When free-falling screen records interference and standing screen does not

Lajos Diósi
Wigner Research Centre for Physics
H-1525 Budapest 114, POB 49, Hungary

29 March 2017, Valletta

Acknowledgements go to:
EU COST Action CA15220 'Quantum Technologies in Space'

Time-dilation in gravity: positional decoherence

Detector in free fall: no decoherence

Just relative velocity (not acceleration) matters

Decoherence time vs decoherence speed

Final speculation: screen at $v = c$?

Time-dilation in gravity: positional decoherence

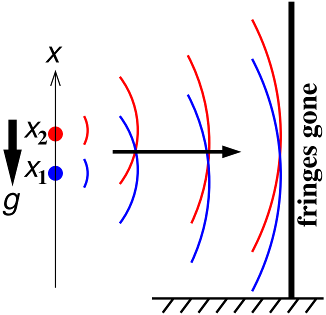
Earth gravity force on c.o.m. of composite object: $F = Mg$
Relativistic correction to mass from internal energy E_i:

$$F = (M + E_i/c^2)g$$

Internal d.o.f. add extreme small random force to c.o.m.:

$$\Delta F \equiv \sqrt{\langle F^2\rangle - \langle F\rangle^2} = \frac{g}{c^2}\Delta E_i = \frac{g}{c^2}\sqrt{k_B C}\,T$$

But: it yields positional decoherence, hope for tests!



$$|x_1\rangle + |x_2\rangle$$

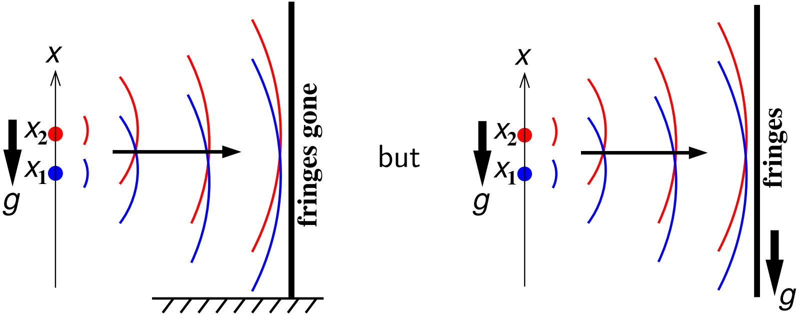
would produce fringes.
But fringes disappear after
decoherence time

$$\tau_D = \frac{\hbar c^2}{g\Delta E_i|x_1 - x_2|}$$

Pikovski-Zych-Costa-Brukner,
Nature Phys. **11**, 668 (2015)

Detector in free fall: no decoherence

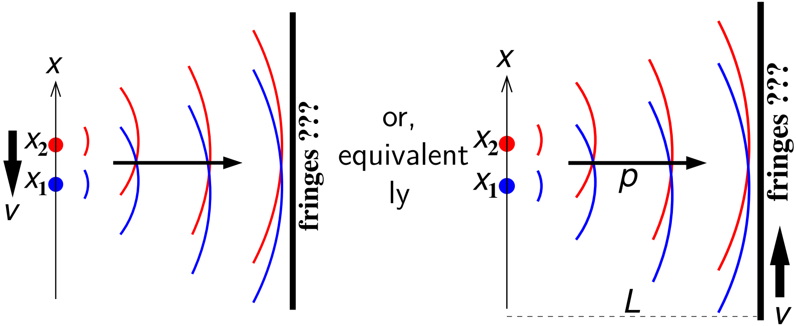
Newtonian Equivalence Principle: no gravity in free-fall.
Positional decoherence should disappear if both object and observer are in free-fall.
L.D.: *Centre of mass decoherence due to time dilation: paradoxical frame-dependence* arXiv:1507.05828



Relative motion of object and detector matters!

Just relative velocity (not acceleration) matters

If object and detector are in relative vertical motion:



Pang-Chen-Khalili, PRL117, 090401 (2016)

$$\text{Arrival times } L\frac{m + E_i/c^2}{p} \text{ fluctuate with } \Delta E_i = T\sqrt{k_B C}$$

Fringe visibility degrades at *decoherence speed*

$$v_D = \frac{\hbar c^2}{\Delta E |x_1 - x_2|}$$

Decoherence time vs decoherence speed

Time-dilation test in two different positional interferometry:

1) Fringe visibility decay in Earth g on static detector, at decoherence time:

$$\tau_D = \frac{\hbar c^2}{g\Delta E_i|x_1 - x_2|}$$

2) Fringe visibility decay on moving detector, at decoherence speed:

$$v_D = \frac{\hbar c^2}{\Delta E|x_1 - x_2|} \quad (= g\tau_D)$$

Option 2) wins over 1) if we compare 'figures of hopelessness'

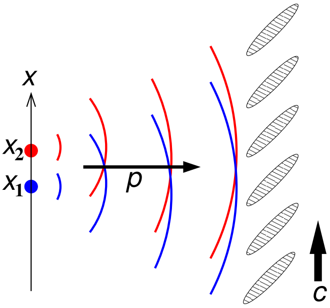
$$\frac{\tau_D}{\tau_D^{env}} \text{ and } \frac{v_D}{c}$$

Selection from Carlesso-Bassi PLA380, 31 (2016) + my v_D:

	t_{exp}	τ_D^{env}	τ_D	v_D	τ_D/τ_D^{env}	v_D/c
Fullerens	10^{-2}	10^{-1}	10^{6}	10^{9}	10^{7}	10^{-1}
Micro-particles		1	10^{12}	10^{15}	10^{12}	10^{5}
Macro-particles		10^{-19}	10^{3}	10^{6}	10^{22}	10^{-4}

Final speculation: screen at $v = c$?

Position detection in realty: laser light
Can we use staggered tilted light packets:



Does it make a screen of $v = c$?
Could bring detection of time-dilation in internal d.o.f. closer.