HXD Status/performance and Calibration plan

Y. Terada

on behalf of the Suzaku-HXD team
Hard X-ray Detector

64 PIN-Si diodes: 10-70 keV, dE~4keV (FWHM)
16 well-type phoswich (GSO): 40-600 keV
Wide-band All-sky Monitor (WAM) as a GRB detector
1. In-orbit Operation (2007)
~1.1 PIN HV operation~

Flare-like event on 28 Jul, 2007

PIN Spectra of W10 PIN-0

- Low energy noise around LD
- HV (W1) 400V → 0V → 300V → 400V
- Now it is quiet
~ PIN HV summary ~

<table>
<thead>
<tr>
<th>Date</th>
<th>W0/</th>
<th>W1/</th>
<th>W2/</th>
<th>W3</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005/08/17</td>
<td>500V/</td>
<td>500V/</td>
<td>500V/</td>
<td>500V/</td>
</tr>
<tr>
<td>2006/05/25</td>
<td>400V/</td>
<td>500V/</td>
<td>500V/</td>
<td>500V/</td>
</tr>
<tr>
<td>2006/10/03</td>
<td>400V/</td>
<td>400V/</td>
<td>500V/</td>
<td>500V/</td>
</tr>
<tr>
<td>Now</td>
<td>400V/</td>
<td>400V/</td>
<td>500V/</td>
<td>500V/</td>
</tr>
</tbody>
</table>

Please check
In-orbit Operation (2007)

~1.2 GSO UD operation~

HXD sub system

Sensor

HXD-AE
(analog elec.)

HXD-DE
(digital elec.)

Spacecraft

AE-DE transfer limitation
1k events x 4 line

Telemetry limitation
32/16kbps
(Data Rate-H/M)

In condition of sun angle, temperature of cold plate of the HXD, charging the battery, etc...

If saturated,

dead time increase

data gap / skip
In-orbit Operation (2007)
~1.2 GSO UD operation~

To avoid the saturation between AE-DE, we checked the setting parameters of the HXD-AE; on 11/Aug/2007, we changed the upper discrimination level of GSO (>1000 keV → ~800 keV).

- Average rate decreased by ~15% as estimated.
- AE-DE rate saturate at low COR regions even after the UD operation (excluded from the cleaned event).
- In the low COR region, lower energy events than GSO UD dominate the rate.
- No further operations are planned.

(Final setting of HXD-AE)

Successfully made the margin of the saturation of the data transfer between the HXD-AE and HXD-DE
In-orbit Operation (2007)
~1.3 WAM gain changed~

We check the PMT gain of WAM 20 units, every day using annihilation line feature after the SAA passage.

- Change AMP gain at 10 April 2007, after the mode check on 10 Feb ’07.
2. Software Updates (V1.x → V2.x)

2.1 Format Changed
- Format of WEL event fits file was changed.
- HXD ftools in HEADAS 6.3-6.4; no backward compatibility to V1.x format files.

- If you need to analyze ver 1.x products, please use format conversion script provided via
  http://suzaku.gsfc.nasa.gov/docs/suzaku/analysis/v2soft.html, and use new ftools.
- The HXD team strongly suggest to use the ver2.x products with new ftools and CALDB.

2.2 GTI Changed
- v1.x GTI includes the time when HXD-AE to –DE transfer is saturated
- v2.0 The epochs when AE to DE transfer is saturated are excluded in the
  GTI to make cleaned event list.
- If you want to ignore AE-DE saturation, please make a GTI file by yourself with hxdgtigen in fifo_full=no mode, and make cleaned events with the GTI from HUE
2.3 PIN (Software) Threshold changed

- 2005.08.19 -- 2005.12.30
- 2006.01.04 -- 2006.05.31
- 2006.06.04 -- 2006.10.31
- 2006.11.02 -- 2007.03.31

Discarded by hxdgrade with ae_hxd_pinthr.fits in making cleaned file.

4 sets of ae_hxd_pinthr_YYYYMMDD.fits in CALDB.
- epoch 1) 2005-08-17 11:00
- epoch 2) 2006-05-25 13:25
- epoch 3) 2006-10-03 23:35
- epoch 4) 2007-07-28 02:00
2.4 GSO gain history

Energy scale calibration with the annihilation line, activation lines, intrinsic lines.

We changed the GSO gain history file in CALDB after ver 2.0.

(V1.x) GSO Gain History File:
  ae_hxd_gsoghf YYYYMMDD.fits
  - list of PHA channel of lines
  - one column per 1 day
  - sometimes pipe-line proc failed.

(V2.x) GSO Gain History Table:
  ae_hxd_gsoght YYYYMMDD.fits
  - products from gsoghf, stable
  - list of parameters of gain trend
  - drifts by the temperature, short-term trend after HV OFF/ON
Important notes:
- Gain determined in the pipeline process is a tentative value.
- Final gain values will appear in CALDB area, (every month).
  → Please reprocess gso events file by yourself.
- There’s a known bug in *hxdpi* in HEADAS 6.3.x, which is fixed in the latest release HEADAS 6.4 last week (Dec 2007).

![Graph]

- No difference between v1 and v2 products
- Bug in *hxdpi* for v2.0, v2.1, v2.2 products (which is fixed in the latest release, 6.4)

3.1 Current status


<table>
<thead>
<tr>
<th>Instrument</th>
<th>Calibration Item</th>
<th>Present Uncertainties (July 2007)</th>
<th>Requirement</th>
<th>Goal</th>
</tr>
</thead>
<tbody>
<tr>
<td>HXD</td>
<td>Absolute effective area</td>
<td>20%</td>
<td>20%</td>
<td>5%</td>
</tr>
<tr>
<td>HXD</td>
<td>Relative effective area</td>
<td>15%</td>
<td>10%</td>
<td>5%</td>
</tr>
<tr>
<td>HXD</td>
<td>Angular response</td>
<td>5%</td>
<td>10%</td>
<td>5%</td>
</tr>
<tr>
<td>HXD</td>
<td>Background modeling (PIN)</td>
<td>5~10%</td>
<td>10%</td>
<td>5%</td>
</tr>
<tr>
<td>HXD</td>
<td>Background modeling (GSO)</td>
<td>3%</td>
<td>10%</td>
<td>3%</td>
</tr>
<tr>
<td>HXD</td>
<td>Energy scale</td>
<td>1% (PIN)</td>
<td>~8%</td>
<td>~8%</td>
</tr>
<tr>
<td>HXD</td>
<td>Absolute timing</td>
<td>360 μs</td>
<td>300 μs</td>
<td>100 μs</td>
</tr>
<tr>
<td>HXD</td>
<td>Relative timing</td>
<td>1.9x10^{-9}</td>
<td>10^{-8}</td>
<td>10^{-10}</td>
</tr>
<tr>
<td>HXD-WAM</td>
<td>GRB absolute timing</td>
<td>2 ms</td>
<td>1 ms</td>
<td>1 ms</td>
</tr>
<tr>
<td>HXD-WAM</td>
<td>Absolute effective area</td>
<td>10~40%, depending on the incident angle</td>
<td>20%</td>
<td>20%</td>
</tr>
</tbody>
</table>
3.2 PIN HV=400V data

In version 2, we can analyze all the PIN data including HV=400V datasets.

- Response files for epochs
  ae_hxd_pinxinome1_20070914.rsp
  ae_hxd_pinxinome2_20070914.rsp
  ae_hxd_pinxinome3_20070914.rsp
  ae_hxd_pinxinome4_20070914.rsp

- NXB models
  estimation for selected WEL units (v1.x) → each Unit and HV settings (v2.x)
Crab spectra

Epoch 1. 2005.8.17 -- 2006.5.13
Epoch 2. 2006.5.13 -- 2006.10.2
Epoch 3. 2006.10.2 -- 2007.7.28
Epoch 4. 2007.7.28 -- **

<table>
<thead>
<tr>
<th>Epoch</th>
<th>Nominal</th>
<th>gamma</th>
<th>norm (@ 1 keV)</th>
<th>chi2/dof</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>constant factor%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>XIS</td>
<td>2.11 (±0.01)</td>
<td>11.6 (+0.2,-0.3)</td>
<td>79.6/89</td>
</tr>
<tr>
<td>1.16</td>
<td>(±0.01)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>HXD</td>
<td>2.09 (±0.01)</td>
<td>10.9 (+0.3,-0.2)</td>
<td>63.6/83</td>
</tr>
<tr>
<td>1.15</td>
<td>(±0.01)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>XIS</td>
<td>2.11 (±0.01)</td>
<td>11.4 (±0.2)</td>
<td>99.3/94</td>
</tr>
<tr>
<td>1.15</td>
<td>(±0.01)</td>
<td></td>
<td></td>
<td></td>
</tr>
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</table>
3.3 Energy response of PIN & GSO

- No difference between the v1 and v2 response matrix
- Please use the v2 rsp for the v2 products.
3.4 GSO response

Nominal GSO response (v2.x)

2007/03/20 HXD nominal, Crab Spectra

- Cross normalization  PIN : GSO = 1: 0.80
- Residual ±10% in GSO band  \( \chi^2/\text{dof} \sim 2.5 \)
- We need further studies on GSO response

With fudge arf file of GSO (v2.x)

- We prepared fudge GSO arf file, which is just adjusted the Crab spectra  \( \chi^2/\text{dof} \sim 1.5 \)
- Cross normalization  
  PIN : GSO = 1: 1.00 for the dataset of 15 Sep 2007  
  PIN : GSO = 1: 0.96 for 20 March 2007 Crab  
  (caused by the angular response, roll angle)
- Need more checks on this fudge factor!! Please be careful
Another photon index (1) Crab Pulse On-Off spectrum

Crab On-Off spectra which can be fitted with a single power law ($\Gamma = 1.5$, cross normalization PIN:GSO = 1:1)

Pulsed component of Crab
Another photon index (2) PSR B1509-58 Pulse On-Off spectra

PSR1509-58 On-Off spectra which can be fitted with a single power law (\( \Gamma = 1.92 \), cross normalization PIN:GSO = 1:1)

Pulsed component spectra of PSR1509-58
3.5 cross normalization between the XIS and the HXD

2007/03/20 HXD nomina, Crabl

Ver 2 products

XIS0: PIN: GSO = 1 : 1.12 : 1.07

※ Same results on NGC2110 (XIS nominal),
XIS:PIN=1:1.13
※ PIN: GSO = 1: 0.96 for this data

\[ N_H = 0.33 \times 10^{22} \]
\[ \Gamma = 2.10 \]
\[ \text{Norm} = 9.54 \]
\[ \chi^2/\text{dof} \sim 1.2 \]

cross normalization (XIS: PIN = 1 : 1.12~1.15) the same as v1.x
3.6 PIN NXB model, updated

Tuned up several parameters on PIN NXB model
Provided via WWW (ISAS & GOF), as an archive data.
ftp://legacy.gsfc.nasa.gov/suzaku/data/background/pinnxb_ver2.0/

- Typical NXB spectrum and LC of a long “Earth” observation (MCG-6-30-1)

Suzakumemo-2007-09

**data vs. model**

80 ksec exposure

- good agreement in 12-70 keV
- NXBs in SAA path and non-SAA path are well modeled
We checked the reproducibility of all available earth data.

_ No long-term trend_

- $s = 3.8\%$, $s_{\text{stat}} = 2.0\% \rightarrow s_{\text{sys}} = 3.2\%$ (15-40 keV, 10ks exposure)
Comment: reproducibility after renormalization

- Renormalization of the spectrum using a higher band is proposed for a better NXB estimation. (suzakumemo-2007-10)
- The improvement could be canceled by statistical errors in high energy band.

→ check using earth observation with long exposure.

- No significant improvement.
  (probably due to statistical error)
- peak-to-peak of the residual is ~5% for earth obs. with exposures >40 ks.
3.7 GSO background

Background level is almost saturated, as expected
GSO background for ver 2.x products

The model is obtained by fitting the light curve of BGD, by an appropriate formula indicated by the properties of the BGD. (This technique is also available for the PIN background, and a part of released PIN BGD is prepared by this model.) The model parameters are determined for each 32 energy band. From 1.2 to 2.0, some minor improvement will be done.

Soon, it is available! (End of December 2007)

- after the PMT gain is determined. \( \to \) normally takes 1.5 months
- delay a little bit in a moment

Now checking in the HXD team
3.8 Timing capability of the HXD

**Pulse profiles**

Periodogram

- A0535+262: 103.375 sec
- Her X-1: 1.29734 sec
- PSR1509-58: 151.3563 msec
- Crab: 33.5000707477 msec

Pulse Profile

- A0535+262
- Her X-1
- PSR1509-58
- Crab

PIN

- 0.5, 1.5, 2

GSO

- 7.5

**History of Period of Crab pulsar**

- Period (msec)
- Difference (nsec)

- MJD: 53600 – 54200
- Jodrell Bank period
- Suzaku

→ No problem at 33msec – 103 sec

P and P_dot (~4.12 × 10^{13} s s^{-1}) consistent with Radio results
Simultaneous observation of Crab pulsar (20 March 2007)

Consistent with 100 μ sec

360±150 μ sec or 270±130 μ sec (in condition...
4. WAM status

*** Summary (2005 Ag. -- 2007 Oct.) ***
confirmed GRB 317 (194)
possible GRB 223 (97)
SGR 68 (6)
Solar flare 166 (28)

Cross calibration with Konus/Wind, RHESSI, Swift BAT
using GRB events and Solar flares

Calibration with Crab spectra by the Earth Occultation technique

Please visit the WAM WWW page (http://www.astro.isas.ac.jp/suzaku/research/HXD-WAM/WAM-GRB/)
5. Future prospects

**PIN low energy spectra (<13 keV → <10 keV)**

Due to thermal noise around LD channel (heat pipe problem)
Try to “model” the time variable noise shape (looking for coincidence param

**PIN effective area**

PIN-XIS cross normalization ~13%
- Tune up parameters in making response matrix via Geant4 Mass Model
- Ground experiments with fright spare PIN diodes

**GSO response (without fudge factor)**

- Energy scale: re-calibration of electronics of HXD-AE
- Tune up parameters in Geant4 Mass Model

**Reproducibility of NXB model(s)**

- Many efforts on modeling empirically
- Study the origin of NXB events by the full simulations of activation events with MGGPOD
Comments: analyses for diffuse sources

Angular response of PIN

HXD arf: correction factor to the HXD nominal rsp
Produced by hxdarfgen
Not support an image input → Please add arfs by yourself
Or wait for the next release

diffuse arf(PI) = Σ (arf(PI) × model) / Σ model

![Graph showing angular response and energy distribution for HXD nominal, XIS nominal, β model case, and flat response.]
### Table: Error Budgets of Scientific Instrument Calibrations

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