New type of long GRBs with additional maxima on the temporal profiles in the high energy gamma-band

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Abstract. In the presented work the results of GRBs temporal profiles analysis in the high energy gamma-band are discussed. Now GRBs high energy gamma-emission was observed both during short and long bursts mostly by detectors onboard Fermi and Agile satellites. The duration of such emission is more than some hundreds seconds and sufficiently longer than \( t_{90} \) in the low energy band. But usually the maximum of high energy emission is in the \( t_{90} \) intervals. However, the investigation of GRBs temporal profiles in the region \( E > 100 \text{ MeV} \) have shown the opportunity of new burst type separation. In the difference of usual GRBs, temporal profiles of new type of bursts in the high energy gamma-band have several characteristic features. For example, GRB090323, GRB090328 and GRB090626 temporal profiles have additional maxima after low energy \( t_{90} \) intervals finished. These bursts temporal profile analysis have shown that faint peaks in low energy bands close to the ends of low energy \( t_{90} \) intervals preceded these additional maxima. The analogues features were separated during some other GRBs by the results of preliminary data analysis, for example, GRB110721A and GRB100724B. We suppose that these GRBs could be considered as different GRB type. The temporal profiles and spectra characteristic properties of new type of bursts are discussed in this article.

1. Introduction
Gamma-quanta with energies \( E_\gamma > 20 \text{ MeV} \) were first registered during GRB in satellite experiment onboard the Compton Gamma Ray Observatory (CGRO) in 1991 [1]. Four experiments onboard CGRO: BATSE, OSSE, COMPTEL and EGRET [2] provided the widest energy range of 10 KeV – 20 GeV. Some tens of events were simultaneously observed by all detectors onboard CGRO [3]. CGRO operated since April 1991 up to June 2000. After CGRO GRBs observations in the energy band 0.1-260 MeV provided by AVS-F apparatus [4, 5] onboard Russian satellite CORONAS-F (NORAD catalogue number 26873, ID 2001-032A) operated during the period from July 31, 2001 to December 6, 2005. Now GRBs high energy emission could be registered in satellite experiment AGILE [6] and Fermi [7] (operated since April, 2007 and June, 2008 correspondingly). The gamma-ray imaging detector (GRID) allows bursts observation in the energy band 30 MeV – 30 GeV. Some tens of GRBs were registered by AGILE and several percents of detected events had high-energy component.

Fermi gamma-ray observatory registered approximately 920 identified GRBs since 2008 July using GBM and 27 GRBs using LAT. The highest energy of photons was registered during GRB 090902B and it was \( \sim 33 \text{ GeV} \) [8]. Several tens of bursts were registered by AGILE but only several percents of these events had high energy \( \gamma \)-component [9].
Extended high energy $\gamma$-emission up to some hundreds of seconds was observed during several bursts both short (for example, GRB 090510) and long (in particular, GRB 090926) by Fermi/LAT [10]. The duration of the extended component was some tens time longer than duration of bursts [11]. It was not any correlation between GRB duration $t_{90}$ in the low energy band and lasting of high energy component according to preliminary data analysis. The examples of temporal profiles of GRBs with extended high energy emission on Fermi data are presented at the Figure 1. Also several GRBs with extended high energy $\gamma$-emission were registered by AGILE [12]. Usually high energy $\gamma$-emission during long GRB registered some later than low energy trigger, but in several cases some observed before GRB and could be interpreted as high energy precursors [11, 13].

Figure 1. The temporal profiles of GRB080825C, GRB090510 and GRB090902B by: (a) Fermi/LAT data (adopted from [10]) and (b) Fermi/GBM data. The arrows have shown $t_{90}$ on GBM data.

2. The new type of long GRB with high energy $\gamma$-emission

As it was mentioned in the previous section, usually high energy $\gamma$-emission during long GRB registered some later than low energy trigger and lasts several hundreds of seconds, but its maxima are within low energy $t_{90}$ intervals. However, in contradiction to other GRB, there were additional maxima on the temporal profiles of GRB090323, GRB090328 GRB090626 and GRB091031 in high energy band located outside low energy $t_{90}$ intervals – see figure 2. Faint peaks in the low energy band located close to the end of $t_{90}$ intervals according to NaI detectors data preceded high energy maxima for such bursts. According to the preliminary results of temporal profile analysis, the whole duration of the high energy $\gamma$-component and its peak position during such events don’t depend from characteristics of temporal profiles in low energy band. We suppose that these bursts could be separated as different GRB type. For comparison the temporal profiles of long GRB090926A at the figure 1 are presented.

Usually GRBs spectra (both time resolved and time integrated) are well described by two-component Band function in the low energy region – see, for example, [14], where first component is proportional to combination of power law with index $\alpha$ and exponential cutoff defined by $E_{\text{break}} = E_{\text{peak}} = (2+\alpha)$ and second one is proportional to power law with index $\beta$. The results of time-resolved GRBs spectroscopy investigation give us dependences of Band function parameter $\beta$ on time [15] for 17 GRB registered simultaneously by GBM and LAT. The detailed analysis of behavior of these dependences have shown that for GRB090323, GRB090328 and GRB090626 parameter $\beta$ was
approximately constant during analyzed events and is in the region -2.3 - -2.6 taking into account error boxes – see Figure 3a. Such behavior is quite different from usual GRB, most of which appear significant variations of the parameter $\beta$ with time according to the results of preliminary data analysis – see Figure 3b. Thus, the results of detailed spectral analysis give us additional evidences to consider GRB090323, GRB090328 and GRB090626 as new subclass of long burst with extended high energy $\gamma$-emission. GRB091031 energy spectrum is analyzed now but $\beta$ = -2.34 (+0.19/-0.31) [16].

Figure 2. The temporal profiles of GRB090323, GRB090328, GRB090626 and GRB091031 by Fermi/LAT data (adopted from [10]) and Fermi/GBM data. The arrows have shown $t_{90}$ on GBM data.
3. Conclusion

The results of low energy spectral index $\beta$ and temporal profiles behavior detailed analysis of GRB090323, GRB090328, GRB090626 and GRB091031 have shown that several characteristics of these events sufficiently differ from ones of other long GRBs with extended high energy $\gamma$-emission. In contradiction to other bursts, these events temporal profiles have additional maxima after low energy $t_{90}$ intervals finished. These maxima preceded of faint peaks in low energy bands close to the ends of $t_{90}$ intervals in low energy bands. Moreover, the behavior of low energy spectral index $\beta$ for these events is quite different from usual GRB according to the results of preliminary data analysis. The discussed properties of these bursts provide several opportunities to conclude that GRB090323, GRB090328 GRB090626 and GRB091031 could considered as new subclass of long burst with extended high energy $\gamma$-emission.

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