JX-ISAS-SUZAKU-MEMO-2007-10
Title: A Guide to better estimation of the PIN Non-X-ray Background
Category: HXD
Author: M. Ishida, A. Sekiguchi, A. Bamba
Date: 2007-11-23

A Guide to Better Estimation of the PIN Non-X-ray Background

Manabu Ishida[1], Akiko Sekiguchi, Aya Bamba
The Institute of Space and Astronautical Science/JAXA

November 23, 2007

1 Overview

Reproducibility of the non-X-ray background (NXB) of the HXD PIN detector is currently 5% for observations with an exposure longer than 40 ks, and worse for a shorter exposure observation (∼10% for a 10ks observation) [1, 2]. Reducing this number leads to enhance significance of source detection and accuracy of spectral parameters. The HXD team has therefore been struggling for a more reliable model of PIN NXB [3].

Meanwhile, we present in this document a quick-fix method to improve the accuracy of the NXB estimation to ±3% for individual observations with an exposure time longer than 40 ks. Our method utilizes a higher end of the PIN energy band that is free from source photons, for renormalizing the background spectrum made from the model background event file. Accordingly, it does not work for a strong power-law source whose spectrum extends over ∼100 keV. The 5% uncertainty of NXB, however, does not matter for such intense X-ray sources, and the method described here is expected to salvage significant amount of weak sources from which X-ray flux seems to be detected at a "frustrating" level.

2 The Nature of the PIN NXB

The nature of PIN NXB is described in full detail in Kokubun et al. (2007). The PIN detector is nearly free from long-lived radio activation by cosmic rays, and the remaining middle or short-lived one relaxes within a few thousand seconds. As a result, the NXB intensity in the 12-80 keV band correlates well with elapsed time since the entry to SAA (`T_SAA`), and on the cut-off rigidity (`COR`). The NXB intensity, however, cannot be reproduced completely by them, and the uncertainty remains at a level of ±5%, which now limits the NXB reproducibility.

It is known that the spectral shape of NXB weakly depends also on `COR` and `T_SAA` (see Fig. 24 of [1]). Although this dependence is already considered in the current background modelling, the verification study is still ongoing. A preliminary analysis indicates that the remaining uncertainty of the spectral shape becomes smaller for longer exposure observations and is ±3% for 40 ks observations [2].

In summary, to reduce the uncertainty of NXB, one is recommended to evaluate the intensity (= normalization) of NXB for each individual observation according to the method explained in the following section. After this is done, the reproducibility is improved to ±3%, which originates from the `COR`/`T_SAA` dependence of the NXB spectral shape as explained above.

Note that the `COR`/`T_SAA` dependence for shorter exposure observations, such as 20 ks or less, needs more study, and we ask GOs to use hitherto adopted ±5%.

3 How to Estimate the PIN NXB with Individual Dataset

In this section, we describe how to estimate the intensity (normalization) of NXB with the Suzaku data of η-Carinae (seq.#100012010) as an example.

[1] Fully responsible for this document

3.1 Make a background spectrum with the same GTI as a source spectrum

We use the model background event file which is included in each Suzaku data package. In creating the background spectral file from the event file, it is important to use the same good time interval (GTI) file as used when the source spectrum is extracted. For this, first extract the GTI file from the cleaned event file.

```
xselect > read event ae100012010_cl.evt
 ...some data screening is made here if necessary...
xselect > bin all
xselect > save goodtime ae100012010.gti
```

It is better to use the cleaned event file, because it is processed to contain only the data with COR ≥ 8. Then apply this GTI file to the model background event file and create a background spectral file.

```
xselect > read event ae100012010hxd_pinnxb_cl.evt
xselect > filter time file ae100012010.gti
xselect > bin spec
xselect > save spec ae100012010_bgd.pha
```

Since the NXB spectral shape depends on COR and T_SAA, it is important to make their distributions common between the source and background spectra for reliable background estimation. This is realized if we use a common GTI file. Due to this reason, a background file created from the data during earth occultation is not reliable.

In Fig. 1 we show a light curve of the PIN, that of the model background before and after applying the GTI file. The model background file covers all the GTIs of the cleaned event file, and even includes

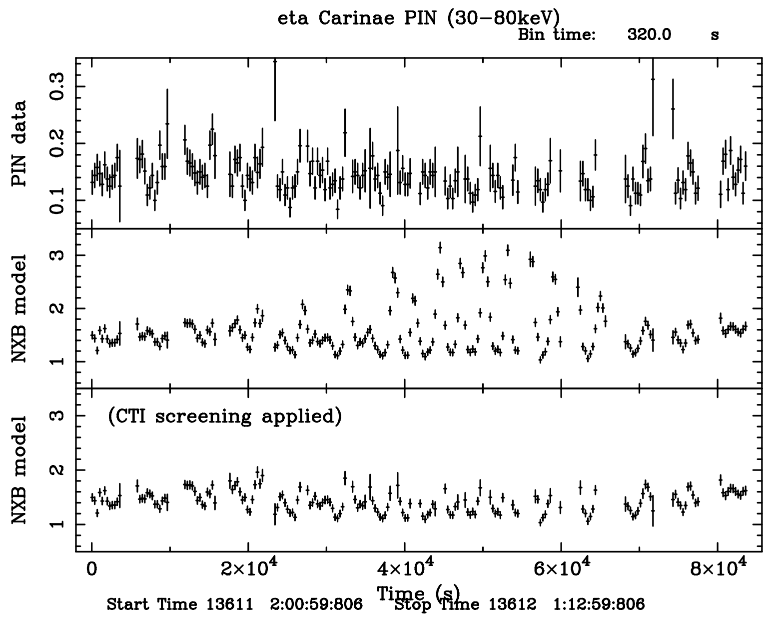

Figure 1: (top) the light curve of the PIN in the 30-80 keV band, that of the model BGD (middle) before and (bottom) after applying the GTI file.

the time region with COR < 8. It is important to exclude those time intervals.

3.2 Find the energy band free from source photons

In Fig. 2, we show the spectra of the PIN and the model background. It is clear that the flux from η-Car is not detected above 30 keV. We can thus evaluate the intensity of NXB of this observation using the band 30-80 keV. Note that the choice of the source-free energy band should be made under the responsibility of each observer.

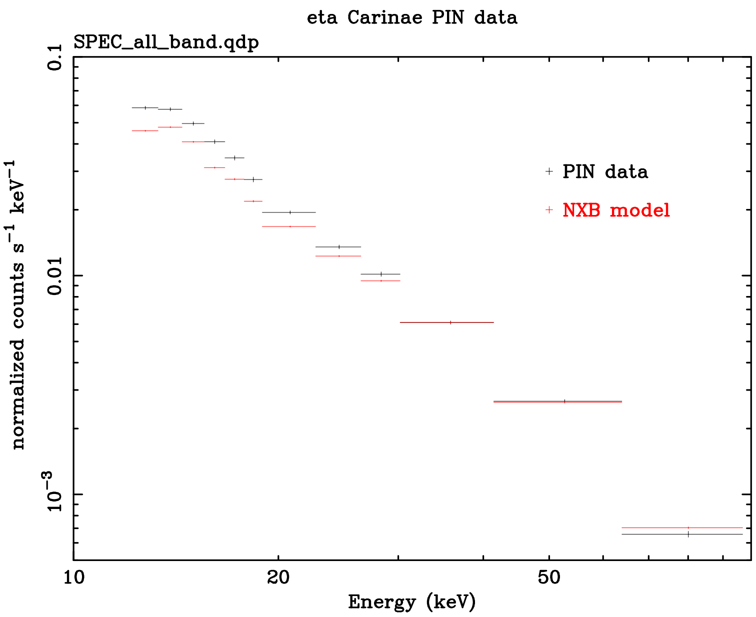

Figure 2: Spectra of the PIN and the model background. The background spectrum is plotted after correcting the photon statistics that is enhanced by a factor of 10.

3.3 Scale the background normalization and estimate the systematic error

In table 1, we compare the counting rates of the PIN and the model background together with their ratio. For reference on statistics, we also summarize the case of using the 40-80 keV band. The PIN exposure time of η-Car is 47 ks. Note that the errors quoted are at the 1σ level. In this observation, the model

Table 1: The level of the model background in the observation seq.#100012010.

Energy band (keV)	Model background (c/s)	PIN data (c/s)	Ratio
30-80 keV	0.1506±0.0006	0.1495±0.0018	1.007±0.013
40-80 keV	0.0861±0.0004	0.0853±0.0013	1.010±0.017

background is overestimated by 0.7%. Hence, before subtracting the background, one has to adjust the normalization of the background spectrum. One of the easiest way to do so is to change the exposure time using the ftool `fparkey`. In the current case, the exposure time of the background spectrum should be increased by a factor of 1.007. Finally, one has to take into account in the same way the systematic error originating from the `COR/T_SAA` dependence of the NXB spectral shape, which is ±3%,.

References

[1] Kokubun M. et al. 2007, PASJ **59**, 53

[2] Mizuno T., Takahashi H., Uehara Y., Nakazawa K., Bamba A., Fukazawa Y., Kokubun M., Watanabe S., and the HXD team, 2007, http://www.astro.isas.jaxa.jp/suzaku/doc/suzakumemo/suzakumemo-2007-09.pdf

[3] Watanabe S., Ushio M., Tanaka T., Kokubun M., Fukazawa Y., and the HXD team, 2007, http://www.astro.isas.jaxa.jp/suzaku/doc/suzakumemo/suzakumemo-2007-01.pdf

Appendix: Evaluation of the NXB Renormalization Method using Earth Occultation Data

T. Mizuno and the HXD-team
e-mail: mizuno@hep01.hepl.hiroshima-u.ac.jp

Last updated on December 28, 2007

A renormalization of the NXB model spectrum utilizing a higher end of the PIN energy band is proposed for a better estimation of the PIN NXB. We, HXD-team, evaluated this method by applying this to long earth observations and found that the improvement is not so significant, as explained below.

We first selected long earth observations (with an exposure more than 40 ks) used in the reproducibility study (SUZAKUMEMO-2007-09; see Table 1). Next we calculated the count rate of the data and the NXB model in 15–30 keV and 30–80 keV, and then scaled the 15–30 keV model rate utilizing the data/model ratio in the higher energy band. The comparison of the residuals, before and after the renormalization, is given in Figure 1. The mean of the residual becomes closer to 0, but the deviation is still large (± 5–6%) and no significant improvement is recognized.

This "non-improvement" can be explained by two facts: Firstly, the correlation of residuals in low- and high- energy band is not so good. As shown in Figure 2 (a comparison of residuals between two bands), some data points significantly deviate from the line of $y = x$ (when residuals in low-energy band is proportional to the high-energy one). In other words, not only the spectral normalization but also the spectral shape deviates from the NXB model in these data. Another fact to be considered is the photon statistics. Typical statistical error in high energy band (30–80 keV) is 1.5 % for 40 ks exposure, which is inevitably introduced in the reproducibility by the renormalization method. The combination of these two results in an insignificant improvement.

In summary, the renormalization method is not guaranteed to work for every observation, and whether the NXB reproducibility of a particular observation can be improved or not is unpredictable. We therefore recommend users to use the value of 3.2% (1 σ) given in SUZAKUMEMO-2007-09 as the systematic uncertainly of the reproducibility. See the memo for more detail. We note that the comparison the data- and the model-spectrum of the PIN in high-energy end (where your source is expected to be dark) is useful to verify that the data processing (e.g., the dead-time correction) is appropriate.

Table 1: List of observation IDs and target names of long earth data * used in this study.

100034010(ABELL_3376), 700007010(MCG-6-30-15), 100008030(NGC_4945), 800013020(HCG62), 801054010(NGC3923), 701031010(MARKARIAN_335), 701001010(NGC4418), 701094010(PKS_1510_089), 401094010(IGR_J16318-4848), 501008010(GC_SOUTH), 801089010(RXJ_0658), 701013010(SWIFT_J0255.2-0011), 401068010(GX_339-4), 802033010(ABELL_2744), 702056010(3C_445), 702058010(NGC_1052), 402001010(EX_HYA)

* The first 40 ks earth occultation data are used to make statistical errors among data comparable. The exposure to earth in MCG-6-30-15 observation is more than 80 ks, and the data is divided into two sets with 40 ks.

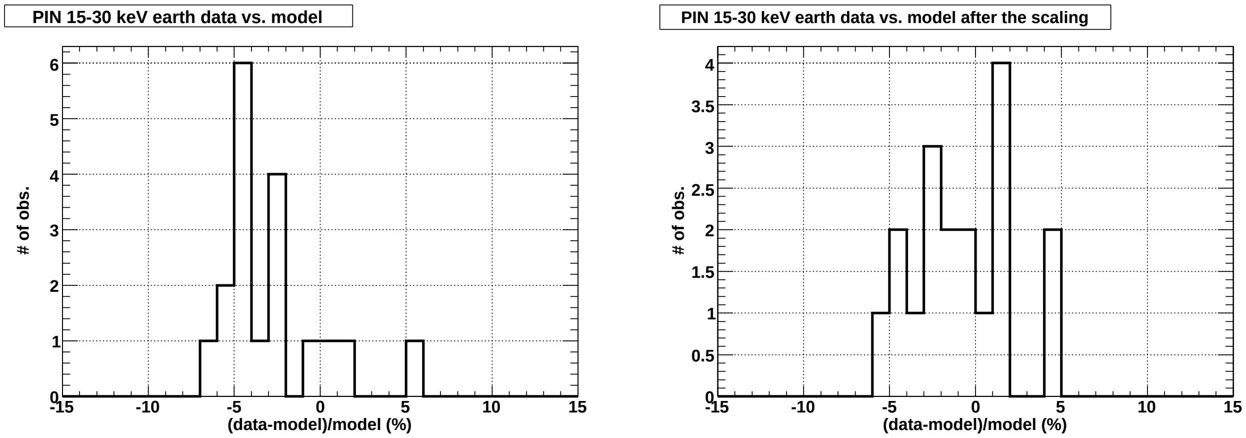

Figure 1: Residuals of 15–30 keV count rate before (left) and after (right) the renormalization using the rate in high energy band (30–80 keV). Total 18 earth observations with 40 ks exposure are used here. (see Table 1)

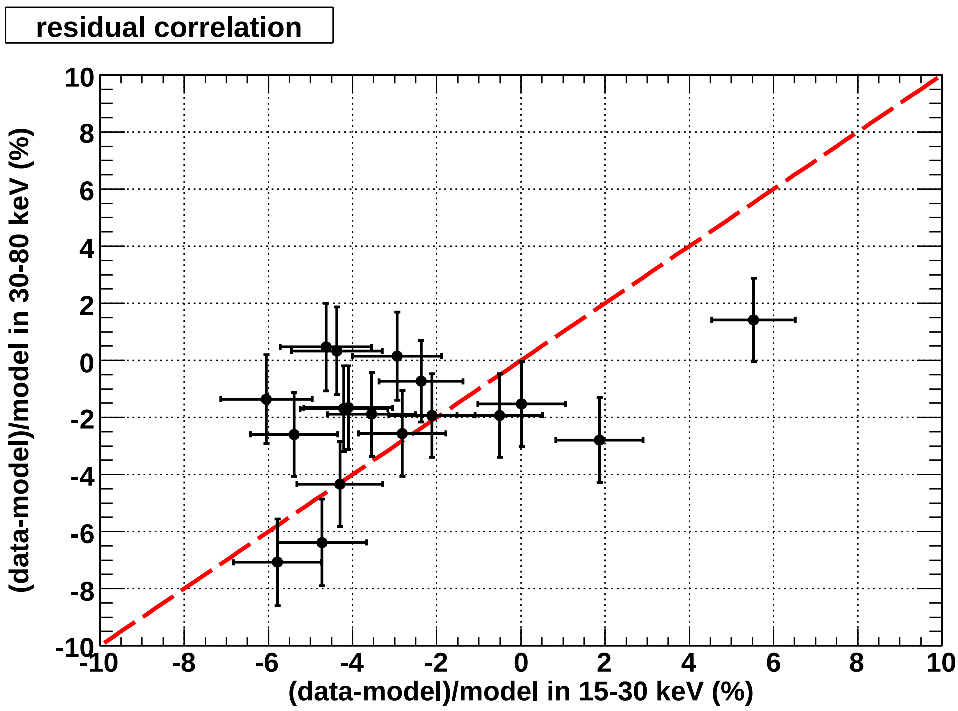

Figure 2: A correlation of the residuals in 15–30 keV and 30–80 keV with a red line representing the case when residuals in low-energy band is proportional to the high-energy ones. Some data points deviate from this line by $\sim 3\sigma$.