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HXD-PIN Background Model Reproducibility of v2 Products

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1 Introduction

The HXD (Hard X-ray Detector) is designed to have a very high signal-to-noise ratio by reducing an instrumental background as much as possible by adopting a novel concept of a well-type phoswich counter (Takahashi et al. 2006), and has achieved an unprecedented low background in the energy ranges of 15–70 keV and 150-500 keV (Kokubun et al. 2006). Although the HXD has no capability of a rocking on-off observation like SAX-PDS and RXTE-HEXTE, a high sensitivity can be obtained by modeling the residual non X-ray background (hereafter NXB) with a good accuracy. Therefore a limiting factor for the sensitivity of the HXD is a reproducibility in the background estimation. Here we examine the background reproducibility of the HXD-PIN data processed with the v2 pipeline, by comparing the background models [1] and the data during the earth occultation in a trend archive [2]. During the period of 2006 March 23 – May 13, background models by a different method (the same method as that of GSO background model) are also provided and are used in this report [3]. Since the earth is known to be dark in hard X-rays and soft gamma-rays, the earth occultation data can be regarded as the NXB for the HXD. For details of the background models, see Watanabe et al. (SUZAKU-MEMO-2007-01) and Fukazawa et al. (SUZAKU-MEMO-2007-02). See also Mizuno et al. (SUZAKU-MEMO-2006-42) for the reproducibility of HXD-PIN NXB of v1 products. The background models used in this study are summarized in Table 1.

2 Spectrum and Light Curve of a Typical Long Earth Observation

Figure 1 compares energy spectra between the real data and the model prediction during the earth occultation of one observation in SWG phase (MGC-6-30-15 observed from 2006 January 9 to 14). Events are selected by the following selection criteria: the cut-off-rigidity is greater than

[1] http://www.astro.isas.jaxa.jp/suzaku/analysis/hxd/pinnxb/pinnxb_ver2.0
[2] ftp://ftp.darts.isas.jaxa.jp/pub/suzaku/trend/ver2
[3] http://www.astro.isas.jaxa.jp/suzaku/analysis/hxd/v1/pinnxb/pinnxb_ver1.2_d/

Table 1: Summary of the background models used in this report

Observation date	URL	METHOD *
2006-03-23 – 2006-05-13	http://www.astro.isas.jaxa.jp/suzaku/analysis/hxd/v1/pinnxb/pinnxb_ver1.2_d/	LCFIT(bgd_d)
other	http://www.astro.isas.jaxa.jp/suzaku/analysis/hxd/pinnxb/pinnxb_ver2.0	PINUDLCUNIT

* FITS header keyword to distinguish the background modeling methods

8 GV, the elapsed time after the passage of SAA (South Atlantic Anomaly) is more than 500 s and the elevation angle from the earth rim is less than −5°. Data recorded in a bit-low mode or those with telemetry saturation are also excluded, and the net exposure for the earth occultation is 85 ks. We see a good agreement of the model with the data in the full energy range of the HXD-PIN (12–70 keV). Figure 2 shows light curves of the same observation in 15–40 keV energy band. Again, we see a good agreement between the model and the data.

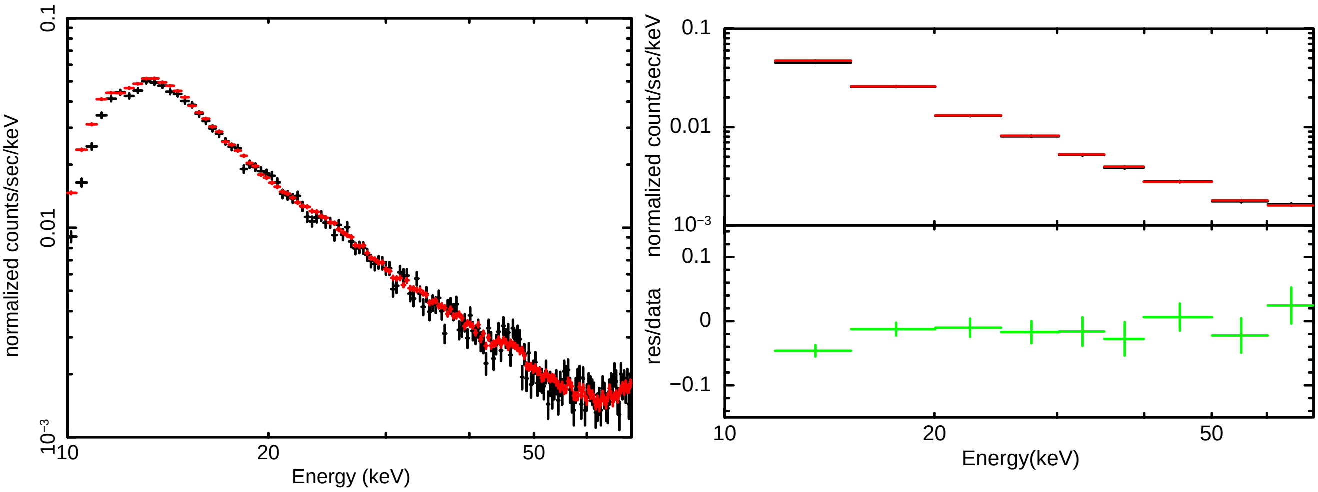

Figure 1: Comparisons of spectra between the data and the background model prediction of the HXD-PIN NXB for one observation taken in the SWG phase (MGC-6-30-15 observed from 2006 January 9 to January 14). Data during the earth occultation (elevation angle less than −5°) is used in the plot. (Left) Unbinned spectra of the data and the model shown by black and red histograms, respectively. (Upper right) Binned energy spectra. (Lower right) Residuals given as the ratio to the data.

3 Reproducibility in the HXD-PIN NXB

One important change from version 1.x background files is that v2 background models contain events from all 64 units of PIN, regardless of whether the bias voltage is 500 V or 400 V. This enables us to study the background reproducibility using all the available earth occultation data, and we compared the NXB count rates between the data and the model in 15–40 keV and 40–70 keV range in Figure 3. There, each observation was split into small pieces with 10 ks exposure in order to make the statistical errors comparable among data points. Since the reproducibility of the background by a default method ("PINUDLCUNIT") is worse in 2006 March-May, probably due to the operational change of the lower discrimination level of the HXD-GSO, a development

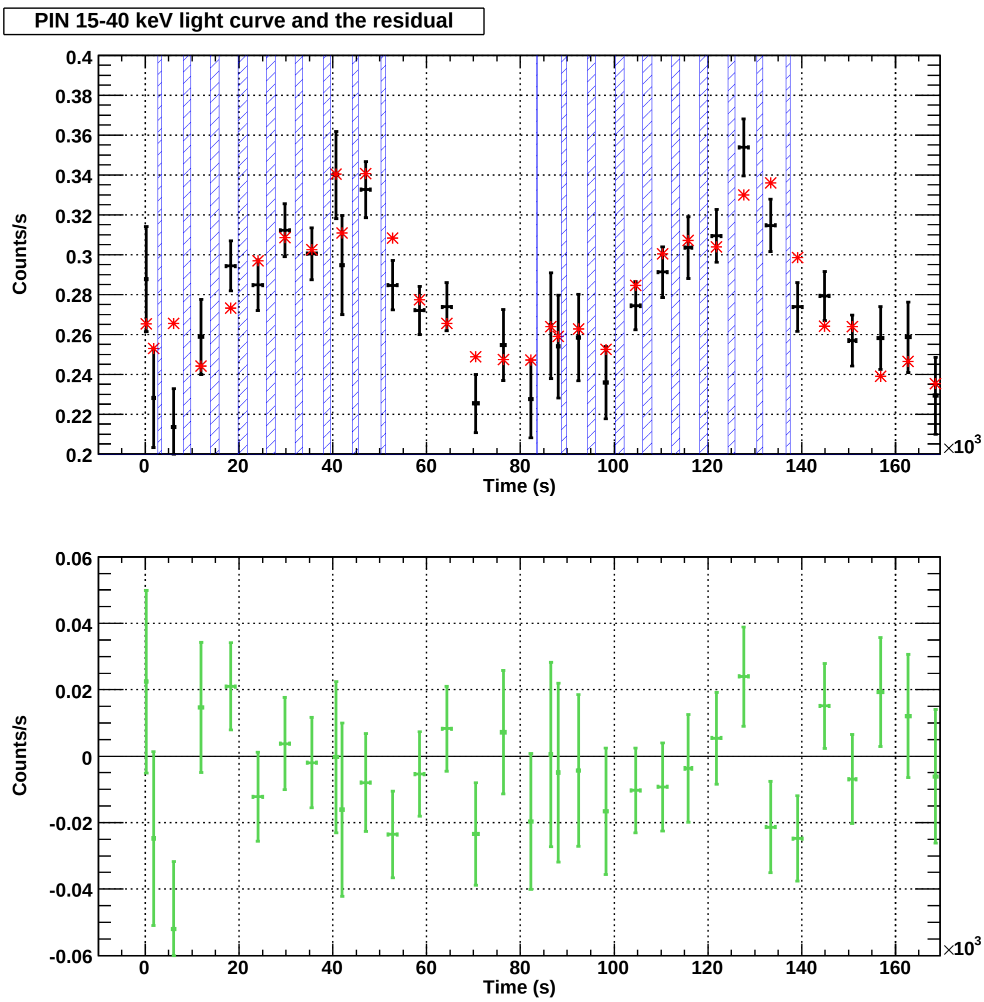

Figure 2: The same as Figure 1, but for comparisons of data and model light curves of the first two days out of total four days observation. Data (black) and the model (red) are compared in the upper panel and the residuals are given in the lower one. Passages of SAA are shown by shaded area for reference.

version of the HXD-PIN background are also distributed and are used in this study (see Table 1). We see that the model reproduces the data in 15–40 keV within ±10 %. More quantitatively, the average of the residual is -0.5 % and the standard deviation is 3.8 %, whereas the statistical error (1σ) is 2.0 %, resulting in the systematic uncertainty of about 3.2 %. In 40–70 keV the statistical error dominates the residuals. (Standard deviation of the residuals and the statistical error is 4.7 % and 4.3 %, respectively.) The same comparison but with longer exposure are given in Figure 4 in which we see some systematic uncertainties in the reproducibility: peak of the residual distribution is below 0 and about 20 % of data points show residuals of 5–10 %. We also examined the trend of residuals (Figure 5) and confirmed that there is no significant change of the reproducibility for about two years since the launch of Suzaku.

As described in Kokubun et al. (2006), the NXB count rate of orbits with a passage of SAA (hereafter the SAA path) is relatively large due to radio isotopes of short half-lives and the reproducibility could be worse. We thus divided the data into two, one in SAA paths (with elapsed time after the passage of SAA less than 6000 s) and the other in non-SAA paths, and compared the data and the background model. The results are summarized in Figure 6. The background count rate is larger and the agreement with the model is worse in SAA paths: the deviation is larger than that in the non-SAA paths and the model underpredicts the data by 5–10 % for about 10 % of data points.

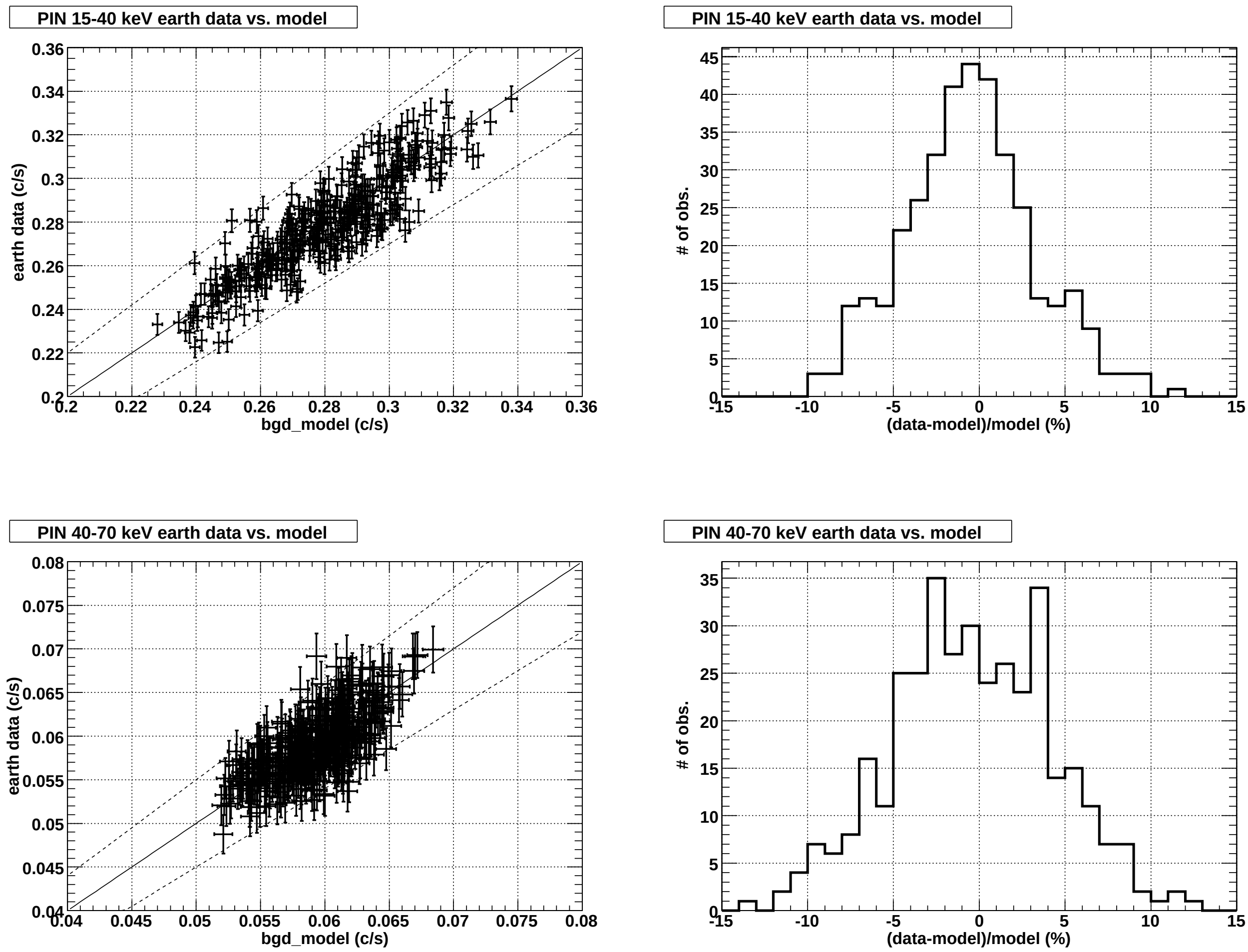

Figure 3: (Top left) A comparison of the NXB count rate in 15–40 keV between the data and the model prediction. (Top right) The residuals in a histogram. (Bottom) The same plots as those in the top panels, but in 40–70 keV instead of 15–40 keV.

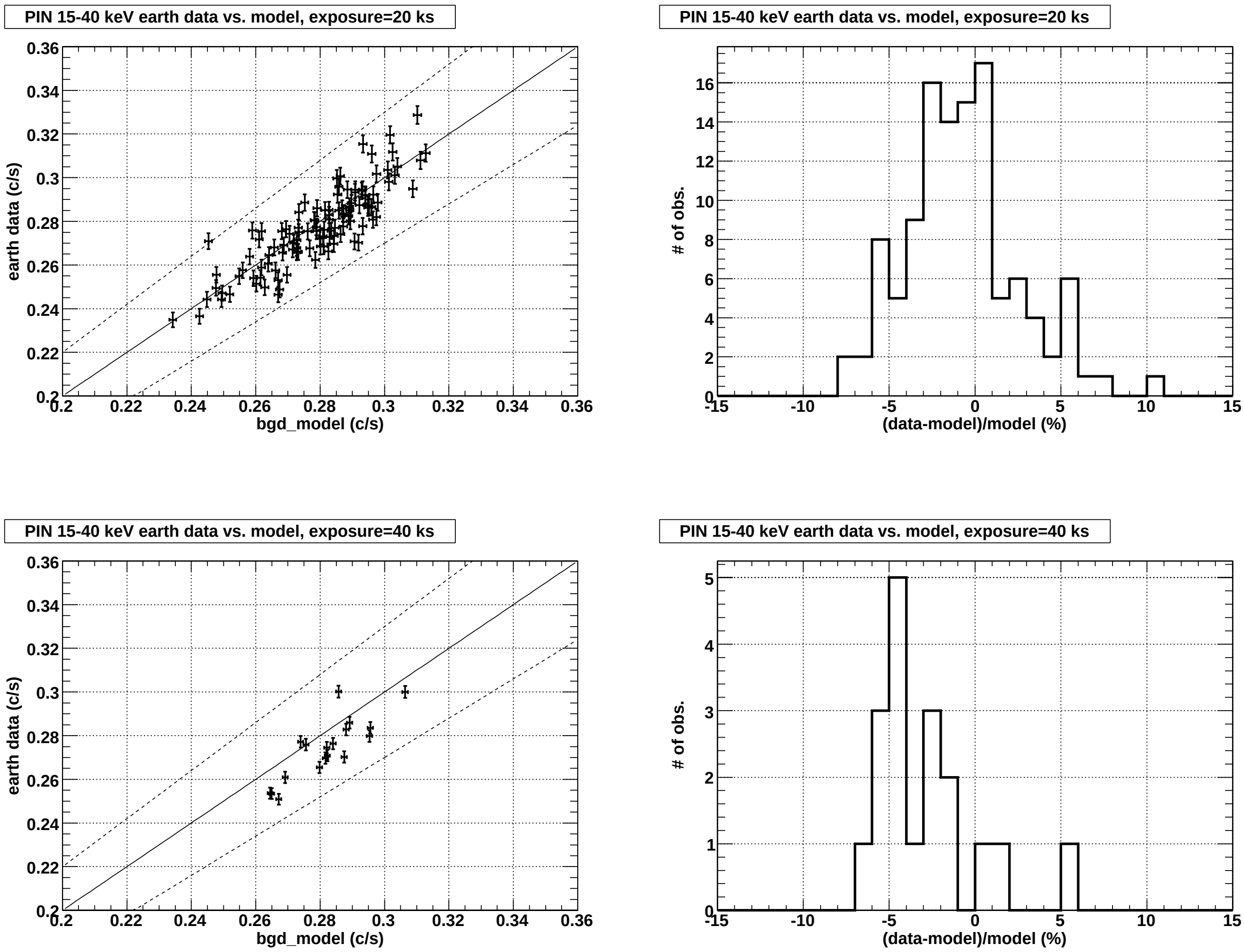

Figure 4: The same plots as those of Figure 3, but data with longer exposure are used.

Reference

- Takahashi, T. et al. 2007, PASJ 59, S35
- Kokubun, M. et al. 2007, PASJ 59, S53
- Mizuno, T. et al., SUZAKUMEMO-2006-42
- Watanabe, S. et al., SUZAKUMEMO-2007-01
- Fukazawa, Y. et al., SUZAKUMEMO-2007-02

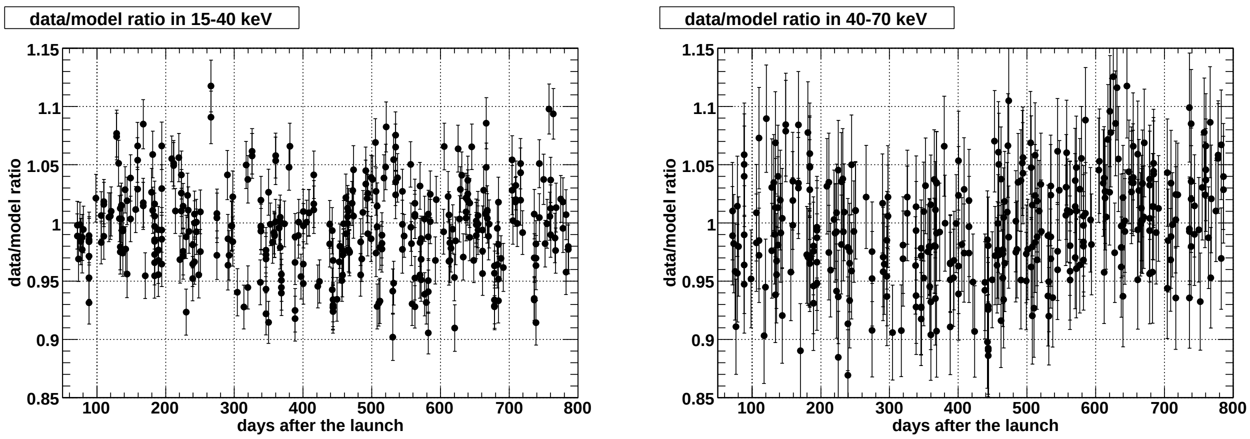

Figure 5: Data to model rations of the NXB count rate in 15-40 keV (left) and 40-70 keV (right) shown as a function of the elapsed day since 2005 July 10 (the day of the launch of Suzaku).

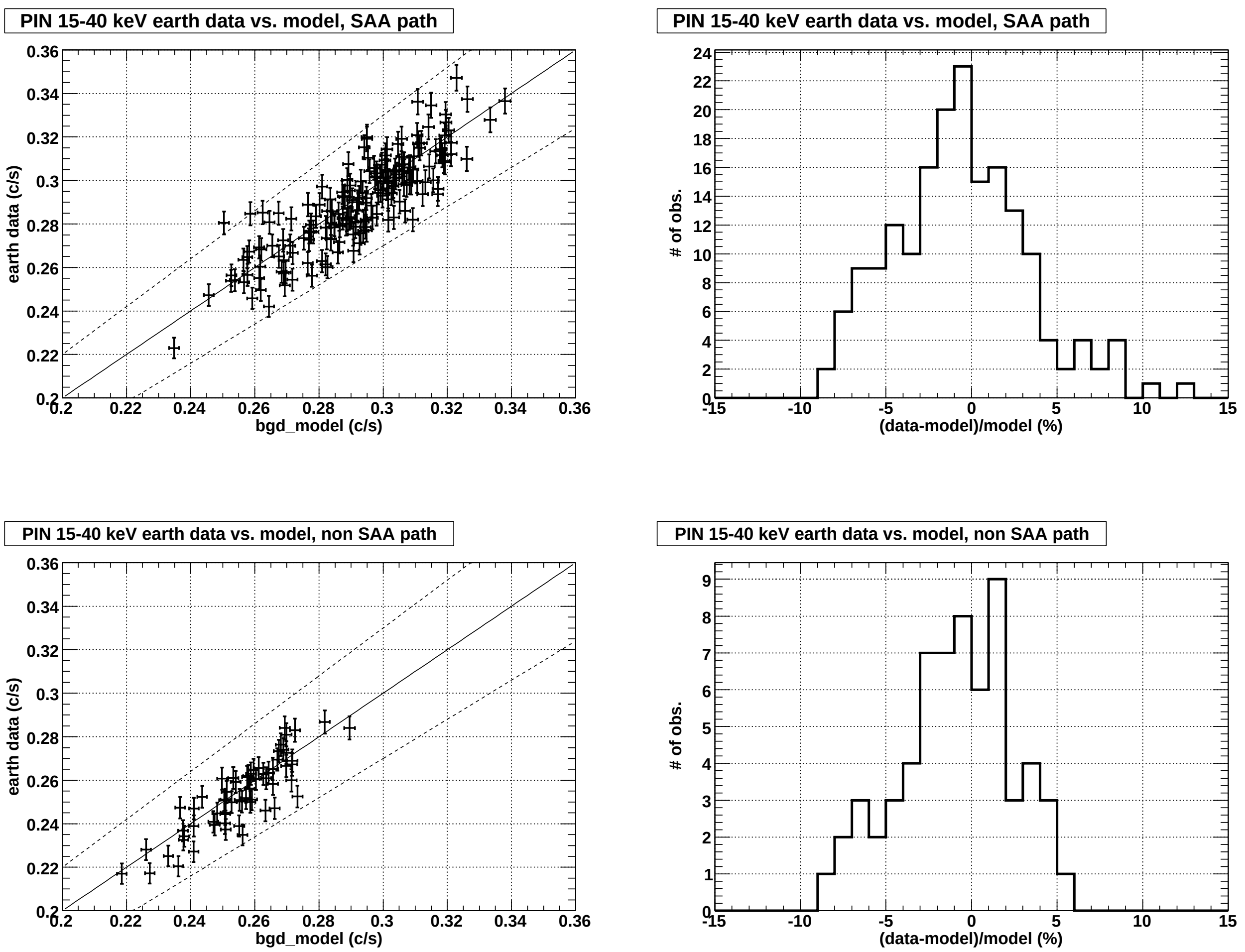

Figure 6: The same plots as those of Figure 3, but data in SAA paths and non-SAA paths are individually shown in the upper panels and lower panels, respectively.