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Title: Reproducibility of the HXD-GSO Non X-ray Background
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Reproducibility of the HXD-GSO Non X-ray Background

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1 Introduction

The GSO/BGO phoswich configuration of HXD (Hard X-ray Detector) scintillation detectors is designed to reduce an instrumental background as much as possible (Takahashi et al. 2006), and achieves an unprecedented low background in the energy ranges of 150-500 keV (Kokubun et al. 2006). This low background enables us to study the spectral shape and time variability accurately around several 100 keV. A limiting factor for the sensitivity of the HXD-GSO is a reproducibility in the background estimation, rather than the statistical error. Here we examine the background reproducibility of the HXD-GSO which covers the energy range above 50 keV, mainly by comparing the background model prediction and the data during the earth occultation of SWG observations, or of GO observations in a trend archive [1]). 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 Non X-ray Background (NXB) for the HXD. Comparison with the blank sky data, where the GSO signal from celestial objects are thought to be negligible, is also performed. For details of the background models, see Fukazawa et al. (SUZAKU-MEMO 2007-02).

2 Spectrum and Light Curve of Typical Long Earth Observations

Figure 1 compares energy spectra between the real data and the model prediction during the earth occultation of one observation in SWG phase (MCG-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 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 that with telemetry saturation are also discarded, and the net exposure for the earth occultation is 86 ks. We see a good agreement of the model with the data within 2% in the full energy range of the HXD-GSO (50–600 keV). Figure 2 shows light curves of the same SWG observation

[1] ftp://ftp.darts.isas.jaxa.jp/pub/suzaku/rev1.2/trend

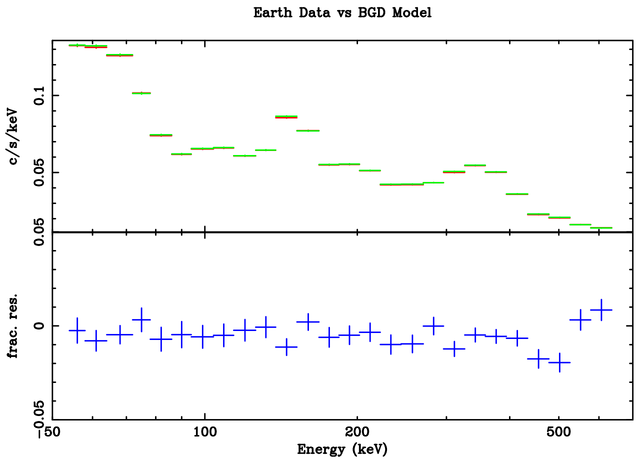

Figure 1: Comparisons of spectra between the data (red) and the background model prediction (green) of the HXD-GSO NXB for one observation taken in the SWG phase (MCG-6-30-15 observed from 2006 January 9 to January 14). Data during the earth occultation (elevation angle less than $-5°$) is used in the plot. Fractional residuals are given as the ratio to the data in the bottom panel.

(MCG-6-30-15), individually for 50–100 keV and 100–200 keV energy band and in 1, 4, 16 ks and 1 day time scales. The behavior of residuals is basically similar to that of the PIN-BGD (Mizuno et al. 2006). In the longer time scales the variance in the residuals is determined by the reproducibility of the background by the model, whereas in the shorter time scales they become large not only statistically but also systematically because of the incompleteness of the modeling. The distribution of the residuals obtained from ten long earth observations are shown in Figure 3. The peak-to-peak of residuals in the 1 day time scale for these 10 observations is $\pm 2\%$ in 50–100 keV and $\pm 1\%$ in 100–200 keV. Please also see chapter 7 of the technical description for Suzaku AO-2 [2] for more detailed information.

[2] http://www.astro.isas.jaxa.jp/suzaku/doc/suzaku_td/node1.html

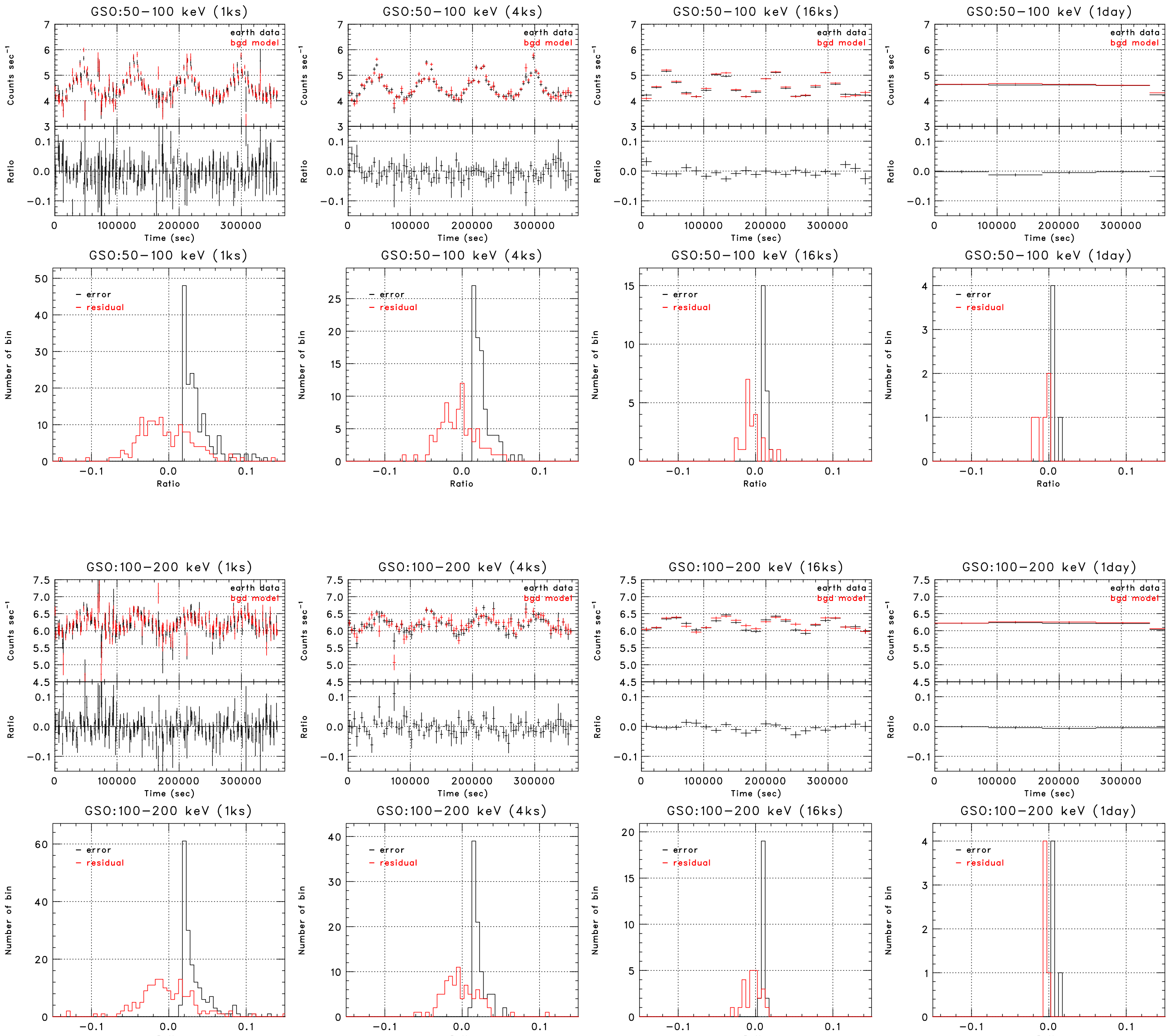

Figure 2: The same as Figure 1, but for comparisons of light curves for various time bins of 1, 4, 16 ks and 1 day, for the MCG-6-30-15 observed from 2006 January 9 to January 14. The first 4 panels show the case in 50–100 keV, while the last 4 panels do the case in 100–200 keV. In each panel, the upper figure shows the comparison of the light curve and residual given as the ratio against the total data count rate, and the lower figure shows the distribution of the residual (red) and the statistical error (black), given as the ratio as the figure above.

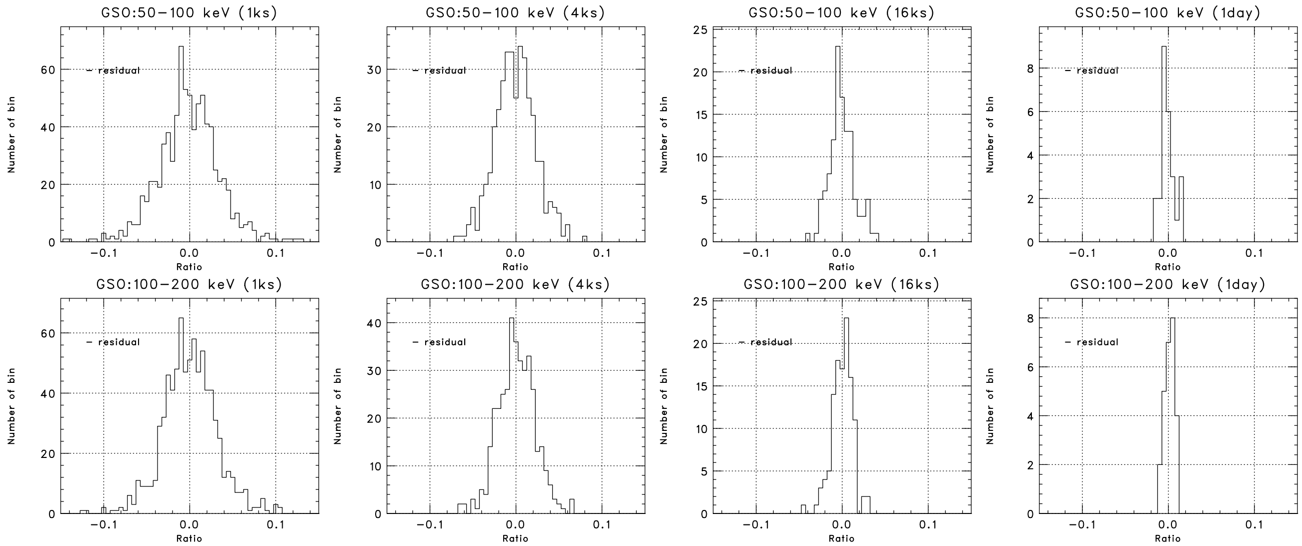

Figure 3: The same plots as the residual distributions shown in Figure 2, but extracted from ten long observations.

3 Comparison with the Earth Occultation Data

In this section, we examine the reproducibility of the HXD-GSO NXB by utilizing the available earth occultation data in 2005 Aug 17 to 2006 Sep 30. The observational mode of the GSO has been changed mainly twice on 2006 March 23 and May 13; the lower discrimination level and pulse-shape discrimination level were changed. The BGD model is produced by considering these two mode changes (see Fukazawa et al. 2007 in detail).

In Figure 4, we compare the NXB count rates between the real data and the background model in 50–100 keV and 100–200 keV range. The GSO observational mode had been changed from 2006 March 23 to May 13, and the data in this period are colored by green. Most of the data and model agree in ~ 3 %, and no significant difference in reproducibility is seen between models even in the period of 2006 March 23 to May 13.

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 is expected to be worse. We thus divided the data in 50–100 keV 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 5, in which data with exposure to earth more than 10 ks are selected. The data and the model agree with each other in 3 % for both non-SAA paths and SAA paths.

Next, in order to look at the trend of the background reproducibility, we compared 50–100 keV and 100–200 keV count rates between the real data and the model prediction against the elapsed day after the Suzaku launch in Figure 6. Most of data agree with model within 3% for any period. There are several data points with a large discrepancy above 4%. These data are concentrated around 2006 March to May, where many trials of observational mode changes were performed only during the earth occultation period to optimize the observational mode. Users should take care in such period, when they compare the data and model for the earth occultation data by themselves, referring to the HXD observational log page [3].

Last, in order to investigate the reproducibility within a time scale of one day, we compared

[3]http://www.astro.isas.jaxa.jp/suzaku/log/hxd/

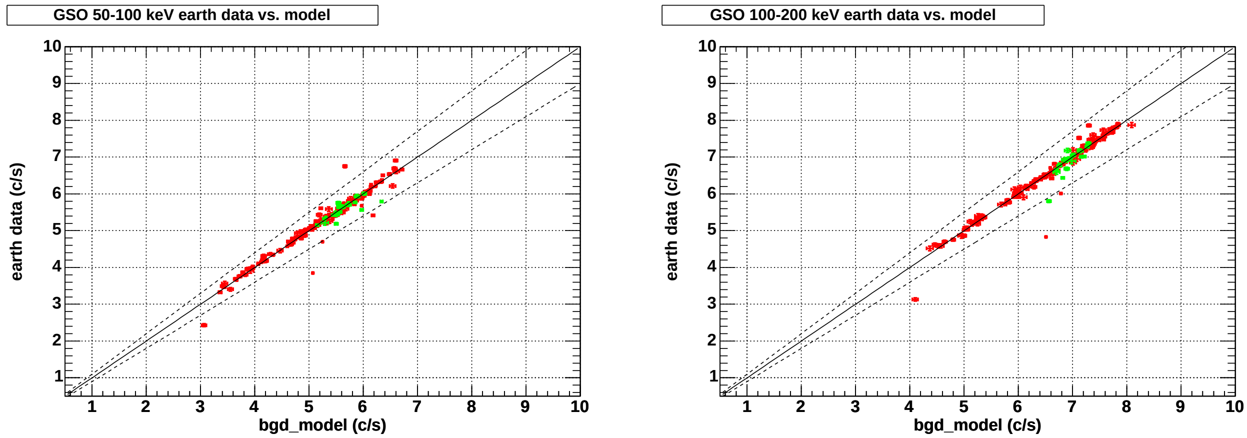

Figure 4: (left) A comparison of the NXB count rate in 50–100 keV between the data and the model prediction. Data from 2006 March 23 to May 13 are shown by green crosses (see text). (right) The same plot but for 100–200 keV.

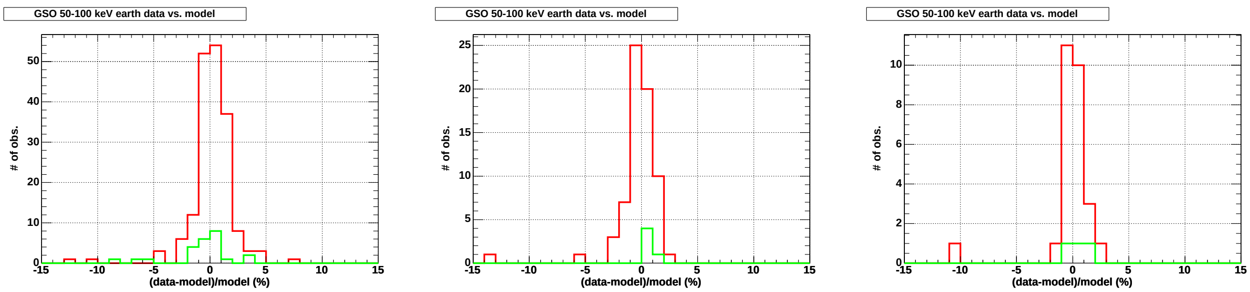

Figure 5: The fractional residual distributions but data with exposure more than 10 ks are selected. Data (50–100 keV) in SAA paths and non-SAA paths are summed together in the left panel, and data in SAA paths and non-SAA paths are individually shown in the middle and right panels, respectively. The green is a plot for the period of 2006 March 23 to May 13.

the light curve of the earth occultation period in various time bins and took a variance of the fractional residual between the data and BGD model. Since the GSO BGD model parameters are determined for each month, the reproducibility possibly differs month by month. Therefore, we plot the variances of each month in Figure 7. Except 2006 May, the variance is almost similar, and thus the modeling is rather stable. However, the variance is significantly large in 2006 May. This is due to the data in the period when one of PINs was very noisy on 2006 May 24–25. In that period, the PINUD count used in the BGD modeling is affected by the noise. Moreover, in the period of 2006 May 25 to 29, when one of four PIN high voltages was down to zero, a total PINUD count of 64 PINs is lower by $\sim$15% and thus the BGD model may predict a lower count rate. Users are encouraged to take a special care in treating the data of this period. The HXD team is going to prepare the BGD data wherein the above effect is taken into account.

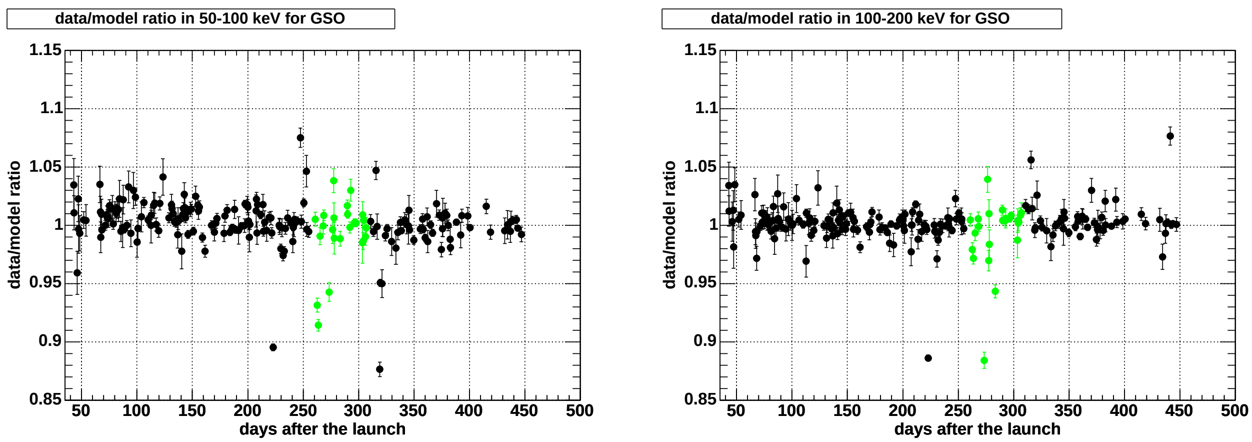

Figure 6: Data to model ratios of the GSO NXB count rate in 50–100 keV (left) and 100–200 keV (right), shown as a function of the elapsed day since 2005 July 10 (the day of the launch of Suzaku). Green data points indicate the period when the GSO observational mode was changed.

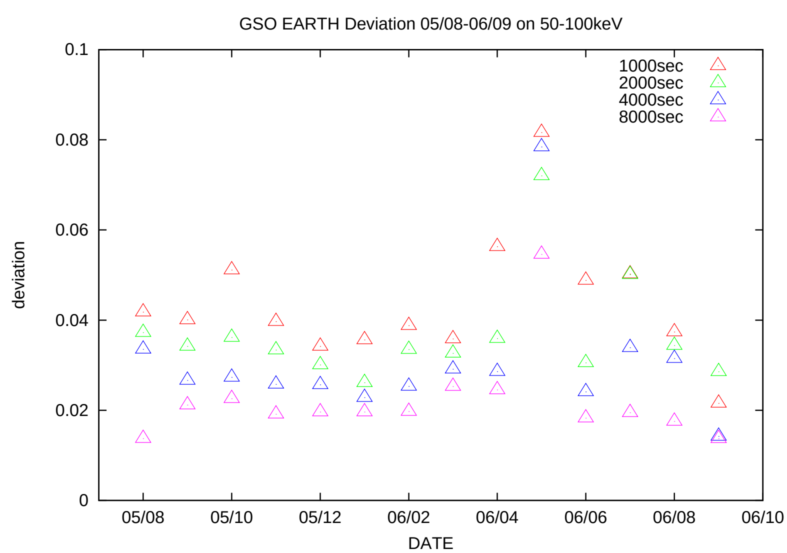

Figure 7: The variance of fractional residuals between the NXB data and BGD model in the light curve for each month. The color indicates different time bins of the light curve.

4 Comparison with the Blank Sky Data

As a final check of the background reproducibility, we compared the NXB model with the sky data which are expected to be a blank sky field for the HXD-GSO. We used so-called clean events which are already cleaned with the same selection criteria at those of § 2. Results by 8 SWG observations are summarized in Figure 8. Unlike the PIN, the CXB is negligible in the GSO band. No systematic difference is seen between the data and BGD model spectra, indicating that the background model is applicable for sky observations. Note that this figure does not mean non-detection of excess hard X-ray emission in these observations below the current accuracy of the GSO NXB model (∼2–3%)

We also compared the data and the NXB model light curves as summarized in Figure 9 for 50–100 keV band. As a result, residuals in some observations may show modulations of a peak-to-peak amplitude up to ~ 0.1 c s^{-1} in a cycle of ~ 1 day.

Reference

- Takahashi T. et al. 2006, accepted for publication in PASJ
- Kokubun M. et al. 2006, accepted for publication in PASJ
- Mizuno T. et al., Suzaku Memo 2006-42
- Fukazawa Y. et al., Suzaku Memo 2007-02

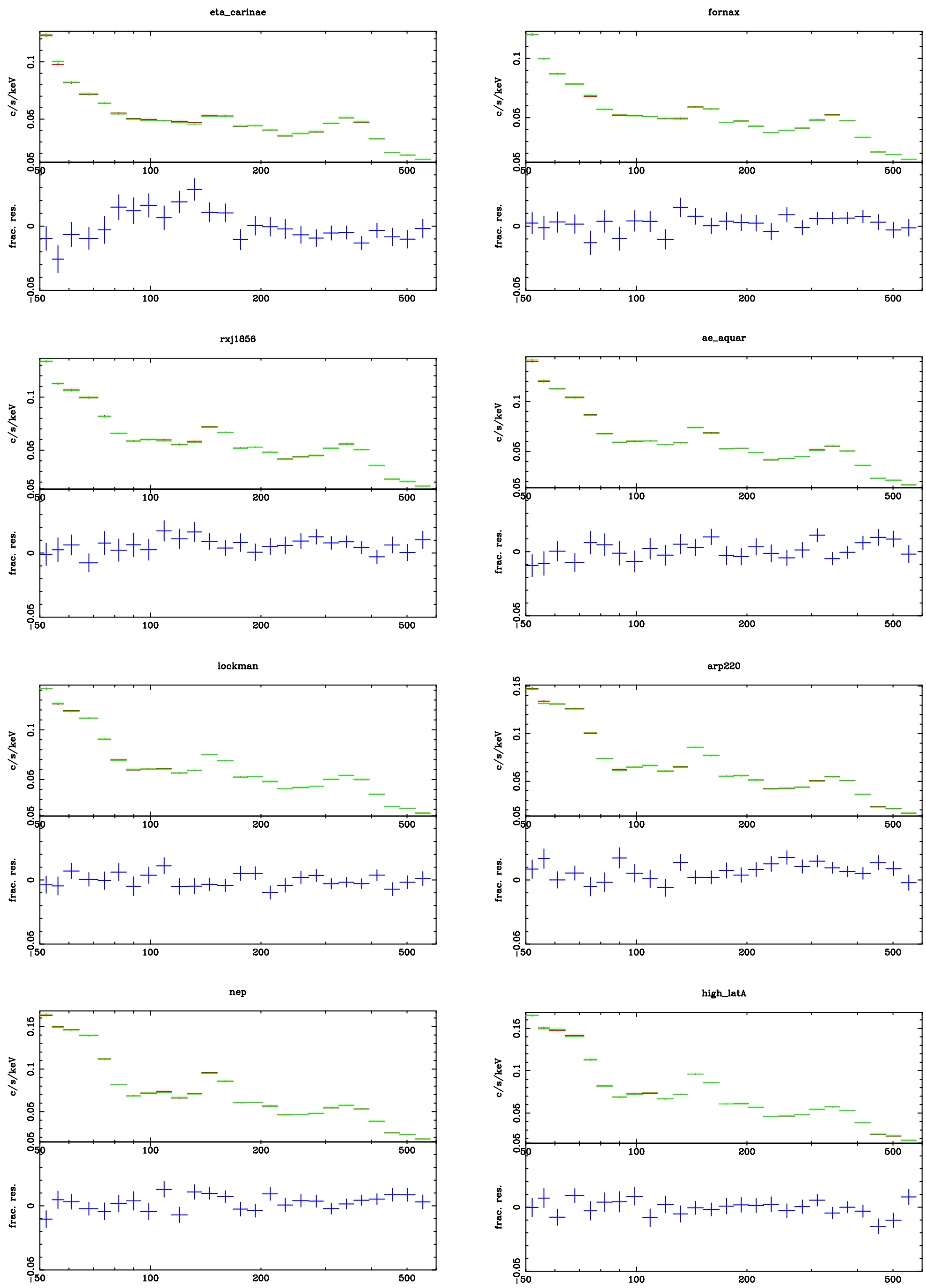

Figure 8: Comparison of spectra between the data (red) and BGD model (green) for observations of objects with no known strong hard X-rays. Data and background model spectra are given by red and green histograms, respectively, with fractional residuals (blue histogram). Observations on 2005 August 29, September 13, October 24 and 30, November 14, 2006 January 7, February 10 and 14 are shown from top to bottom.

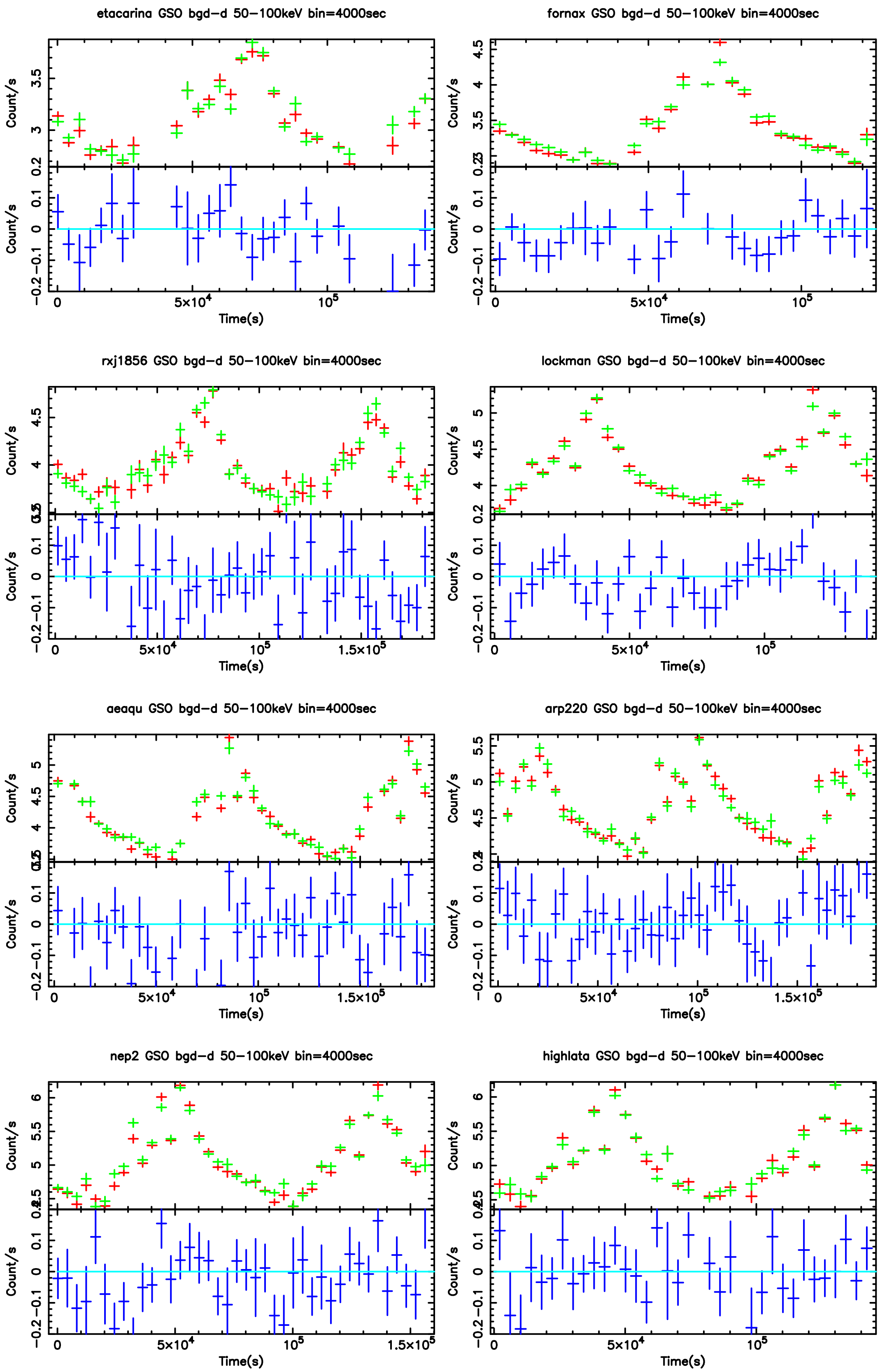

Figure 9: The same as Figure 8 but for 50–100 keV light curves instead of spectra. In each panel, the upper figure shows the light curve and the lower figure shows the residuals.