TIME STRETCHING OF THE GEV EMISSION OF GRBS: FERMI LAT DATA VS GEOMETRICAL MODEL

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Numerous observations confirm that the high energy ($> 100\,\mathrm{MeV}$) emission of gamma ray bursts is delayed with respect to the low energy emission. However, the difference of light curves in various high energy bands has not been studied properly.

In this paper we consider all the bursts observed by Fermi-LAT since 2008 August 4 to 2011 August 1, for which at least 10 events with energies $1\,\mathrm{GeV}$ or higher were observed. There are 4 of them: 080916C, 090510, 090902B, and 090926A. We study their light curves in two bands, $(100\,\mathrm{MeV}, 1\,\mathrm{GeV})$ and $(1\,\mathrm{GeV}, 300\,\mathrm{GeV})$. The Kolmogorov-Smirnov test is used to check whether the light curves for these two bands are the same. No significant difference was found for 080916C and 090510. However, we observed with statistical significance of 3.3σ, that the higher energy light curve of 090926A is stretched with respect to the lower-energy one, and with statistical significance of 2.2σ, that the lower energy light curve of 090902B is stretched with respect to the higher-energy one.

We suggest a simple geometrical model to explain this result. The main assumption is the jet opening angle dependence on radiation energy – the most energetic photons are emitted near the axis of the jet. We also assume that all bursts are the same in their reference frames (that is their light curves differ because of different redshifts and off-axis angles). To test this model, we compute the total energy of the burst, and confirm that it is below the constraint. We also compute the fraction of observable bursts in $(100\,\mathrm{MeV}, 1\,\mathrm{GeV})$ band, which can also be observed in higher energies. This fraction matches the observations. Finally, we predict the distribution of observable stretching factors, which may be tested in the future when more observational data will be available.

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1. INTRODUCTION

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For the purposes of this review, by anomalies one can understand violations of the Ehrenfest theorem according to which all matrix elements of the classical equations of motion (considered as operators) vanish. Thus, anomaly is established if we find, for example, a nonvanishing matrix element of the Dirac equation for a charged particle:

$$\langle\bar{\psi}(\hat{D}+im)\psi\rangle \;\neq\; 0, \tag{1}$$

where $\hat{D} = \gamma_\mu D_\mu$ and D_μ is the covariant derivative and m is the mass of the charged particle.

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1. M. Ackermann, M. Ajello, K. Asano, M. Axelsson, L. Baldini, *et al.*, Astrophys.J.Suppl. **209**, 11 (2013), 1303.2908.

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ВРЕМЕННОЕ РАСТЯЖЕНИЕ ГЭВ ИЗЛУЧЕНИЯ ГАММА-ВСПЛЕСКОВ: FERMI LAT И ГЕОМЕТРИЧЕСКАЯ МОДЕЛЬ

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Наблюдения показывают, что излучение гамма-всплесков с энергией выше 100 МэВ систематически наблюдается позже, чем низкоэнергичное излучение. Различия же кривых блеска в различных диапазонах высокоэнергичного излучения (> 100 МэВ) изучены хуже.

В данной работе мы изучаем различия кривых блеска в диапазонах (100 МэВ, 1 ГэВ) и (1 ГэВ, 300 ГэВ). Для исследования выбраны все 4 гамма-всплеска из каталога Fermi, наблюдения которых содержат не менее 10 фотонов с энергией > 1 ГэВ: 080916C, 090510, 090902B, 090926A. Кривые блеска 080916C и 090510 в двух рассматриваемых диапазонах не различаются статистически значимо, однако для 090926A установлено со статистической значимостью 3.3σ, что излучение в диапазоне (1 ГэВ, 300 ГэВ) растянуто относительно менее энергичного, также для 090902B установлено со статистической значимостью 2.2σ, что излучение в диапазоне (100 МэВ, 1 ГэВ) растянуто относительно более энергичного.

Мы предлагаем простую геометрическую модель, объясняющую этот результат. Основное предположение – чем выше энергия излучения, тем ближе к оси джета оно излучается. Мы также предполагаем, что все всплески одинаковы в собственной системе отсчета (то есть, различия кривых блеска объясняются исключительно разницей в красном смещении и углом наблюдения). В рамках модели соблюдается ограничение на максимально допустимую энергию всплеска. Также получена доля всплесков среди наблюдаемых в диапазоне (100 МэВ, 1 ГэВ), которые также можно увидеть в диапазоне (1 ГэВ, 300 ГэВ). Полученная доля согласуется с наблюдениями. Наконец, предсказано распределение коэффициентов растяжения, которое может быть проверено по мере накопления наблюдений.

Figure captions

Fig. 1. Model Overview. Here the red and the blue cones represent the volumes through which low and high energy plasma propagates. In case depicted the observer's off-axis angle is smaller than the opening angle of the low energy jet, so, due to the relativistic beaming effect, the most of the observable low energy photons will travel along the straight line from the central engine. Also, the observer's off-axis angle is larger that the opening angle of the high energy jet, so the high energy radiation will still originate near the center of the jet (because it is the only place where there are high energy radiators). The observation time of a photon is a sum of two things: the time interval spent in plasma as a radiator (which approximately equals to the distance from the central engine to the point of emission); and the time interval from emission to detection (which is the distance from the point of emission to the observer's location). Given a position of the shock front, this sum is larger for high energy photons. Because of that, high energy emission will be observed later throughout the burst duration, therefore the high energy light curve will be stretched.

Fig. 2. Imaginary part of the anomalous triangle graph. The intermediate fermions are on mass shell. (The signs are the same as in Fig. 1)

Fig. 3. Three-body intermediate state in the imaginary part. (The signs are the same as in Fig. 1)

Fig. 4. Radiative correction to the two-body contribution to the imaginary part. (The signs are the same as in Fig. 1)

Fig. 5. Graphic representation of the Banks–Casher evaluation of the quark condensate $\langle \bar{q}q \rangle$. Dashed lines with crosses represent external (vacuum) gluonic fields.

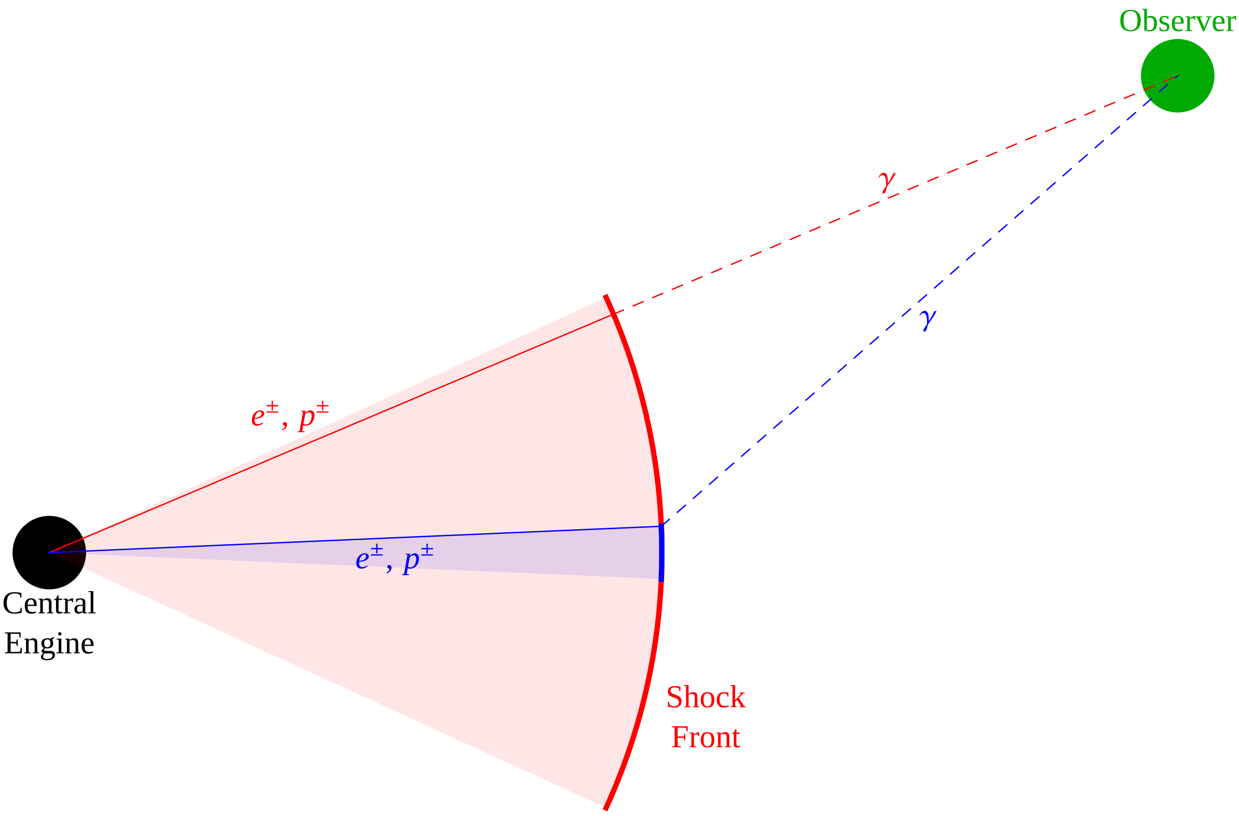

Figure 1. Piskunov, Fig. 1