A Vision: Gravity is Caused by Spontaneous Wave Function Collapse

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Supports by: EU COST Actions (Grants CA23115, CA23130)

5 Oct 2026, Castiglioncello

Facts and Vision

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Spontaneous Collapses cause gravity

Facts and Vision

Spontaneous Collapse (SC) violates $\nabla_b T^b_a = 0$.

Facts

For a single non-relativistic free object:
both x and p are diffusing around the inertial trajectory
inertial trajectory restores in the **dragged frames**
$\nabla_b T^b_a = 0$ restores non-relativistically
N objects: N locally dragged frames restore $\nabla_b T^b_a = 0$
Local frame drags on the Minkowski background$\subset$new metrics

Vision

In classical $\mathbf{g_{ab}}$, propose SC on the quantized field $\hat{T}_{ab}$.
Vary the metric g_{ab} until $\langle \nabla_{\mathbf{b}} \hat{\mathbf{T}}^{\mathbf{b}}_{\mathbf{a}} \rangle = \mathbf{0}$.
Clap your hands if $\mathbf{g_{ab}}$ is similar to Einstein's.
LD: **Quant.Rep. 1**, 277 (2019); **4**, 566 (2022)

Spontaneous Collapse (SC) of Wave Functions

60 yy: Károlyházi, Pearle, GRW , D, Gisin, Penrose, Bassi, Adler, Tilloy,..., Oppenheim

SC:

1. a hypothesis beyond standard quantum theory
2. same as standard C, but without measurement devices
3. happens universally, spontaneously every where and time
4. explains spontaneous emergence of classical data from $|\psi\rangle$
5. keeps massive degrees of freedom well localized

   Schrödinger cats never come to existence, die at birth.
   but
6. **violates** continuity of $\langle \hat{x} \rangle_t$ and conservation of $\langle \hat{p} \rangle_t$

Stochastic Schrödinger Equation (SSE)

Spontaneous Collapses yield random $|\psi\rangle$,
Schrödinger equation is replaced by SSE:

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

Tiny violations: energy/momentum conservation, continuity:

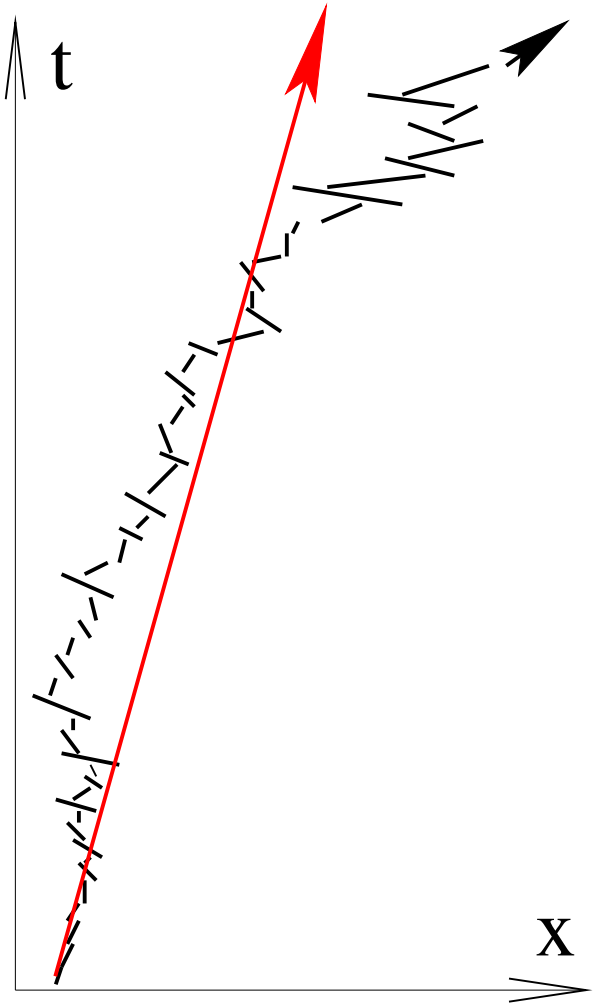
not detected so far - efforts could start just 10-15 yy ago

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

In relativistic terms:

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

Inertial motion: Newton vs SC



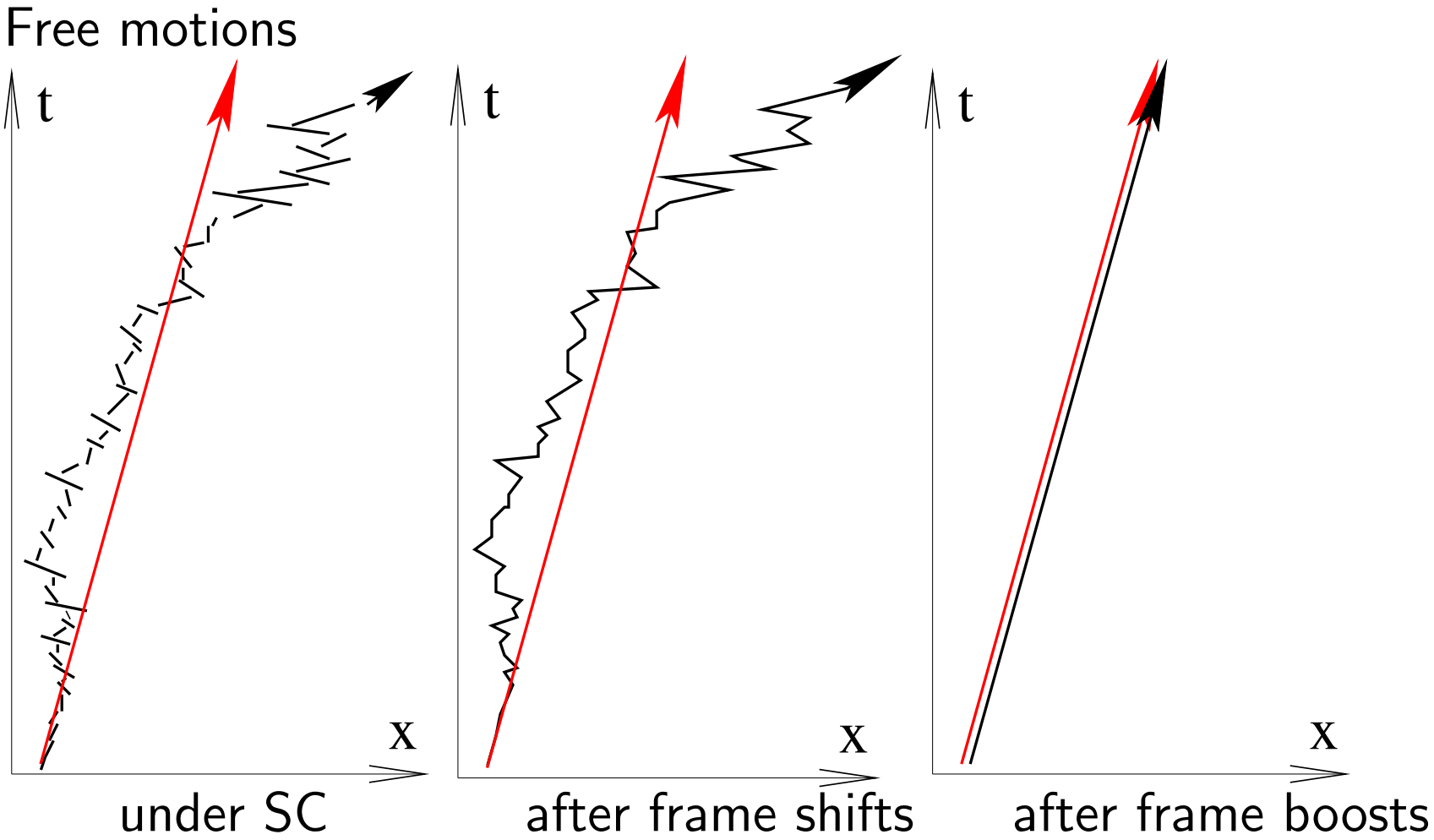
Newton's definition of inertial frame: Free motion is rectilinear at constant speed.

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



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 $\hat{H}$, $\hat{R} = \hbar^{-1}\mathrm{Herm}\hat{x}_c\hat{p}_c$

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

Solutions $\equiv$ solutions of "old" SSE seen from the frames 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. same as standard C, but without measurement devices
3. happens universally, spontaneously every where and time
4. explains spontaneous emergence of classical data from $|\psi\rangle$
5. keeps massive degrees of freedom well localized

   Schrödinger cats never come to existence, die at birth.

   and
6. **retains** continuity of $\langle\hat{x}\rangle_t$ and conservation of $\langle\hat{p}\rangle_t$

   but
7. contains "essential" quantum-mechanical non-linearity
8. waits implementation in DP nonrelativistic SC theory first

Essential quantum non-linearity

due to frame draggings shift du and boost dv

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

$\sigma^2 = \langle \hat{x}_c^2 \rangle$, $R = \hbar^{-1}\mathrm{Herm}\hat{x}_c\hat{p}_c$ are **non-tangible** in single processes $\Rightarrow$ 'essential' non-linearity of quantum dynamics.
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 energy-momentum conservation:

$$\left\langle \nabla_b \hat{T}^b_a \right\rangle_\psi \neq 0$$

What if local frame drags do not restore the conservation rule?
Nevermind!
Local frame drags $\subset$ New metric g.
Let us vary metric g, cancel fluctuations of $\langle \nabla_b \hat{T}^b_a \rangle_\psi$, reach

$$\left\langle \nabla^{\rm cov}_b \hat{T}^b_a \right\rangle_\psi = 0$$

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. A lateral cost: quantum nonlinearity, hopefully innocent.
The Vision should be tested on DP theory of SC first.
LD: **Quant.Rep. 1**, 277 (2019); **4**, 566 (2022); ... (20??)