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NUCLEAR PHYSICS B
PROCEEDINGS
SUPPLEMENTS

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

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The γ-ray burst GRB970508 was observed simultaneously by the Gamma Ray Burst Monitor (GRBM) and one of the X-ray Wide Field Cameras (WFC) aboard BeppoSAX. The latter provided a position within 1.9′ radius. A series of follow-up observations with the Narrow Field Intruments (NFI) was then performed in a period from ~ 6 hours to 6 days after the main event. A previously unknown source, which we associate with the afterglow of the GRB, was discovered in the error box. We find that, after the initial burst, X-ray emission is still present and decays as $\sim t^{-1.1}$ up to $\sim 6 \times 10^4$ s. This is followed by a burst of activity with a duration $\sim 10^5$ s. The energy produced in this event is a substantial fraction of the total energy of the GRB, which means that the afterglow is not a remnant of the initial burst (the GRB) that fades away smoothly. Our results support the idea that the processes generating the GRB and its afterglow are the same.

1. OBSERVATIONS

The GRBM [1] was triggered on May 8 1997 at 21:41:50 U.T. by a GRB. The event was simultaneously detected in one of the WFC [2]. A first preliminary (~ 10′) position was derived [3] and used to program a follow-up observation with the NFI. Simultaneously this position (followed then by a refined 3′ one [4] and the 50″ derived from NFI [5]) were distributed to a network of observatories for follow-up observations in all wavelengths. This led to the identification of an optical transient just 4 hours after the burst [6] and eventually to the spectroscopic observation that set the distance of the optical transient at $z > 0.83$ [7].

The field was acquired by the NFI ~ 6 hours after the GRB. A previously unknown X-ray source, 1SAX J0653.8−7916 was detected in this observation (hereafter TOO1) by the MECS (units 2 and 3) [8] with $F(2\text{-}10\ \mathrm{keV}) = (0.7 \pm 0.07) \times 10^{-12}\,\mathrm{erg\ cm^{-2}\ s^{-1}}$ and the LECS [9] with $F(0.1\text{-}2\ \mathrm{keV}) = (1.2 \pm 0.4) \times 10^{-12}\,\mathrm{erg\ cm^{-2}\ s^{-1}}$ at celestial coordinates (J2000) R.A. = 6h53m46s.7, Decl. = +79°16′02″ (estimated error radius of 50″), within the WFC error circle. This source was not detected in the ROSAT all sky survey (Voges, private communication).

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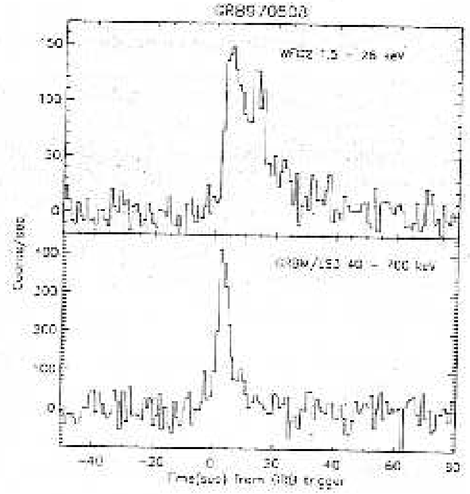

Figure 1. Light curves of GRB970508 in the GRBM (bottom) and WFC (top).

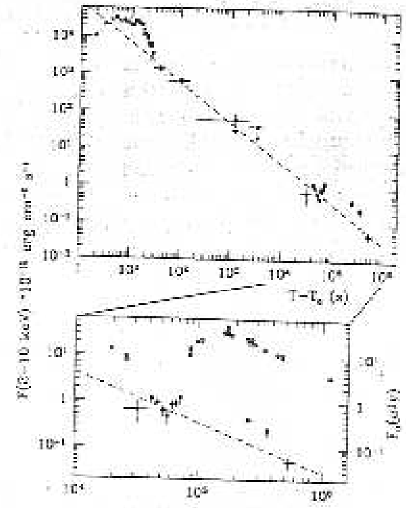

Figure 2. X-ray light curve (2-10 ke... from the GRB to the afterglow (upper pa... starred=WFC, filled squares=NFI). The dash... line is the best fit power law to the WFC da... (excluding the GRB) and the first part of TO... data stream, before the increase at 6×10^4... The lower panel is a blown-up that inclu... the optical data (R band, open circles) fr... [17],[18],[19],[20],[21],[22], [23],[24]. The verti... right hand scale refers to the optical data. (Fr... [25])

2. DISCUSSION

The combination of the WFC sensitivity and fast follow-up with the NFI allowed to follow the evolution of the X-ray emission of the GRB from 1 to 10^5 s. We find that after the initial burst, the X-ray emission continues and extends upto $\sim 6 \times 10^4$ s following a $t^{-1.1}$ law. About 1/3 of the total energy of the GRB is released in this part of the afterglow (see also [11]). While this behaviour is similar to that observed in GRB970228 [11], GRB970402 [12] and GRB970828 [13], this is the 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 $\sim 10^5$ s. The energy produced released in the 2-10 keV band by this event is already ~ 10% of the total energy ... the GRB and corresponds to ~ 30% of that of t... first part of the afterglow.

Therefore, not only the afterglow carries an e... ergy comparable to that of the main event, b... also shows bursting activity on a time scale ~ 1... times larger than that of the GRB. The overa... evolution of the afterglow and the GRB could ... then described by a power law on the top of whi... bursts of different time scales occur, in particul... on $1 - 10$ s (the GRB proper) and on $\sim 10^5$... Moreover, (see fig. 3), the spectral behaviour o... served during X-ray bursting activity is similar ...

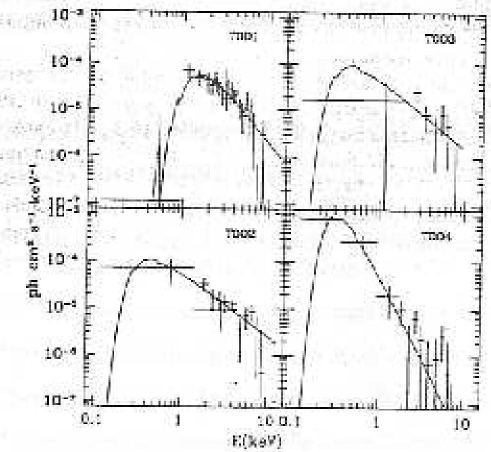

Figure 3. X-ray afterglow spectra from LECS(0.1–2 keV) and MECS units 2+3 (2–10 keV). The data are fitted with absorbed power-law. What is remarkable here, is that the afterglow spectrum becomes harder when the flux increases (see fig. 2) and then becomes soft again, thus behaving in the same way as during the GRB proper. This fact strongly supports the idea that the same processes are responsible for gamma and X-ray emissions.

that observed during the GRB proper, in that the spectrum becomes harder when the flux increases and then softens again as the flux decreases. This results suggest that the same process is responsible for the GRB and the afterglow. In the fireball scenario (e.g [14], [15], [16]), models in which both the GRB and the afterglow are produced by the same mechanism (e.g. external shock models) are therefore preferred. The increase of the bursting duration with time agrees with the general fireball scenario, where the timescales are primarily determined by the superluminal motion of a shell, whose Lorentz factor decreases very rapidly as the shell expands. The optical turn up (fig. 2, lower panel) appears to follow the X-ray burst with no substantial delay (lag $< 2 \times 10^4$ s), suggesting a same origin for the optical and X-ray events. It then appears unlikely that the optical turn up is produced by an energy dependent effect, as a shift of the break energy [15,16]. The reason of the different evolution of GRB970508 compared to GRB970228 after the initial phase is not clear. It could be associated with the very soft primary event of GRB970508 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

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The inclusion of Figure 2 in this proceeding is courtesy of L. Piro et al. [25].

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