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# Selection effects in the BeppoSAX gamma-ray bursts sample

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**Abstract.** The BeppoSAX satellite opened a new era in gamma-ray bursts (GRBs) astronomy thanks to the capability of its Wide Field Cameras to accurately and promptly localize GRBs and of its X-ray telescopes to detect their fading X-ray counterparts. This led to the detection of counterparts at other wavelengths and to the determination of the GRB distance scale. However, the BeppoSAX instrumentation was not designed on this scope, and it is therefore not optimized to it. This could result in an inhomogeneous sample of events. In this paper we analyze the potential selection effects that can affect the sample of GRBs simultaneously detected in the Gamma Ray Burst Monitor and in the Wide Field Cameras, due to the characteristics of this BeppoSAX instrumentation.

**Key words:** gamma-rays: bursts

## 1. Introduction

The BeppoSAX instrumentation was not specifically designed to search for prompt and delayed X-ray counterparts to GRBs. This could be done because the BeppoSAX payload is rather flexible and complete, but still it suffers from some instrumental limitations for GRB investigations, mainly due to the fact that the Gamma Ray Burst Monitor (GRBM, Frontera et al. 1997; Feroci et al. 1997; Costa et al. 1998) is a secondary function of the anticoincidence shields of the PDS experiment and to the limited (∼5%) sky coverage by the Wide Field Cameras (WFC, Jager et al. 1997). These limitations imply that some selection effects can be expected in the sample of GRBs localized by the WFC. On the basis of the instrumentation design and of the procedures used so far for localizing GRBs we can expect the following GRB characteristics to be possibly biased: coordinates, gamma-ray intensity, X-ray intensity, duration. This is made clear by considering the three basic procedures used so far:

(a) Upon a GRBM trigger, the WFC 1-s ratemeters are searched for a possible counting excess at the time of the trigger. The integration time to detect a count rate increase that can determine a GRBM trigger is currently set at 1 s. This implies that GRBs shorter than 1 s are selected against just by the triggering and screening procedure. Also, the GRBM detectors are individually very sensitive but, as explained in Sect. 4, the trigger condition could cause a selection on the gamma-ray intensity of the event.

(b) The WFC 8-s ratemeters are continuously searched for counting excesses, independently of the GRBM triggers. Given the 8-s integration time this operates a selection both on duration and on X-ray intensity.

(c) When the nominal position of a BATSE/LOCBURST trigger (Kippen et al. 1997; Paciesas et al. 1999) is within or close to the WFC field of view, the 8-s ratemeters are searched for counting excess. Therefore, in addition to the same effect on duration and X-ray intensity as above, since the BATSE localization capabilities improve at higher intensities this procedure implies a selection on gamma-ray intensity.

## 2. Selection on coordinates

The satellite attitude is constrained by the requirement that the solar panels face a direction within 30° from the Sun direction. In addition, for the first year of operation, during the NFI primary pointings the WFCs were preferentially pointed as close as possible to the Galactic plane. These two facts resulted in a non-uniform sky coverage by the WFC, and consequently in a non-uniform sky distribution (Fig. 1) of the BeppoSAX/WFC well-localized GRBs. A further selection favours the celestial poles because for these high latitudes the periodic Earth occultation of the WFC field of view, due to the satellite orbital motion, is shorter, making the net WFC exposure time at these directions longer than at equatorial directions.

## 3. Selection on X-ray intensity

Since the WFC sensitivity is not a priori matched with the GRBM sensitivity a selection in X-ray intensity is naturally expected. Given the poor positioning capabilities of

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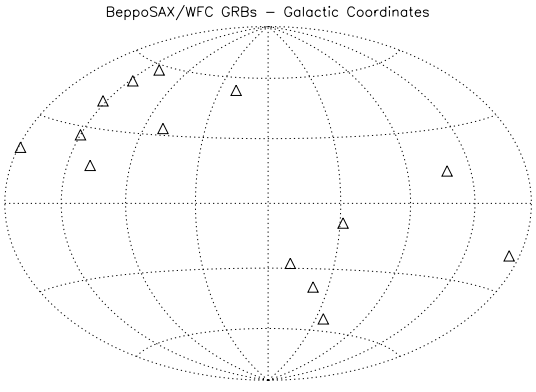


**Fig. 1.** Sky distribution of the BeppoSAX GRBs (as of November 1998) in Galactic coordinates, showing the non-uniform distribution

**Table 1.** Extrapolated $2-20$ keV flux of GRBM detected events, obtained extrapolating the spectral best-fit law (spectral GRBM analysis from G. Ghirlanda 1999, Thesis)

| GRB | $\alpha^a$ | $\beta^a$ | $E_0^a$ keV | $T^b$ s | Aver. GRBM flux$^c$ | Extr. WFC flux$^d$ | Ratio X/$\gamma$ |
|---|---|---|---|---|---|---|---|
| 971223 | $-2.16^e$ | - | - | 25 | 3.33 | 4.5 | 1.35 |
| 971210 | $-0.79$ | $-5.29$ | 357 | 15 | 26.4 | 0.9 | 0.03 |
| 971029 | $-0.66$ | $-1.95$ | 70 | 110 | 37.0 | 3.8 | 0.10 |
| 970816 | $-0.44$ | $-0.85$ | 101 | 10 | 194 | 2.4 | 0.15 |
| 970317 | $-1.31$ | $-1.72$ | 246 | 68 | 3.23 | 0.5 | 0.15 |
| 971026 | $-1.09$ | $-4.86$ | 612 | 20 | 24.7 | 1.5 | 0.06 |

[a] Parameters from the phenomenological law after Band et al. (1993).
[b] GRB duration.
[c] $10^{-8}$ erg cm$^{-2}$ s$^{-1}$ in $40-700$ keV (average).
[d] $10^{-8}$ erg cm$^{-2}$ s$^{-1}$ in $2-10$ keV (extrapolated).
[e] Fit with a simple power law.

the gamma-ray experiments there is no obvious method to definitely check whether the BeppoSAX sample is X-ray selected or not. However, the following considerations suggest that such a selection is not effective.

First, all the GRBs that are known (through a BATSE accurate localization, i.e. LOCBURST, Kippen et al. 1997) to have occurred within the WFC field of view have shown a detectable X-ray counterpart. Second, we have taken a small sample of GRBs detected by the GRBM and extrapolated the best-fit to the average $40-700$ keV energy spectra downwards to the WFC energy range ($2-20$ keV). Of course, this procedure includes large uncertainties in the spectral parameter extrapolation due both to statistical errors and to the assumption that the same law holds at low energies. However, the results are reported in Table 1 and show the expected fluxes for these bursts. In all cases they are in a range of quite easy detectability with the WFC.

Even if the above considerations are in no way conclusive, they suggest that the WFC sensitivity happens to be well matched with the GRBM and BATSE sensitivity.

## 4. Selection on gamma-ray intensity

A selection in gamma-ray intensity in the BeppoSAX/WFC GRBs could be expected due to the triggering mechanisms of the GRBM. In fact, the GRBM experiment is composed of 4 detectors placed in a box-like configuration, 90° one to the other. The trigger condition requires a simultaneous 4 $\sigma$ excess in at least 2 detectors. Events occurring within the WFC field of view are basically on axis for either unit #1 or #3 of the GRBM, and this implies the geometric area of the adjacent detectors to be almost null. Therefore, the onboard trigger relies on scattering effects due to the satellite structures and/or the Earth atmosphere. The typical efficiency for such a scattering is of the order of $10-20\%$. However, the BeppoSAX-SOC has also the ability to recognize events detected by the GRBM but not triggered by the onboard software. The net result is that the peak fluxes of the BeppoSAX GRBs include very weak events, that samples the low-flux tail of the BATSE $\log N - \log S$ distribution. Therefore it appears to be no significant selection on the gamma-ray intensity of the sample of GRBs detected by BeppoSAX/WFC and GRBM.

## 5. Selection on the GRB duration

The best evidence for a duration selection in the BeppoSAX/WFC GRB sample is provided by the fact that out of 14 events detected till November 1998, the shortest is about 6 s long. From the BATSE duration distribution, one would have expected about $20-30\%$ of them to be shorter than 1 s. A further indication is given by a search of the BATSE GRBs in the GRBM triggers database over a 1-year period. This work (Preger et al. 1999) shows that only few GRBs out of $\sim$60 have a $T_{90}$ duration shorter than 1 s (mainly because of the GRBM 1-s integration time for the trigger).

## 6. Conclusions

In our analysis we found a significant selection on the BeppoSAX GRB coordinates, while there is no evidence for a selection on X- or gamma-ray intensity. As expected, there is a significant bias on the duration in the BeppoSAX/WFC GRBs sample. To partially overcome this problem the BeppoSAX Science Operation Center is setting-up a procedure for screening data from the GRBM and WFC with a time resolution of 100 ms (also checking BATSE triggers, on a temporal rather than spatial basis) (Smith et al. 1999).

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