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The GRBs simultaneously detected by *Beppo*SAX and BATSE(*)

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Summary. — We used the *Beppo*SAX-Wide Field Cameras archive and the most updated BATSE catalog (including events non triggered on flight) to search for the GRBs that were temporally and positionally contained within the WFC field of view. We applied the WFC standard software to find any variable (unknown) X-ray source falling within the BATSE error box. As the detected sources are the best candidate X-ray counterpart of the GRBs, we extracted the light curve and the spectrum in the 3–25 keV energy range and we analyzed them jointly with the BATSE data. Our study should be able to reveal all the X ray emission episodes associated with the most classical GRBs as well as possibly dim gamma events with a much larger X-ray flux (*i.e.,* XRF, XRR).

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1. – Introduction

BATSE and *Beppo*SAX-Wide Field Camera (WFC) operated simultaneously for 3.8 years. During this period, the WFC triggered few tens of GRB-like transient events, 17 of which were not detected by the Gamma Ray Burst Monitor in the 40–700 keV energy range. Temporal and positional coincidences of these X-ray transients were found in the BATSE data [1] and the comparison of their spectral and temporal properties with those of the larger BATSE GRB sample showed that they are normal GRBs (*i.e.,* similar light curves and total duration) with a considerably softer spectrum [2].

In the last 2 years, the larger population of GRBs detected also by other instruments than BATSE, led to the classification of GRB in at least 3 classes based on the fluence ratio $F_X(2\text{–}30\,\text{keV})/F_\gamma(30\text{–}400\,\text{keV})$. Classical GRBs have $F_X/F_\gamma < 0.3$, X-Ray Rich (XRR) have $F_X/F_\gamma > 0.3$, X-Ray Flash (XRF) have $F_X/F_\gamma > 1.0$. The larger Hete-II sample recently allowed a more complete analysis of the properties of XRF/XRR compared to GRBs [3].

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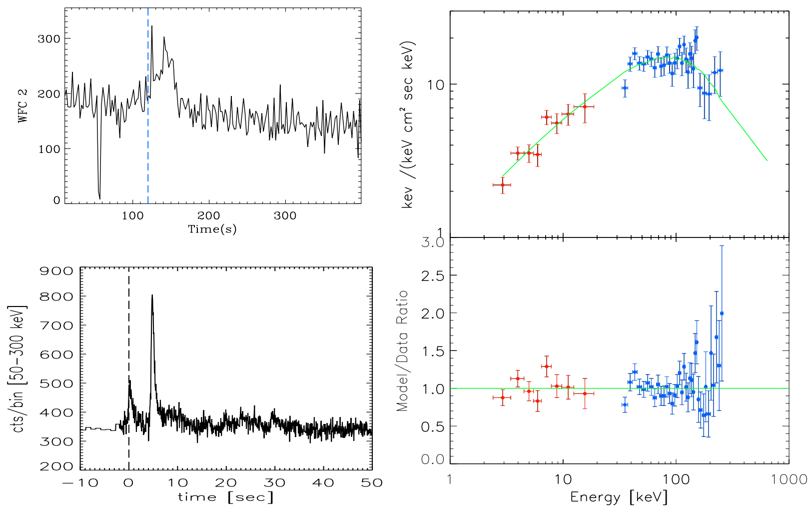

Fig. 1. – On the left: the 2.5–25 keV WFC light curve (top panel) and the corresponding 50–300 keV BATSE light curve (bottom panel) for the GRB991105, one of the detected event. The BATSE trigger time ($t \sim 120$ s) is represented by the dashed line (top panel). On the right: the joined 3–1000 keV energy spectrum fitted with a Band model. The WFC (BASTE) data are represented by the points with energy lower (greater) than 20 keV

With the aim of comparing the spectral/temporal properties of XRF, XRR and GRBs we performed a systematic search for any possible event simultaneously detected by the BATSE and the WFC.

2. – Observations and results

The most updated BATSE catalog includes 4540 GRBs, collected between 1991 April 21 and 2000 May 26, of which 2702 were triggered on flight [4]. The remaining 1838 events, not being strong enough to activate the BATSE on flight trigger system, were detected by an off-line analysis [5]. The WFC archive includes 5626 pointings, of which 4385 were performed when BATSE was active. Each camera covers a $40° \times 40°$ (full width zero response) field of view in the 2–25 keV energy range. We performed a cross correlation between the BATSE catalog and the WFC archive, searching for any GRB whose trigger time falls within a WFC observation period and whose coordinates belong to the $20° \times 20°$ (full width at half maximum) WFC field of view. We restricted the search to half the total WFC FOV in order to have the highest coded mask response to detect faint unknown transient sources.

We found 41 BATSE GRBs with error boxes falling in the selected region: 24 of them correspond to triggered events (4 short, 20 long) and 17 to non-triggered ones (2 short, 15 long) ([1]). In 11 of these 41 cases, there is a temporal coincidence with a BATSE GRB in the X-ray light curve accumulated using the whole WFC FOV. All of them correspond to long GRBs and no evidence are found for the short events.

In the (-100 s, $+200$ s) interval around the BATSE trigger time, we analyzed the

([1]) The distinction between short and long events corresponds to a duration < 2 s and > 2 s, respectively, as defined in the γ-ray band.

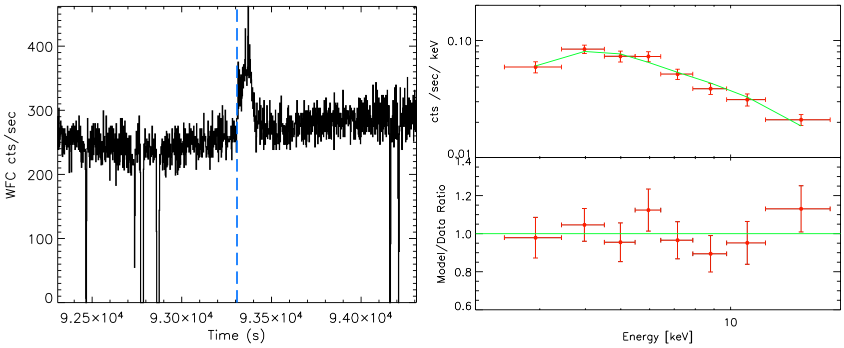

Fig. 2. – WFC light curve and energy spectrum in the 2.5–25 keV energy range for the GRB981217, characterized by an X-ray transient event and a weak γ-ray flux.

sample of the 41 coincidences, dividing this period in 20 s time intervals. Using the WFC source detection software, we found a transient X-ray source consistent with the position and the duration of the BATSE event only for 7 of the 11 observations showing temporal coincidence in the X-ray light curve. We identified it as the X-ray prompt emission of the GRB.

In fig. 1 we show the X-Ray and the γ-ray light curves for one of the GRBs simultaneously detected by the WFC and BATSE and the energy spectrum obtained with the WFC and BATSE data. The BATSE spectral data were reduced using public software. Using the Band model, we fitted the data obtaining a χ^2_{red}/d.o.f. of 1.2/99 and best fit parameters ($\alpha = -1.27^{+0.03}_{-0.04}$, $\beta = -4.96^{+1.4}_{-0.04}$, $E_0 = 115.3^{+13.7}_{-11.7}$) consistent with the typical X-ray and γ-ray spectra observed in GRBs [6]. One of the coincidences shows a particulary low γ-ray flux (0.4 photons cm^{-2}s^{-1}) but an intense X-ray emission. In fig. 2 we report the X-ray light curve and the energy spectrum of this event. We obtained a χ^2_{red}/d.o.f. of 0.9/5 fitting the data with an absorbed power law model. The N_H is consistent with galactic absorption, the photon index is $\alpha = 1.24^{+0.16}_{-0.14}$ and the fluence is $F_X(2\text{–}30\,\text{keV}) = 8.3 \times 10^{-7}$ ergs cm^{-2}. The fluence ratio, $F_X/F_\gamma = 0.34$, is typical for the XRR class.

Despite of the difficulties to detect sources, it is interesting to study the statistical properties of the coincidences searching the GRBs in a larger admittance area. In fig. 3 we report the histograms of the peak flux and the duration of the BATSE GRB (triggered and non triggered) for the detectable events and for three different WFC fields. Considering the full coded WFC fov, the number of the possible coincidences increases to 187 and most of them (89) are dim GRBs. The bottom panels of fig. 3 shows that the number of the coincidences does not seem to depend on the duration of the bursts. Due to the presence of very dim GRBs in this larger sample, we expect to find other cases like the one shown in fig. 2. These events are the best candidates as XRF and XRR.

3. – Conclusions

We cross-correlated the 4540 GRBs in the current BATSE catalog with the 4385 WFC pointings, performing the most updated search for GRBs simultaneously detected by the BATSE and the WFC.

We found 11 associations in which the analysis of the WFC light curve shows evidence of a burst in coincidence with the γ-ray event. They correspond to long GRBs and no evidences are found for short events. For seven observations, we identified the burst in

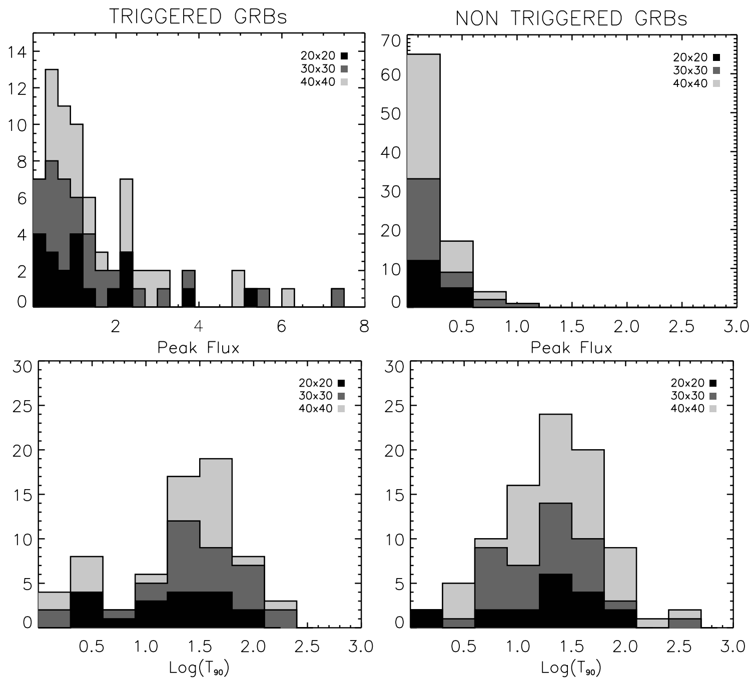

Fig. 3. – Histogram of the peak flux in units of photons cm^{-2} s^{-1} (top pannel)and the duration of the BATSE GRB, in units of second, for the possible coincidences (bottom panels). The results are shown for $20^\circ \times 20^\circ$ and $30^\circ \times 30^\circ$ fields and for the WFC FOV.

the light curve as the X-ray prompt emission of the GRB. Moreover, we found that one of these coincidences has $F_X/F_\gamma = 0.34$ and can be classified as XRR. The systematic analysis of the whole sample is ongoing. This study will allow us to infer the number population of XRF and XRR in the WFC archive. The jointly broad band γ-to-X-ray spectral analysis will also allow us to investigate the relation between the γ-ray and the X-ray prompt emission during the first phase of the burst.

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