

BATSE Observations of Fast X-ray Transients Detected by BeppoSAX-WFC

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Abstract. The *BeppoSAX* Wide Field Cameras have been successful in detecting gamma-ray bursts in the 2–26 keV energy range. While most detected bursts are also strong emitters at higher energies, a significant fraction have anomalously low gamma-ray flux. The nature of these “Fast X-ray Transients” (FXTs), and their relation to gamma-ray bursts (GRBs), is unknown. We use BATSE untriggered continuous data to examine the >20 keV gamma-ray properties of the events detected in common with *BeppoSAX*. Temporal and spectral characteristics, such as peak flux, fluence, duration, and spectrum are compared to the full population of triggered BATSE GRBs. We find that FXTs have softer spectra than most triggered bursts, but that they are consistent with the extrapolated hardness expected for low-intensity GRBs.

1 Introduction

Several papers in these proceedings detail how measurements made with the *BeppoSAX* Wide Field Cameras (WFCs) have revolutionized gamma-ray burst (GRB) astronomy in two key areas: First, the timely, arc-minute burst locations provided by the WFCs led directly to ground-breaking discoveries of multi-wavelength afterglow emission and host galaxies at cosmological distances. Second, the 2–26 keV WFC burst measurements extend GRB spectroscopy into the x-ray band, where few previous observations exist. This latter capability has led to the exciting discovery of several “Fast X-ray Transients” (FXTs), which resemble GRBs in their x-ray properties and spatial distribution, but lack the strong gamma-ray emission typical of “classical” GRBs [1]. Some bursts with a strong x-ray spectral component were observed previously with *Ginga* [2], hinting that the WFC FXTs could represent a class of x-ray rich GRBs. However, a completely unrelated and unknown phenomenon cannot be ruled out.

The key to understanding the relation between FXTs and GRBs lies in the gamma-ray domain, where we have the most knowledge of classical GRB behavior to compare with. Unfortunately, observational data are scarce due to the weakness of the gamma-ray emission from these events. In this paper, we present preliminary results on the gamma-ray properties of WFC FXTs compared to those of classical GRBs using data from the *Compton*-BATSE Large Area Detectors (LADs, >20 keV). BATSE is the only instrument to detect signif-

icant gamma-ray emission from WFC FXTs, and thus provides the best means of understanding their true nature.

2 BATSE Observations

BATSE and *BeppoSAX*-WFC operated simultaneously for 3.8 years, ending with the termination of the *Compton* Observatory on 4 June, 2000. In this interval, ~ 53 GRB-like transient events were observed by the WFCs – 17 of which were classified as FXTs due to their lack of detectable gamma-ray emission in the SAX GRB Monitor (40–400 keV). Based on the WFC source locations, we know that 12 of these FXTs were observable (unocculted by Earth) by BATSE, but none activated BATSE’s on-board transient event trigger system. This indicates that the 50–300 keV peak fluxes were near, or below $\sim 0.2 \text{ ph} \cdot \text{cm}^{-2} \cdot \text{s}^{-1}$ (1024 ms timescale).

To investigate with higher sensitivity than the on-board trigger allows, we performed a *post facto* search for the 10 FXTs where BATSE continuous data are available. Nine of the 10 candidates were detected with $\geq 5\sigma$ significance in the 20–100 keV energy range. These detections are strengthened by the fact that the times and independent BATSE locations of the events agree (within the uncertainties) with those measured with the WFCs (see Figure 1).

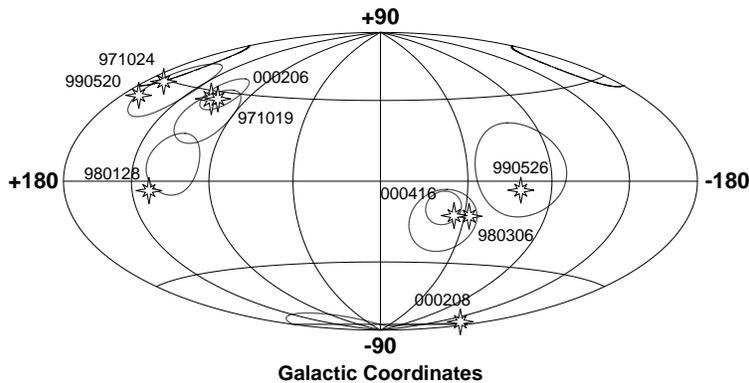


Fig. 1. Locations (and dates) of the nine WFC FXTs detected with BATSE in this study. The BATSE 1σ error circles (solid lines) are compared to the independent WFC locations (stars whose size is not representative of the ~ 10 arc-minute uncertainties).

3 Gamma-Ray Properties of FXTs Compared to GRBs

Qualitatively, the nine FXTs detected in the BATSE search are very similar to GRBs in their temporal and spectral characteristics. For instance, they have rapidly varying lightcurves, durations from ~ 1 –50 s, and strong spectral evolution. To quantify the comparison, 4-channel, 1024-ms data were used to compute several standard GRB parameters, including peak flux, fluence, duration, and

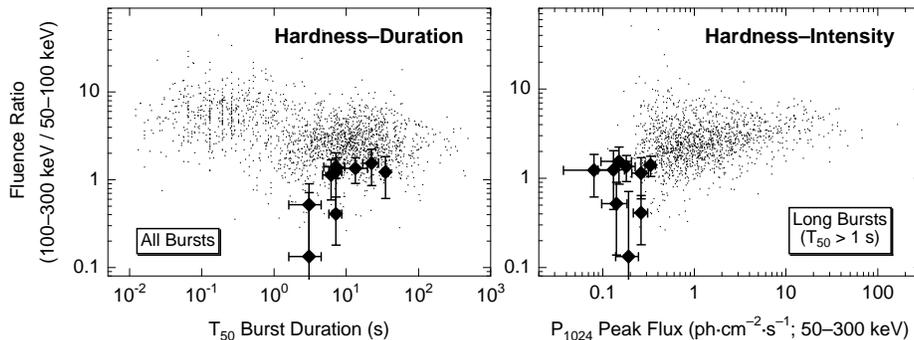


Fig. 2. Gamma-ray parameters of nine FXTs (diamonds) compared to GRBs from the BATSE trigger catalog (dots). The plot at right shows only “long” GRBs ($T_{50} > 1$ s).

hardness ratios. These quantities were produced using the same software and procedures employed for all BATSE GRBs, so we can make direct comparisons to the large BATSE GRB trigger catalog [3].

As can be seen in Figure 2 (left), the FXTs have durations comparable to the long class ($T_{50} > 1$ s) of GRBs, but are noticeably softer than the average long GRB based on their fluence hardness ratios. This spectral difference is also apparent in the distribution of peak flux hardness ratios. However, since the FXTs are less intense than most triggered GRBs, spectral differences may be expected due to the well-known GRB hardness–intensity correlation (e.g., [4]). As shown in Figure 2 (right), the FXTs appear to be generally consistent with the extrapolated hardness–intensity trend of long-duration bursts (albeit three of the FXTs are anomalously soft). This result offers tantalizing evidence that the FXTs could be a natural extension of known GRB characteristics.

To investigate this result in more detail, 16-channel, 2.048-s data were used to fit the time-averaged gamma-ray spectrum of each FXT. Due to the large statistical uncertainties in these weak events, only simple spectral models with few free parameters are justified. We find that both the single power law model and the “Comptonized” model [4] yield acceptable fits to the data. Figure 3 shows examples of two FXT spectra and their best-fit spectral models.

The Comptonized model, which includes curvature parameterized by the $\nu\mathcal{F}_\nu$ peak energy E_{peak} , was used by Mallozzi et al. [5] to fit all time averaged 16-channel spectra of 1023 bursts from the BATSE 4B catalog. In Figure 4, the fitted values of E_{peak} for 802 long GRBs from this collection are compared to those of the FXTs. Apart from the three soft outliers mentioned above (note also the large errors), the FXTs appear to be consistent with E_{peak} –intensity trend of the GRB sample. For further clarity, this trend was modeled by fitting a power-law function to the distribution of E_{peak} in eight intensity bins (each containing ~ 100 long GRBs). The 68% confidence region for this fit is indicated by the two dashed lines in Figure 4. The extrapolated fit is clearly consistent with most of the FXT spectra, in agreement with the previous result based on hardness ratios.

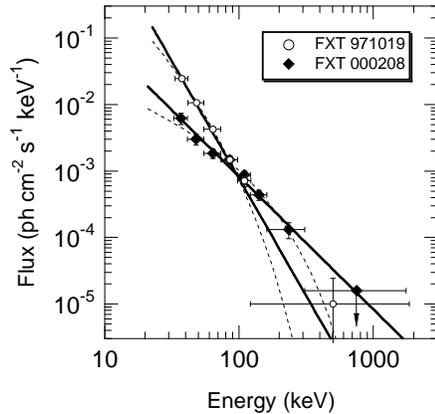


Fig. 3. Time-averaged energy spectra of two FXTs measured with BATSE. Solid and dashed lines indicate the best-fit power-law and Comptonized models, respectively.

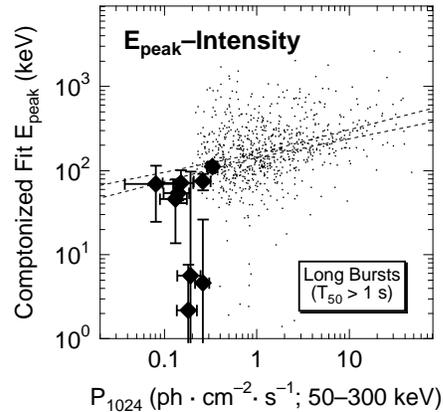


Fig. 4. Best-fit time-averaged E_{peak} vs. peak flux for FXTs (diamonds) and long GRBs (dots). Dashed lines indicate the 68% confidence region of a power-law fit to the GRB E_{peak} -intensity correlation.

4 Conclusions and Future Work

Thanks to the high sensitivity of BATSE, we have been able to directly compare the gamma-ray properties of FXTs to those of the full GRB population. The preliminary result is that FXTs appear to be consistent with an extrapolation of known GRB behavior – indicating that they represent a previously unexplored sector of the GRB population. If confirmed, this result implies that there are a large number of undetected bursts with peak energies in the x-ray regime. In fact, the untriggered BATSE burst catalog of Stern et al. [6] suggests that the all-sky rate of FXT-like events with $P_{1024} \gtrsim 0.1 \text{ ph} \cdot \text{cm}^{-2} \cdot \text{s}^{-1}$ is $\sim 400/\text{yr}$. This represents nearly half of all long GRBs in their catalog! It is tempting to speculate that these x-ray rich events could represent a large population high-redshift GRBs. In future work, we will attempt to confirm the findings presented here by jointly analyzing the x-ray and gamma-ray spectral data from WFC and BATSE. We will also investigate in more detail the similarities between the WFC FXTs and the large sample of untriggered BATSE events.

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