PROCEEDINGS OF SCIENCE

Needs for a new GRB classification following the fireshell model: "genuine short", "disguised short" and "long" GRBs

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Thanks to the observations by the *Swift* and *Fermi* satellites, it became clear that the traditional classification of GRBs in two classes ("short/hard" and "long/soft") is, at best, misleading. Following the theoretical approach of the fireshell model, we discuss a new GRB classification based on intrinsic physical properties which includes at least three classes: "genuine short", "disguised short" and "long", whose names resembles the traditional ones just for simplicity. Observational facts supporting this classification are presented, including the implications for the "$E_{p,i}$–E_{iso}" correlation.

Gamma-Ray Bursts 2012 Conference -GRB2012,
May 07-11, 2012
Munich, Germany

 http://pos.sissa.it/

PoS(GRB 2012)043

Observations of Gamma-Ray Bursts (GRBs) in the recent years have revealed that the legacy classification between long and short bursts has to be revised. Within the Fireshell scenario [see e.g. Refs. 9, 10, and references therein], both short and long bursts are canonical bursts, consisting of two different phases: the Proper-GRB (P-GRB), the emission of photons at the fireshell transparency, and then the extended afterglow, a multi-wavelength emission due to the interaction with the circumburst medium (CBM) of the fireshell baryonic remnants. We discriminate between long and short bursts by the amount of energy emitted in the first phase with respect to the second one. This difference is determined by the fireshell baryon loading parameter B, that quantifies the baryonic remnants engulfed by the fireshell: $B = M_B c^2/E^{e\pm}_{tot}$, where M_B is the baryon mass and $E^{e\pm}_{tot}$ is the initial energy of the plasma inside the fireshell. When $3\times 10^{-4} \lesssim B < 10^{-2}$ we have a long burst and the extended afterglow phase is energetically predominant. On the other hand, when $B \lesssim 10^{-5}$, the P-GRB phase is predominant and we observe a short burst. Within the Fireshell scenario, we have introduced a third intermediate class: the "disguised" short GRBs. They appear like short bursts, because their morphology is characterized by a first, short, hard episode and a following deflated tail, but this last part, coincident with the peak of the extended afterglow, is actually energetically predominant. The origin of these peculiar sources, first analyzed by Norris & Bonnell [8], is ascribed in the Fireshell model to a very low average density of the environment ($\sim 10^{-3}$ particle/cm^3, compatible with galactic halos). The prototype of this class of bursts is GRB 970228 (see Fig. 1). Recently we have identified three additional examples: GRB 060614 (see Fig. 1), GRB 050509b (see Fig. 2) and GRB 071227 (see Fig. 2). They were classified in the literature in different ways. Instead, they are all canonical GRBs with an energetic major contribution from the extended afterglow, and are therefore "disguised" short GRBs. As expected, the sole extended afterglow part of these GRBs follows the Amati relation, while the P-GRB part does not. This is consistent with the Amati relation being fulfilled only by the long GRBs and not by the short [see e.g. Ref. 1]. We are analyzing the implications on this scenario of the correlation recently found by Bernardini et al. [11] (see also Ref. [12] as well as Poster P-III-6 by Bernardini et al. in this same Conference and the corresponding paper in this same Proceedings).

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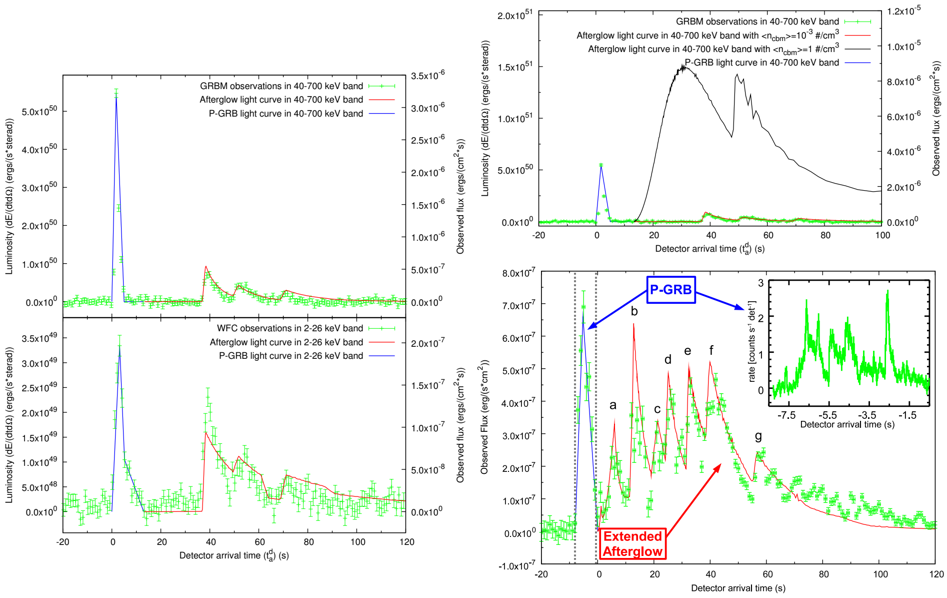

Figure 1: Left: The "canonical GRB" light curve theoretically computed for the prompt emission of GRB 970228. BeppoSAX GRBM (above) and WFC (below) light curves (green points) are compared with the extended afterglow peak theoretical ones (red lines). The onset of the afterglow coincides with the end of the P-GRB (qualitatively represented by blue lines). We have $B \sim 5.0 \times 10^{-3}$ and $n_{cbm} \sim 10^{-3}$ particle/cm^3. Such a low CBM density deflates the afterglow peak luminosity (see also top right panel). The extended afterglow component, considered alone, is consistent with the Amati relation. See details in Refs. [2, 3]. **Top Right:** The theoretical light curve for GRB 970228 BeppoSAX GRBM observations (red line, see left panel) is compared with the extended afterglow theoretical light curve in the 40–700 keV band obtained rescaling the CBM density profile to an average value $n_{cbm} \sim 1.0$ particle/cm^3 keeping constant its shape and the values of the fundamental parameters of the theory $E^{e\pm}_{tot}$ and B (black line). The P-GRB duration and luminosity (blue line), depending only on $E^{e\pm}_{tot}$ and B, are not affected. This clearly shows that the low CBM density can deflate the extended afterglow peak luminosity, changing a canonical long GRB with a small precursor into a "disguised" short GRB (see Refs. [2, 3]). **Bottom Right:** The "canonical GRB" light curve theoretically computed for the prompt emission of GRB 060614. Swift BAT light curve (green points) is compared with the extended afterglow peak theoretical one (red lines). The onset of the extended afterglow coincides with the end of the P-GRB (represented qualitatively by the blue lines). We have $B \sim 2.8 \times 10^{-3}$ and $n_{cbm} \sim 10^{-3}$ particle/cm^3. Again, such a low CBM density deflates the afterglow peak luminosity (see panel above). The P-GRB component alone is not consistent with the Amati relation, while the extended afterglow one is consistent (in fact the whole event is consistent and the P-GRB is negligible with respect to the extended afterglow when they are considered together). See details in Ref. [5].

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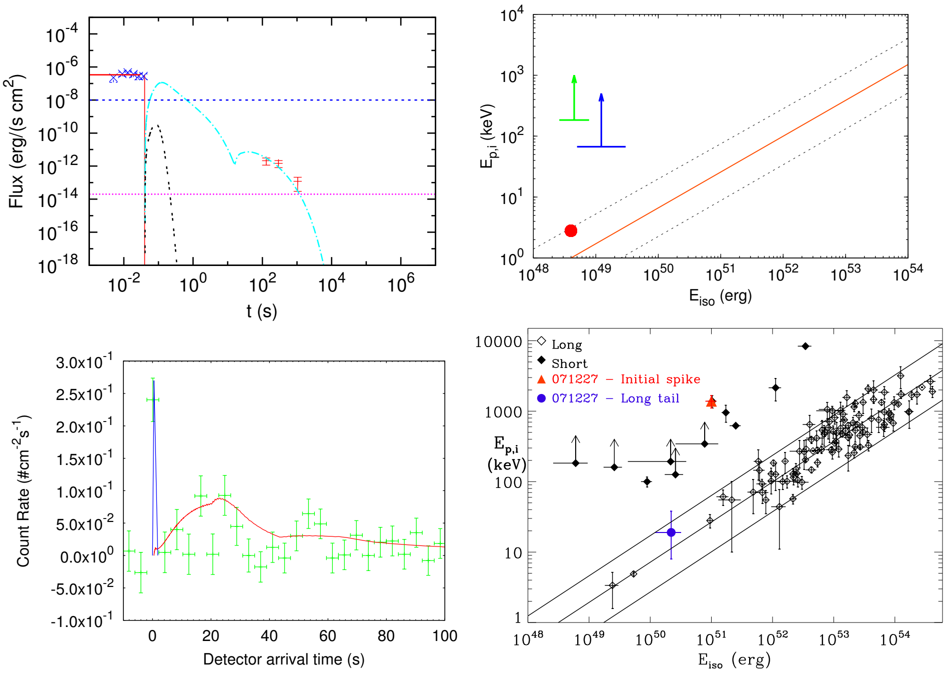

Figure 2: Top: The "canonical GRB" light curve theoretically computed for GRB 050509b (left). The Swift BAT data (blue crosses) are identified with the P-GRB (qualitatively represented by the red box). The peak of the extended afterglow in the BAT energy range (black double-dashed curve) is below the BAT noise level (blue dashed horizontal line) and therefore it has not been observed. The Swift XRT data (pink points) are consistent with the theoretical light curve in the corresponding energy band of the decaying part of the extended afterglow (cyan dash-dotted line). Also the XRT noise level (pink dotted horizontal line) is plotted. We have $B \sim 5.0 \times 10^{-4}$ and $n_{cbm} \sim 10^{-3}$ particle/cm^3. Again, such a low CBM density deflates the afterglow peak luminosity. The extended afterglow component, alone, is consistent with the Amati relation (red circle on the right panel), while the P-GRB is not consistent (two lower limits for different spectral assumptions are shown). The GRB location, at ~ 40 kpc from the host (see [4] and references therein), is compatible with the inferred low value of the CBM density. See details in Ref. [7]. **Bottom:** The "canonical GRB" light curve theoretically computed for the prompt emission of GRB 071227 (left). Swift BAT light curve (green points) is compared with the extended afterglow peak theoretical one (red lines). The onset of the extended afterglow coincides with the end of the P-GRB (represented qualitatively by the blue lines). We have $B \sim 2.0 \times 10^{-4}$ and $n_{cbm} \sim 10^{-3}$ particle/cm^3. Again, such a low CBM density deflates the afterglow peak luminosity. The P-GRB component alone is not consistent with the Amati relation (right), while the extended afterglow one is consistent. See details in Ref. [6].

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