AXAF Science Center

Harvard–Smithsonian
Center for Astrophysics

MEMORANDUM

November 2, 1995

To: Distribution

From: M. Juda

Subject: Bright Sources and the HRC

File: hrc_source_constraint.tex

1 Introduction

Extremely bright sources cannot be observed with the HRC because the large amounts of charge extracted from the MCP at high event rates leads to a permanent degradation of the MCP response. In this memo I address the constraints that the measured drop in gain at high x-ray dose and observatory operations place on the brightness of sources to which the HRC can be safely exposed. Based on these constraints I propose a maximum rate of 200 events s^{-1} for sources on-axis. I also present plots of the energy-to-counts conversion factors for use in predicting HRC count rates from sources.

2 HRC Gain vs. Extracted Charge

During characterization tests performed as part of the HRC MCP selection program, sample MCPs from both Galileo and Phillips were subjected to high x-ray exposures and their gains were measured at various doses. The results of the test on Galileo MCPs were reported by A. Kenter[1]. In this test the MCP modal gain had dropped by 10% from an initial value of 3×10^7 after an exposure of 3.9×10^8events cm^{-2}. Given the size and pitch of the MCP pores this dose corresponds to roughly 500 events per pore. There was no noticeable effect on the MCP QE at much larger doses than this during the test. Even at a 50% drop in gain, the pulse height distribution was narrow enough that there was no significant loss of events below the lower level discriminator. Similar results were obtained from Phillips MCPs[2]. I will use 500 events per pore as a conservative upper limit on the allowed dose.

3 X-Ray Spot Size and Dither

The size of the spot to which the HRMA will focus on-axis x-rays on-orbit will depend on the spectrum of the source. Between 50% and 90% of the x-rays from a source on-axis are expected to fall within a 20 μm radius and roughly 10% to 20% of the events are expected to fall within the size of a single pore[3]. The foot-print of a 20 μm radius spot covers about 10 pores. Based on this spot size an undithered observation can collect 5000 events from a source before reaching the upper limit on the allowed dose. Spacecraft dither can be as fast as 0.1 arcsec s^{-1} or $\sim$ 5 μm s^{-1} on the HRC. If the maximum dither rate is used and the dither pattern does not cross or repeat itself, a rate as high as 1000 events s^{-1} can be observed without exceeding the threshold; of course, the region used would receive its dose limit.

A rate of 1000 events s^{-1} is much higher than the maximum useful science rate. HRC telemetry has only sufficient capacity for an average rate of 185 events s^{-1}. At rates larger than this the position information from a significant number of the events cannot be telemetered. Perhaps more critically, rate induced gain depression for sources is expected to become important at only a few events per second. Nevertheless, consideration of a limit this high is necessary in cases where the use of center blanking mode could be used to reject events from a bright source in order to observe a nearby faint source or surrounding diffuse emission. However, the blanking function only prevents the events from being processed and included in telemetry; it does not prevent the degradation they may cause due to charge extraction.

I propose a value of 200 events per second as the maximum allowed source rate for safe observations. This value leaves some margin of safety relative to the limit, allowing slower dither rates or crossing in the dither pattern.

4 Source Rate Predictions

The count rate in the HRC can be easily calculated for any given source spectrum and foreground absorption. The energy-to-counts conversion factor (ECF) provides a convenient means of determining the expected count rate from a source with a known spectral flux and absorption[4]. The ECF is given by:

$$\mathrm{ECF} = \frac{\int_0^\infty \frac{dN(E)}{dE} \mathrm{e}^{-\sigma(E)N_H} A(E)dE}{\int_0^\infty E\frac{dN(E)}{dE}dE};$$

where $\frac{dN(E)}{dE}$ is the source photon flux (photons cm^{-2} s^{-1} keV^{-1}), σ(E) is the absorption cross section as a function of energy, and $A(E)$ is the combined effective area of the HRMA and HRC as a function of energy. The integrals need only be carried out over the interval 0.05–10.0 keV since the HRC detection efficiency provides a lower limit and the HRMA reflectivity provides an upper limit to the useful energy band.

Figure 1 is a contour plot of the ECF for a source with a power law spectrum ($\frac{dN(E)}{dE} = KE^{-\alpha}$) as a function of photon spectral index and absorbing column density. Contours are labeled in units of 10^{11} counts cm^2 erg^{-1}. Figures 2 and 3 are similar plots for bremsstrahlung and black-body source spectra. As an example of using these plots, assume we want to predict the rate from an AGN with an x-ray luminosity of 10^{44} erg sec^{-1} at a distance of 1000 Mpc. The AGN has a power law spectrum with a a photon index of 1.5 and an absorbing column density of 5×10^{20} cm^{-2}. The unabsorbed flux from the source is 8.36×10^{-13} erg cm^{-2} s^{-1}. Using figure 1, for this photon index and absorbing column we find the value of the ECF is $\sim 0.357 \times 10^{11}$ counts cm^2 erg^{-1}. The expected HRC count rate is 0.0298 counts s^{-1}.

The ECF plots can also be used in the opposite direction. Given a maximum rate of 200 counts s^{-1} any source having a power law spectrum with a photon index of 2 and an absorbing column of 1×10^{21} cm^{-2} must have an unabsorbed x-ray flux less than 6.4×10^{-9} erg cm^{-2} s^{-1} to allow observation.

References

[1] Almus Kenter, 1995 June 23 memo to: S. Murray, M. Zombeck, J. Swider, Subject: "Life Test".

[2] S. E. Pearce et al. 1995, "Synchrotron calibration of alkali halide coated microchannel plate detectors in the 50–330 eV and 2000–6000 eV bands", in SPIE Proceedings Vol. 2518.

[3] Figure 3.2, ASC.TD.401, Science Instrument Notebook, Rev. 2.0 April 1995.

[4] M. V. Zombeck, 1995, Mathcad document `HRCMODEL.MCD`

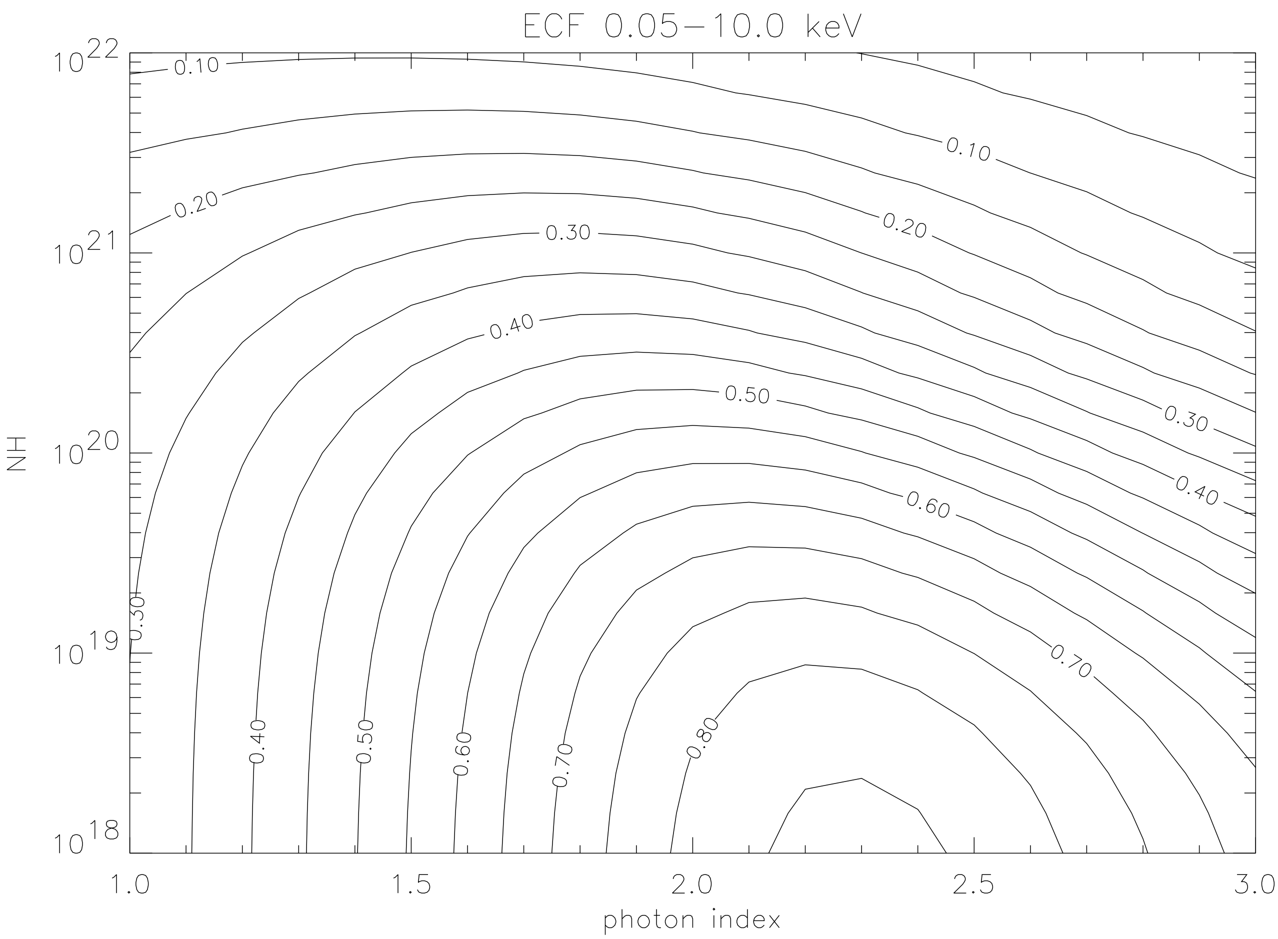

Figure 1: Energy-to-counts conversion factor for the HRC observing a power law spectrum as a function of photon spectral index and absorbing column density. Contours are labeled in units of 10^{11} counts cm^2 erg^{-1}.

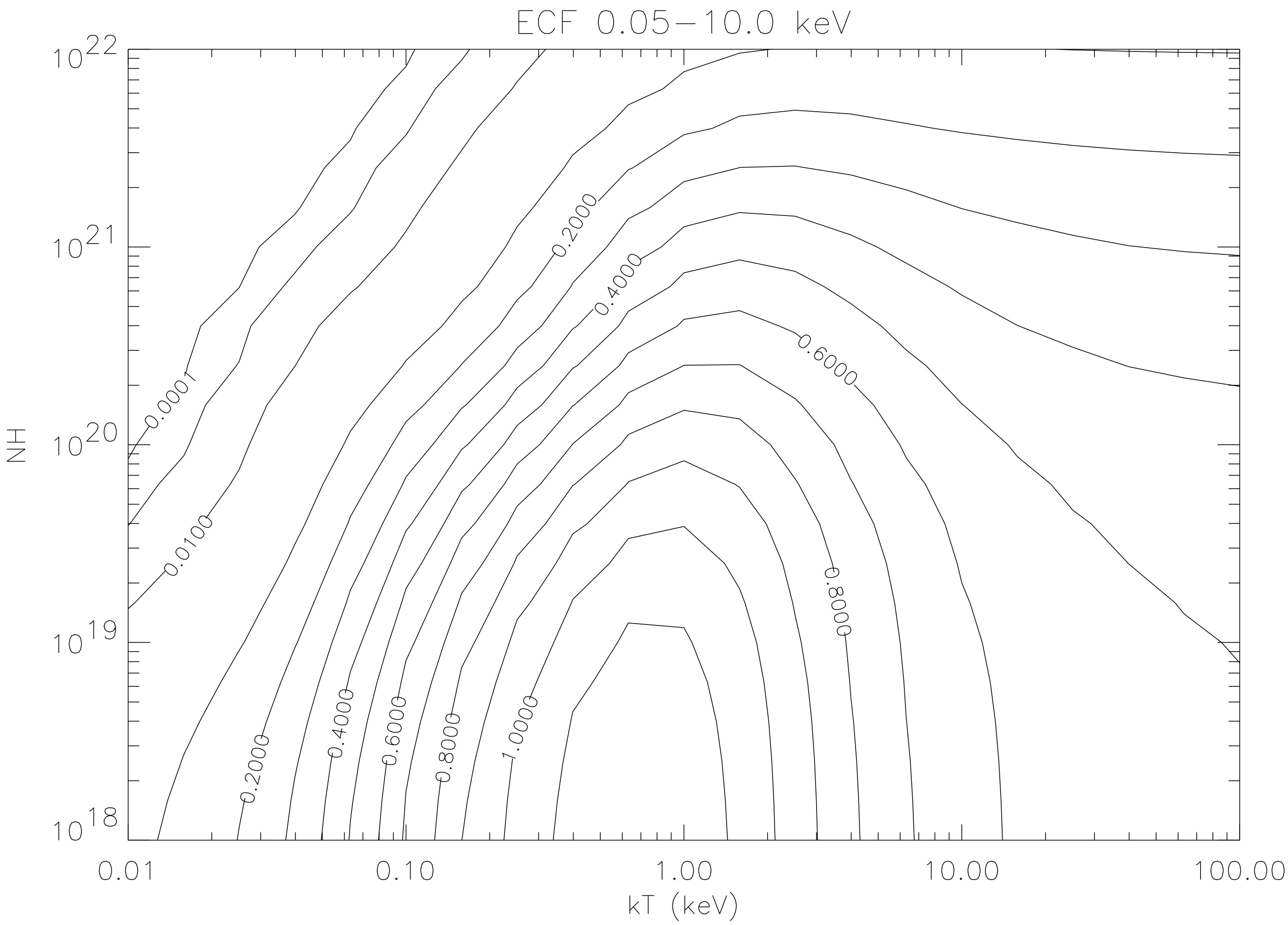

Figure 2: Energy-to-counts conversion factor for the HRC observing a bremsstrahlung spectrum as a function of temperature and absorbing column density. Contours are labeled in units of 10^{11} counts cm^2 erg^{-1}.

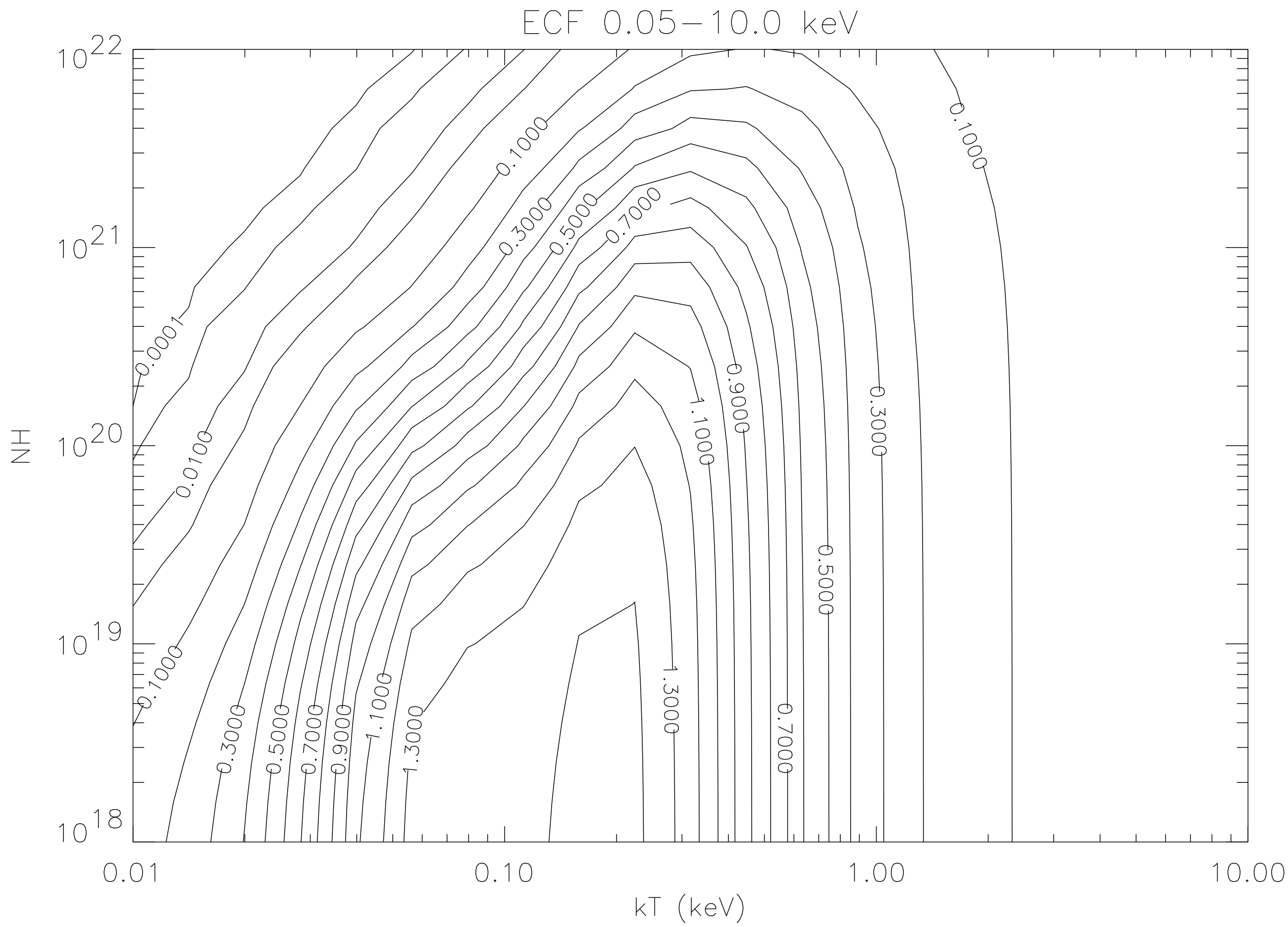

Figure 3: Energy-to-counts conversion factor for the HRC observing a black-body spectrum as a function of temperature and absorbing column density. Contours are labeled in units of 10^{11} counts cm^2 erg^{-1}.