Extragalactic TeV Photons and the Zero-Point Vibration Spectrum Limit

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1. Introduction

Very-high-energy (VHE) photons, $E_\gamma > 100$ GeV, are recorded by ground-based observatory facilities, clusters of atmospheric Cherenkov telescopes, etc. Extragalactic sources of VHE photons are active galactic nuclei, such as blazars (Markarian 501 [1], quasar 3C 279 [2]), while within the Galaxy VHE photons are produced, for instance, by the Crab Nebular pulsar (2 kpc; E_γ over 100 TeV). The LHAASO observatory reported photons with energies of 1...1.4 PeV; it is possible that some of these quanta came from outside the Galaxy [3].

The universe is not entirely transparent to such hard photons, as they are absorbed by the extragalactic background light (EBL, which includes also photons with energies $E_b = 0.01\ldots4$ eV in addition to the cosmic microwave background radiation, CMB) through the electron-positron pair production. The threshold depends on the electron mass m_e, $E_\gamma E_b > m_e^2$, Brightness of VEH-sources (and limiting energies E_γ) increase dramatically during ***flares***.

Let us consider three sources of VHE photons, with their redshift z, distance L, and energy limit E_γ; the distance is estimated via the expression (we assume the linear expansion model $a(t) \propto t$) $L = c\, t_0\, z/(1+z)$, or

L[Mpc] $= 4283\, z/(1+z)$ (that is, we use $H_0 = t_0^{-1} = 70$ km s^{-1} Mpc^{-1}):

- ⊛[a] the Mkn 501 blazar [1] (HEGRA) $z = 0.0336$, $L = 140$ Mpc, $E_\gamma = 20$ TeV;
- ⊛[b] the 3C 279 radio-quasar [2] (MAGIC) $z = 0.536$, $L = 1.495$ Gpc, 2 $E_\gamma = 0.3\ldots0.5$ TeV;
- ⊛[c] GRB 221009A [4,5] (LHAASO/Carpet-2) $z = 0.1505$, $L = 560$ Mpc, $E_\gamma = 18$ TeV/251 TeV.

2. TeV gamma-ray crisis?

The gamma-ray burst (GRB) of October 9th, 2022, had a record-breaking brightness; details on the Carpet-2 facility recording a 251 TeV photon were reported at the workshops of the Theoretical Physics Department of the Institute for Nuclear Research (S. Troitskiy, V. Romanenko)[(1)] [4, 5]. Figure shows the mean free pathh of VHE photons along with the spectra of the EBL and the Mkn 501 blazar taken from [1].

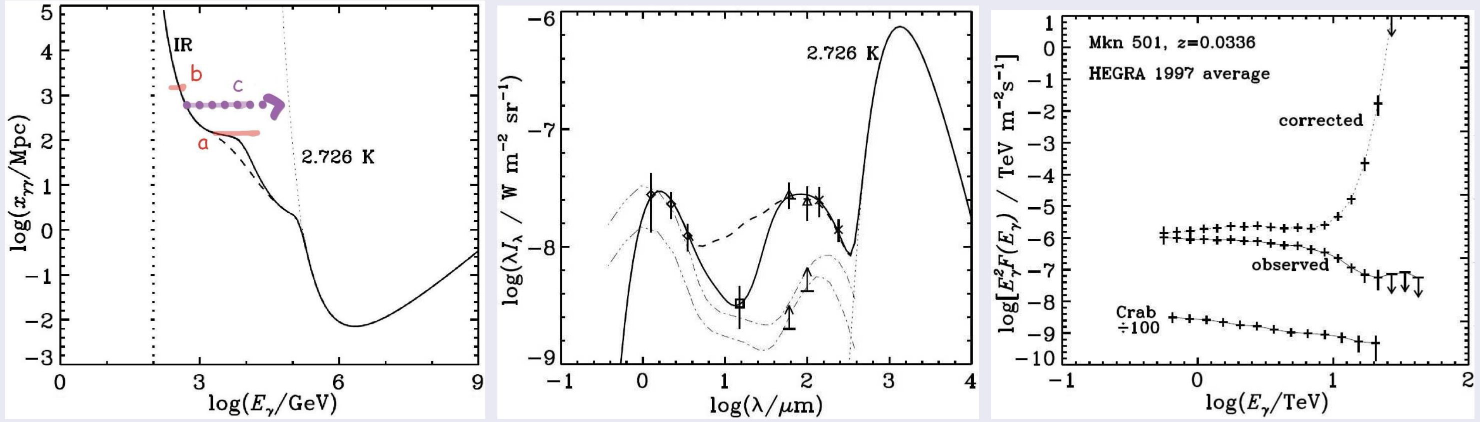

Figure: Mean free path of VHE photons; the EBL spectrum and the Mkn 501 spectrum correction [1].

New measurements are being made, the spectra of background light (EBL) and Tev sources are being discussed; however, many authors believe that the extragalactic background light (EBL) is anomously transparent for TeV photons, cf. Figure (the corrected Mkn 501 spectrum), and that explaining the anomaly requires a certain new physics [1–6] (such as axion-like particles [3] or models violating the Lorentz invariance [6]).

It is simpler, however, to connect this anomaly to a manifestation of the zero-point vibration spectrum limit U_{ZV}. We assume that the ZV-ensemble is isotropic in the reference system, where the CMB radiation is isotropic (up to $\sim 10^{-5}$, or $v \sim \pm$ 3 km/s) as well.

(1) There are some problems with this photon: the proximity of the Galactic disk and the presence of 2–3 marginal muons [4].

3. The limit of zero-point vibration (ZV) spectrum[2]

An unstable particle (with a lifetime τ_0), whose decay is associated with ZVs of the energy scale U_0, when moving relative to the ZV + CMB "ether" with the Lorentz factor γ_e will sense this ZV spectrum boundary (i. e., the ZVs decreasing in the backward direction) and will live some longer than mere $\gamma_e \tau_0$, if $U_0 > U_{ZV}/(2\gamma_e)$.

The 16 TeV and 0.3 eV photons form e^+e^- pairs in a zero-momentum frame with the factor $\gamma_e = 0.5\sqrt{E_\gamma/E_b} \approx 3.7{\cdot}10^6$, and the required ZV energy is about $U_0 \approx 10^6$ eV (the pair mass).

If we assume that the ZV anomaly is already in effect, then an estimate is possible:

$$U_{ZV} \approx 2\gamma_e U_0 \approx 7.4\ \text{TeV}.$$

It would be interesting to measure the anomalous increase in lifetime (compared to $\gamma\tau_0$) for particles featuring β-decay; given that $U_0^{(\beta)} \approx 80$ GeV (the W$^\pm$-boson mass), it is possible to estimate the Lorentz factor of the anomaly onset:

$$\gamma_e^{(\beta)} = U_{ZV}/(2U_0^{(\beta)}) \approx 46.$$

In addition to muons (VEPP-4/5)[3], $\beta^\pm$-decaying nuclides, such as ^{3}H (τ_{β^-}=12.3 y) and ^{7}Be (τ_{β^+}= 53 d) are of special interest; (u,d)-quarks already have Lorentz factors γ_q about 35…70 in their nucleons, and this feature is very significant[4].

It is generally accepted that the ZV spectrum is extended till the Plack energy. There exists, however, a 5D theory [7] in which the Planck length λ_{Pl} is a composite quantity that does not correspond to any characteristic scale, and where gravity does not have to be quantized.

(2) It is hardly possible to stretch such a good thing as zero vibrations to infinity.
(3) The $\mu^\pm$-collider idea (Budker, Skrinsky, etc.) is advancing somewhat, see MICE.iit.edu.
(4) For the bottle-beam neutron anomaly, see arXiv: 1812.00626, the velocity of thermal neutrons v_{beam} is too low; but bottle-neutrons often come in contact with the wall nucleons (protons), while their d-quark velocities ('relativism') can decrease – as can the lifetime.

4. Periodic (annual) changes in beta decay rates

Several experiments yielded evidence for the variability of beta decay rates (a number of nuclides was involed) [8]; the amplitude of annual oscillations is of the order 10^{-3}, or 0.1%. The situation is still a way controversial because environmental influences could be in effect as well [8].

The Earth orbital velocity is about 30 km/s, and it adds to or subtracts from the Sun velocity relative to the CMB, $v_\odot \approx 368$ km/s; this corresponds to annual disturbances of quarks Lorentz factor $\gamma_q(1.001 \pm 10^{-4})$ – quite a small variation.

Perhaps for the τ-anomaly of scale ~0.1, it is sufficient to accelerate tritons to moderate speeds, v/c ~0.1 (i.e., triton momentum about 0.3 GeV).

5. References

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