigma^2\hat{p}_c]$ "Lindbladian" notation

Solutions $\equiv$ solutions of "old" SSE seen from the frame co-moving with the diffusive fluctuations of $\langle\hat{x}\rangle_t, \langle\hat{p}\rangle_t$.

Spontaneous Collapse (SC) with frame drag

just like old SC:

1 a hypothesis beyond standard quantum theory
2 similar to standard C, but without measurement devices
3 happens universally and spontaneously every where and time
4 explains spontaneous emergence of classical data from $|\psi\rangle$
5 retains the Born probabilities $|\langle\phi|\psi\rangle|^2$
6 keeps massive degrees of freedom well localized
6 Schrödinger Cats are cruelly persecuted, they never come to existence, if you create one in our lab, she will die at birth.

plus

7 retains continuity of $\langle\hat{x}\rangle_t$ and conservation of $\langle\hat{p}\rangle_t$

but

8 contains "essential" quantum-mechanical non-linearity
9 waits implementation for microscopic SC theories

Essential quantum non-linearity

Faster Than Light communication?
Perhaps no!
SC will destroy FTL telegraph faster than Nicolas Gisin can finish constructing it in his lab.

FTL telegraph assumes an entangled composite system AB of remote parts A and B, and standard collapse in B where B can be a single "massless" spin-half system. In SC theories, collapse of the spin does not happen unless it gets entangled with a massive system C, which means A has to be entangled with a massive system BC. System A, too, must be a massive system otherwise SC has ignorable effect on it.

Spontaneous Collapses cause gravity

SC tinily violates conservation of energy, momentum, continuity:

$$\left\langle \nabla_b \hat{T}_a^b \right\rangle \neq 0$$

What if local frame drags on fixed (Minkowski) metric does not help? Nevermind!

Local frame drags (re-cordination) on fixed metric $\equiv$

$\equiv$ "dragged" new metric on fixed coordinates

Let fluctuations of $\langle \nabla_b \hat{T}_a^b \rangle$ drag metric with themselves, to reach

$$\left\langle \nabla_b^{\mathrm{cov}} \hat{T}_a^b \right\rangle = 0$$

on the curved space-time!

Spontaneous Collapses can, contrary to lessons of 50 yy, conserve energy-momentum (in quantum mean) at the cost, rather a prize, that they generate gravity. The costly part is the, hopefully innocent, quantum nonlinearity.

Newtonian limit of the vision should be tested on DP theory of SC.