DOES WAVE FUNCTION COLLAPSE CAUSE GRAVITY?

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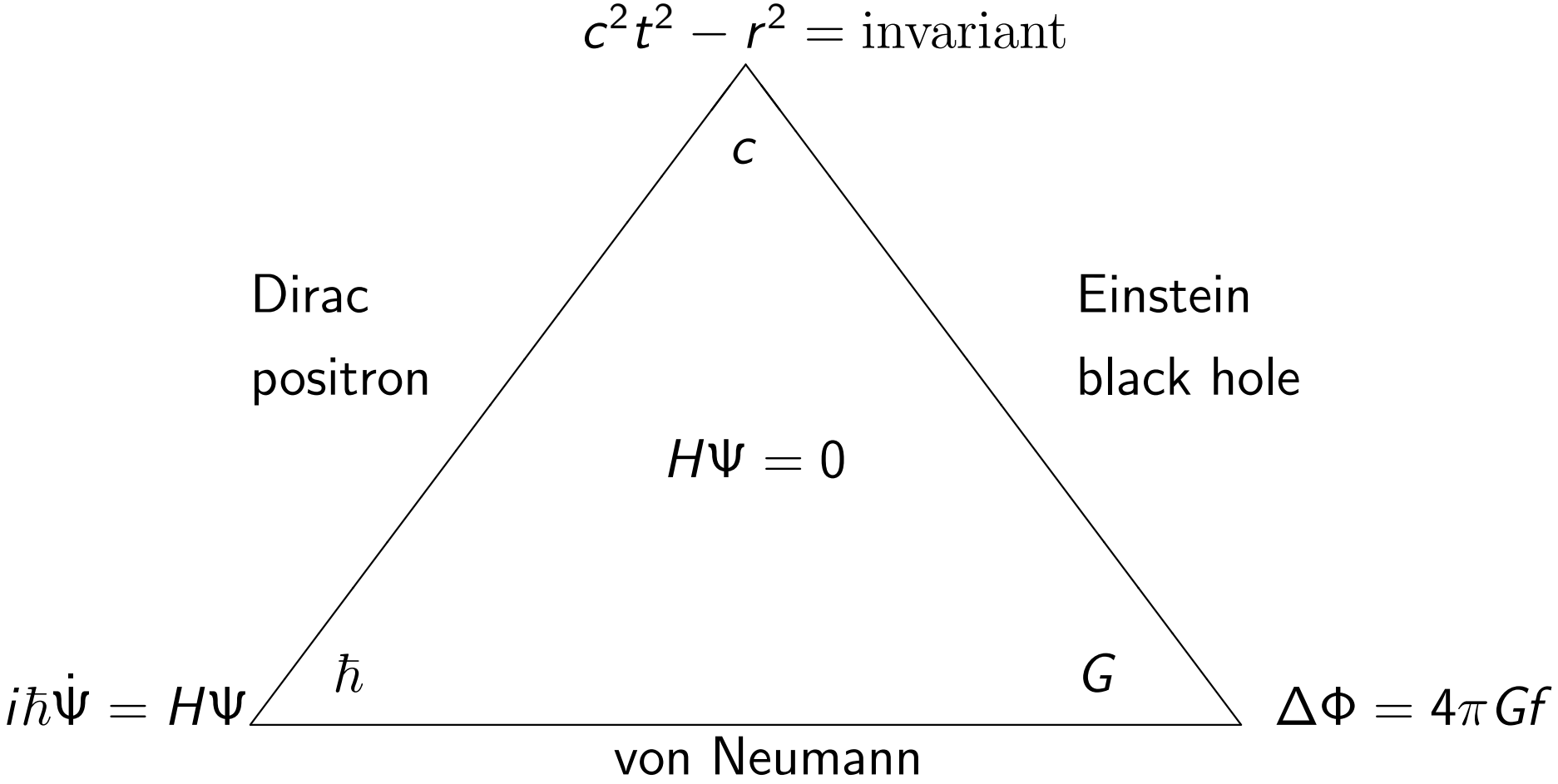
Outline

Bottle-neck of Quantum Gravity: Q OR G?

Mainstream blames G, sidestream blames Q.



What's wrong with Wheeler-DeWitt Eq. $H\Psi = 0$?

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$$H\left(g, \frac{\partial}{\partial g}, q, \frac{\partial}{\partial q}\right)\Psi(g,q) \;=\; 0$$

g = 3-geometry, q =matter fields

- Generic solution $\Psi(g,q)$ implies no 4-geometry
- No room for von Neumann measurement theory
- "Schrödinger Cat" states

A remedy would be a certain (hypothetic) universal decoherence to forbid "Schrödinger Cat" states, to enforce wave function collapse into states localized in g.

Ttechnical key-element is our smart choice for:

- Distance $\ell(g_1,g_2)$ between 3-geometries, to measure "catness"
- Modification of WDW Eq. to decohere Ψ for large ℓ

FULL RELATIVISTIC OPTION IS LARGELY UNEXPLORED.
GO NEWTONIAN! DECENT MODELS, EXPER' PROPOSALS.

Newtonian decoherence distance

Choice for the distance (to measure "catness"):

$$\ell^2(\mathbf{g}_1, \mathbf{g}_2) \;=\; \frac{1}{4\pi G}\int |\mathbf{g}_1 - \mathbf{g}_2|^2 dV$$

$\mathbf{g}_1, \mathbf{g}_2$: Newtonian acceleration fields. In mass densities f_1, f_2:

$$\ell^2(f_1, f_2) = G\int\int [f_1(\mathbf{r}) - f_2(\mathbf{r})][f_1(\mathbf{s}) - f_2(\mathbf{s})]\frac{d\mathbf{r}d\mathbf{s}}{|\mathbf{r}-\mathbf{s}|}$$
$$= 2U(f_1, f_2) - U(f_1, f_1) - U(f_2, f_2)$$

Popular alternatives (Ghirardi et al, Pearle 1986-):

$$\ell^2_{GRW/CSL}(f_1, f_2) = \gamma_{GRW/CSL}\int [f_1^\nu(\mathbf{r}) - f_2^\nu(\mathbf{r})]^2 d\mathbf{r}$$

$\nu = 1/2$ for GRW, $\nu = 1$ for CSL.

ADD UNIVERSAL DECOHERENCE AND QUANTUM STATE COLLAPSE TO QM!

Newtonian decoherence/localization dynamics

- Decay time of catness (Penrose 1996, D. 1987)

$$\tau_d = \frac{\hbar}{\ell^2(f,f')} = \frac{\hbar}{2U(f,f') - U(f,f) - U(f',f')}$$

- Master equation for the density matrix (D. 1987)

$$\frac{d\hat{\rho}}{dt} = -\frac{i}{\hbar}[\hat{H},\hat{\rho}] - \frac{1}{2\hbar}\ell^2(\hat{f}_L,\hat{f}_R)\hat{\rho}$$

$$= -\frac{i}{\hbar}[\hat{H},\hat{\rho}] - \frac{G}{2\hbar}\int\int [\hat{f}(\mathbf{r}),[\hat{f}(\mathbf{s}),\hat{\rho}]]\frac{d\mathbf{r}d\mathbf{s}}{|\mathbf{r}-\mathbf{s}|}$$

- SSE=stochastic Schrödinger Equation (D. 1986/89)

$$\frac{d\psi}{dt} = -\frac{i}{\hbar}\hat{H}\psi + \text{non-linear stochastic term}$$

DO WE HAVE TESTABLE PREDICTIONS?

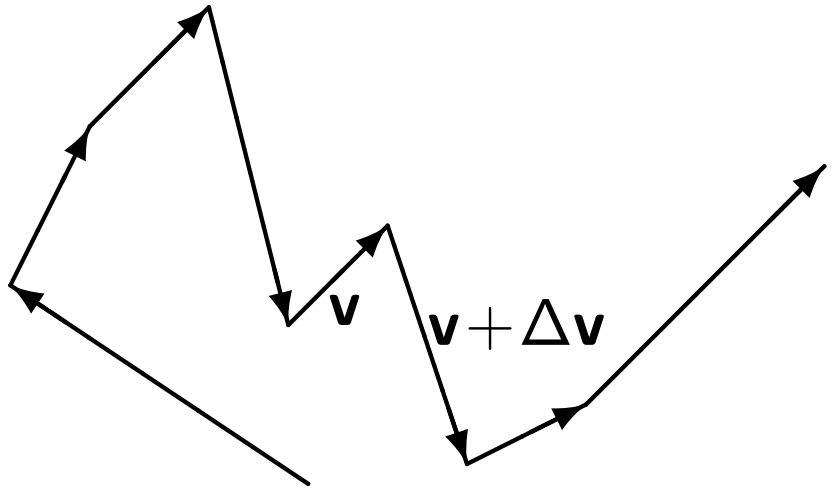
Proposed tests

Detecting Newton-G-related loss of coherence in:

- nucleon decay (Pearle & Squires)
- flavor oscillations of neutrinos from distant cosmic sources (Christian)
- light propagation from distant stars (Christiansen & Ng & vanDam)
- gravity wave interferometer LIGO/VIRGO (Amelino-Camelia)
- nano-mechanical oscillator (Marshall & Simon & Penrose & Bouwmeester)
- optically levitated dielectric nano-sphere (Romero-Isart)
- ...

ARE THERE MORE CHARACTERISTIC EFFECTS THAN EXCESS NOISE? THERE WOULD BE — IN A MORE RADICAL THEORY.

Gravity caused by wave function collapse?



In the above Newtonian model

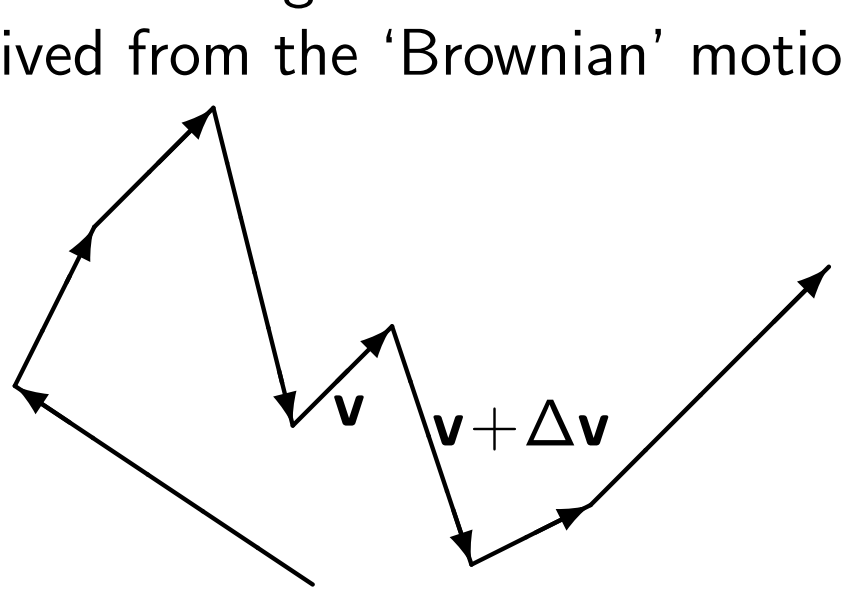
- decoherence/collapse superimposes "Brownian" diffusion/jumps on c.o.m. motion of massive objects.
- Newtonian interaction potential is included by hand
- Can't we turn it around? Attribute Brownian diffusion/jumps to emergent **g** gravity around the mass?

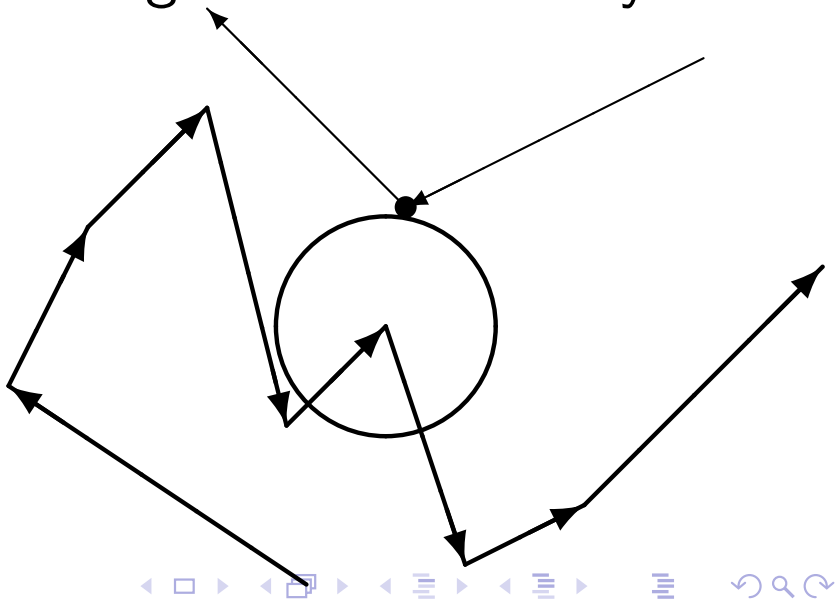
WHAT IF COLLAPSE IMPLIES THE NEWTONIAN FIELD?

Excursion: Ambient pressure from 'Brownian' trajectory I

Motivation: For a single free mass M, one might like to derive the presence of an average attractive Newtonian field $\overline{g} = -GM/r^2$ *from* the features of the random path of the c.o.m., broken by the repeated collapses.

Exercise: In a non-standard 'Brownian' motion model the presence and the average value of a central compressing force can exactly be derived from the 'Brownian' motion.

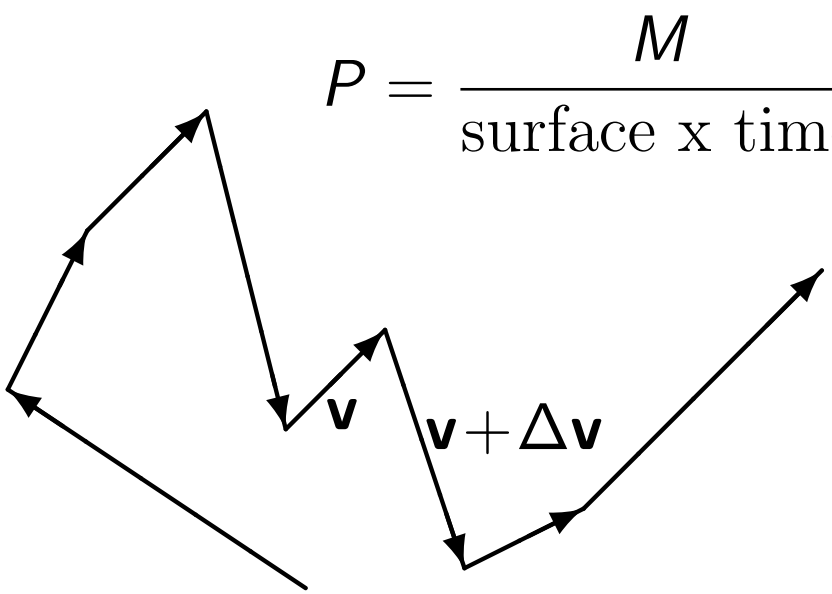


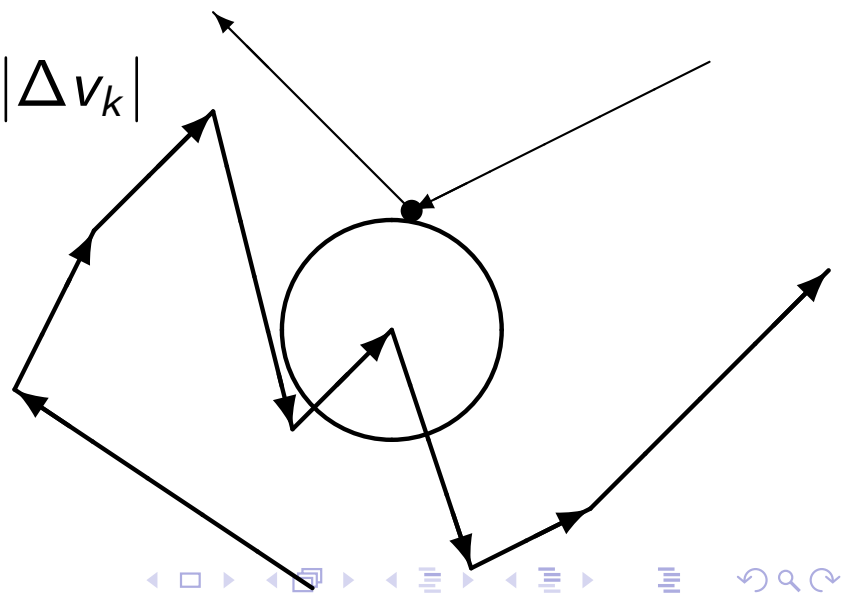


Excursion: ... pressure from trajectory II

Classical rigid ball of radius R, mass M, in thin gas of small rigid ball molecules that hit the "Brownian" ball. Brownian trajectory becomes a random broken line which encodes the ambient pressure P!
Imagine you sit inside the Brownian mass, experience the sequence $\Delta v_1, \Delta v_2, \ldots, \Delta v_k, \ldots$ of velocity jumps. You shall conclude that *there must be* and average compressing force acting on the surface of the Brownian Mass (a hydrodamic pressure, this time):

$$P = \frac{M}{\text{surface x time}} \sum_{k=1}^{n} |\Delta v_k|$$





Back to collapse induced gravity

- G-related wave function collapse $\Rightarrow$ "Browinian" c.o.m. motion
- Newton interaction put by hand
- Einstein equivalence (Newton Law $\Delta M\mathbf{v} = \mathbf{F}\Delta t$) violated
- Can "Brownian" motion be attributed to emergent $-G/r$ Newton field?
- Would restore Einstein equivalence (Newton's Law)
- Analogue: Ambient Pressure
- Very preliminary calculations
- $G \Rightarrow G_r$ $\sim$collapse intensity at length scales r

ARE THERE MORE CHARACTERISTIC EFFECTS THAN EXCESS NOISE? SHORT DISTANCE DROP OF G?

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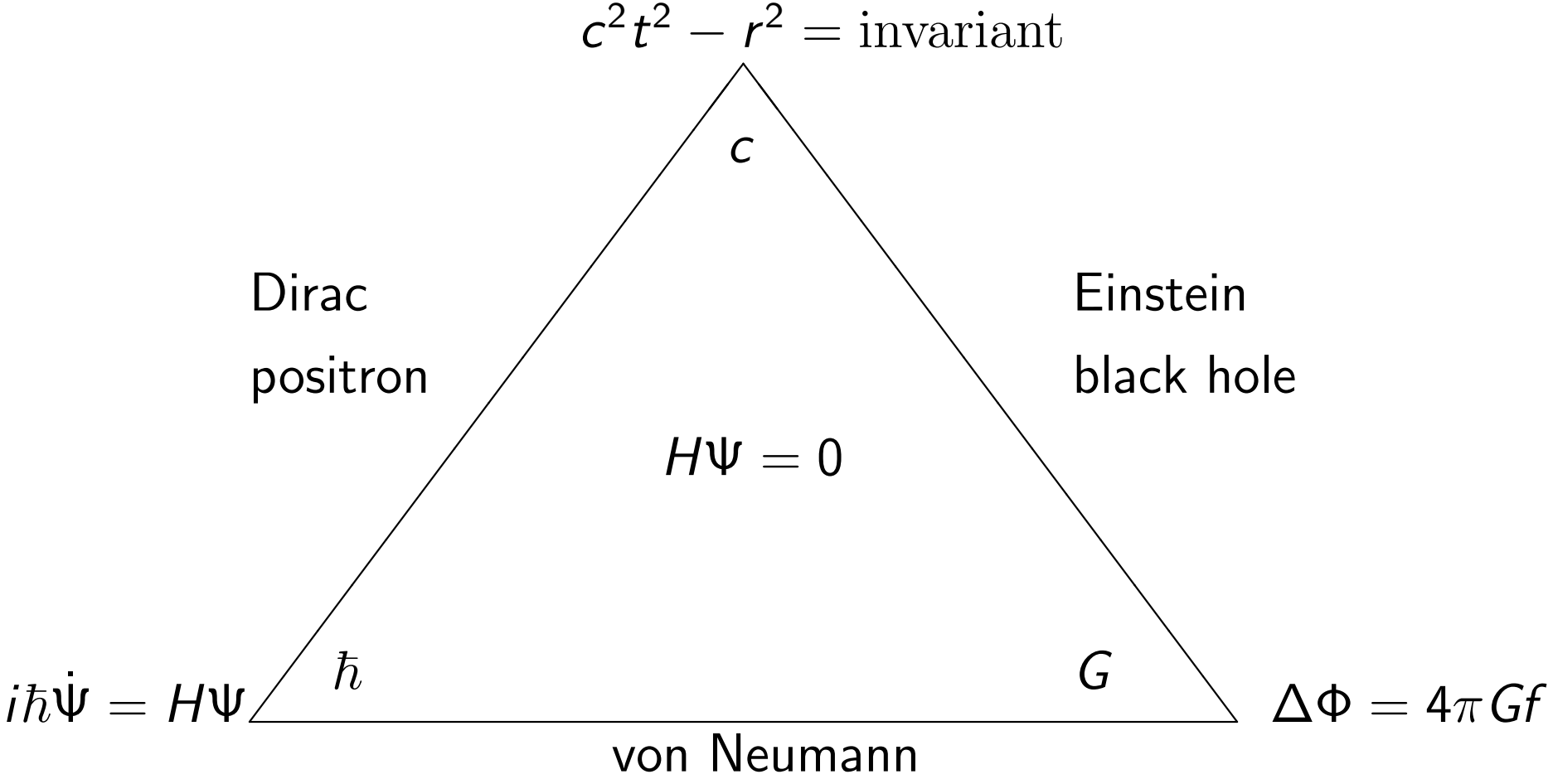

VON NEUMANN → VON NEUMANN + EMERGENT GRAVITY?