Short-Bright GRBs: spectral properties

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Abstract. We study the spectra of short–bright GRBs detected by BATSE and compare them with the average and time resolved spectral properties of long–bright bursts. We confirm that short events are harder than long bursts, as already found from the comparison of their (fluence) hardness ratio, but we find that this difference is mainly due to a harder low energy spectral component present in short bursts, rather than to a (marginally) different peak energy. Moreover, we find that short GRBs are similar to the first 1 sec emission of long bursts. The comparison of the energetic of short and long bursts also suggests that short GRBs do not obey the peak energy–equivalent isotropic energy correlation recently proposed for long events, implying that short GRBs emit lower energy than long ones. Nonetheless, short bursts seem to emit a luminosity similar to long GRBs and under such hypothesis their redshift distribution appears consistent with that observed for long events. These findings might suggest the presence of a common mechanism at the beginning of short and long bursts which operates on different timescales in the these two classes.

INTRODUCTION

Evidences supporting the possible different nature of short and long GRBs are: (1) their bimodal duration distribution ([8]) with mean duration of 20 sec and 0.3 sec for long and short events, respectively; (2) their different temporal properties (e.g. number and width of pulses in the light curve, [13], [12], [10]); (3) the larger hardness ratio of short bursts ([8], [16], [14]). Moreover, theoretical models for the progenitors of GRBs associate short bursts to the merger of compact objects in a binary system ([7], [11]) while long GRBs seem to be connected to the core–collapse of massive stars ([18], [17]).

Despite the increasing understanding of the nature of long duration γ–ray bursts, the population ( 1=3) of sub-second short GRBs is still largely not understood. This is mainly due to (i) the low signal-to-noise ratio which strongly limits the analysis of the prompt (temporal and spectral) emission of short events, and (ii) the lack of any firm afterglow measurement for short GRBs, which indeed represented a major advance in unveiling the mystery of long bursts.

SHORT VS. LONG: SPECTRAL PROPERTIES

The emission properties of long GRBs have been studied in details ([2], [15]) by fitting their time average ([2]) and time resolved ([13], [4]) broad-band high-resolution spectra. Nonetheless, the comparison with the spectral properties of short bursts has been based
mainly on the analysis of their fluence hardness ratio (e.g. [3], [19]) which is marginally representative of the effective spectral shape. For this reason we analyzed ([6]) a sample of bright–short BATSE bursts (selected with peak flux $10^{12}$ phot/cm$^2$ sec between 50-300 keV) by fitting their $\gamma$–ray spectra (30–1800 keV) with the standard spectral functions (e.g. [15]). The set of spectral parameters (namely the low energy photon spectral index $\alpha$ and the EF$_E$ peak energy $E_{\text{peak}}$) were compared with those of long bright bursts ([15]) both considering time integrated and time resolved spectra.

As shown in fig.1 (Left) short and long GRBs present different $\alpha$ distributions and only marginally different $E_{\text{peak}}$ distributions (with a small Kolmogorov-Smirnov test probability - i.e. 4% and 10%, respectively - for the two population to be similar). The average values are $\bar{h}\alpha i = 0.84 \pm 0.15$, $\bar{h}E_{\text{peak}} i = 305 \pm 22$ keV and $\bar{h}\alpha i = 0.58 \pm 0.10$, $\bar{h}E_{\text{peak}} i = 355 \pm 30$ keV for long and short GRBs, respectively. This suggests that short bursts have (average) harder spectra than long events, as also indicated by the analysis of their hardness ratio, but, intriguingly, this difference is due to a considerably harder low energy spectral component present in short bursts rather than to a different peak energy. The comparison of short GRBs with the time resolved spectral properties of long bursts shows that short events have spectra similar to the first 1 sec of long GRBs, as shown in fig.1 (Right), with a high KS probability of 23% and 80% for $\alpha$ and $E_{\text{peak}}$ to be similar. This might suggest that a similar mechanism operates for the complete duration of short bursts and in the first 1 sec of long GRBs.

**SHORT VS. LONG: ENERGY AND LUMINOSITY**

The analysis of the intrinsic properties of (still few) long bursts with known redshift ([1]) highlighted a possible correlation ($E_{\text{iso}} \propto E_{\text{peak}}^{1.93}$) between the equivalent isotropic burst energy $E_{\text{iso}}$ and the spectral peak energy $E_{\text{peak}}$. This correlation has been also confirmed by Hete–II ([9]) and a similar relation has been found between $E_{\text{peak}}$ and the...
burst isotropic luminosity $L_{iso}$ ([20]). If short bursts were similar to long events they might satisfy these correlations between $E_{iso}$ ($L_{iso}$) and $E_{peak}$. However, no redshift of short GRBs has been measured so far. Nonetheless, we can still verify ([6]) the above hypothesis assuming a variable redshift (between 0.1 and 10) and scaling the observed spectral properties of the sample of bright short bursts in the source rest frame.

Fig. 2-a shows that for any assumed $z$ short bursts (solid curves) populate a region below the $E_{peak} - E_{iso}$ correlation of long bursts ([1] - solid line). On the other hand (fig 2-b) the luminosity of short events is consistent with the proposed relation for long bursts ([20] - solid line). In conclusion short and long bursts seem to emit a similar equivalent isotropic luminosity but different (lower in short bursts) energy due to their different duration. Nonetheless, short and long bursts might still have similar emitted energies if short bursts are less collimated than long events although, in this case, short bursts would have a much larger luminosity. Under the first hypothesis we can further extract from the $L_{iso}$-$E_{peak}$ relation the possible redshift distribution of short bursts (fig 2-right, solid line). This is consistent with the observed $z$ distribution of long events (fig 2-right, dotted line) and again supports a possible similarity of short and long GRBs.
DISCUSSION

The comparison of the spectral properties of short and long bursts pointed out that short bursts are harder than long events due to a (average) harder low energy spectral component (rather than to a different peak energy). The spectra of short bursts are similar to the first 1 sec of the emission of long bursts. Intriguingly, short bursts present a similar intrinsic luminosity but a lower (isotropic) energy than long bursts if the recently found correlations between these quantities were true also for short GRBs. Under such hypothesis the implied redshift distribution of short bursts results similar to that observed in long GRBs, and this prediction will be tested in the forthcoming Swift era. Nonetheless, short GRBs might still have a similar energy to that of long bursts if their collimation angle is much larger than that of long events, but in this case their intrinsic luminosity should be much larger than that of long bursts. These results suggest the presence of a common mechanism operating at the beginning of short and long bursts which could explain their similar spectral properties and luminosity. If this is the case a possible difference in the burst dynamical evolution (e.g. fallback of the pre-GRB ejected material) might play a crucial role in distinguishing these two classes.

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