ASTRO-H

Instrument Calibration report
HXI Energy Gain
ASTH-HXI-CALDB-GAIN

Version 0.2

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ISAS/ GSFC

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DOCUMENT TITLE : HXI Energy Gain			
ISSUE	DATE	PAGES AFFECTED	DESCRIPTION
Version 0.1	November 2015	All	First Release
Version 0.2	September 2015	7-8	Second Release

Introduction

1.1 Purpose

This document describes how the energy gain calibration curves are produced from the ground and the in-orbit data. The CALDB file structure is define in the ASTH-SCT-04 and available from the CALDB web page at http:// hitomi.gsfc.nasa.gov.

1.2 Energy Gain Calibration Curve

Arrived X-ray signals with certain pulse heights are first converted to 0-1023 integer (ADC) values by 10-bit ADC circuit onboard ASIC. This ADC values become the primitive X-ray energy information that we can obtain on the satellite. Since we discuss physics in energy space, these ADC values must be converted to energy via software on ground. This ADC-to-energy conversion is done in “hxisgdpha” software by using the gain calibration curve table, which is included in CALDB. This table consists of 128 strips×2 sides×5 layers=1280 Spline functions in total, each giving the relation between ADC and corresponding energy for the individual strips in HXI camera. The ADC-energy relations are obtained by fitting the X-ray spectra from the on-board ^{241}Am source, or from the designated calibration targets, which both give line feature with known energy in their spectra. This gain calibration curve should be updated every time when the gain of HXI-camera varied due to following example situations.

1. Changing the sample-hold timing in ADC circuit.
2. Changing the triggering threshold level (affect gain, especially in lower energy).
3. Changing the shaping time in ADC slow shaper (“ifss” in terms of ASIC parameter).
4. Changing the operating bias voltage.

1.3 Scientific Impact

This gain calibration curves will directly affect the science. The CALDB should be immediately updated if necessary. Otherwise, it may form some fake instrumental structures in HXI spectrum.

Release CALDB 20160310

Filename	Valid date	Release date	CALDB Vrs	Comments
ah_hxi1_gain_20140101v001.fits	2014-01-01	20160310	001	
ah_hxi2_gain_20140101v001.fits	2014-01-01	20160310	001	

2.1 Data Description

The data used to construct the current release are taken during the on-ground calibration experiment in a low-temperature chamber using the flight models of the HXI sensors. The test was conducted in October and December 2014 for HXI2 and HXI1, respectively. X-ray and gamma-ray lines from several radio isotopes were used to calibrate absolute energy scale.

Signals from the on-board ^{241}Am source which is planned to be used for in-orbit energy calibration, was not used since the counting rate is significantly lower than those from irradiated radio isotopes. Table 1 summarizes utilized emission lines and data file names.

Table 1. The list of the radio-isotope-irradiation data used for generating the present CALDB.

	Lines (keV)	HXI1 file name	HXI2 file name
^{241}Am	13.9, 59.5	141213_020034~074059, 141214_192655	141023_060219~ 102601
^{133}Ba	30.8, 80.0	141213_080406~ 113603	141024_215956~ 141025_000045
^{57}Co	122, 136	141214_064531~ 105814	141025_155012
^{55}Fe	5.9	141213_164142~ 141214_002130	141025_011118~ 092038
Noise	0.0	141212_224607	141023_153356

2.2 Data Analysis

The data were analyzed with ROOT ver 6.02.05. Signals from all readout strips, except for the two edges of each side (the first and the last readout strips), which are registered as "bad channels", were utilized in the analysis. X-ray and gamma-ray lines seen in pulse-height histograms of each readout channel were fitted using a Gaussian function to determine line-center in ADC values. For those are summation of several unresolvable lines (e.g., 17.9 keV, 30.8 keV), multiple Gaussian functions are used to reconstruct the complex features. Relative strengths between the consisting Gaussian functions are fixed to certain results (e.g., Akovali et al. 1994 for ^{241}Am), which are given by other detectors with higher energy resolution. To avoid fitting to the non-Gaussian (Gaussian + low-energy tail) part of the lines in CdTe DSD, only the high-energy half, of which shape can be approximated by a Gaussian, was used in the fitting.

Since low energy photons are strongly absorbed by the 1st and the 2nd layers, 5.9 keV (^{55}Fe) and 13.9 keV lines (^{241}Am) are not effectively detected by the lower detector layers. In contrast, higher-energy photons, e.g. 122 keV from ^{57}Co, penetrate DSSDs, and counting statistics of the line in DSSD can be poor. In such cases, it is necessary to stack spectra within an ASIC (32 readout strips) to obtain sufficient statistics to fit the lines. In addition, since the n-side of Si layer has lower energy resolution than that in p-side, neighboring lines can be blended and difficult to be used in analysis. For these reasons, combinations of lines that are used to construct energy gain curve differ among layers as summarized in Table 2.

Table 2. X-ray and gamma-ray lines used to construct energy gain curves of individual detector layers. Check marks represent utilized lines, while hyphens are those not used. In each cell, two entries correspond to the p/Pt side (left) and the n/Al side (right) status. In order to improve statistics, data from 32 ch (1 ASIC) were analyzed cumulatively where designated as "Sum".

Line Energy	Layer 1	Layer 2	Layer 3	Layer 4	Layer 5
5.9 keV	✓/✓	-/-	-/-	-/-	-/-
13.9 keV	✓/-	✓/-	✓/-	Sum/-	-/-
17.8 keV	✓/-	✓/-	✓/-	✓/-	Sum/Sum
20.8 keV	✓/-	✓/-	✓/-	✓/-	-/-

26.3 keV	✓/-	✓/-	✓/-	-/-	-/-
30.8 keV	✓/✓	✓/✓	✓/✓	✓/✓	✓/✓
35.0 keV	✓/-	✓/-	✓/-	✓/-	✓/✓
59.5 keV	✓/✓	✓/✓	✓/✓	✓/✓	✓/✓
81.0 keV	✓/Sum	✓/Sum	✓/Sum	✓/Sum	✓/✓
122 keV	Sum/Sum	Sum/Sum	Sum/Sum	Sum/Sum	✓/✓
136 keV	-/-	-/-	-/-	-/-	-/Sum

Based on the line fitting, an ADC-versus-energy relation is determined for each line. Data points are smoothly connected using a third-order spline function. To cover wider ADC channel range, the spline function is linearly extrapolated down to ~ -50 keV and up to ~140 keV using the derivatives defined in the edge knots of the spline function.

2.3 Result

Figure 1 shows examples of resulting gain calibration curves of HXI1. Due to non-linear properties of the ADC circuit and triggering technique employed in the electronics, the ADC-energy relation tends to be convex in the p/Pt sides, and concave in the n/Al sides. Deviations from a linear relation (bottom panel in the figure) is ~10 % over the relevant range.

Figure 2 is the energy-converted spectrum of ^{241}Am. Although the energy gain curve is constructed using discreet energy points, spline interpolation provides acceptable results; for example 26 keV line energies in the 4th and the CdTe layer are reconstructed within ~ 2%.

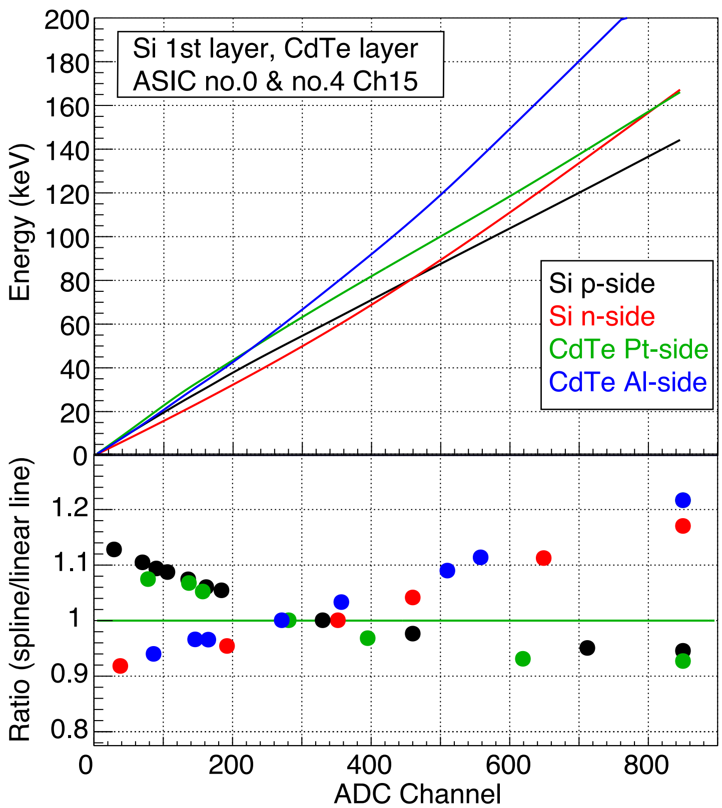

Figure 1. Examples of obtained Spline functions. Representative channels out of p/Pt-side and n/Al-side are drawn in black/green and red/blue solid lines (top panel), respectively. The bottom panel shows the ratio between a linear line (0-60 keV) and the Splines.

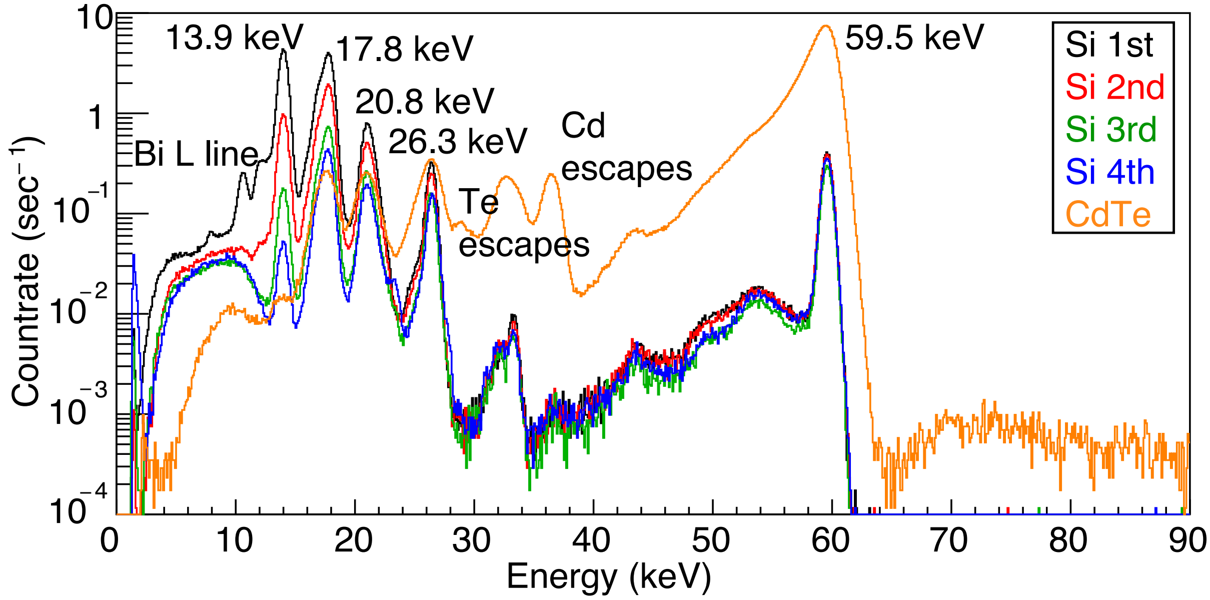

Figure 2. Energy-converted spectrum of ^{241}Am obtained with HXI1. Each is summation of whole p/Pt side strips in respective layers.

2.4 Final Remarks

Not applicable.

Release CALDB 20160920

Filename	Valid date	Release date	CALDB Vrs	Comments
ah_hxi1_gain_20140101v002.fits	2014-01-01	20160920	004	ah_hxi1_gain_20160819v001.fits
ah_hxi1_gain_20140101v002.fits	2014-01-01	20160920	004	ah_hxi2_gain_20160819v001.fits

3.1 Updates from CALDB 20160310

Since its line center was poorly constrained due to low statistics, the 17.8 keV line of ^{241}Am is no longer used as a calibration point for the CdTe layer (layer 5 in Table 2). It was giving an unnecessary effect to the gain calibration curve at >30 keV band, which is crucial for the CdTe layer.

Several changes are also made to the methods in fitting the line feature in the pulse-height histograms. The reference paper for the line-center energy and relative line ratio in ^{241}Am X-ray lines is changed from Akovali et al. (1994) to a higher accuracy result Lepy et al. (2008). In addition, in order to minimize the effect from non-Gaussian features, the fitting ranges for each line became slightly narrower to avoid fitting the constant continua, and Landau function is utilized to approximate the Gaussian + low-energy tail feature in CdTe spectrum.

3.2 Result

The modification done in 3.1 especially affected the calibration in lower energy band spectrum of the Si-layers. Figure 3 shows a comparison of reconstructed ^{241}Am spectrum in 12-23 keV. Only the result for 1st Si layer is shown here as an example. Since the reference figures for the line ratio is changed, line shapes slightly changed and peak energies are shifted ~0.1 keV higher and ~0.2 keV lower for lines in 17.8 keV and 20.8 keV, respectively. The peak energies of the reconstructed spectrum are consistent with those in Lepy et al. (2008) within ~0.3% (0.5 bin). This alternation has resolved the 15-20 keV structure in the residual between Crab nebula spectrum and its well-studied spectral model. See asth_hxi_caldb_lsfqe_v0.2.doc for details.

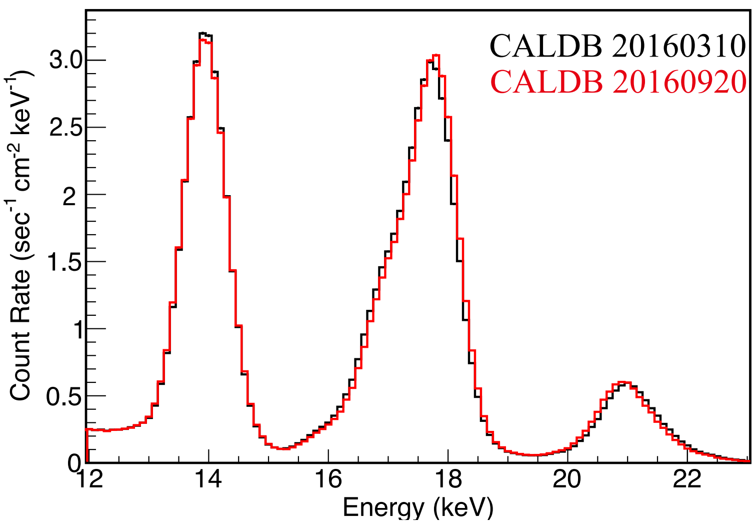

Figure 3. Comparison of HXI-1S ^{241}Am spectrum processed with CALDB 20160310 with that with CALDB 20160920. Only the result of 1st Si layer is shown here.

3.3 Final Remarks

Not applicable.