Wide-field Cameras for GRB Observations in X-rays and EUV

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1 Introduction

Recent observations of the *ASCA* satellite resulted in the first identification of a GB source (Murakami et al. 1994). This success confirmed the importance of simultaneous observations in different wavelength bands for GB studies. Besides the *ASCA* results, there were several observations of GBs in X-ray band with the *Ginga* (Yoshida et al,.1989), V 78/1 (Laros et al. 1984) and other satellites. It became clear that GBs emit 4 – 8% of their energy in the 2 – 10 keV range. The main task now is to have an equipment which will be able to monitor the sky in X-rays in a mode similar to that of GRO observations, i.e. the telescope should have an all-sky field-of-view (FoV) and should work continuously.

A telescope with these features but operating at soft X-ray energies may directly determine the GB distance scale, due to interstellar absorption of the photons with energies less than 2 keV, as was pointed out first by Schaefer (1993). Flaring sources similar to GBs in time scale may be found also in the EUV (hundreds of angstroms) with the help of very wide-field cameras. Of course each such device – in X-ray, soft X-ray and EUV bands – will discover many transient objects, flaring events, will study time variability of bright "stationary" sources etc. In this paper we describe several instrumental approaches in these fields.

2 The "BARS" all-sky X-ray monitor

We have designed an all-sky X-ray monitor for continuous observations in the 2 – 25 keV energy band. The detectors are 6 standard proportional counters. Each detector has a 100 μm Be window of 170 cm^2 area. The counters are filled with 90% Xe + 10% methane gas mixture under 400 mm Hg pressure so that the resulting quantum efficiency is greater than 15% in the total energy range. Such devices have been used onboard the space station "Astron" for several years. Detectors used in the "Bars" experiment have no collimation. The counters are to be placed at the spacecraft at such a mode that their fields-of-view will look along 6 orthogonal axes, so that they observe the whole sky. The effective area of each counter varies as cosine of an incidence angle of photons, so it is possible o estimate roughly the direction of each event. For the brightest sources the error radii should be of the order of $5 - 6^{\circ}$. Several electronic boxes supply all the voltages and analyze spectral and timing information. There are two operational modes:

(a) all the pulses are divided in four energy channels: 2 – 3.5, 3.5 – 6, 6 – 10 and 10 – 25 keV, and the accumulated number of pulses for each channel from each detector with time resolution of 64 ms goes to the telemetry system,
(b) the time of arrival and amplitude are determined for each pulse from each counter and are telemetered to Earth.

The maximal count rate from each counter is 40 000 c/s. This telescope may operate only in the Earth's shadow. The total mass of the telescope is 60 kilogram.

At a low-Earth orbit and at latitudes below 40^{circ} the main background component is diffuse X-rays, if a counter is oriented looking to the galactic poles. In this case the background countrate is about 1000 c/s in the 2–10 keV band. While looking to the galactic center region the countrate rises up to 5000 c/s and consists mainly of the sum of many discrete source fluxes.

For sensitivity estimates we use a composite spectral form of a typical GB:

$$\begin{aligned} dN/dE &= A \cdot E^{-0.7} \text{ photons/cm}^2 \text{ s keV} \quad \text{for E} < 10keV, \\ dN/dE &= 2A \cdot E^{-1} \text{ photons/cm}^2 \text{ s keV} \quad \text{for E} = 10 - 100keV, \\ dN/dE &= 200A \cdot E^{-2} \text{ photons/cm}^2 \text{ s keV} \quad \text{for E} > 100keV. \end{aligned}$$

Estimated background levels together with such a spectrum means that, e.g., if the duration of a GB is 1 s, our sensitivity at the level of 5σ is about 10^{-8} ergs/cm^2 s for the 2 – 10 keV energy range; it corresponds roughly to bursts with $7 \cdot 10^{-7}$ ergs/cm^2 fluence detected by the *BATSE* experiment onboard the Compton Observatory in the 50 – 300 keV band.

This spectrometer if produced and fully tested, but economical difficulties prevent its actual launch to space.

3 Soft X-ray counter with a thin beryllium window

For soft X-ray observations of discrete sources, proportional counters usually have thin organic windows of several μm thickness. But if the problem is to design a very wide-field telescope for sky monitoring and detection of short-lived events in the 0.1 – 1 keV range, this approach can hardly be applied, for the following reasons:

(a) if the counter has no collimation, the soft diffuse X-ray background becomes the main background component. But while in the region of $E > 1$ keV its photon spectrum has a power law with an exponent of -1.4, in the range $E < 1$ keV, this exponent becomes -2 (McCammon & Sanders 1990), which substantially reduces the signal to noise ratio. Contrary to this, the GB spectra

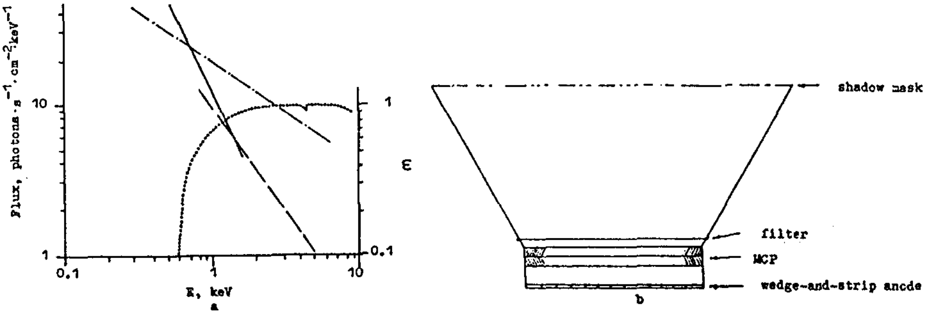

Fig. 1. a – solid line: soft X-ray diffuse flux for a detector with 1 steradian FoV, dashed line: the same for a diffuse background in the 2 – 10 keV range, dash-dotted line: flux from the GB with fluence of 10^{-5} ergs/cm^2 and 1 sec duration. Dotted curve: quantum efficiency of a counter with a 4 μm Be window. b – schematic view of the EUV shadow camera.

become flatter with decreasing photon energy down to 1 keV and less, which worsens the situation.

(b) The energy resolution of a counter is proportional to $E^{0.5}$ and becomes greater than 50% with energy decreasing below 1 keV. This means that the softest photons from very intense background intensities pollute the background at higher energies.

(c) The typical efficiency of a thin film counter has non-zero values lower than carbon K-edge of 0.28 keV and is close to zero between 0.28 and 0.7 keV, i.e. exactly where it is very important to analyse GB spectra for the determination of a probable Galactic absorption.

We propose to use a counter with a 4 μm Beryllium window as a detector for observations of soft X-ray GB components. Its efficiency is shown on Fig. 1a. The advantage of using a thin Beryllium window is clearly seen – it has a significant efficiency exactly in the $E > 0.6$ keV range and has no sensitivity at lower energies, where the background is high. An additional and very important technical advantage of such a counter is that there is no need for a heavy and complicated gas-flow system.

The *ASCA* team has successfully designed an imaging gas scintillation counter with a 10 μm Be window (Makishima 1993), and it is expected that present-day technology permits the construction of a detector with a 4 μm Be foil.

Based on the composite spectrum, we estimat that such a counter with an area of 100 cm^2 will detect the soft components of GBs with 1 s duration and $5 \cdot 10^{-6}$ ergs/cm^2 fluence at the 5σ level, and will determine $N_{\rm H}$ quantities with a precision of about 30% at the 1σ level for $N_{\rm H} > 10^{21}$ atoms/cm^2.

4 Wide-field shadow camera for EUV observations

Microchannel plates (MCP) are widely used as detectors in EUV astronomy. Until now, there are no telescopes with FoV of more than several degrees working in the EUV band.

The main idea of a proposed device is to use a large MCP together with a two-dimensional shadow mask (the latter is used commonly in X-ray telescopes). MCPs are now produced with dimensions up to about 6×6 cm^2 and achieve a linear resolution of better than 100 *mum* (Lampton 1991). We propose to use such a MCP and a coded mask with 12×12 cm^2 dimensions consisting of a 0.1×0.1 mm^2 random cell array to obtain a 60° FoV with $6'$ angular resolution. To achieve this, the mask should be placed 5.3 cm above the MCP, and the read-out of pulses produced by incident photons will be performed by an appropriate anode. The overall efficiency of such a camera for 100 – 300 Å photons is expected to be greater than 0.2.

The main background component in the EUV band will again be the diffuse photon background. There are powerful geocoronal emission lines at 304 Å, 584 Å etc. (Labov & Bowyer 1991). To get rid of this emission and to achieve the lowest background level of about 2000 photons/cm^2 s sr the preferrable range is 100 – 200 AA, which may be selected by a wide-band filter. The schematic view of the wide-field camera is shown on Fig. 1b. Sensitivity estimations show that it will be about 10^{-8} ergs/cm^2 s for a 1 s flash, which corresponds to $4 \cdot 10^{-5}$ ergs/cm^2 fluence in the 50-300 Å band for a GB. On the other hand this sensitivity corresponds to 100 photons/cm^2 s, i.e. the brightest sources like HZ 43 will be discovered after only 10 seconds of observations. This indicates a very attractive future for such cameras.

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