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GRANAT/SIGMA observation of GRB 920723 soft gamma-ray afterglow

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Abstract. We present GRANAT/SIGMA observations of the soft gamma-ray afterglow immediately after the bright GRB 920723. After ~ 6 s, the burst light curve makes a smooth transition into an afterglow where flux decays as $t^{-0.7}$ for at least $\sim$1000 s. At least $\sim$20% of main burst energy is emitted in the afterglow. The hardness of the afterglow spectrum corresponds to the power law spectral index ≈ 1, which is significantly softer than the main burst.

Key words: gamma-rays: bursts

1. Introduction

Fast and accurate localizations of gamma-ray bursts by *Beppo*SAX helped to establish the connection of GRB with the decaying X-ray, optical, and radio sources. These observations are well explained by the relativistic fireball model (e.g. Sari et al. 1998). The fireball observations immediately after the burst, when the Lorenz factor, temperature and density are at maximum, are of great interest. Unfortunately, afterglows observations earlier than ≈ 10 hours after the burst were impossible.

We present GRANAT/SIGMA observation of the GRB 920723 light curve revealing a soft gamma-ray afterglow with flux decaying as a power law $\sim t^{-0.7}$ which starts immediately after the main burst and lasts for at least 1000 s.

2. Observations

SIGMA is the coded-mask telescope operating in the $35-1300$ keV energy band (Paul et al. 1991). The main field of view is $11.4^\circ \times 10.5^\circ$, but some fraction of gamma-rays from sources within $\sim 35^\circ$ to the pointing direction reaches the detector through the gaps in the passive shield and produces arc-shaped images. This "secondary optics" was described in detail by Claret et al. (1994a).

Gamma-ray burst GRB 920723 was observed by SIGMA through the secondary optics. The burst lasted for $\approx$ 6 s. The peak count rate in the $35-300$ keV band was 7900 cnt s^{-1}, much higher than the average background rate 310 cnt s^{-1}. The WATCH all-sky monitor provided a 0.2° localization (Sazonov et al. 1998) and observed the fading X-ray emission in the $8-20$ keV band during more than 40 s after the main burst (Terekhov et al. 1993). PHEBUS measured the peak flux 5 10^{-5} erg s^{-1} cm^{-2} and fluence 1.4 10^{-4} erg cm^{-2} in the $100-500$ keV energy band (Terekhov et al. 1995).

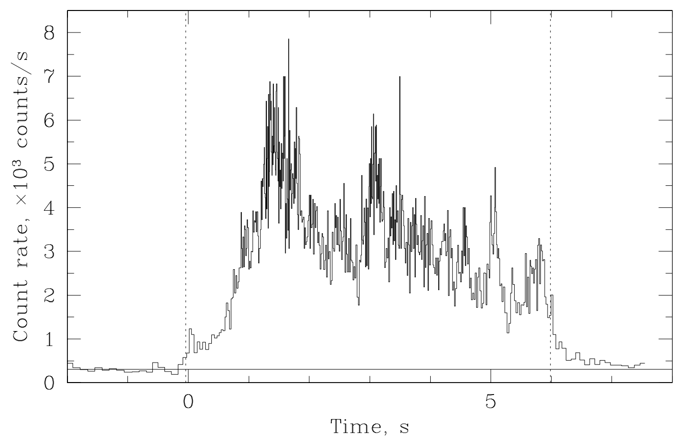

Fig. 1. GRB 920723 light curve with time resolution $\lesssim 0.1$ in $35-300$ keV band

We present here the light curve of this burst observed by SIGMA. Since GRANAT operates on the high apogee orbit, the SIGMA background is very stable and usually does not show any significant variations on the time scales shorter than $\sim 10^3$ s. Therefore, it can be accurately modeled by a low degree polynomial throughout the whole ≈ 20 hour observation. The background can be reliably subtracted in the vicinity of the burst and the light curve can be accurately measured. A complete analysis of SIGMA background subtraction uncertainties is presented elsewhere (Burenin et al. 1999).

3. Results and discussion

Figure 1 shows the burst light curve in $35-300$ keV band with the time resolution $\lesssim 0.1$ s. The zero time is at the

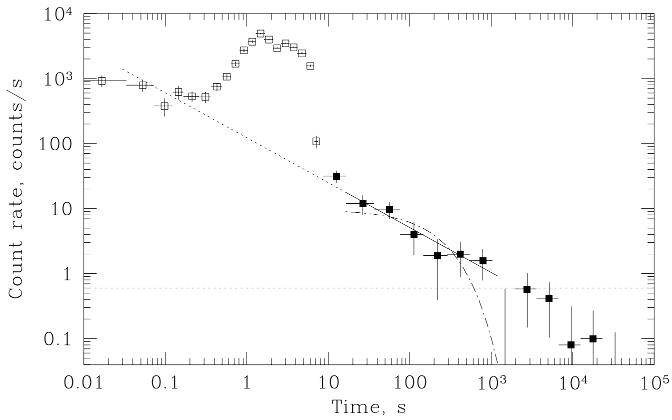

Fig. 2. The background-subtracted burst light curve. Zero time is at the burst trigger

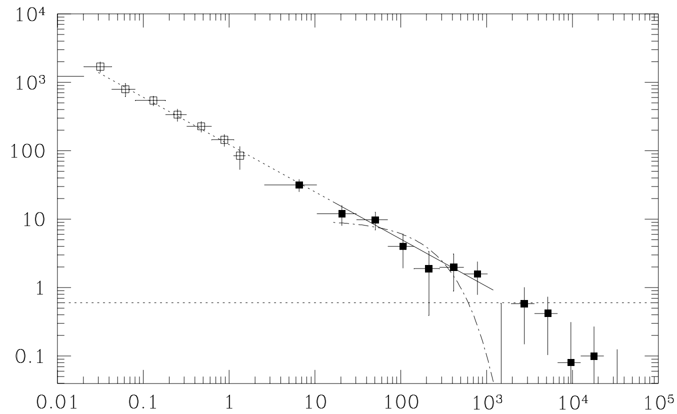

Fig. 3. Same as Fig. 2, but the reference time was set at 6 s after the trigger. The main burst is not shown here because it is at $t < 0$ with this choice of reference time

burst trigger. Figures 2 and 3 show the burst light curve in logarithmic coordinates of both time and flux. The light curve shape in the logarithmic coordinates strongly depends on the choice of the reference time. In Fig. 2, the reference time is chosen at the moment of the burst trigger (Fig. 1). The horizontal dotted line represents a 95% upper limit on the possible internal background variations on the 300 s time scale. There appears to be a power-law decay of flux starting after $10 - 20$ s after the trigger. This behavior is consistent with GRB entering the stage of self-similar fireball expansion soon after the main burst.

The solid line in Fig. 2 shows the power law fit in the time interval $20 - 1000$ s, and the dash-dotted line shows the exponential fit. Power law provides a better description of the data than the exponential decay — χ^2 is 1.5 and 6.5 per 4 dof, respectively. The best fit power law index is -0.69 ± 0.17 ($\Delta\chi^2 = 2.7$ and 5.7 for the indices -1 and -1.2) which is considerably flatter than *Beppo*SAX slopes (e.g. Costa et al. 1998). This power law tail contains at least $\sim 20\%$ of the main burst fluence. Interestingly, the extrapolation of the power law (shown by the dotted line in the Fig. 3) points to the small peak near the beginning of the main burst (see also Fig. 1).

Figure 3 shows the burst light curve with the reference time chosen at the moment when the burst flux began the gradual decline, approximately 6 s after the trigger (Fig. 1). With this choice of zero time, the data in the $0.01 - 20$ s time interval lies on the extrapolation of the above power law fit; adding these data to the fit results in the power law index -0.70 ± 0.03. Note, in this case, the power law flux decay lasts over approximately four orders of magnitude of time.

The spectral evolution of the burst flux can be characterized by the ratio of WATCH flux in the $8 - 20$ keV band (Terekhov et al. 1993) and SIGMA flux in the $75 - 200$ keV band[1]. During the main burst ($0 - 6$ s after the trigger), the WATCH/SIGMA flux ratio corresponds to the power law energy spectral index 0.05 ± 0.04. After 6 s, we observe a much softer spectrum — spectral index is 1.06 ± 0.08 for $6 < t < 7$ s, 1.08 ± 0.23 for $8 < t < 16$ s, and 1.01 ± 0.25 for $16 < t < 32$ s. This drastic spectral change supports the idea that afterglow starts at $t \simeq 6$ s after the trigger.

SIGMA data provides the first convincing observation of the power law afterglow in the soft gamma-rays and immediately after the burst. It fills the gap between *Beppo*SAX WFC and NFI observations. A very important issue is whether such afterglows are common to GRB. A preliminary analysis of other SIGMA bursts revealed no other convincing afterglows, primarily because of the faintness of other bursts; on the basis of SIGMA data alone, we cannot rule out that the soft gamma-ray afterglow is a common phenomenon. A preliminary analysis of the PHEBUS data confirms the detection of the afterglow in GRB 920723 and reveals a similar afterglow in GRB 910402 (Tkachenko et al. 1998). The results of our systematic search for soft gamma-ray afterglows in the GRANAT data will be presented in the future.

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[1] Effective area for the secondary optics observation was calibrated using the PHEBUS data for this burst (Terekhov et al. 1995).

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