E HEXTE A B S

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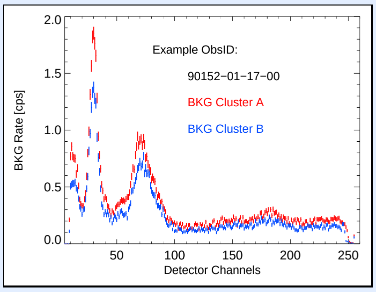
Abstract

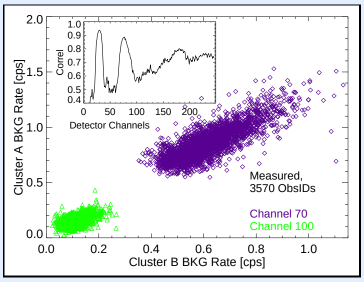
Since the launch of *RXTE* in 1995 the HEXTE instrument mostly operated in its standard "rocking" mode where the pointing direction of each of its two clusters alternates between source and background measurements in such a way that one cluster is always looking at the source while the other samples the background. During the extraction of source light curves and spectra each cluster uses its own background measurements for correction. This allowed HEXTE to achieve signal to background ratios of <1% for long observations ($\gtrsim$400 ks) of weak sources. Starting in 2005 December the rocking mechanism of cluster A began to display increasingly frequent interruptions and since 2006 July is permanently fixed in the on-source staring position. We have developed a prototype FTOOL, `hextebackest`, which for a given observation uses the background measured by cluster B to produce an estimated cluster A background spectrum. The tool uses a set of channel dependent parameters to perform a linear transformation of the count rates. We explain how these parameters were derived, compare estimated and measured cluster A backgrounds for archived rocking observations, and present examples of the application of the method.

Introduction

The High Energy X-ray Timing Experiment (HEXTE) on the Rossi X-ray Timing Explorer (*RXTE*) consists of two clusters, A and B, of 4 NaI/CsI phoswich scintillation detectors, sensitive to X-rays from 15 to 250 keV (Rothschild et al., 1998). Both clusters used to measure their individual backgrounds, which are different form each other mainly but not only due to the fact that cluster B has only 3 operating quadrants. For an example of the measured background spectra, see Fig. 1. While cluster B is continuing to perform the standard 32 s rocking, cluster A is now permanently fixed on-source, i.e., there are no quasi-simultaneous background measurements for cluster A anymore. However, the cluster A background can be estimated based on the measured cluster B background. Both rates are well correlated for each detector channel (inset Fig. 2), with varying correlation coefficients which become especially high in the background lines around 30 and 70 keV (detector channels ~ energy channels for HEXTE). We extracted the background spectra of several 1000 exposures performed during AO9. Fig. 2 demonstrates the correlation in two selected channels, one associated with a peak in the spectrum and one not.



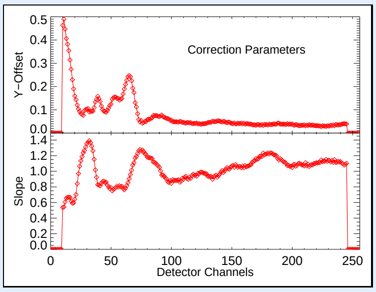
F 1: Background spectrum measured by HEXTE's clusters A (red) and B (blue) for AO9 observation ObsID 90152-01-17. Note that there is an instrumental cutoff below channel ~ 10 and above channel ~ 246 (starting from 0).



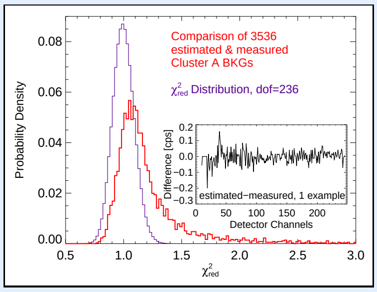
F 2: Cluster A versus cluster B background rates measured in channels 70 (purple) and 100 (green) for 3570 ObsIDs of AO9. The inset shows the correlation coefficient between the A and B rates for all channels based on these observations.

Linear Correction Parameters

We performed linear fits to the A vs B background rates for each detector channel based on the AO9 data set using `poly_fit` in IDL and taking A and B uncertainties into account. Note that the 3570 ObsIDs are the result of pre-selection: (1) observations with high A or B rates in the lower channels have been omitted to screen against sources in the background FOV, (2) since observations performed far from the SAA show different background correlations, they have also been omitted. Fig. 3 shows our preliminary correction parameters. In Fig. 4 the estimated and measured cluster A spectra are compared (red) – the former based on the AO9 cluster B measurements and the parameters – using the statistic $\chi^2_{\rm red} = \sum[d^2/(\sigma^2_{\rm est}+\sigma^2_{\rm meas})]/{\rm dof}$ for each observation, where d is the estimated minus the measured spectrum, $\sigma_{\rm est}$ and $\sigma_{\rm meas}$ are the spectral uncertainties, and the number of valid channels, dof, is 236 (see Bevington & Robinson 1992, for comparing two independent data sets). With respect to the theoretical distribution (purple) a small shift and a tail of higher χ^2 values can be seen. We are in the process of determining if further systematic cleaning of the data set can improve the correction parameters.



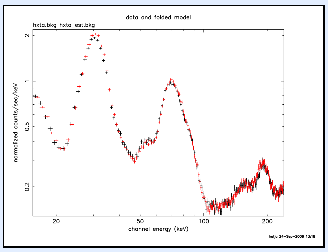
F 3: Results of linear fits, $rate\_A = m(channel) \times rate\_B + \Delta y(channel)$, for 3570 ObsIDs. **Top:** Offset Δy. **Bottom:** Slope m. Both parameters have been set to 0 for channels below 10 and above 246.



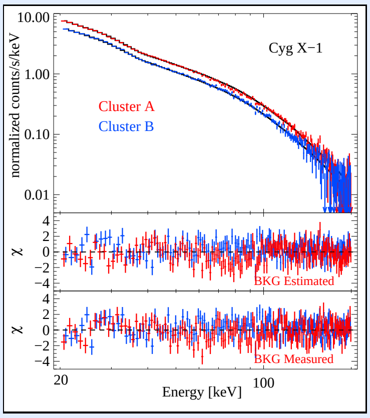
F 4: χ^2 comparison of the estimated and measured cluster A backgrounds for the AO9 ObsIDs (red). The theoretical distribution is also shown (purple). The inset shows the difference between the estimated and measured A backgrounds for one typical observation.

Applications

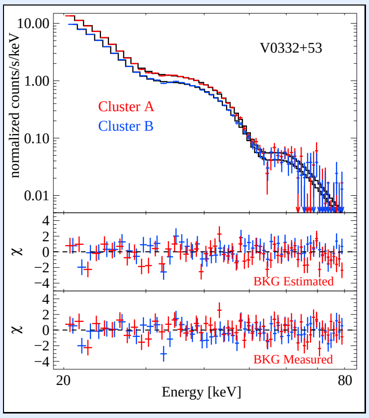
The method outlined above will soon be generally available to derive HEXTE A background spectra for current observations. It is foreseen that the next HEASOFT release contains the FTOOL `hextebackest` which takes an input .pha file, performs the linear correction for all channels, and writes a corrected output .pha file. A FITS file with the correction parameters will be part of the CALDB. As a hidden parameter of `hextebackest` it will by default be remotely accessed. See "`fhelp hextebackest`" for more details (e.g., on spectral binning). The preliminary parameters shown in Fig. 3 will be the first version to be released. Here we show that for recent observations of bright sources they give satisfactory results in the sense that the same source fits as with the measured cluster A backgrounds are obtained applying systematic uncertainties of 2% or less. We also performed this correction for a 2006 Jan. exposure of the transient pulsar Swift J1626.6−5156 for which no measured cluster A background is available (see poster by W. Coburn). Limited tests with spectra from AO4 and earlier show that the correction parameters are not adequate for older observations.



F 5: Estimated (red) and measured (black) cluster A background for the Cyg X-1 observation shown in Fig. 6. As confirmed by the source fit the estimated background is a good match, however, small deviations, especially in the line peaks, remain.



F 6: **Top:** HEXTE cluster A (red) and B (blue) counts spectra with the best fit `cutoffpl` model (black) for an observation of the black hole binary Cyg X-1 performed on 2004 Nov. 30. The spectrum has been averaged over 5 ObsIDs. The spectrum used for the cluster A background subtraction has been estimated based on the cluster B background and the correction parameters.
Middle: Residuals using the estimated cluster A background, best fit parameters: $\Gamma = 1.53^{+0.02}_{-0.02}$, $E_{\rm cut} = 132^{+8}_{-7}$ keV, $K = 1.22^{+0.07}_{-0.07}$ photons/keV/cm^2/s at 1 keV.
Bottom: Residuals using the measured cluster A background, best fit parameters: $\Gamma = 1.54^{+0.02}_{-0.02}$, $E_{\rm cut} = 134^{+8}_{-7}$ keV, $K = 1.25^{+0.07}_{-0.07}$ photons/keV/cm^2/s at 1 keV.
The two fits thus lead to consistent results without applying additional systematics in order to take uncertainties in the cluster A background estimate into account. For a recent study of the broad-band *RXTE* spectrum of the black hole binary Cyg X-1 see Wilms et al. (2006).



F 7: **Top:** HEXTE cluster A (red) and B (blue) counts spectra with the best fit two-cyclotron-lines model (black) for an observation of the transient pulsar V0332+53 performed on 2004 Dec. 12. The spectrum used for the cluster A background subtraction has been estimated based on the cluster B background and the correction parameters.
Middle: Residuals using the estimated cluster A background, best fit parameters: $\Gamma = -0.15^{+0.75}_{-0.57}$, $E_{\rm cycl1} = 28.83^{+0.08}_{-0.07}$ keV, $E_{\rm cycl2} = 51.5^{+0.6}_{-0.6}$ keV.
Bottom: Residuals using the measured cluster A background, best fit parameters: $\Gamma = +0.50^{+0.51}_{-0.55}$, $E_{\rm cycl1} = 28.83^{+0.08}_{-0.07}$ keV, $E_{\rm cycl2} = 51.3^{+0.6}_{-0.6}$ keV.
The two fits thus lead to consistent results, in this case, however, systematics of 2% had to be applied in order to take uncertainties in the cluster A background estimate into account. For a recent study of the broad-band *RXTE* spectrum of the transient pulsar V0332+53 see Pottschmidt et al. (2005).

Summary and Conclusions

We developed a method to derive HEXTE cluster A background spectra through linear transformation of measured cluster B backgrounds. With cluster A not performing background measurements anymore since 2006 July this is crucial for analyzing new cluster A data. The FTOOL `hextebackest` to produce estimated backgrounds will soon be available. It will use correction parameters from the CALDB. We demonstrated that our preliminary set of correction parameters is well suited to determine cluster A backgrounds for recent observations of Cyg X-1 and V0332+53. We are working on further improving the correction parameters and on an extra set for "non-SAA" ObsIDs.

References

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