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In-flight calibration and detector response matrices for WXM/HETE-2(*)

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Summary. — The HETE-2 carries the Wide-field X-ray Monitor (WXM) which consists of four identical one-dimensional position-sensitive proportional counters and the electronics for signal processing. It is placed beneath two one-dimensional coded aperture masks and sensitive to X-rays from 2 to 25 keV. The detector response matrices (DRMs) of the WXM is calculated numerically based on the pre-flight ground measurements for each anode wire. Since the launch of HETE-2, in-flight calibrations have been carried out utilizing data of Crab nebula. An unexpected excess appeared in low energy spectra (2–4 keV) of the WXM since December 2002. We found the excess being on an increasing trend. It is possibly explained by a gradual loss of the aluminum-coated Kapton film which covers the coded masks. We developed the new DRMs generator based on the variation of the thickness of aluminum-coated Kapton film.

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1. – Introduction

The High Energy Transient Explorer 2 (HETE-2) is a small satellite for researching cosmic high-energy transient phenomena [1]. It was launched into an equatorial orbit

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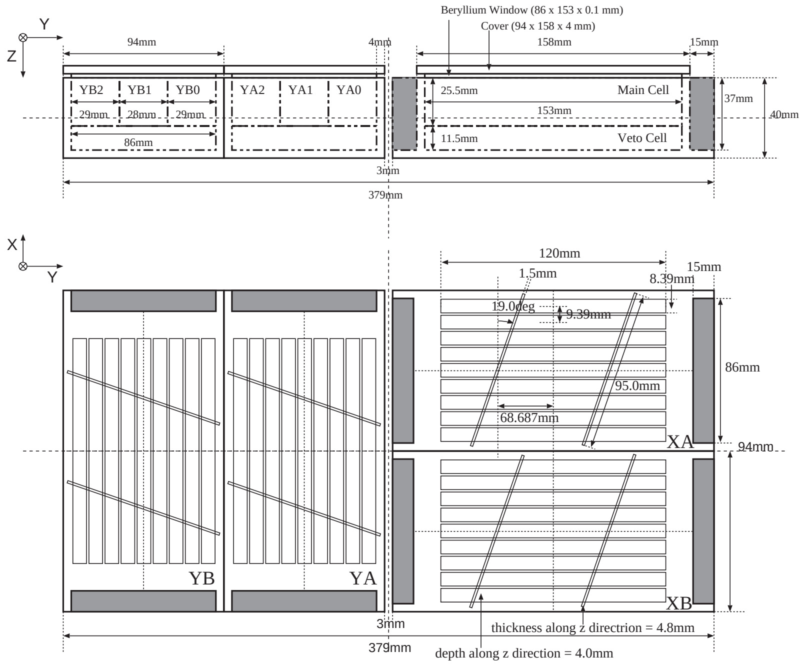

Fig. 1. – A cross section and a top view of the WXM.

with an inclination of about 2 degrees at the altitude of about 600 km. The aims of the HETE-2 mission are to detect and localize Gamma-Ray Bursts (GRBs), and also to monitor the activity of the galactic transients such as Soft Gamma Repeaters and X-ray bursts. The most unique feature of HETE-2 is its capability of quick determination and dissemination of GRB locations. When the instruments on-board HETE-2 detect a GRB, its position is determined immediately using the Wide-field X-ray Monitor (WXM) and Soft X-ray Camera (SXC). Since the WXM plays a leading role in GRB localizations, the precise in-flight calibration for the detector response matrices (DRMs) of the WXM is very important. In-flight calibrations have been carried out utilizing data of the Crab nebula since the launch of HETE-2.

Fig. 1 shows a cross section and a top view of the WXM which consist of four identical one-dimensional position-sensitive proportional counters (PSPCs). The PSPCS is filled with Xenon gas (97%) and CO_2 gas (3%) and covering the energy range of 2–25 keV with a field of view $70° \times 70°$. See Shirasaki *et al.* (2003) [2] for detailed detector performance and geometry.

2. – Observations and spectral analyses

The Crab nebula is in the field of view of the WXM during winter seasons. The finest pulse height data (in "raw data" format) were collected for the DRMs calibration. Since the DRMs differ by an incident angle of the source, the Crab nebula observations at several incident angles were performed.

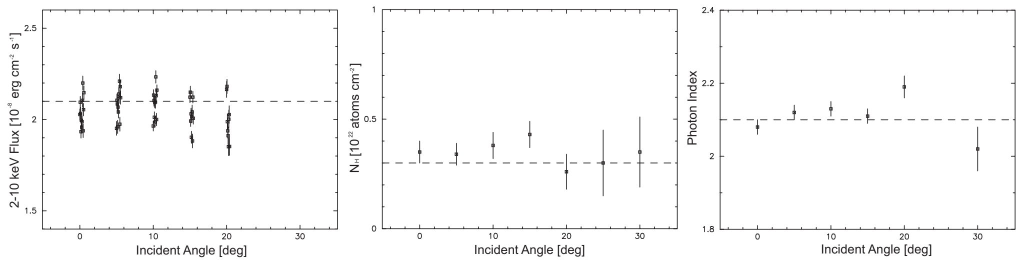

Fig. 2. – The spectral parameters of the Crab nebula at the various incident angles. The left figure shows the variation of the energy flux at 2–10 keV as a function of the incident angle. Each circle at a certain angle represents the individual wire. The photon index and $N_{\rm H}$ are fixed to the literature values 2.1 and 0.3×10^{22} cm^{-2}, respectively [3]. The middle figure shows the variation of $N_{\rm H}$ as a function of the incident angle and the photon index is fixed to 2.1. The right figure shows the variation of the photon index and all spectral parameters are free in these fits. In all figures, the dashed line shows the literature value.

2˙1. *Spectral parameters of crab nebula at various incident angles*. – We performed the WXM spectral analyses of the Crab nebula and compared the spectral parameters with the literature values in Toor and Sweard (1974) [3]. These values are 2.1×10^{-8} erg cm^{-2} s^{-1}, 0.3×10^{22} cm^{-2} and 2.1 for the energy flux in 2–10 keV, N_H and the photon index respectively. Figure 2 shows the spectral parameters of the Crab nebula at the various angles on 2001. As seen in the left panel in fig. 2, the energy fluxes in 2–10 keV are consistent at almost all angles with the literature value. The middle panel in fig. 2 shows N_H slightly diffrent from the literature value. We conclude the systematic uncertainty to be about $\pm 0.15 \times 10^{22}$ cm^{-2}. The right panel in fig. 2 represents that the photon index are consistent with the literature value at almost all angles.

2˙2. *Unexpected excess in low energy spectra of WXM*. – An unexpected excess appeared in low energy spectra (2–4 keV) of the WXM since December 2002 at all angles and wires. Figure 3 shows the examples of the WXM spectra at the incident angle of 10 dgrees. In the left panel in fig. 3, we can see an unexpected excess in low-energy spectra. The characteristic of the unexpected excess are the followings. Firstly it appears at

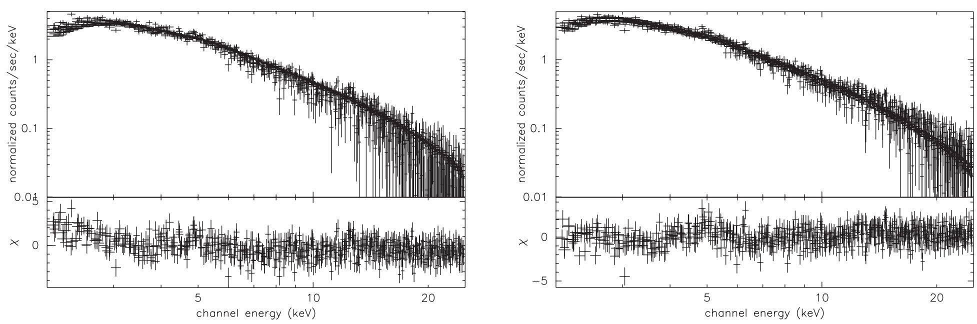

Fig. 3. – The examples of the Crab nebula spectra at the incident angle of 10 degrees. There is an excess in low energy spectra (2–4 keV) of the left figure. In the right figure using the new DRMs, there is no excess in low energy spectra.

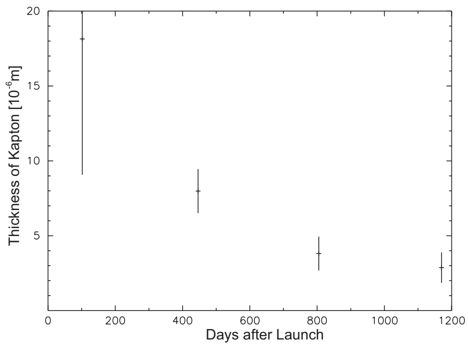

Fig. 4. – The variation of the thickness of the alminum-coated Kapton film. There is a decreasing trend in time.

all angles and wires. Secondly it has increasing trend in time. Thirdly it appears in only low-energy (2–4 keV). These suggest the change of the low-energy response of the WXM. The thermal shield (aluminum-coated kapton film) likely affects the low-energy response of the WXM. There are several reports that the thermal shield is eroded by oxygen atom O^*. We developed a model for calculating the absorption by the thermal shield parameterizing the thickness of the material ("Kapton" model). Then, the observed spectra of the Crab nebula are fitted by a model of Kapton $\times$ N_H $\times$ Power-Law. The thickness of thermal shield is calculated by this model with fixing the N_H and the photon index to the known Crab nebula values. With the analysis of the Crab nebula spectra from the year 2001 to 2004 using the method which we showed in above, it is possible to express the soft excess as the change of the thickness of thermal shield. Figure 4 shows the variation of the thickness of thermal shield as a function of time. We found that the thickness of thermal shield has a decreasing trend in time. Then, we developed the new software to generate DRMs based on the thickness of thermal shield as a function of time. The right panel in fig. 3 shows the energy spectrum using the new DRMs. There is no excess in low energy spectrum and the new DRMs could express the Crab nebula N_H value in the accuracy of $(0.3 \pm 0.2) \times 10^{22}$ cm^{-2}.

3. – Conclusion

Since the launch of HETE-2, in-flight calibrations of the WXM have been carried out utilizing data of Crab nebula. An unexpected excess appeared in low-energy spectra (2–4 keV) of the WXM since December 2002 at all angles and wires. It could be caused by changes in the thickness of thermal shield. Modified DRMs have been developed considering the thickness change of thermal shield as a function of time. The spectral analyses using the new WXM DRMs give an acceptable N_H value for the Crab nebula.

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