AXAF Science Center

Harvard–Smithsonian
Center for Astrophysics

MEMORANDUM

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To: Distribution

From: M. Juda

Subject: HRC Response to the SXRB

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1 Introduction

The HRC instrument includes improvements over the *Einstein* and *ROSAT* HRIs that will result in lower non-x-ray backgrounds. The MCPs are fabricated from a "low noise" glass to reduce the internally generated background. The non-x-ray background in the "low noise" MCPs has been measured in the laboratory with and without lead shielding. Extrapolating the measurements to 100% shielding imply an internal background of ~ 0.04 counts s^{-1} cm^{-2}. The HRC detectors will be surrounded on five sides by an active anti-coincidence shield, signals from which will be used to significantly reduce the cosmic ray induced background within the data. The on-orbit particle background incident on the detector is expected to be 0.2 counts s^{-1} cm^{-2}. The anti-coincidence shield should permit $\sim$99% of this to be identified resulting in a residual rate of 0.002 counts s^{-1} cm^{-2}. The expected on-orbit background from all sources is ~ 0.05 counts s^{-1} cm^{-2}.

The soft x-ray background (SXRB) is expected to be a significant contributor to the observed on-orbit background but given a known instrument response and previous observations of the SXRB, the magnitude of its contribution can be modeled. This memo presents estimations for the SXRB contribution to the HRC background for both the imaging and spectroscopy detectors.

2 SXRB Intensity

There have been several surveys of the SXRB[1, 2, 3, 4]. Among these surveys there is substantial agreement as to the SXRB surface brightness distribution on the sky for different energy bands. Figure 1 shows the observed spectral dependence of the surface brightness from the UW sky survey[1] and its extension to the 0.07-0.11 keV band[5, 6]. Also included

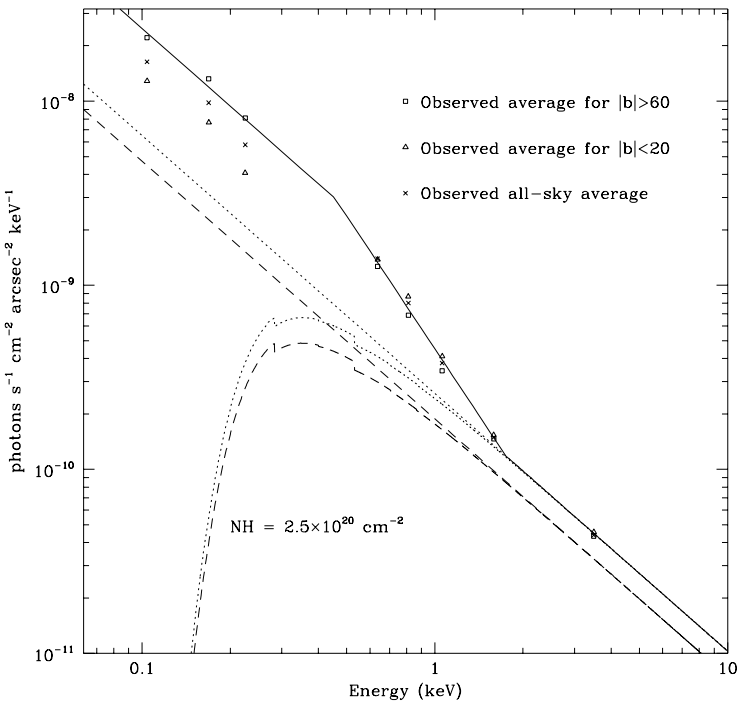

Figure 1: Observed SXRB spectrum from the UW sky survey. Different symbols indicate the average surface brightness for different regions of the sky. The dashed curves are for power law models of the extragalactic background contribution with the spectrum: 8 $E^{-1.4}$photons s^{-1} cm^{-2} sr^{-1} keV^{-1} for the long dashes (11 $E^{-1.4}$ for the short). The extragalactic model is plotted with and without absorption by the neutral material in the galaxy. The HI column density of 2.5×10^{20} cm^{-2} is typical for galactic latitudes greater than 60°. The solid curve is an empirical fit to the average spectrum for high galactic latitude.

in the figure are models for the extragalactic contribution to the SXRB with and without absorption. The observed background provides a spectral shape that can be used in predictions of the HRC response to the SXRB. The solid curve is an approximation of the average spectrum for high galactic latitudes; this is simply three power law segments:

$$42\ E^{-1.4} \text{ for } E < 0.457 \text{ keV}$$

$$19.2\ E^{-2.4} \text{ for } 0.457 < E < 1.745 \text{ keV}$$

and

$$11\ E^{-1.4} \text{ for } E > 1.745 \text{ keV},$$

where the dimensions on the spectrum are photons s^{-1} cm^{-2} sr^{-1} keV^{-1}.

A power law approximation is actually a poor match to the expected spectrum below ~1 keV, where thermal emission from the galaxy is expected to dominate the SXRB. It would be best to use an appropriate line emission dominated spectrum in predicting count rates in this energy region because the HRC energy response contains many features. Unfortunately, the exact spectrum is not known but the calculated rates are only slightly changed by adopting a Raymond and Smith collisional ionization spectrum. There is also significant variation in the SXRB at high galactic latitudes; the best count rate prediction would be made by selecting the observed rates in the direction of the observation.

3 Expected HRC-I Count Rate

I have used the three-segment power law approximation to predict the average SXRB rate the HRC-I should see at high galactic latitude. The HRC-I effective area as a function of energy function was produced from the on-axis HRMA effective area curve, a geometric obscuration of 0.9, the transmission of the UV/ion shield with 6000 Å of Lexan and 700 Å of aluminum[7], and the quantum efficiency of a CsI coated MCP[8]. Figure 2 shows the spectrum multiplied by the HRC-I effective area. Also shown in the figure is the result using a model for an absorbed extragalactic power law. Integrating these two curves over the 0.1–10.0 keV band the following HRC-I count rates are obtained: for the average high galactic latitude spectrum, 3.04×10^{-7} counts s^{-1} $arcsec^{-2}$ or 0.013 counts s^{-1} cm^{-2} and for the absorbed extragalactic component, 7.19×10^{-8} counts s^{-1} $arcsec^{-2}$ or 0.0030 counts s^{-1} cm^{-2}. Unabsorbed, the extragalactic power law component produces 0.0040 counts s^{-1} cm^{-2}. Martin Zombeck performed a similar analysis using MathCAD with slightly different results due to his assumed SXRB input spectrum. Clearly galactic emission will dominate the observations at high galactic latitude. Roughly half of the rate in the high galactic latitude prediction is from x-rays with energies less than 0.5 keV and about 85% is from energies below 1 keV.

4 Expected HRC-S Count Rate

We can perform a similar calculation for the HRC-S. A more interesting case may be that for the background in the low energy portion of the dispersed LETG spectrum. As a specific example, I consider here the contribution from the SXRB at 30 arcmin in the dispersion

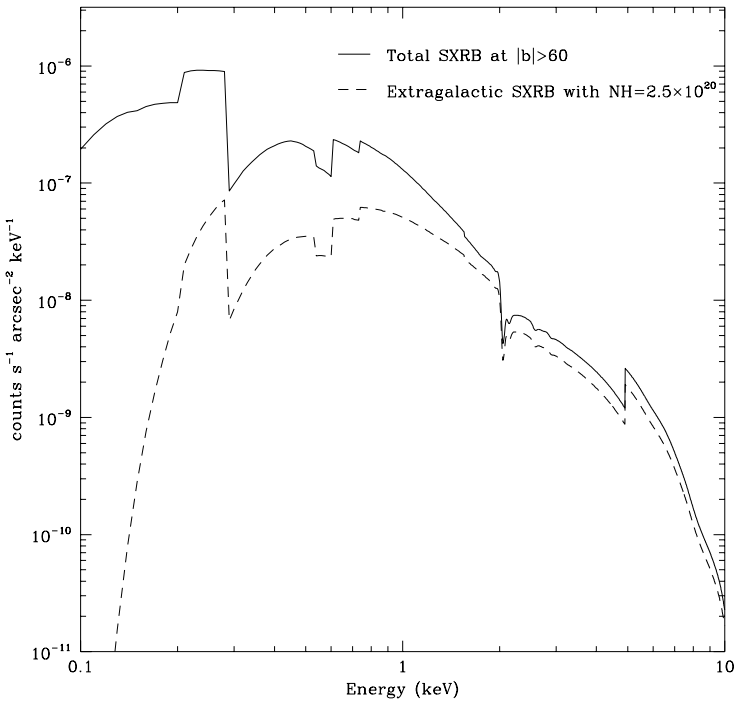

Figure 2: Product of model spectra and the HRC-I effective area. The solid curve uses the three-segment power law spectrum that approximates the SXRB at high galactic latitude as discussed in the text. The dashed curve is for a model of the extragalactic contribution: 8 $E^{-1.4}$ photonss^{-1} cm^{-2} sr^{-1} keV^{-1} with absorption by a hydrogen column density of 2.5×10^{20} cm^{-2}.

direction. This location corresponds to ~ 87 Å or 0.143 keV in the LETGS first order. The zero order image of the SXRB 30 arcmin off-axis will appear as a background to the dispersed spectrum. The HRMA effective area at 30 arcmin off axis has been tabulated and can be found in `/afs/cfa/axaf/cal_db/HRMA/area/axaf_eval.out`. The UV/ion shield over this part of the HRC-S has 2500 Å Lexan and 300 Å aluminum. I assume a CsI photocathode, rather than KBr, in line with the HRC PIs current plans. The LETG introduces an additional geometric obscuration factor of 0.7. The zero order diffraction efficiency of the LETG is $\sim$0.25 but depends somewhat on energy. Diffracted SXRB x-rays from other off-axis angles will also contribute to the background at this location on the detector. The LETG first order diffraction efficiency must be combined with the HRMA area appropriate for the energy-dependent, off-axis angle. For a given energy, the two off-axis angles that contribute first order diffracted photons are calculated then the HRMA effective area determined. In finding

the effective HRMA area at these angles, I have approximated the vignetting as

$$A(\phi) = A(0) \times \mathrm{e}^{-\phi/45},$$

where A is the area and ϕ is the off-axis angle measured in arcmin, this functional form crudely describes the behavior for energies less than $\sim$1 keV (note: this was done only for calculating the contribution of diffracted x-rays not the zero order). Integrating the average high galactic latitude background spectrum over the interval 0.05–10.0 keV results in a rate of 1.09×10^{-7} counts s^{-1} arcsec^{-2} or 0.0046 counts s^{-1} cm^{-2}.

5 Concluding Remarks

The ASC data system has a requirement to generate models for various background components including that of the sky background. The SXRB will generate a significant, if not dominant, component of the on-orbit background of the HRC; however, the magnitude of this contribution is calculable based on the known response of the HRC-I and HRC-S detectors and previous measurement of the surface brightness of the SXRB. The instrument response will be measured during the currently planned calibrations, with the possible exception of the response of the LETGS (HRMA/LETG/HRC-S) to x-rays from large ($>$ 30 arcmin) off-axis angles. Maps of the SXRB from the data of the *ROSAT* sky survey[4] provide the most detailed information on the spatial structure of the SXRB below 2 keV. In the next version of these maps it is planned to provide information on finer spatial scales and narrower pulse-height bands. The broad-band spectral behavior of the SXRB below 0.3 keV is currently best characterized by data from the Wisconsin sky survey[1]. The ASC should acquire the best available data on which to base predictions for the SXRB contribution to individual observations.

References

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