GROUND CALIBRATIONS OF THE MEDIUM ENERGY EXPERIMENT ON BOARD THE X-RAY ASTRONOMY SATELLITE SAX

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Abstract. The scientific instrumentation on board SAX (cfr. Piro et al. *these proceedings*) includes a Medium Energy Concentrator / Spectrometer (MECS), operating in the 1.3-10 keV energy range, which consists of three identical instruments, composed by a grazing incidence Mirror Unit with a focal length of 185 cm and by a position sensitive Gas Scintillation Proportional Counter. We give a brief description of the ground calibrations of the MECS, performed at the X-ray PANTER facility, and of their analysis. A more presentation can be found in Boella et al. (1995).

1. Introduction

The main objectives of the Medium Energy Concentrator / Spectrometer (MECS) on board SAX are: 1) broad band spectroscopy in the range 1.3-10 keV with a resolution of $E/\Delta E = 0.08 \times (E/6)^{-1/2}$, where E is in keV and ΔE is the FWHM; 2) imaging with angular resolution at the arcmin level; 3) study of time variability on time scales down to the millisecond. To reach the desired sensitivity levels with the allowed dimensions of the satellite, the MECS consists of three identical instruments, each composed by a Mirror Unit (MU) with a Xenon filled position sensitive Gas Scintillation Proportional Counter. In these proceedings we present a brief description of the ground calibrations of the MECS, performed at the X-ray PANTER facility (section 2), and of their analysis (sections 3,4,5,6).

2. The Ground Calibrations

The three flight MECS instruments, together with the LECS flight unit (Parmar et al., *these proceedings*) have been extensively calibrated at the 130 meter long X-ray PANTER facility of the Max-Planck-Institut für Extraterrestriche Physik in Munich, during a period of 7 weeks in October-November 1994. The limited size of PANTER beam did not allow a simultaneous calibration of all units, therefore two MECS instruments, hereafter named ME2 and ME3, were calibrated together during a first run and a third MECS unit, hereafter ME1, and the LECS were calibrated during a second run. The measurements were made at: 0.92 keV (Cu-Lα), 1.25 keV (Mg-Kα), 1.48 keV (Al-Lα), 1.74 keV (Si-Kα), 2.02 keV (P-Kα), 3.12 keV (Ag-Lα), 4.52 keV (Ti-Kα), 5.44 keV (Cr-Kα), 6.44 keV (Fe-Kα), 7.52 keV (Ni-Kα) and 8.1 keV (Cu-Kα). For each energy three main kind of measures were performed: 1) MUs (on-axis and off-axis); 2) flat fields of the detector units alone; 3) multipinhole scans of the detector units alone. The statistical quality of the data is very high, (e.g. typical MU acquisition runs contain about half a million events).

3. Spatial Gain Dependency

A dependency of the gain on the position is present in all three detectors and can be calibrated by analysing individual spectra of each spot of the multipinhole measurements. The core of each line has been fitted with a gaussian, and the peak position in channels has been associated to the spot position in pixels, obtaining a set of sparse values $G_i = G(x_i, y_i)$. For each run a gain map has been derived with a biquadratic interpolation of the above values. The values have then been normalized to the gain at the detector center, obtaining a relative gain map $g(x, y) = G(x, y)/G(x_0, y_0)$. We have found that the relative gain is extremely stable with energy, as well as unaffected by temporal variations of the absolute gain, therefore we have averaged the gain maps of all runs at all energies to produce a single high accuracy gain map per detector. The range of the relative gain (assuming 1.00 at the detector center) is 0.9-1.1 for ME1, 0.99-1.06 for ME2 and 0.96-1.03 for ME3. The rms error on the relative gain is extremely small, $< 0.2\%$ over almost all the field of view.

4. Absolute Gain and Spectral Calibration

The absolute gain was monitored continuously using the built-in Fe^{55} calibration sources. For the spectral calibration analysis we used data from the on-axis MUs runs, in order to minimize any dependence of the detector gain

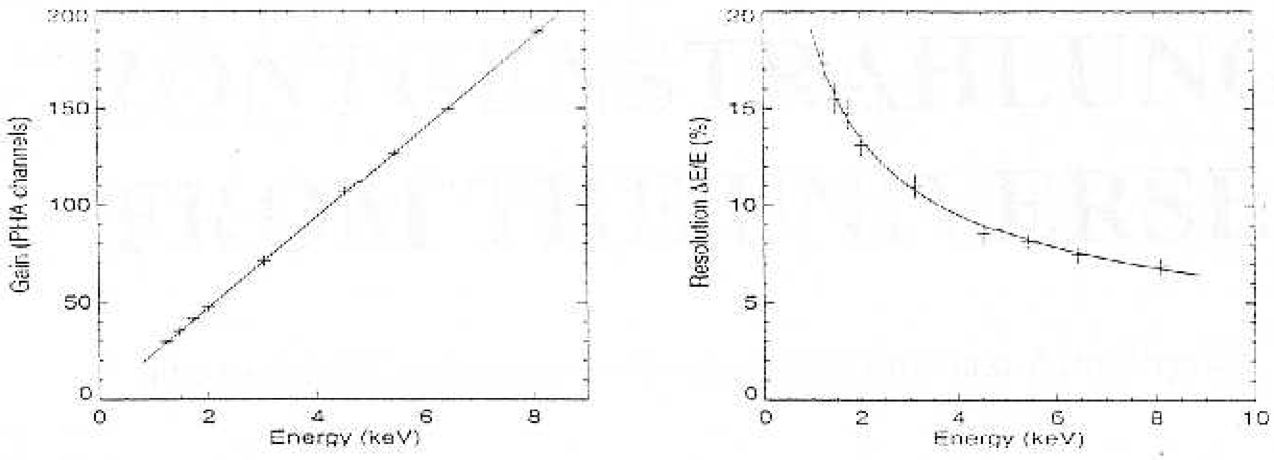

Fig. 1. a) and b): gain vs. energy relationship and spectral resolution vs. energy relationship for the ME3 unit.

from the position. The calibration lines were generally fitted using a single gaussian curve, although in some cases (e.g. the Titanium line) the presence of a secondary peak required a more complex model. From the results of this analysis, compensating for the time variations of the gain by using the built-in Fe^{55} sources, we calibrated the gain versus energy relationship (fig. 1a) and the spectral resolution versus energy relationship (fig. 1b).

5. Effective Areas

For this analysis we have used the MU and flatfield measurements; we have also corrected for the instrumental background by using background measurements. For each energy we have considered events from the entire detector, except those falling around two small areas were the calibration sources are located. In figure 2 we show the comparison between the theoretical behaviour, as derived from ray tracing simulations of a point source located at the same distance as the PANTER X-ray source, and the data for the ME1 unit. As can be seen the experimental points are in excellent agreement with the model, the largest deviations being of ≃ 2%.

6. Spatial Calibration

The preliminary analysis of the MECS PSF which we have performed has been restricted in 3 ways: 1) by considering only the on-axis PSF; 2) by assuming only a radial dependence of the PSF; We have used a model for the PSF which is the sum of 2 components: a gaussian, $G(r) = c_g \exp(-r^2/2\sigma^2)$, and a generalized lorenzian, $L(r) = c_l[1 + (r/r_l)^2]^{-m}$, where r is the distance from the peak of the emission and c_g, c_l, σ, r_l and m are the parameters of the model which have been derived by fitting the radial profiles accumulated from the calibration data at the energies of: Mg, Al, Si, P, Ag, Ti, Cr, Fe and Cu. By imposing that the integral of the PSF over the entire plane be equal to unity, we have reduced the number of independent parameters to 4: σ, r_l, m and R, where $R = c_g/c_l$. The dependency of these 4 parameters on the energy has been reproduced through simple algebraic functions. The complete analytical expression for the PSF reads:

$$PSF(r,E) = \frac{1}{2\pi\left[R(E)\sigma^2(E) + \frac{r_l^2(E)}{2(m(E)-1)}\right]} \times$$

$$\left\{R(E)\exp\left(-\frac{r^2}{2\sigma^2(E)}\right) + \left[1 + \left(\frac{r}{r_l(E)}\right)^2\right]^{-m(E)}\right\}$$

where $R(E)$, $\sigma(E)$, $r_l(E)$ and $m(E)$ are algebraic functions of E.

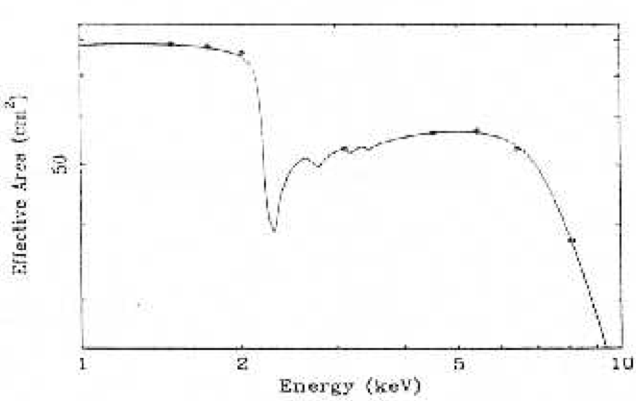

Fig. 2. On Axis Effective Area for the ME1: Panter Measurements vs. Ray-Tracing Simulation.

References

Boella et. al in *Proceedings of the SPIE Conference on X-ray and EUV/FUV Spectroscopy and Polarimetry held in San Diego 11-19/9/95.*
Parmar et. al *these proceedings.*
Piro et. al *these proceedings.*