IL NUOVO CIMENTO Vol. 28 C, N. 3 Maggio-Giugno 2005
DOI 10.1393/ncc/i2005-10060-2

Slow components in the X-ray light curves of Gamma-Ray Bursts(*)

L. Vetere(1)(2), E. Massaro(1), E. Costa(2) and P. Soffitta(2)

(1) *Dipartimento di Fisica, Università La Sapienza - Piazzale A. Moro 2, I-00185 Rome, Italy*
(2) *INAF, IASF - Sezione di Roma - via del Fosso del Cavaliere, I-00113 Rome, Italy*

(ricevuto il 23 Maggio 2005; pubblicato online il 19 Settembre 2005)

Summary. — Gamma-ray burst light curves show quite different patterns: from very simple to extremely complex. For some events the time profile in the 2–5 keV range is characterised by peaks superposed on a slowly evolving pedestal. We describe this behaviour with the presence of two components (slow and fast) having different time scales. The slow component is usually less pronounced in the 5–10 keV and almost disappears at higher energies. We present a time and spectral study of the slow components of several GRBs detected by the Wide Field Cameras on board BeppoSAX. The origin of the slow components is likely different from that of the fast ones and can be related either to the presence of a hot photosphere or to the overlapping of the prompt emission with the initial phase of the afterglow.

PACS 95.85.Nv – X-ray.
PACS 98.70.Rz – γ-ray sources; γ-ray bursts.
PACS 01.30.Cc – Conference proceedings.

1. – Introduction

The shapes of GRBs' light curves are very different: they can be very simple or extremely complex, in particular those showing several peaks and spikes are observed in long duration events. This particular behaviour has been studied many times looking for possible relations between different parameters of the light curve. Using the entire database of the Wide Field Cameras we realized that the light curves of several GRBs seem to be made of two components: a fast and structured emission superposed on a slower and smoother one. We found that 15 GRBs out of 56 (27%) show this pattern, although almost the 20% of all the events in the database are too faint to exclude the presence of this component. In this contribution we present some results of the analysis performed on 11 well structured events.

(*) Paper presented at the "4th Workshop on Gamma-Ray Burst in the Afterglow Era", Rome, October 18-22, 2004.

TABLE I. – *Values of the Hardness Ratios and the spectral indices of the slow component.*

GRB	HR_1	HR_2	HR_3	Γ_1	Γ_2
GRB980515	1.27	1.38	1.76	0.98	0.92
GRB980519	0.6			1.56	
GRB990123	1→1.09	1→0.79	1→0.863	0.97→0.91	0.97→1.14
GRB990704	0.71			1.22	
GRB990705	1.4	1.21	1.7	1.01	1.12
GRB990908	0.86	0.58	0.5	1.27	1.54
GRB000528	2	→ 0.46	→ 0.91	0.65	→ 1.69
GRB001011	0.67			1.45	
GRB001109	0.75			1.21	
GRB010222	0.6			1.39	
GRB010412	0.83			1.12	

2. – Time and spectral modelling of Slow Components

For each burst we produced the light curves in three different energy bands (2–5, 5–10, 10–26 keV) and derived the model for the time evolution of the Slow Component (hereafter SC) in each band. We used a simple analytical expression for the SC time evolution able to represent adequately even asymetric rise and fall of the light curve. This law is combination of a power law with an exponential function and contains only four free parameters:

$$F_s(t) = At^B \exp[Ct^D]. \tag{1}$$

The parameters' values were found by adapting F_s to the local minima of the light curves. The goodness of the result was verified *a posteriori* by comparing at different energies the light curves of the Fast Components (hereafter FC) obtained by subtracting the SC from the original data. In the majority of cases SCs were found quite soft and disappear at high energies, but for about one third of the events SCs grow from 2–5 keV to 5–10 keV and to 10–26 keV. Some examples are given in the next section.

To obtain spectral information we computed the Hardness Ratios (HR) between the counts in the three used energy bands both for the SC that for the FC comparing them with the corresponding values of the original one. We then estimated the corresponding spectral indices Γ by convolving a power law input spectrum with the WFC response matrix in the direction of the burst. We will indicate with HR_1 the HR between 2–5 keV and 5–10 keV energy range, HR_2 the HR between 5–10 keV and 10–26 keV, while HR_3 is computed between 2–5 keV and 10–26 keV. In analogy Γ_1 is the spectral index for 2–5 keV and 5–10 keV energy ranges and Γ_2 for the 5–10 keV and 10–26 keV ranges. In table I are presented the calculated values of the Hardness Ratios and the spectral indices for the SC.

Having verified that the SC is not caused by merging of single pulses increasing their width at lower energies, we then searched for a possible spectral relation between the SC and the initial phase of the afterglow. A more detailed analysis will be presented in another paper (Vetere *et al.* 2005, submitted).

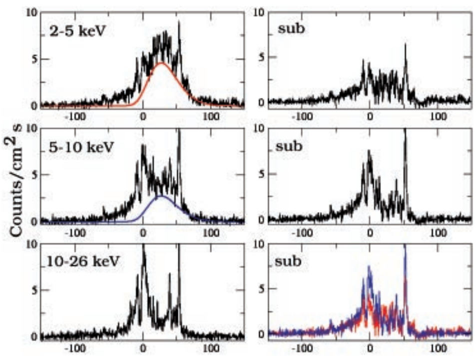

Fig. 1

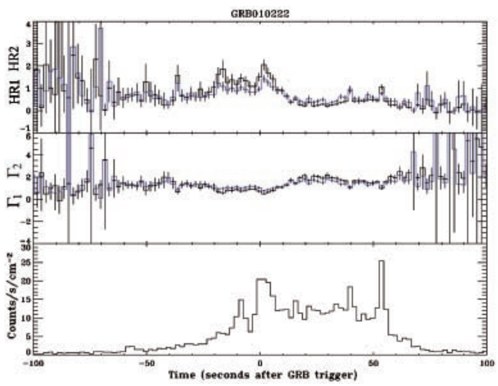

Fig. 2

Fig. 1. – X-ray light curves of GRB010222 in the three considered energy ranges. Left panels show the total counts and the SC model; right panels show the corresponding FCs after the SC subtraction.

Fig. 2. – First panel: evolution of HR_1 and HR_2 for GRB 010222. Second panel: evolution of Γ_1 and Γ_2. The last panel shows the total light curve (FC+SC) in the 2–26 keV energy range

3. – Examples

As stated above the GRB light curves can be divided in two main types characterised by the presence or not of a detectable SC in the highest energy band (10–26 keV). Here we present a case for each type.

3˙1. *GRB010222*. – It is a very strong burst detected by the WFC1 with a redshift $z = 1.477$ [1] and an estimated isotropic energy output $E_{tot} = (154.2 \pm 17) \times 10^{52}$ erg [2]. The 2–5 keV light curve shows several peaks superposed on an evolving SC which decreases at 5–10 keV and seems to disappear at 10–26 keV. SC parameters were estimated from the 2–5 keV light curve, the same function was used to fit the SC at 5–10 keV, leaving free only the normalisation.

The comparison of the light curve at 10–26 keV with the FCs in the other bands shows that they really look alike indicating that the SC was well modelled (fig 1). Photon indices were estimated from the HRs for the total light curve and the SC (fig 2).

3˙2. *GRB990123*. – It is the strongest bursts detected by the WFC with a redshift $z = 1.6$ [3] and an isotropic energy output $E_{tot} = (278.3 \pm 31.5) \times 10^{52}$ erg [2]. Unfortunately the X-ray light curve is not complete because of earth occultation just before the end of the burst The LC at 2–5 keV is characterised by the presence of a SC, but here it is growing at higher energies. The model of eq. (1) was not able to describe well the SC and it was necessary to consider the sum of a couple of functions shifted in time.

4. – Summary and conclusions

Our analysis provided evidence of a SC in the X-ray light curves of some GRBs indicating that their emission is due probably to two different mechanisms: one that produces the higly varying structure and another responsible of the SC, seen in the 27%

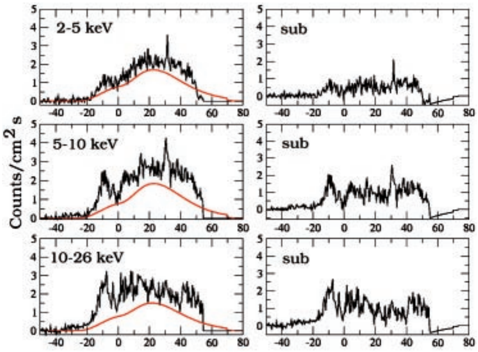

Fig. 3

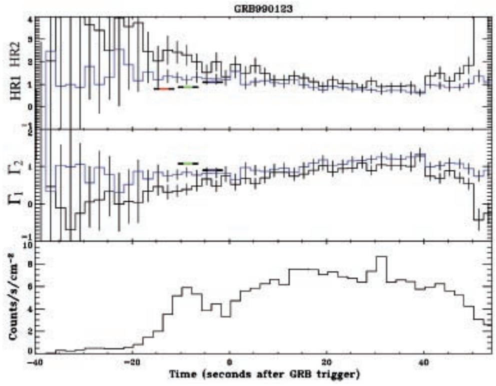

Fig. 4

Fig. 3. – X-ray light curves of GRB990123 in the three considered energy ranges. Left panels show the total counts and the SC model; right panels show the corresponding FCs after the SC subtraction.

Fig. 4. – First panel: evolution of HR_1 and HR_2 The three ticks represent (left from right) the SC's HR_3, HR_2 and HR_1 values. Second panel: evolution of Γ_1 and Γ_2 for GRB 990123, the two ticks represent (left from right) the SC's Γ_2 and Γ_1 values. The last panel shows the total light curve (FC+SC) in the 2–26 keV energy range.

of the events detected by the WFCs. We tried to investigate if this second mechanism could be the initial phase of the afterglow and did not find evidence of a direct relation between the SC spectra and those the afterglows. The latters are usually characterised by a photon index $\Gamma \simeq 2$ while the Γ values of SCs are all smaller (see table I). Note that the Γ values of the all bursts (FC+SC), which are stable in time, seem to set around ~ 2 approaching the end of the bursts. This could be actually the beginning of the afterglow. Moreover, SCs seem to be generally softer than the FCs and likely the spectra are not given by a single power law, as indicated by the different values of Γ_1 and Γ_2 at variance with the afterglow spectra.

REFERENCES

[1] Stanek K. Z., Garvanich P., Jha S. and Pahre M., IAU Circ., No 7586 (2001).
[2] Amati L. *et al.*, *A&A*, **390** (2002) 81.
[3] Kulkarni S. R., Djorgovski S. G., Odewahn S. C. *et al.*, *Nature*, **398** (1999) 389.