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NUCLEAR PHYSICS B
PROCEEDINGS
SUPPLEMENTS

Monitoring of high energy X-ray sources with the BeppoSAX GRBM

C. Guidorzi[a], L. Amati[b], M. Feroci[b], E. Costa[b], F. Frontera[a], D. Dal Fiume[c], M. Orlandini[c]

). [a]Dipartimento di Fisica - Universitá di Ferrara

[b]Istituto di Astrofisica Spaziale - C.N.R. - Roma

[c]I.Te.S.R.E. - C.N.R. - Bologna

The Gamma-Ray Burst Monitor (GRBM) aboard the BeppoSAX satellite has already shown good capabilities in the detection of Gamma-Ray Bursts (GRB). We have also tested its performance as monitor of the hard X-ray flux from strong celestial sources, using the Earth Occultation Technique. A verification of the on-ground calibrations of the instrument was performed deriving the flux of the Crab Nebula. In this paper we report results on Crab and light curves of other sources detected.

1. INTRODUCTION

The Gamma-Ray Burst Monitor (GRBM) [1] aboard BeppoSAX has already shown good capabilities in the detection of Gamma-Ray Bursts (GRB). The GRBM consists of four Lateral Shields (LS), surrounding the PDS experiment and forming a square well (each slab has 1135 cm^2 geometrical area). The data transmitted include the count rates of each LS in two energy bands: GRBM band and AntiCoincidence (AC) band (integration time = 1 sec).

GRBM band : 40 - 600 keV (nominal values);

AC band : > 100 keV (nominal value).

To know the flux of a detected GRB, once its direction is known, we need to know with sufficient accuracy the angular response (that is the angle-energy dependence of the efficiency) of the LS for that direction, i.e. we must know a priori the GRBM calibration.

Besides, once the angular response of each LS is known, it is possible to extract the light curve of the source with the Earth Occultation Technique (EOT) using many observations, even if the direction of the source with respect to the LS changes with time.

The on-ground calibration was already carried out using some radioactive sources and an angular response was obtained as a function of the direction and energy of the sources [2]. Then we have extracted an in-flight calibration by measuring the flux of the Crab Nebula in correspondence with many different directions; we have chosen this source because of its stability in the two energy bands of our interest (and, obviously, because it is periodically hidden by the Earth).

In this paper we report some results about the in-flight calibration made with the Crab Nebula and light curves of some variable X-ray sources.

2. THE EARTH OCCULTATION TECHNIQUE

To evaluate the contribution of an X-ray source to the whole count rate measured by a given LS, we have used the so called EOT, similarly to what has been done by BATSE onboard the CGRO satellite [3]. More precisely, if the celestial coordinates of the source and the ephemeris of the satellite are known, we can calculate the time windows in which the source is visible for an observer in the place of BeppoSAX.

In correspondence with the extremes of these time windows, we have the occurrence of the so called Occultation Events (OE). In particular, at the beginning of each time window (i.e., when the source rises from the Earth limb) we say that an End Of Occultation (EOO) has occurred; in the same way, at the end of each window (when the source goes down behind the Earth limb) we call

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this event as a Beginning Of Occultation (BOO).

For every OE we consider a 200 sec time interval [1] centered on the occurrence time of the event; as the time resolution of our ratemeters is 1 sec, each interval is divided into 200 temporal bins. Then, for both classes of OE, we compute the average value of the counts measured inside each time bin. Finally, we obtain two time profiles describing respectively the BOO and the EOO of the given source, simply by plotting the average values of the counts in correspondence with each time bin (we called this "Phase Summing Method" for obvious reasons) (see fig. 1).

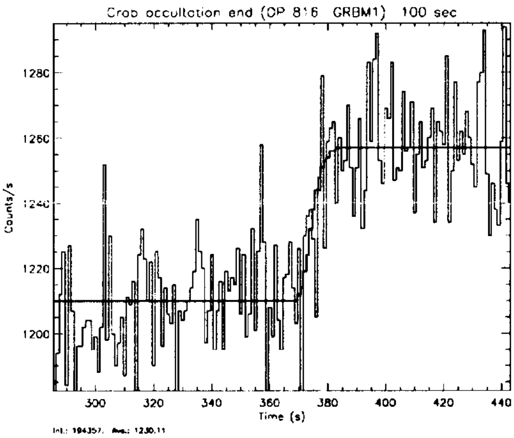

Figure 1. Time profile of an EOO, obtained with the Phase Summing Method for the Crab Nebula on August, 22, 1996, when its direction was normal to the LS #1; GRBM energy band: 40 - 600 keV. You can also see the best fit.

To give an estimate of the flux due to the source, we perform the fit of the time profile with the following function $f(t)$ (t is time):

$$f(t) = Av(t) + B \tag{1}$$

where $v(t)$ is the "visibility function": it is equal to the fraction of flux that has not been absorbed by the Earth atmosphere; $v(t)$ is evaluated through an algorithm developed by the author. A and B are free parameters representing the flux of the source and the background level, respectively.

We expect that the Phase Summing Method cannot reveal fluxes lower than about 100 mCrab in the GRBM band and 150 mCrab in the AC band.

[1] Sometimes we used 150 sec and 400 sec time intervals too.

3. RESULTS

The in-flight calibration performed with the Crab Nebula has substantially confirmed the on-ground calibration. Table 1 reports important results on the Crab Nebula, like its flux on the LS #1 and #3 in the GRBM and AC energy bands.

To estimate the LS efficiencies ϵ, we used the Crab Nebula's spectrum $n(E) = 9.7\ E^{-2.1}$ photons/cm^2/s/keV and its flux f_{crab} crossing normally one LS:

$$f_{crab}^{(GRBM)} = 1135 \int_{40}^{600} n(E)\, dE \simeq 164\ \frac{\text{ph}}{\text{s}} \tag{2}$$

$$f_{crab}^{(AC)} = 1135 \int_{100}^{+\infty} n(E)\, dE \simeq 63\ \frac{\text{ph}}{\text{s}} \tag{3}$$

$$\epsilon = \frac{\overline{A_n}}{f_{crab}} \tag{4}$$

where $\overline{A_n}$ is the weighted average of the count rates of Crab.

Using the Phase Summing Method together with the calibration data obtained with the Crab Nebula, we have also extracted light curves of other high energy X-ray sources, which have shown an irregular variability during the second half of 1996: Cygnus X-1 (B.H.C.) (see figg. 2, 3), GRS1915+105 (superluminal motion B.H.C.) (see fig. 4), GRO1744-28 (transient peculiar source) (see fig. 5).

4. CONCLUSIONS

The measures of the Crab Nebula's flux obtained in both energy bands seem to indicate that the LS #1 has a slightly better efficiency than the LS #3 (see Table 1).

Table 1
Count rates A_n measured for the Crab Nebula when its direction was normal to the LS #1 and #3 (the two best known and with the best efficiency) for the GRBM and AC energy bands and for three different time windows used for the fit (150, 200 and 400 sec respectively). In the sixth column we report the weighted averages $\overline{A_n}$ of the count rates belonging to the same row; in the last column the efficiency ϵ is reported.

LS	*Band*	A_n (count/s) (Δt = 150 s)	A_n (count/s) (Δt = 200 s)	A_n (count/s) (Δt = 400 s)	$\overline{A_n}$ (count/s)	*Efficiency* ϵ
1	GRBM	46.1 ± 1.6	47.2 ± 1.4	47.9 ± 1.0	47.3 ± 0.7	$\mathbf{0.288 \pm 0.004}$
3	GRBM	42.2 ± 2.3	44.9 ± 2.1	47.5 ± 2.0	45.1 ± 1.2	$\mathbf{0.275 \pm 0.007}$
1	AC	21.1 ± 0.8	20.8 ± 0.7	18.6 ± 0.6	19.9 ± 0.4	$\mathbf{0.316 \pm 0.006}$
3	AC	19.3 ± 1.3	20.3 ± 1.2	16.9 ± 1.1	18.7 ± 0.7	$\mathbf{0.297 \pm 0.011}$

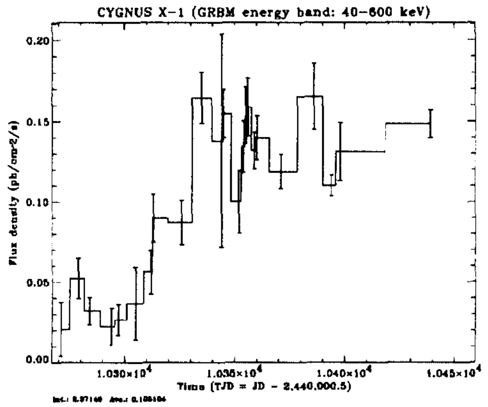

Figure 2. Light curve of CYGNUS X-1 in the GRBM energy band extracted by the author with the EOT. Time interval: July 96 - December 96. The soft-to-hard transition occurred in the middle of August 1996 is clearly visible.

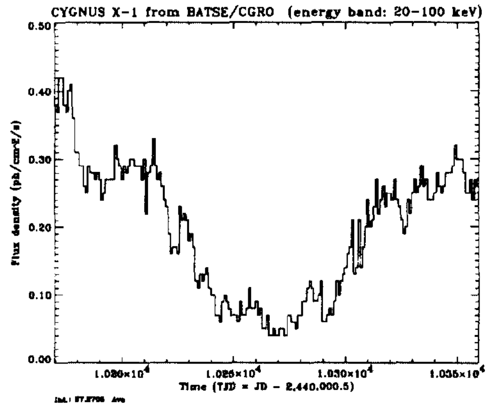

Figure 3. Light curve of CYGNUS X-1 in the energy band 20-100 keV extracted by BATSE [4]. Time interval: March 96 - October 96. Both experiments show the soft-to-hard transition occurred in the middle of August 96.

According to the BATSE data, the light curve of Cygnus X-1 extracted with the Phase Summing Method shows clearly the soft-to-hard transition occurred in August 1996 (see figg. 2, 3).
Also the light curves of the variable sources GRS1915+105 and GRO1744-28 show strong variations in the flux occurred in 1996/1997 (see figg. 4, 5).
In summary, we can say that if we process the GRBM data with the Phase Summing Method (based on the EOT), then it is possible to monitor variables high energy X-ray sources, like B.H.C. and other transient peculiar sources, provided that their flux is not lower than about 0.1-0.2 Crab in the GRBM and AC energy bands.

REFERENCES

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2. Amati et al. 1997, Proc. GIFCO.
3. Zhang et al. 1995, Exp. Astron. 6, 57-62.
4. Zhang 1997, ApJ Lett. Vol. 477, L95.

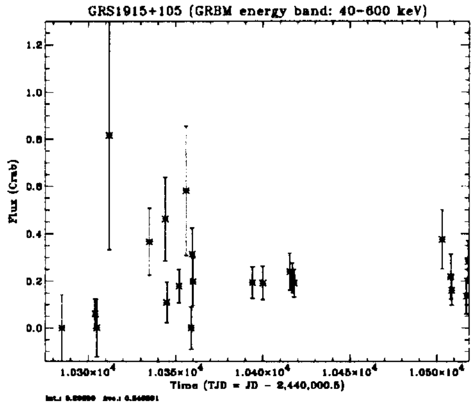

Figure 4. Light curve of GRS1915+105 in the GRBM energy band extracted by the author with the EOT. Time interval: August 96 - March 97.

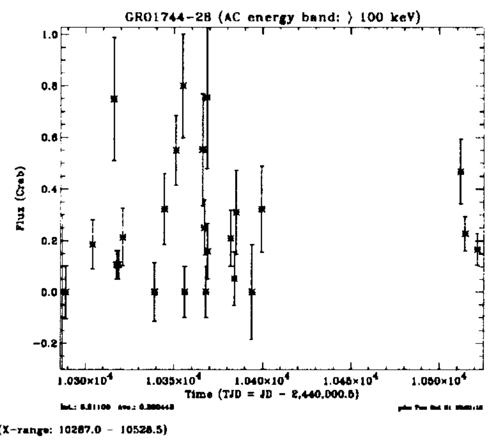

Figure 5. Light curve of GRO1744-28 in the AC energy band. Time interval: August 96 - March 97.