Testing the Spectral cross-calibration of the Swift/BAT and the RXTE/PCA by the simultaneous observation of Crab

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Abstract
We report the spectral cross-calibration test of the Swift BAT and the RXTE PCA using simultaneous observation of Crab, which were taken on August 3, 2011 and provided 970 sec of completely overlapping data. Given the complementary energy band coverage of the Swift BAT (15-150 keV) and RXTE PCA (3-50 keV), the observation will help us understand and improve the cross-calibration between the instruments. We present the joint spectral fit results and discuss the remaining cross-calibration uncertainties.

Observation and Data reduction
Swift/RXTE simultaneous Crab observation: 2011-08-03 22:59-23:21 UTC

Instruments
- Swift Burst Alert Telescope (BAT): 32,768 CdZnTe detectors with a coded aperture mask
- RXTE Proportional Counter Array (PCA): 5 proportional counters with a collimator

Data reduction/analysis
- BAT: Mask-weighted spectrum using the event-by-event data
  Applying the standard data reduction procedure
  Energy range: 14-150 keV, systematic error (batphasyserr)
- PCA: Spectrum from all layers of PCAU 1-4
  Energy range: 3-50 keV, 0.8% systematic error

Discussion
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- The PCA constant factor is 20-25% higher than that of BAT.

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  The spectrum might be affected by the gradual shift in the gain of the detectors.
- The PCA constant factor is 20-25% higher than that of BAT.
  The PCA effective area is adjusted so that the Crab 2-10 keV flux to be 2.4 x 10^8 erg cm^2 s^-1 (Jahoda et al. 2006). This flux is ~10% higher than other X-ray missions (e.g. ~2.2 x 10^8 erg cm^-2 s^-1). Addition to the 3-4% smaller flux of the Crab due to the gain shift in BAT (above), the BAT normalization is systematically smaller by 5-10% comparing to that of the other hard X-ray missions based on the cross-calibration work using GRBs (Konus-Wind, Suzaku/WAM and Swift/BAT; Sakamoto et al. 2011) and Cyg X-1 (Swift/XRT, Swift/BAT, Suzaku/XIS and Suzaku/HXD; presentation in Swift 2009 conference). Combining all those factors, the normalization in the PCA spectrum is expected to be 20-25% higher than that of BAT.

Table: Best fit spectral parameters (90% error in parentheses)

<table>
<thead>
<tr>
<th>Instrument</th>
<th>N_H [10^21 cm^-2]</th>
<th>PhIndex</th>
<th>K@20 keV [10^2 ph cm^-2 s^-1 keV^-1]</th>
<th>(\chi^2/dof)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BAT</td>
<td>----</td>
<td>2.159 (0.050)</td>
<td>1.575 (0.067)</td>
<td>C(BAT)</td>
</tr>
<tr>
<td>PCA</td>
<td>5.7 (1.6)</td>
<td>2.122 (0.006)</td>
<td>1.907 (0.005)</td>
<td>----</td>
</tr>
<tr>
<td>BAT-PCA</td>
<td>5.8 (1.6)</td>
<td>2.123 (0.006)</td>
<td>1.533 (0.033)</td>
<td>1.0 (fixed)</td>
</tr>
<tr>
<td>BAT-PCA</td>
<td>3.3 (fixed)</td>
<td>2.116 (0.003)</td>
<td>1.525 (0.033)</td>
<td>1.0 (fixed)</td>
</tr>
<tr>
<td>BAT-PCA (14-50 keV)</td>
<td>----</td>
<td>2.143 (0.012)</td>
<td>1.564 (0.042)</td>
<td>1.0 (fixed)</td>
</tr>
</tbody>
</table>

FIGURES

Fig 1 (right) Effective area curves of Swift/BAT (blue) and RXTE/PCA (red). The dotted lines show the energy range used in the spectral analysis.

Fig 2 The Crab spectrum of BAT fit with a simple power-law model. The observed flux is 3-4% smaller than the Crab data collected in previous years. The “canonical” Crab photon index is 2.15 and the 15-150 keV flux is 2.11 x 10^8 erg cm^-2 s^-1.

Fig 3 The Crab spectrum of PCA fit with an absorbed simple power-law model. The best fit result does not change by fixing N_H to 3.3 x 10^{21} cm^-2 (BeppoSAX NFI's value). The observed flux is ~10% higher than the previous X-ray missions such as BeppoSAX and ASCA.

Fig 4 The joint BAT and PCA fit of the Crab data fit with an absorbed simple power-law model. There is no systematic residual from the best fit parameters based on the joint fit. The PCA constant factor is 1.24 (in case of fixing the BAT constant to 1) which is higher than the known calibration uncertainty in BAT (see discussion).

Summary
- The BAT-PCA joint spectral fit:
  - No systematic residual in the Crab spectral shape.
  - The PCA normalization of the Crab spectrum is 20-25% higher than that of BAT (once the up-to-date BAT gain correction has been applied, it will be 15-25%).