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GRB without hard to soft evolution and their high energy emission

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Abstract: Spectral properties of some GRB with presence of high energy component within RHESSI, HETE and SWIFT t_{90} intervals are discussed. In some cases the temporal profiles of GRB in low and high energy bands are similar but in some cases they are different and maxima are not coincided. We found the same type GRB in CGRO database too – for example, GRB930131. Moreover, for some GRB from CGRO and AVS-F database in which spectra contradict Band model high energy component are present the hard to soft spectral evolution is absent – for example, for GRB930506 (t_{90}=22.144 ± 0.091) E_{peak} on burst begin less than E_{peak} during other burst parts - E_{peak}(1-3s)=540 ± 58 keV, E_{peak}(3-7s)=1064 ± 38 keV, E_{peak}(7-23s)=850 ± 32 keV, and according to one of fits last spectrum is the hardest during burst. All GRB with such properties are long GRB for standard BATSE and other classifications including taking into account burst hardness ones. We suppose that such type GRB consist a new subgroup of long GRB.

Typical GRB spectra

The analysis of gamma-ray burst spectral evolution give some trends that may constrain the emission mechanisms. Some works on spectral evolution used GRB "hardness", defined by the ratio between two detector channels or with more physical variables such as the spectral break or peak power energy E_{peak} [1], which is the maximum of $E \times F_n$, where E is photon energy and F_n is the specific energy flux. Such hardness parameters were typically decreasing monotonically while the flux rises and falls [2] or their behavior correspond to flux temporal profile one [3]. Moreover, for most part of GRB E_{peak} decay exponentially in bright, long, smooth BATSE GRB pulses as a function of photon fluence F [4]. Usually GRB spectra (both time resolved and time integrated) are well described by two-component Band function [5]:

$$f(E) = \begin{cases} A\left(\frac{E}{100}\right)^{\alpha} \exp\left(\frac{-E(2+\alpha)}{E_{peak}}\right), & E < \frac{(\alpha-\beta)E_{peak}}{2+\alpha} \\ A\left(\frac{(\alpha-\beta)E_{peak}}{100(2+\alpha)}\right)^{\alpha-\beta} \exp(\beta-\alpha)\left(\frac{E}{100}\right)^{\beta}, & E \geq \frac{(\alpha-\beta)E_{peak}}{2+\alpha} \end{cases},$$

where first component proportional to combination of power law with index α and exponential cutoff

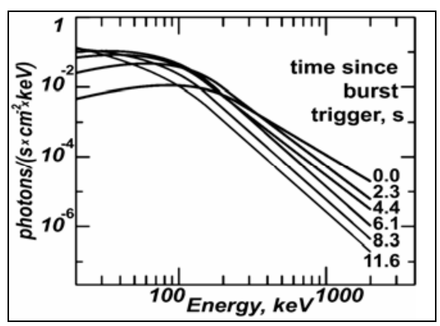

Figure 1: GRB spectral evolution for GRB910927.

defined by $E_{break}=E_{peak}/(2+\alpha)$ and second component is proportional to power law with index β. Typical spectral evolution during GRB is shown at Figure 1. Hard to soft and hardness-intensity correlations are presented for most part of GRB, power law indexes in Band model decrease to GRB end. The observed values and variability of all three parameters of Band function of typical GRB give the limitations on theoretical models of GRB sources. For example, many models of the spectral break require α to stay constant (e.g., self-absorption) or to have negative values (e.g., fireball models). Studying GRB with atypical spectral features allows us to make some conclusions about GRB source models too.

GRB with high energy tails

GRB with presence of high energy component (more than some MeV) in spectra were found in 1991 by common analysis of CGRO data. There were 4 experiments onboard CGRO: BATSE, COMPTEL, OSSE and EGRET [6]. Each experiment consists of different type detectors, some of them have been functioned as temporal profile ones. Some tens GRB were detected simultaneously by all these detectors [7] and the widest energy range for gamma emission registration on satellite experiment for the some GRB is ~10 keV ÷ ~20 GeV. One typical example of GRB with high energy component in spectrum is GRB920622 [8] – see Figure 2. The common structure of these temporal profiles consistent in various

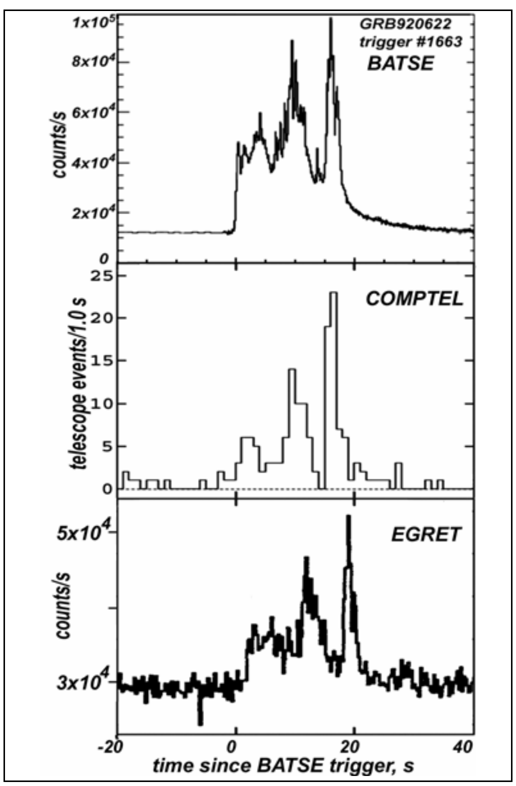

Figure 2: The GRB920622 (BATSE trigger #1663) temporal profiles on BATSE, COMPTEL and EGRET data.

energy bands: the same amount of global peaks on temporal profiles are presented and approximate ratio of relative peak intensity are the same too – first peak has lowest intensity, last peak has highest one. In some GRB spectra the new spectral components not corresponded to Band model were found [9]. GRB 941017 is typical example of such burst (Figure 3). As for GRB920622 the common structure of these GRB temporal profiles are in agreement in various energy bands too. Spectrum of this burst (see Figure 3b) contradicts to Band model in the high energy region. Second components of Band model for GRB941017 spectra in various energy regions are shown as dashed lines at Figure 3b. Approximations

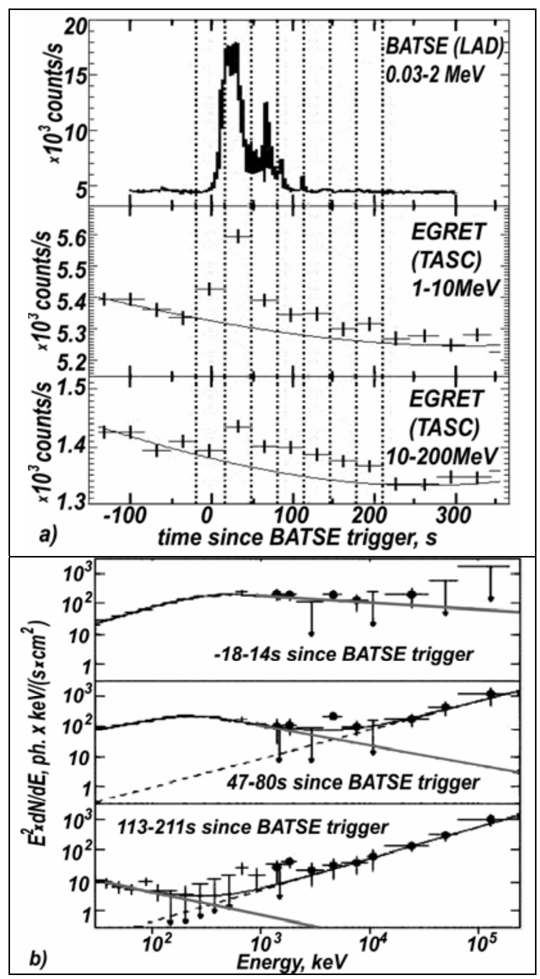

Figure 3: The temporal profiles on BATSE and EGRET data (a) and spectrum (b) of GRB941017 [4].

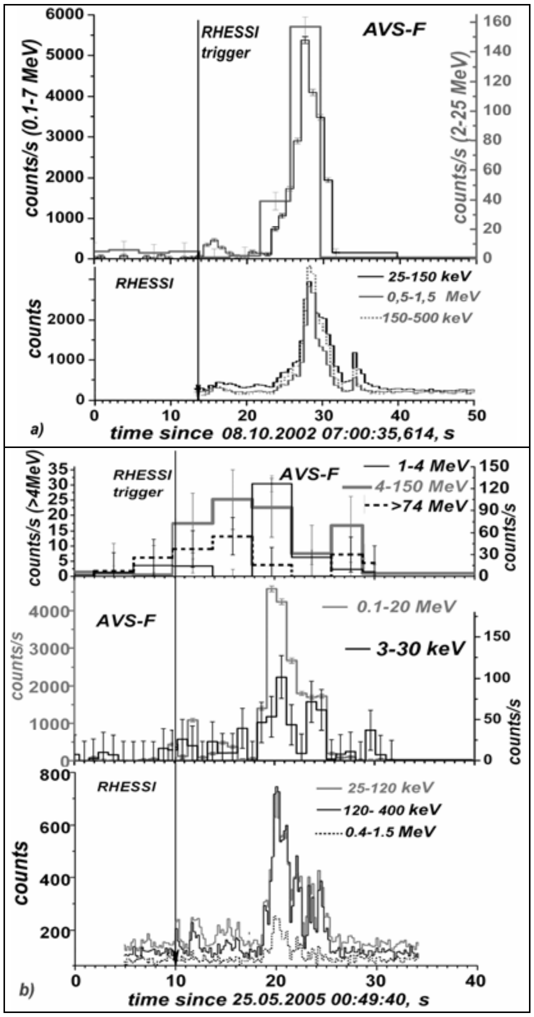

Figure 4: The temporal profiles on AVS-F data [11] and RHESSI ones [12] for GRB021008 (a) and GRB050525 (b).

for high energy part of this burst spectra are shown as grey ones. The difference between these two types of spectral shapes is well seen.

One of the next steps of GRB high energy emission investigation by satellite data started with beginning functionality of Russian satellite CORONAS-F (NORAD catalog number 26873, ID 2001-032A), which operated from July 31 2001 to December 6 2005. AVS-F apparatus onboard this satellite allows us to study GRB in two energy bands – 0.1÷22MeV and 2-260 MeV by data of last flight calibrations with time resolution 1s and 4s correspondingly [10, 11].

One of bursts during which high energy γ- emission

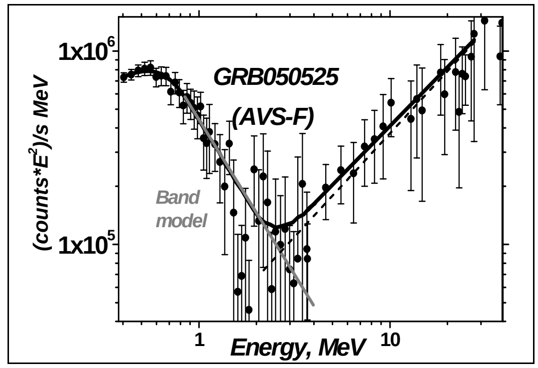

Figure 5: The energy spectrum of GRB 050525 by AVS-F data.

was detected by AVS-F apparatus was GRB021008 (detected by RHESSI at 07:00:50 [12]). For it $t_{90RHESSI} \approx 13$ s, $t_{90AVS} \approx 12$ s in low energy AVS-F band and 8 s in high energy AVS-F band [11].This burst temporal profiles on AVS-F and RHESSI data are shown at figure 4a. As for GRB920622, GRB941017 and some other GRB the common structure of these burst temporal profiles is in agreement in various energy bands. During AVS-F data analysis some GRB with different temporal profiles in various energy bands and with not coincidence of maxima are found. GRB050525 is typical example of such type bursts – see Figure 4b. There are some maxima in GRB050525 temporal profile in low energy band on RHESSI data and one at 20 s has highest intensity. But in high energy band (>4 MeV) and in very low energy band (3-30 keV) temporal profiles of this burst quite different and moments of maximum intensity differ from ones in low energy band. The same is for some EGRET GRB, the summarized spectrum of this burst (see Figure 5) contradict Band model in high energy region too – it's second components of Band model shown as grey line, approximation for high energy part is shown as dashed one. Than we analyze CGRO database and found that some GRB from CGRO database with high energy emission have temporal profiles with different time structure in BATSE and other experiments energy bands too, for example GRB930131 – see Figure 6: there are two peaks both in BATSE and COMPTEL ranges but relative intensities of these peaks maxima $I_1/I_2 \sim 5$ in low energy band (BATSE) and $I_1/I_2 \sim 0.3$ in high energy band (COMPTEL). It seems that these GRB constitute different GRB groups taken into account

Table 1. GRB990123 and GRB930506 spectral properties evolution [9].

GRB	t, s	α	β	E_{peak}, keV
990123	0-33	-0.62±0.01	-2.58±0.06	734±13
typical	33-66	-0.88±0.01	-2.77±0.08	543±10
	1-3	-1.06±0.04	-1.90±0.06	540±58
930506	3-7	-0.89±0.01	-1.84±0.02	1064±38
	7-23	-1.24±0.01	-1.87±0.01	850±32

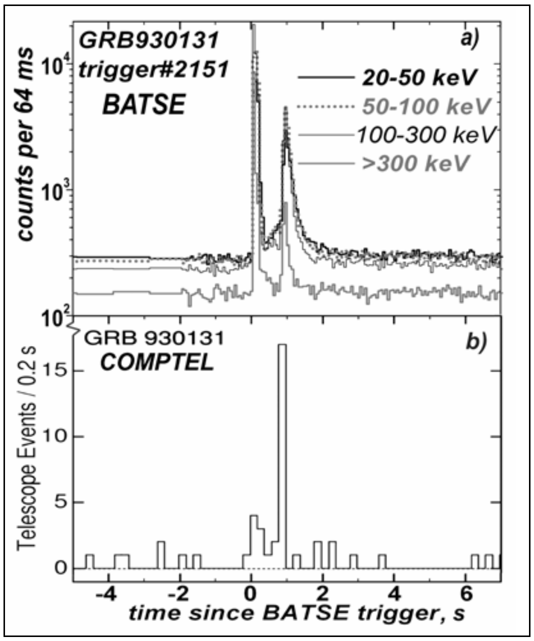

Figure 6: GRB930131 (trigger #2151) temporal profiles on BATSE (a) and COMPTEL (b) data.

that for some this type GRB hard to soft evolution in spectrum is absent. During GRB930506 there is no monotonically decay for E_{peak}, α and β [9, 13]. One of fitted parameters sets in Table 1 is presented: last spectrum is the hardest during the burst. In GRB050525 spectra hard to soft evolution is ill-defined too. In spectra of all GRB without hard to soft evolution the component which contradict Band model in high energy region are present.

Conclusions

Some GRB with presence of high energy component (more than some MeV) within BATSE t_{90} intervals were detected by other experiments onboard CGRO and later such component within RHESSI, HETE and SWIFT ones were detected by AVS-F apparatus onboard CORONAS-F satellite too. In some cases the temporal profiles of GRB in low and high energy bands are similar but in some cases they are different and maxima are not coincide both in CGRO and CORONAS-F databases (for example, GRB930131 and GRB 050525) Moreover, for some GRB in which spectra contradict Band model high energy component are present the hard to soft spectral evolution is absent or ill-defined – for example, for GRB930506 and for GRB050525. There are some difficulties in standard models for explanation such spectrum and temporal profile behavior, so, such GRB can compose new subclass.

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