

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

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1 Overview

Reproducibility of the non-X-ray background (NXB) of the HXD PIN detector is currently $\pm 5\%$ [1]. 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 [2].

Meanwhile, we present in this document a quick-fix method to improve the accuracy of the NXB estimation to $\pm 3\%$ 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 $\pm 5\%$, 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 $\pm 3\%$ for 40 ks observations [3].

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 $\pm 3\%$, 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 $\pm 5\%$.

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.

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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 $COR \geq 8$. 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

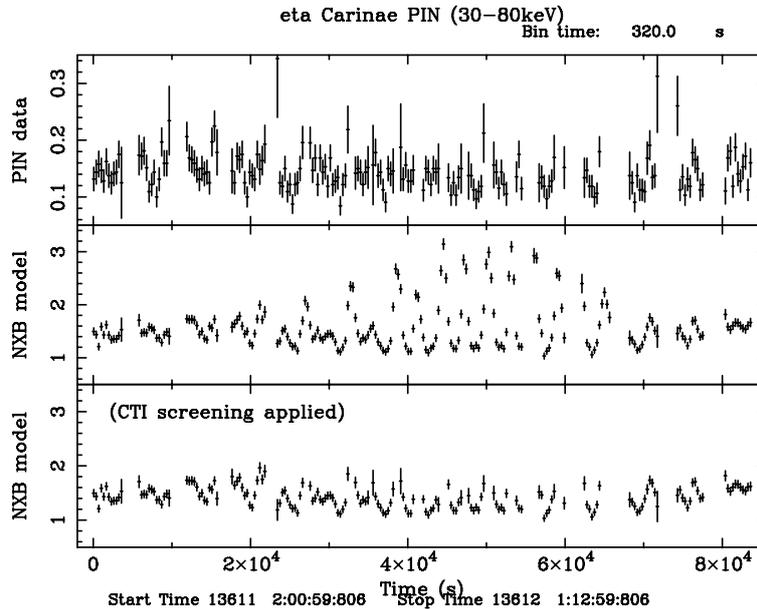


Figure 1: (top) the light curve of the PIN in the 30-80 keV band, that of the model BGD (middle) before and (bottom) after applying the GTI file.

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.

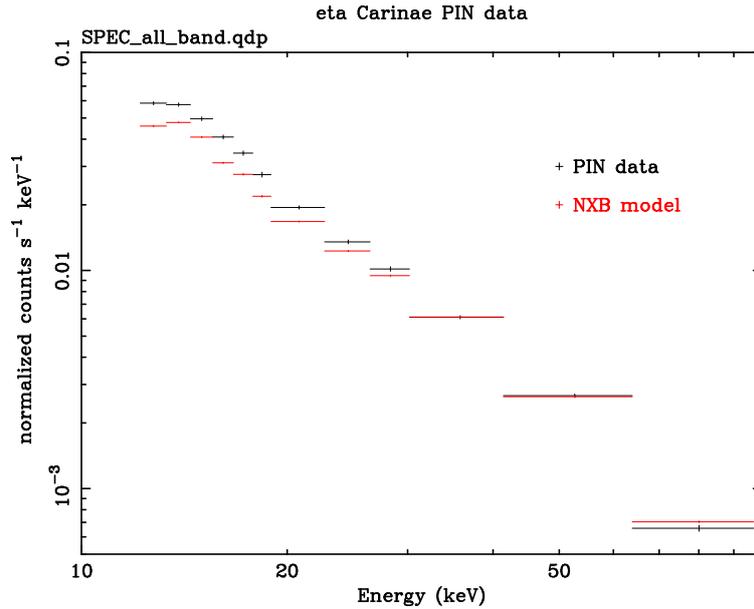


Figure 2: Spectra of the PIN and the model background. The background spectrum is plotted after correcting the photon statistics that is enhanced by a factor of 10.

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 fool `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 $\pm 3\%$.

References

- [1] Kokubun M. et al. 2007, PASJ **59**, 53
- [2] 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>
- [3] 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>