In-orbit calibration and performance of the HETE-2 WXM

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Abstract

The Wide-field X-ray Monitor (WXM) is one of the scientific instruments carried on the High Energy Transient Explorer 2 (HETE-2) satellite launched in October 2000. The WXM consists of four identical Xe-filled one-dimensional position-sensitive proportional counters, two sets of one-dimensional coded apertures orthogonally mounted above the counters, and the main electronics. The WXM counters are sensitive to X-rays between 2 keV and 25 keV within a field-of-view of about 1.5 sr with a total detector area of about 350 cm^2. The combination of the apertures and the counters provides GRB locations with accuracy of 10 arcmin. The WXM plays a major roll in the GRB localization and its spectroscopy in the energy range between 2 keV and 25 keV. Observing Crab nebula and Sco X-1, we have calibrated the detector alignment between the WXM and the optical camera system with 2 arcmin accuracy. The energy response of the detectors has also been calibrated using the Crab spectrum. We report in-orbit performance of the WXM instrument.

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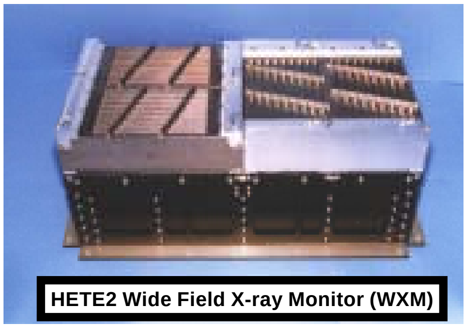

Fig. 1. Photograph of the WXM detector. The left half of counters composes an X detector which measures the projection angle of the burst direction in the XZ plane, and the right half composes a Y detector which measures the projection angle in the YZ plane. The Z axis is along the vertical direction in the picture and X axis is the sideways direction. The X detector is composed of XA (the other side) and XB detectors (this side), and the Y detector is of YA (left) and YB (right) detectors.

1. The WXM instrument

The WXM instrument is located at the center of the HETE-2 spacecraft [1]. The WXM consists of two identical units (X-detector and Y-detector) of one-dimensional position sensitive X-ray detectors and each unit consists of two identical proportional counters named XA, XB, YA and YB (Fig. 1.). They are placed in orthogonal directions to each other for measuring the X and Y directions independently. Each proportional counter has three anode channels and they are called XA0, XA1 and XA2 for the case of XA counter. One unit consists of a one-dimensional coded mask and two 1-D position-sensitive proportional counters (PSPCs) placed 187 mm below the mask. The PSPC is filled with xenon (97%) and carbon dioxide (3%) at 1.4 atm pressure at room temperature, and have beryllium entrance windows of 100 μm thickness. The geometrical area of the entrance windows is 88 cm^2. The energy coverage is from 2 to 25 keV.

The field of view of the X unit is geometrically limited to the direction $\theta_x = -38^\circ \sim +40^\circ$ and $\theta_y = -44^\circ \sim +44^\circ$, and that of the Y unit is to the direction $\theta_x = -46^\circ \sim +43^\circ$ and $\theta_y = -39^\circ \sim +39^\circ$, where θ_x and θ_y are angles measured from the vertical direction on the XZ and YZ plane of the detector coordinate system, respectively. The location of the GRB is determined by measuring a set of two shift distances of the mask pattern shaded on the X and Y detectors independently. More details are described in [2][3][4].

2. In-orbit calibration

To calibrate the alignment between the WXM optical axis and the spacecraft Z axis, we have observed Crab Nebula and Sco X-1. The data used for this analysis were taken during Nov 2001 $\sim$ Jan 2002 and Dec 2002 for Crab, and Apr $\sim$ Jun 2001 and May $\sim$ Jun 2002 for Sco X-1. The source locations in the WXM field of view are plotted in Fig. 2. The region of $\theta_x = -30 \sim 33^\circ$ and $\theta_y = -37 \sim 34^\circ$ are calibrated by these observations. In Fig. 3, the localization

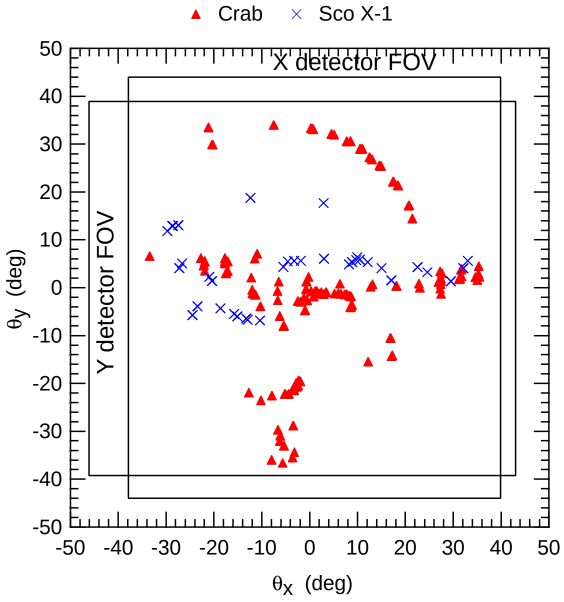

Fig. 2. Locations of Crab and Sco X-1 during the WXM alignment calibration.

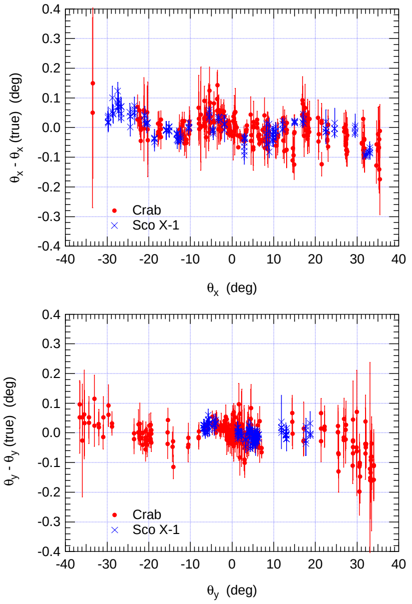

Fig. 3. Localization errors are plotted against the source direction θ_x and θ_y.

error of θ_x and θ_y are plotted against θ_x and θ_y, respectively. The errors of the directions are less than 0.1° at any calibration region and no significant directional dependence is seen. The overall one sigma systematic error is estimated to be $1.83' \pm 0.14'$ for each θ_x and θ_y direction.

Fig. 4. shows the results of spectrum fitting for Crab Nebula, and the calculated fitting parameters are plotted against incidence angle of Crab Nebula. The used spectrum model is a powerlaw model with solar abundance absorption. The photon indices range from 2.05 to 2.20 and incidence angle dependence is slightly seen. A possible reason for this is uncertainty of the model of a gain profile in the PC, since the increase of incidence angle decrease the average absorption depth and introduces systematic error in energy conversion. Energy flux for the canonical Crab spectrum for 2∼10 keV is $2.1 \cdot 10^{-8}$ erg/cm^{-2}/s, so the fitting result is 10% larger for near vertical incidence. As a whole, systematic uncertainty of power index, absorption column density and absolute flux are $\sim \pm 0.1$, $\sim \pm 0.2 \cdot 10^{22}$ cm^{-2} and 10%, respectively.

3. In-orbit performance

In Fig. 5., the WXM localization error size (90% C.L.) reported to the Gamma-ray burst Coordinate Network (GCN) is shown as a function of total fluence in 2∼25 keV. The minimum fluence of the localized GRB is 10^{-7} erg/cm^2,

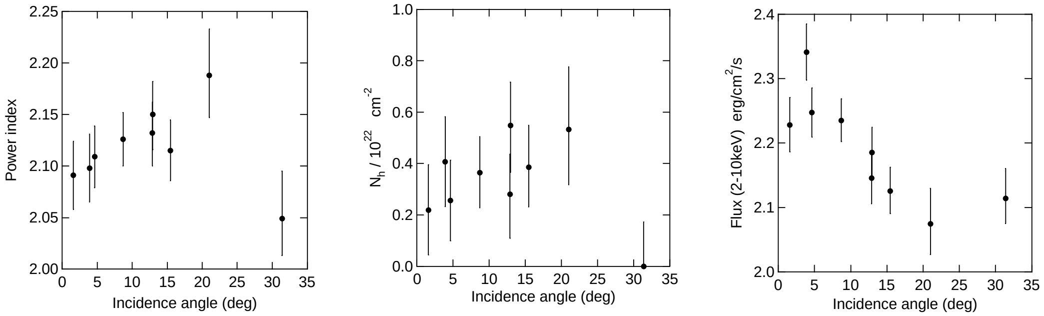

Fig. 4. The results of spectrum fitting of Crab Nebula. The left panel shows the photon index vs incident angle of Crab Nebula, the middle shows the same plot for the absorption column density, and the right shows the same plot for the 2 ∼ 10 keV flux.)

for which typical error size is 1000 arcmin^2, equivalent error radius 18′. For GRBs with fluence larger than 10^{-5} erg/cm^2, the error is dominated by systematics. The minimum fluence of the GRB localized by the flight processing is $5{\cdot}10^{-7}$ erg/cm^2 and typical error radius is 14′. From the observation of August 2002 till April 2003, the rate of the real time localization is about once per month and the whole localization rate is 28 per month.

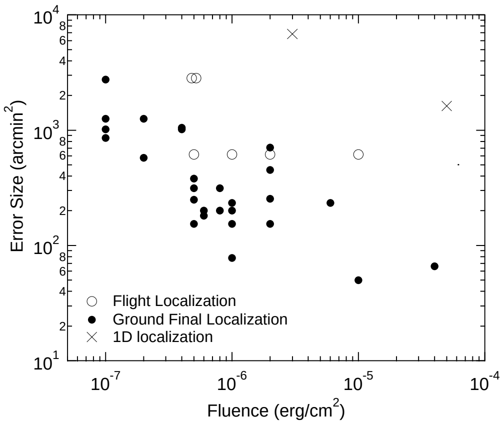

Fig. 5. Summary of the WXM localization since November 2001. The horizontal axis represents total fluence in 2∼25 keV and the vertical axis the size of error circle/box. Solid circles shows the final result of the ground localization reported to the GCN, open circles shows the flight localizations reported in 10 minutes from the GRB trigger, crosses are the locations determined by only one of the X or Y detector.

References

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