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The temporal behaviour of Gamma Ray Bursts and their afterglows from BeppoSAX data

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Abstract. BeppoSAX detected a few GRBs with both GRB Monitor and Wide Field Cameras. Fast follow–up observation of the field with Narrow Field Instruments of SAX and with other X–ray telescopes has allowed for the detection and monitoring of the GRB afterglows. We discuss the temporal behaviour of the two events better studied both in the whole band and in the band where Narrow Field Instruments and Wide Field Cameras overlap.

INTRODUCTION

The nature of Gamma-Ray Burst (GRB) has been the object of many investigations based on the improvement of the amount and quality of data collected in the hard X/soft gamma-ray band and on the quest for counterparts in other wavelengths mainly based on the Inter–Planetary Network positioning. While the first approach has been extremely successful culminating with the outstanding results of BATSE (isotropy and not homogeneity) the second has collected a sequence of results, everyone significant and interesting but somehow deceiving as an ensemble, while not really giving the perception of converging to a result. This difficulty derived from the intrinsically poor positioning capability of available GRB detectors. Instruments based on the comparison of the signal on detectors with different orientation have a resolution that cannot go below a few degrees. Experiments based on the delay of the detections from far away satellites can arrive to the arcminute range but after a long and cumbersome processing of data: in practice all the error boxes have been inspected months or years after the burst. This could only be suitable for steady sources or very slowly decaying transients associated with the GRB.

In the first part of 1997 BeppoSAX has provided the real breakthrough in this domain. BeppoSAX payload is a combination of different instruments [1]. While the telescopes [2,3] probe a narrow field with high sensitivity, performing its observation plan as any regular observatory, the two Wide Field Cameras (40 x 40o at zero response) [4] are continuously monitoring in the 2–30 keV band, with good time and energy resolution, two other regions of the sky. The Gamma-Ray Burst Monitor [5] electronics provide an onboard trigger on suspect GRBs and high temporal resolution recording of data under these trigger conditions. The combination of these two was very effective. On the GRBM trigger time the Science Operation Center looks for an excess in the WFCs ratemeters. If this is found an image is made at time corresponding to this excess. The burst appears as a point source right at that time while other excesses such as scattered solar flare or magnetospheric events is cancelled by the coded mask image reconstruction process.

The peculiarity of having all the instruments onboard BeppoSAX under the same scientific and operation control has allowed for the development of a fast follow-up pointing of the NFIs in the case of serendipitous occurrence of a GRB in the field of view of one of the two Wide Field Cameras. In these cases BeppoSAX can provide 1) a first light curve starting from 10 s before the trigger in the band 40–700 keV. 2) An X-ray light curve (2–30 keV) from long time before the GRB, during it and after, only limited by the sensitivity to the reduced fluxes of the GRB. 3) A light curve with the Narrow Field Instruments of the afterglow source from about 6 hours until it has decayed to levels of the order of $5\ 10^{-14}$ erg/cm^{2}s.

BEPPOSAX RESULTS ON GRBS AND THEIR AFTERGLOWS

Three afterglow sources have been unambiguously detected with this method on GRB970228 [6,7], GRB970402 [8] and GRB970508 [9–11]. In case of GRB970111 [12,13] we only had a marginal detection. In fig.1 we show the light curves of the 4 GRBs for which we have performed a fast follow-up pointing. No obvious dependence of the existence of the afterglow source on the shape of the light curve of the GRB has been found yet. It seems that the bursts with the stronger afterglows have a higher X to γ ratio already during the GRB. Therefore the search for the transition from the burst to its afterglow is a primary target of this investigation.

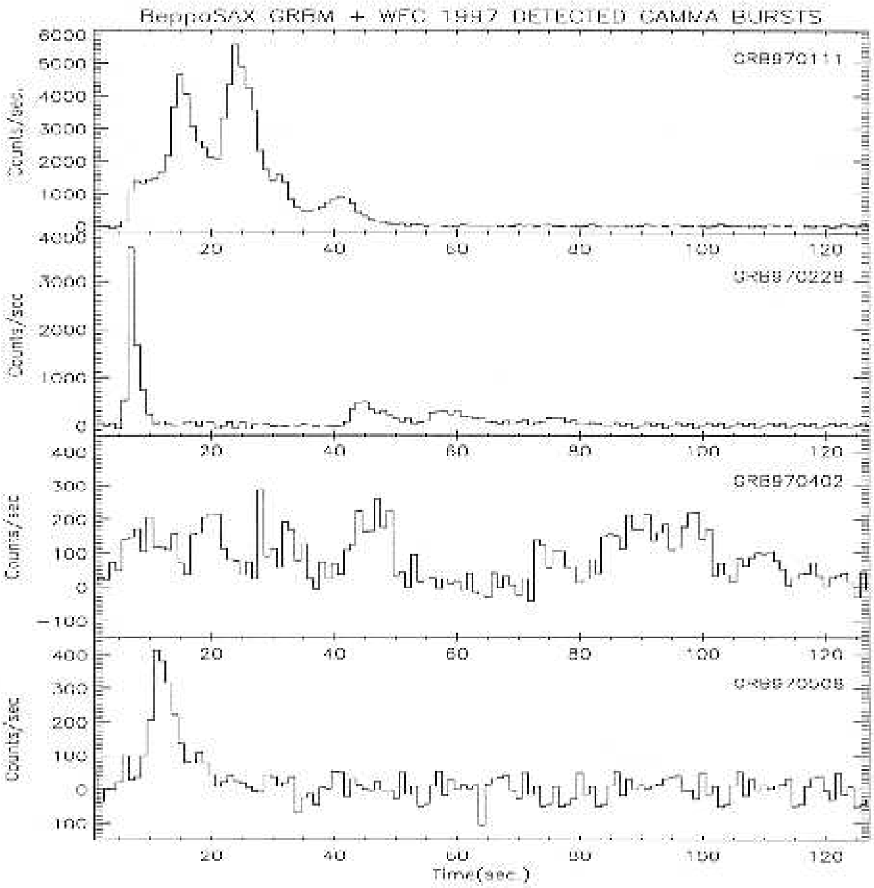

FIGURE 1. Light curves of the four bursts for which a fast NFI pointing was performed

In fig.2 we show the long term temporal behaviour of the two bursts better studied so far. GRB970228 afterglow was detected around 8 hours after the burst [6] and faded during the observation. The source was followed to decay for days by SAX, ASCA and ROSAT following a power law curve. By extrapolating this curve to the time of the GRB we found a value surprisingly consistent with the flux of a train of pulses following the main event and also visible in fig.1. After an interruption of data due to the passage at the South Atlantic Anomaly and the Earth occultation the source is no more detected with WFCs and the upper limit is not much significant with respect to the decay law. Light curve of GRB970508 [11] is less regular. During the first pointing (after 6 hours) the source was varying but not with a monotonic decay. In subsequent pointing, as shown in the fig.2 it decayed with a light curve very far from a power law. This could suggest the existence of a gap between the GRB and its afterglow and possibly a behaviour similar to that of the optical counterpart that peaked two days after the GRB. But in this case data from Wide Field Camera are available up to more than two minutes after the GRB. It is apparent that after the GRB a faint afterglow source is present at levels that can be reasonably connected with those of the subsequent NFI observations. In the present very incomplete picture it seems more likely that the power law is an average trend and the actual light curve can include significant flare activity around this trend. Moreover data on GRB970828 from XTE and ASCA seem to confirm both the continuity of the light curve and the presence of turbulent behaviour.

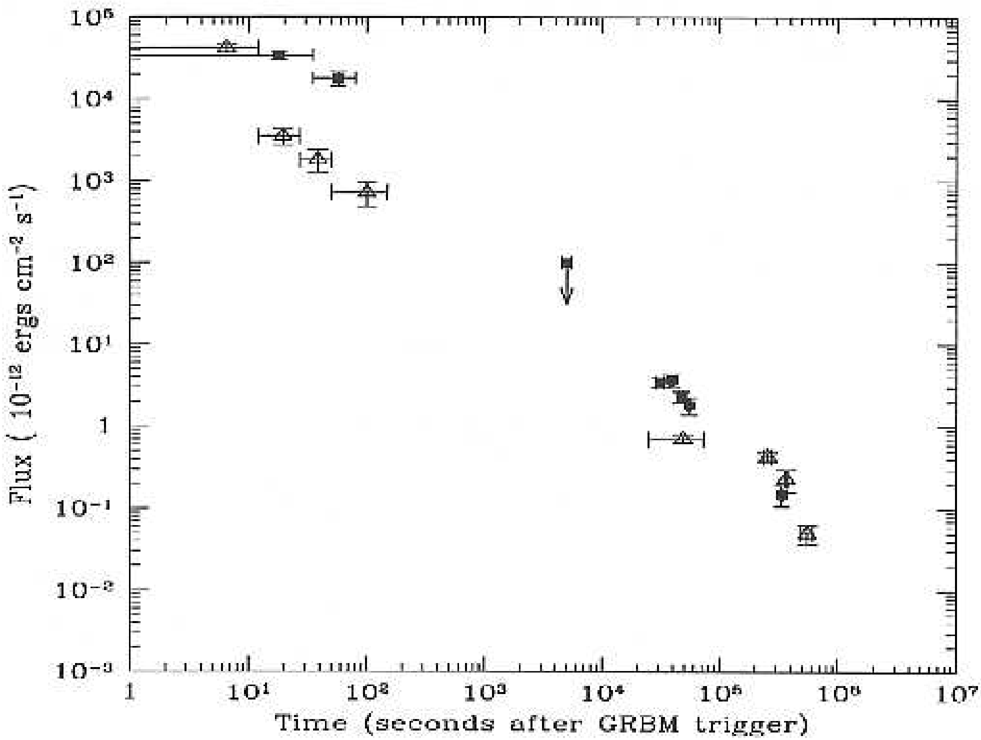

FIGURE 2. GRB970228 X–ray light curves from BeppoSAX Wide Field Cameras and Narrow Field Instrumentsof GRB970228 (squares) and GRB970508 (triangles). For the first part of the burst the average flux is displayed

SOLID RESULTS AND NEW PERSPECTIVES

If we want to resume the main risults of BeppoSAX on GRBs from the point of view of light curves we can state that:

- GRBs may be followed by a X-ray source not detected at the best available sensitivity before the burst, and fading as long as monitored after;
- the afterglow sources decay with a curve fitted by a power law with an exponent ranging from 1.1 to 1.5;
- due to the above functional form the energy content of the afterglow in the 2–10 keV band depends on the unknown part of the light curve. If the X–ray tail of the burst slowly evolves into the afterglow the total energy radiated in the X–ray band is of the same order of the total energy radiated from the GRB in the "conventional" band;
- the decay does not follow the same form for all the GRBs and the flux can show a flaring activity around a template power law curve.

These data still contain a large amount of conjectures. In particular the light curve of the GRB in the first 1–10 minutes is of the highest interest. With the continuous improvement of methods of analysis of faint sources with WFCs, the gap of data between the WFC detection and the NFI pointing is slowly reducing on the low time side. On the other side the possibility to perform faster TOO pointings of the GRB field is presently challenged by the new and slightly slower pointing system based on one gyroscope only. Nevertheless the capability of analyzing quick look data on the existence and on the coordinates of the GRB has significantly improved and will be used to to further reduce delays of TOO pointing of NFIs.

REFERENCES

1. G. Boella, et al., A&A Supp. Ser., **122**, 299-307 (1997)
2. Parmar A.N. et al. 1997, A&AS, 122, 309
3. Boella, G., Chiappetti, L. et al., 1997b, A&AS, 122, 327
4. Jager, R., et al. 1997, A&A Suppl. Ser., **125**, 557
5. F. Frontera, et al., A&A Supp. Ser., **122**, 357-369 (1997)
6. Costa, E. et al. 1997, Nature, 387, 783
7. Frontera, F. et al. 1997, ApJL, in press (astro-ph/9711279)
8. Piro, L. et al. 1997, IAU Circ. 6617
9. Costa, E. et al. 1997, IAUC 6649
10. Piro, L. et al. 1997b, IAUC 6656
11. Piro, L. et al. 1997, A&AL, in press (astro-ph/9710355)
12. Butler, R.C., et al. 1997, IAU Circular n. 6539.
13. M. Feroci, et al., in preparation