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Bounds on Lorentz Invariance Violation

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Short topic overview

- Quantum theory and gravity merge at E_{pl} (≈ 1.22 * 10^28 eV)
  - Lorentz invariance violation
  - Modification of vacuo dispersions relation

- Prediction of effects on much lower scale
  - Effects on:
    - γ-γ pair-production
    - absorption of γ rays
    - time of flight of γ rays (paper)

$$\Delta t = s\frac{n+1}{2}D_n(z)\left(\frac{\Delta E}{E_{\mathrm{QG,n}}}\right)^n.$$

- Linear and quadratic modification possible

$$\eta_1 = s\, E_{\mathrm{Pl}}/E_{\mathrm{QG},1}$$

$$\eta_2 = 10^{-16} \times s\, E^2_{\mathrm{Pl}}/E^2_{\mathrm{QG},2},$$

- No variation at $\eta = 0$ (null hypothesis)

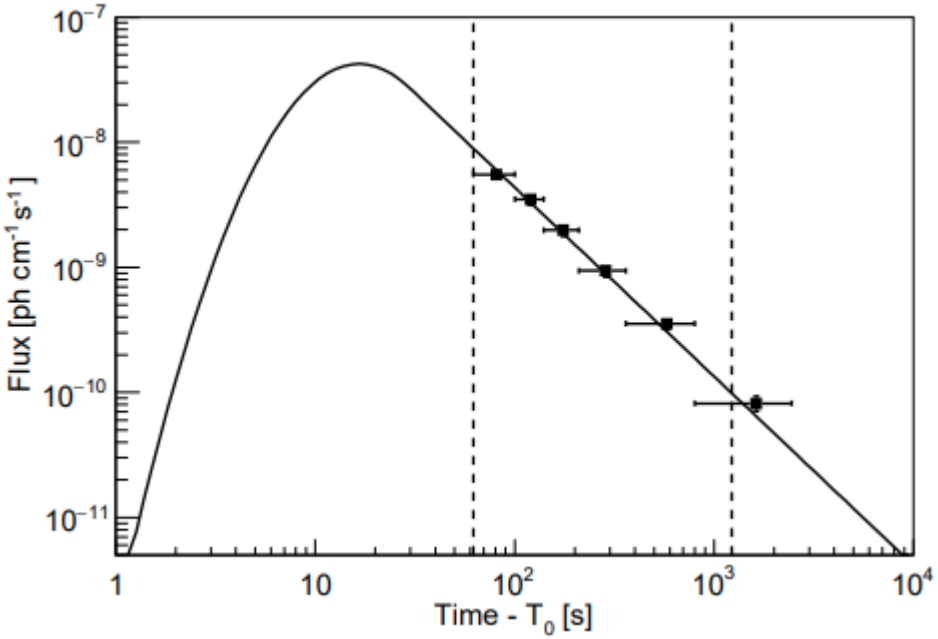
- Observations on
  - Gamma ray bursts (GRB, paper)
  - active galactic nucleuses
  - Crab pulsar

- MAGIC (Cherenkov telescopes) detection of a GRB
  - GRB 190114C: January 14, 2019 at 20:57:03 UTC
  - E = 0.3 – 1 TeV

Problems

- Very high Energy γ rays get absorbed by the extragalactic background light
  - observed spectrum softer than intrinsic one

- Measurements are a smooth power law
  - energy-dependent time delay can make problems
  - Model needed for maximum likehood
    - minimal approach
    - theoretical approach (based on multiwavelength observation)


10^{-7}
10^{-8}
10^{-9}
10^{-10}
10^{-11}
Flux [ph cm^{-1}s^{-1}]
1
10
10^{2}
10^{3}
10^{4}
Time - T_0 [s]

Results

- Minimal Approach theoretical model doesn’t suggest a time delay
  - Comparable to the null hyposis
- Linear modification of the photon dispersion relation factor 4 lower than most constraining lower limits from other TOF methods
- quadratic case more sensitive to the highest photon energies

forward looking

- Observed GRB was featureless
  - ➢ Observations of feature-rich (VHE) GRB could be more promising
    - would enhance the analysis sensitivity to LIV effects

- Observations of AGN's and Crab pulsars could also result in other results