# Trans-Planckian non-relativistic motion is not an oxymoron

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# No QG effects below 10<sup>19</sup>GeV?

High Energy Physics wisdom:

- QG is beleived to dominate on the trans-Planckian scale
- QG effects are totally ingorable below the Planck-scale
- Non-relativistic (NR) QM can not overlap with QG
- Planckian or trans-Planckian slow  $\ll c$  motion is an oxymoron
- ... like "QG in the Lab"

# Still there is a loophole to QG in the lab

Google's wisdom ("quantum gravity in the lab"):

- 10 results before 2000
- 12.600 results until 2019 (7 June)

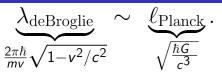
How can this deal exist? My <del>wisdom</del> hint:

- HEP requests  $10^{19} GeV$
- ... per elementary particle unavailable after Big Bang
- $10^{19}$ GeV $\sim 10^{16}$ erg per massive object available in the lab E = 10kg $\times (10$ km/s)<sup>2</sup> =  $10^{16}$ erg $\sim E_{\rm Pl}$

Loophole from high energies toward the lab: massive d.o.f. to test Planck-scale!

Next: Planck lenght  $\ell_{Pl}$  can be hit earlier than Planck energy  $E_{Pl}$ .

## Trans-Planckian de Broglie wavelength



 $\lambda_{\rm dB}$  sinks to and below  $\ell_{\rm Pl}$  in two ways:

- Relativistic way: elementary particles velocity v closes c, requests 10<sup>19</sup>GeV/particle — forget it!
- NR way: velocity v remains ≪c but mass grows macroscopic might be viable in the lab

$$\lambda_{
m dB} = rac{2\pi\hbar}{10 {
m g} imes 10 {
m km/s}} \sim 10^{-33} {
m cm} \sim \ell_{
m Pl}$$

1) NR (trans-)Planckian m = 10g Schrödinger cat:  $|v = -10km/s\rangle + |v = +10km/s\rangle$ 

2) NR (trans-)Planckian vibration of m = 10kg body:  $\lambda_{\rm dB} = \frac{2\pi\hbar}{m\omega a} = \frac{2\pi\hbar}{10 \text{kg} \times 100 \text{kHz} \times 10^{-2} \text{cm}} \sim 10^{-33} \text{cm} \sim \ell_{\rm Pl}$ 

#### What happens at the Planck scale?

- Bronstein 1935: Notion of space-time continuum may be lost.
- Wheeler 1962: Foamy space-time
- Hawking 1983: Non-unitary (decohering) dynamics

No accepted dynamics for scales  $\ell_{\rm Pl}$  (Garay 1995, Hossenfelder 2013) Phenomenology:  $\ell_{\rm Pl}$ -scale metric fluctuations Simplest choice: stochastic conformal fluctuations

$$\{g_{ab}\} = (1+h) \text{diag}(1, -1-1-1), \quad |h| \ll 1$$

Lorentz-invariant correlation (D 2019):

$$\mathbb{E}h(x)h(y) = \ell_{\rm Pl}^2 \int \frac{d^4k}{(2\pi)^4} \frac{\theta(-k^2)}{-k^2} e^{-ik(x-y)}, \qquad (1)$$

Write *h* as  $h = 2\Phi/c^2$ , take  $c \to \infty$ , then *c* cancels!

$$\mathbb{E}\Phi(t,\mathbf{x})\Phi(s,\mathbf{y}) = \frac{\hbar G}{|\mathbf{x}-\mathbf{y}|}\delta(t-s).$$

# Trans-Planckian NR Schrödinger cats decohere

... and die.

NR QM becomes modified by the stochastic Newton-potential:

$$egin{aligned} rac{d\Psi}{dt} &= -rac{i}{\hbar}\left(\hat{H} + \sum m_n \Phi(\hat{x}_n,t)
ight)\Psi \ &\mathbb{E}\Phi(t,\mathbf{x})\Phi(s,\mathbf{y}) &= rac{\hbar G}{|\mathbf{x}-\mathbf{y}|}\delta(t-s), \end{aligned}$$

causing G-related decoherence in NR QM (D 1987, Penrose 1996). Trans-Planckian NR Schrödinger cat decays

$$rac{|-10$$
 km/s $angle + |10$  km/s $angle \Rightarrow \left\{ egin{array}{cc} |-10$  km/s $angle & 50\% \ | 10$  km/s $angle & 50\% \end{array} 
ight.$ 

at the DP-decay time

$$10^{-15} - 10^{-9}s$$
.

- NR wavefunction of (isolated) massive d.o.f. acquires trans-Planckian structure.
- Hence NR QM should get some corrections for large masses.
  - We have no theory there since we have no safe QG theory.
  - Yet, QG-phenomenology says: metric fluctuates heavily there.
  - Fluctuations are ignorable for any NR atomic object.
  - Cumulative effect of fluctuations does matter for massive d.o.f.
  - Their primary effect is decoherence of massive d.o.f.
  - DP version seems to clear NR states of their trans-Planckianity.
- Trans-Planckian & non-relativistic? Yes, in massive d.o.f., theorists should do something about QM there.
- QG & lab? Yes! Quantum control of "big-enough" d.o.f. would come soon (10yy? ask e.g. Aspelmayer).