BeppoSAX observations of GRB970508: first evidence of bursting activity continuing on very long time scale


Istituto Astronomico, Università degli Studi "La Sapienza", Via L. da Vinci 33, 00161 Roma, Italy
Istituto di Relatività, Via F. Codecà, 00131 Roma, Italy
BeppoSAX Science Data Center, Via E. Fermi 61, 00131 Roma, Italy
Istituto Fisica Cosmica e Universale, Via della Ricerca Scientifica 16, 00044 Frascati, Italy
Istituto Rassegna, C.N.R., Via Gobetti 101, 40129 Bologna, Italy
Space Research Organization in the Netherlands, Koninklijke Academie van Wetenschappen, 3584 CA Utrecht, The Netherlands
Istituto Fisica Cosmica e Tecnologie Relative, C.N.R., Milano
Space Research Department of ESA, ESATFC PO 299 21800K Neiweiberg, The Netherlands
Columbia Astrophysics Laboratory, Columbia University, New York, 10027, USA

The X-ray burst GRB1970508 was observed simultaneously by the Gamma-Ray Burst Monitor (GRBM) and one of the X-ray Wide Field Cameras (XFWC) aboard BeppoSAX. The latter provided a position within 1 s of the former. A series of follow-up observations with the Narrow Field Imager (NFI) was then performed in a period from 6 hours to 6 days after the main event. A previously unknown source was associated with the afterglow of the GRB, as previously reported. We find that, after the initial burst, the X-ray emission is still present and changes as $\alpha = 0.5$ to $\alpha = 0.6$ at a rate of $10^{-4}$. The energy of this event is a substantial fraction of the total energy of the GRB, which implies that the afterglow is not a remnant of the initial burst (the GRB) that faded away smoothly. One of the main results is the evidence that the afterglow lasts for about 4 hours after the burst.

1. OBSERVATIONS

The GRBM [1] was triggered on May 5 1997 at 21:41:30 C.T. by a GRB. The event was simultaneously detected in one of the XFWC [2]. A preliminary position of the XFWC was derived from the image of the GRBM. A preliminary position was derived from the XFWC [3], and used to perform a follow-up observation with the NFI. Simultaneously, this position was derived from the XFWC images [4], and the position derived from the XFWC [5] were distributed to a network of observatories for follow-up observations in all wavelengths. This led to the identification of an optical transient 4 hours after the burst [6] and eventually to the spectroscopic observation that set the distance of the optical transient at $z = 0.33$ [7].

The event was acquired by the NFI 6 hours after the burst. A previously unknown X-ray source, ISAS J09518-7810, was detected by the MRSC (units 2 and 3) [8] with $F(2-10 keV) = 0.7 \times 10^{-10} \, erg/cm^2/s$ and the LEC [9] with $F(0.1-2 keV) = 1.2 \times 10^{-10} \, erg/cm^2/s$. The source is at a distance of 3 Mpc. The radio emission at 8.6 cm was detected by the NRAO [10].

Figure 1. Light curves of GRB970508 in the GRBM (bottom) and XFWC (top).

Figure 2. X-ray light curve (2-10 keV from the GRB to the afterglow (upper part, sources XFWC, middle sources XFWC, lower source XFWC). The data points are the mean of the XFWC observations taken within 1 min. The XFWC observations were not affected by the X-ray afterglow.

2. DISCUSSION

The combination of the WFC sensitivity and the X-ray afterglow allowed to follow the evolution of the X-ray emission of the GRB from 1 to 10 s. We find that, after the initial burst, the X-ray emission continues and extends to $\approx 6 \times 10^{-3}$ following a $t^{1/2}$ law. About 1/3 of the total energy of the GRB is released in this part of the afterglow (see also [11]). While this behavior is similar to that observed in GRB960601 [12], GRB970508 [13], GRB970508 [14], this first time that the afterglow was detected immediately after the primary event. However, the subsequent evolution deviates from this power law, being dominated by a burst of activity with a duration $\approx 10^{-3}$ s. The energy produced released in the 2-10 keV band by the event is $\approx 10^{-3}$ of the total energy of the GRB and corresponds to $\approx 10^{-3}$ of that of the first part of the afterglow.

Therefore, not only the afterglow carries an energy comparable to that of the main event, but it also shows a burst activity on a time scale $\approx 10^{-3}$ times larger than that of the GRB. The energy evolution of the afterglow and the GRB could be then described by a power law on the top of a burst of different time scales, in particular on $\approx 10^{-3}$ s (the GRB proper) and $\approx 10^{-2}$ s. Moreover, the time evolution of the afterglow and the GRB could be then described by a power law on the top of a burst of different time scales, in particular on $\approx 10^{-3}$ s (the GRB proper) and $\approx 10^{-2}$ s. Moreover, the time evolution of the afterglow and the GRB could be then described by a power law on the top of a burst of different time scales, in particular on $\approx 10^{-3}$ s (the GRB proper) and $\approx 10^{-2}$ s.
that observed during the GRB proper, in that the spectrum becomes harder when the flux increases and then soften again as the flux decreases. This result suggests that the same process is responsible for the GRB and the afterglow. In the fireball scenario (e.g. [13], [14]), models in which both the GRB and the afterglow are produced by the same mechanism (e.g. external shock) are therefore preferred. The increase of the burst duration with time agrees with the general fireball scenario, where the timescales are primarily determined by the supnutation motion of a shell, whose foot is accelerated very rapidly as the light expands. The optical turn up (Fig. 2, lower panel) appears to follow the X-ray burst with no substantial delay (lag < 2 × 10^{-4} s), suggesting the same origin for the optical and X-ray energy. It then appears unlikely that the optical turn up is produced by an energy dependent effect, e.g. the decay of the burst energy [15,16]. The reason for the different evolution of GRB970618 compared to GRB9706128 after the initial phase is not clear. It could be associated with the very soft primary event of GRB970618 or with a different environment in which the fireball expands. It is however possible that similar bursts happened in the other GRB's but have been missed due to the sparse sampling of the light curves.

3. ACKNOWLEDGMENTS

These results, as well as those derived from the quick look positioning and distribution of the co-ordinates, would have never been obtained without the extraordinary efforts of the scientists and engineers of the BeppoSAX team. We would like to thank in particular L. Scarlata and G.C. Parmi for the help in editing the strategy of follow-up observations, the Mission Planners B. Raci, M. Capano and S. Rici, the SOC scientists A. Coletta, G. R. Giannini, M. Smith, A. Tonomi, V. Tavani and G. Spolin, the operation team L. Moretti and G. Frontera for the fast response, L. Granata and G. Cresciogranata for the fast processing of raw data and P. Giommi, F. Fiore for the analysis of TOO data. The inclusion of Figure 2 in this proceeding is courtesy of L. Piro et al. [26].

REFERENCES

3. Costa E. et al. 1997 LAUC 0608