Title: GRB neutrinos and quantum-gravity-induced in-vacuo dispersion

Speakers: Giovanni Amelino-Camelia

Collection/Series: Lee's Fest: Quantum Gravity and the Nature of Time

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Abstract:

I report on recent progress of investigations of in-vacuo dispersion for GRB neutrinos, also highlighting the connection with a previous study done in collaboration with Lee Smolin investigating in-vacuo dispersion for GRB photons. The present status of IceCube neutrino observations provides preliminary encouragement for a scenario based on in-vacuo dispersion and the KM3-230213A neutrino recently annouced by KM3NeT fits rather naturally within the in-vacuo-dispersion scenario motivated by IceCube data.

4 June 2025 (Lee's fest)

some anecdotes

~ **1993** John Stachel creates an opportunity for me to talk briefly with Lee
(something like an aspiring guitarist meeting, say, Eric Clapton)

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1998 I find out that Lee is "secretly" advertising my work on the phenomenology of in-vacuo dispersion for photons (Eric Clapton likes my music!!)

~ **2002 amusingly awkward:** Lee candidates me as director of Sapienza's physics dept

2009, when it is established that one of us <u>is</u> (nearly) **superfluous:** about the work Lee and I did on the phenomenology of in-vacuo-dispersion for photons, using GRB090510 data (PhysRevD80,084017)

~ **2000**

what about in-vacuo dispersion for neutrinos???

The prediction of a neutrino emission associated with Gamma Ray Bursts is generic within the most widely accepted astrophysical models

according to pre-IceCube predictions, IceCube should have seen a few GRB neutrinos in each year of operation but it has reported no GRB neutrinos!

of course it would not be too surprising if pre-IceCube models of neutrino production by GRBs were incorrect,
but invacuo dispersion offers an alternative explanation:
IceCube looks for GRB neutrinos within a window of about 100 seconds of the GRB trigger,
but with even just with "Planckian" in-vacuo-dispersion you might need a much bigger time window

test in-vacuo dispersion statistically:

if the time window is large it's inevitable to select (also) some "accidental GRB-neutrino pairs", neutrinos unrelated to a GRB which just happens to be within the chosen large time window and directionally compatible with the GRB

in order to best setup the statistical analysis it is convenient to notice that in-vacuo dispersion amounts to linear relationship between the energy E and a certain ratio between the observation-time difference Δt and the redshift-dependent function D(z)

$$\Delta t = \eta \frac{E}{M_P} D(z) \qquad \text{with} \qquad D(z) = \int_0^z d\zeta \frac{(1+\zeta)}{H_0 \sqrt{\Omega_\Lambda + (1+\zeta)^3 \Omega_m}}$$

Jacob+Piran [JCAP0801,031(2008)]

we can absorb the redshift dependence into an "accordingly rescaled Δt", which we call Δt^*

$$\Delta t^* \equiv \frac{\Delta t}{D(z)}$$

This then affords us the luxury of analysing data in terms of a linear relationship between E and Δt^*

$$\Delta t^* = \eta \frac{E}{M_P}$$

GAC+D'Amico+Rosati +Loret, arXiv1612.02765, NatureAstronomy1,0139
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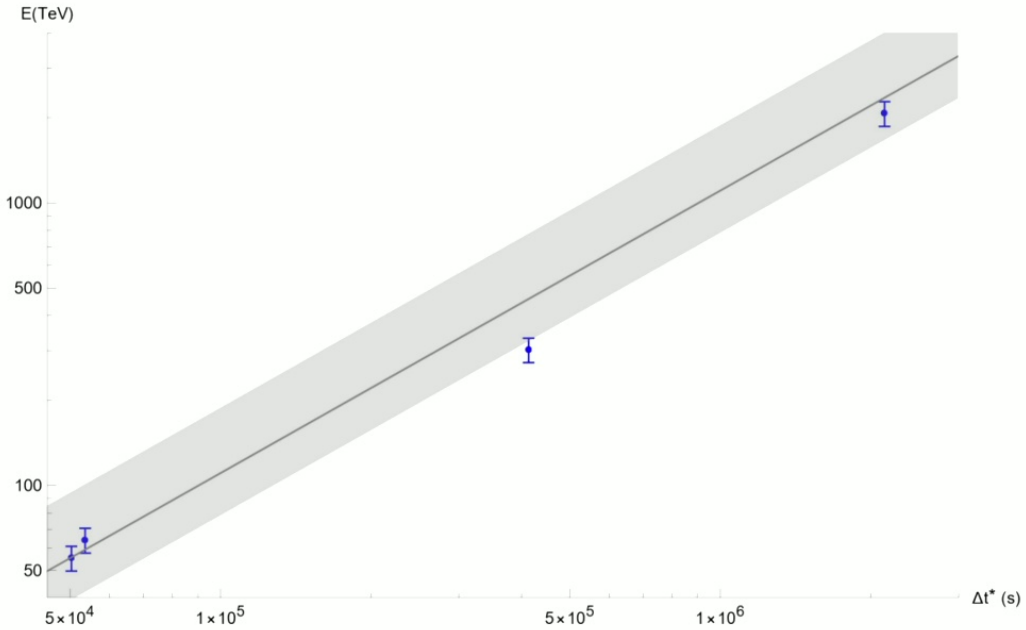


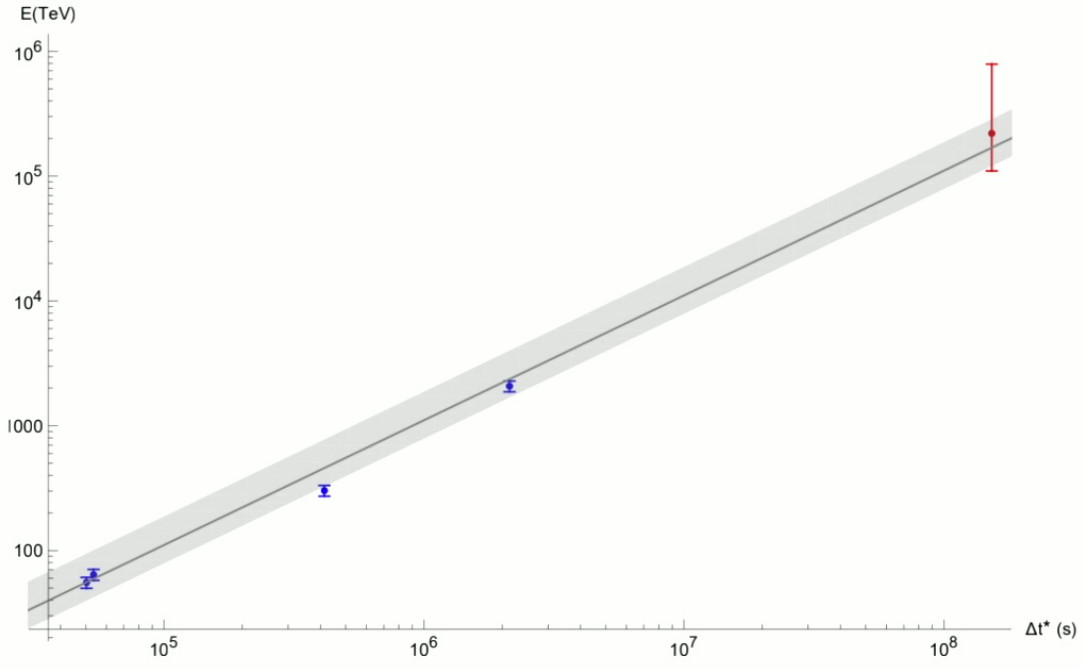
*** background is an issue: one should expect on average 1.2 GRB-neutrino pairs accidentally in good directional agreement and whose observation times are accidentally compatible with the shaded region**

*** but finding 4 "GRB-neutrino candidates" lined up as nicely as in figure is not very likely (should happen accidentally with a probability of only 0.7%)**

first chance of testing the "predictive power" of this picture:
on 12 February 2025 the KM3NeT collaboration reported the observation of the KM3-230213A Neutrino, a truly remarkable neutrino, with energy of ~220PeV (~100 times bigger than previous record)

and KM3-230213A cannot be cosmogenic or atmospheric and also a blazar origin is not plausible…
it would make perfect sense if KM3-230213A was a GRB neutrino, but there is no GRB in good temporal and directional coincidence with KM3-230213A

there is only one GRB directionally compatible with KM3-230213A but it was observed much earlier:



to be continued…

P.S.: on the day when I first met Lee the conversation ended when I pretended to have another meeting (I did not want to abuse too much of his time but it didn't look like he was ever going to tell me he needed to attend to more important matters than talking to someone who just finished his PhD studies)

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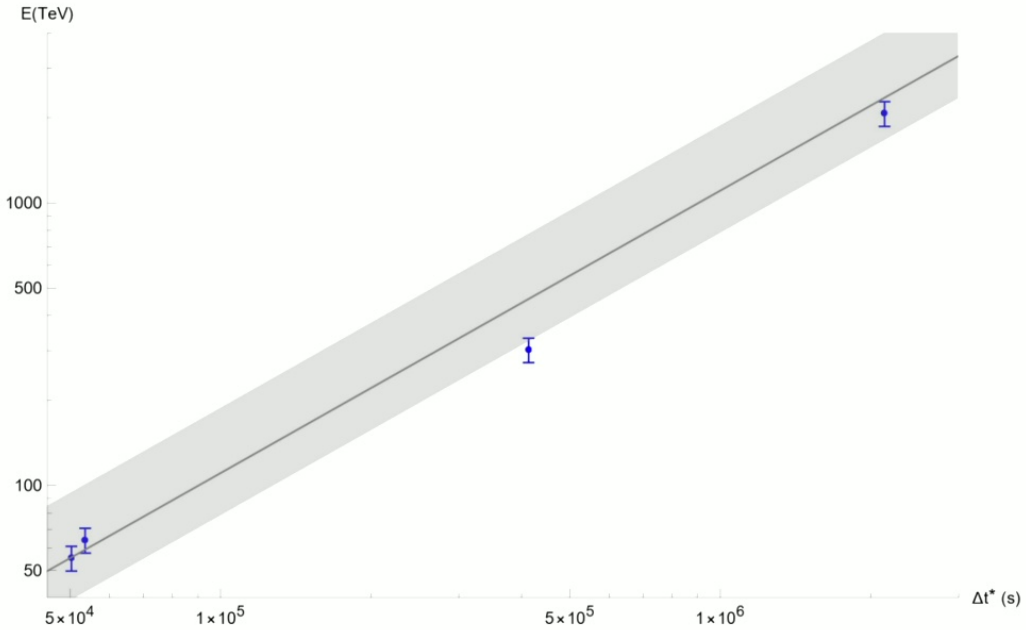

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