CHANDRA HETG Observations at high X-Ray Fluxes

CC-mode vs. TE mode calibration
and
effects of dispersed secondary images
Grating Configuration and Calibration Sources

Figure 1.— Three calibration sources observed in TE mode at different fluxes and configurations (see Table 1). The top shows the full dispersed image of obsid 10659 at a low flux. The two panels to the right show two zooms of the zero order image, which in this case indicates pileup blackouts at the center, but not much of a halo beyond the point spread function scatter. The middle and bottom panels show the same for obsid 11817 at a factor 10 higher flux, and obsid 13220 at a factor 20 higher flux. In the latter two ratios arms have been placed off the CCD array and a transmission filter has been applied to the zero order image.

TABLE 1 CALIBRATION SOURCE PROPERTIES

<table>
<thead>
<tr>
<th>Sources</th>
<th>Obsids</th>
<th>Flux (1)</th>
<th>Flux (2)</th>
<th>$N_H$ (3)</th>
<th>exposure (4)</th>
<th>Mode</th>
<th>Subarray</th>
<th>Z-Sim (5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4U 1957+115</td>
<td>10659</td>
<td>35</td>
<td>0.80</td>
<td>0.15</td>
<td>10</td>
<td>TE</td>
<td>15, 440</td>
<td>-6.8</td>
</tr>
<tr>
<td>10660</td>
<td>0.80</td>
<td>15</td>
<td>0.15</td>
<td>20</td>
<td>CC</td>
<td>–</td>
<td>15, 440</td>
<td>-6.8</td>
</tr>
<tr>
<td>10661</td>
<td>0.80</td>
<td>20</td>
<td>0.15</td>
<td>10</td>
<td>TE</td>
<td>15, 440</td>
<td>–</td>
<td>-6.8</td>
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<tr>
<td>4U 1728-34</td>
<td>2748</td>
<td>85</td>
<td>2.00</td>
<td>2.51</td>
<td>30</td>
<td>TE</td>
<td>1, 400</td>
<td>-7.49</td>
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<tr>
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<td>2.00</td>
<td>30</td>
<td>2.51</td>
<td>160</td>
<td>CC</td>
<td>–</td>
<td>–</td>
<td>-4.0</td>
</tr>
<tr>
<td>GX 13+1</td>
<td>11817</td>
<td>330</td>
<td>7.94</td>
<td>3.16</td>
<td>30</td>
<td>TE</td>
<td>1, 350</td>
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<tr>
<td>11818</td>
<td>7.94</td>
<td>30</td>
<td>3.16</td>
<td>30</td>
<td>CC</td>
<td>faint</td>
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<td>-8.0</td>
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<td>7.94</td>
<td>10</td>
<td>3.16</td>
<td>10</td>
<td>CC</td>
<td>graded</td>
<td>–</td>
<td>-8.0</td>
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<td>660</td>
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<td>CC</td>
<td>–</td>
<td>-6.14</td>
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<td>1.99</td>
<td>30</td>
<td>TE</td>
<td>1, 300</td>
<td>–</td>
<td>-11.3</td>
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<tr>
<td>13221</td>
<td>15.8</td>
<td>40</td>
<td>1.99</td>
<td>40</td>
<td>CC</td>
<td>–</td>
<td>–</td>
<td>-6.14</td>
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<td>Cyg X-2</td>
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<td>540</td>
<td>13.2</td>
<td>0.32</td>
<td>70</td>
<td>CC</td>
<td>–</td>
<td>-6.14</td>
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<tr>
<td>8599</td>
<td>13.2</td>
<td>70</td>
<td>0.32</td>
<td>50</td>
<td>CC</td>
<td>–</td>
<td>–</td>
<td>-6.14</td>
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<td>10881</td>
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<td>100</td>
<td>8.2</td>
<td>0.32</td>
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<td>–</td>
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<td>3.36</td>
<td>50</td>
<td>CC</td>
<td>–</td>
<td>-11.3</td>
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</table>

Notes: (1) [mCrab], (2) [$10^9$ erg cm$^{-2}$ s$^{-1}$], (3) [10$^{22}$ cm$^{-2}$], (4) [ks], (5) [mm]
Higher orders in CC-Mode
ACIS calibration: energy scale and gain

Fig. 3.— First order OSIP plots (+1st orders on the right side) using the first 10 events in the resolved event lists and first orders (y-scale) only. The x-scale is the target sorted wavelength column. The top four show the pipeline corrected MEG and HEG orders for CC-mode and TE mode for the 35 mCrab calibration source 4U 1957-115, the bottom four panels show the same for the bright 0.6 Crab source Cyg X-2.

Fig. 4.— CTI correction as applied in CC mode for MEG (Top three panels) and HEG (bottom three panels) and compared to TE mode. For each grating the top panel shows the TE mode pipeline CTI correction to the CC mode spectra, the middle panels show the resulting spectrum when the actual y-pix value is used for each event when applying the CTI correction, the bottom the pipeline CTI correction applied on TE mode spectra.
ACIS calibration: grade distributions

Fig. 5.— Grade distributions for 4U 1957+11 in TE (top) and CC (middle) mode at \( \sim 35 \) mCrab. The bottom panel shows Cyg X-2 in CC mode at 540 mCrab. The colors are grade 0 (black), grade 2 (red), grade 3 (green), grade 4 (blue), and grade 6 (magenta).
HETG spectra of fluxes < 35 mCrab
HETG spectra of very bright sources

- Cyg X–2, OBSID 8170
- 4U 1636–56, OBSID 6635
- GX 349+2, OBSID 13221
- GX 13+1, OBSID 11818
- GX 5–1, OBSID 5888
- Cyg X–1, OBSID 3815
- 4U 1630–47, OBSID 13714
- GRS 1915–105, OBSID 7485
- GRS 1915–105, OBSID 4587
- GX 339–4, OBSID 4571

9th IACHEC, Warrenton VA, May 13 2014
Fig. 9.— Five cases of X-ray scattering halos and its dispersion observed with HETG in TE mode. The colored regions indicate the extraction region for MEG (red) and HEG (blue) spectra. The green arrow marks the orientation towards the north. The central oval is the zero order extraction region.

(a) The HETG extraction regions and arrays of Cyg X-2 (∼450 mCrab) are moderately absorbed with about $3 \times 10^{21}$ cm$^{-2}$ column density in the line of sight.

(b) The same for Cyg X-1 (∼650 mCrab) at $8 \times 10^{21}$ cm$^{-2}$.

(c) For 4U 1630-47 (∼200 mCrab) at $1 \times 10^{23}$ cm$^{-2}$.

(d) GRS 1915+105 (∼400 mCrab) at $5 \times 10^{22}$ cm$^{-2}$.

(e) is the calibration source 4U 1957-115 (∼35 mCrab) at $1 \times 10^{21}$ cm$^{-2}$.

Fig. 10.— A sketch illustrating the effect of various spectra lo b s t r u c t i o n st o t h e extracte d dispersed source spectrum due to collapsed dispersed image in C C - m o d e . A t t h e f o r m o s t a s p e c t r a l o v e r l a p s o f t X - r a y s d u e t o a c o l l a p s e d d i s p e r s e d h a l o s p e c t r u m . T h e t o p p a n e l illustrates the image effect, the middle two panels the effect so n t h e M E G - 1 st (black) and MEG +1 st (red) spectra. While the soft halo spectrum is likely very similar, there are different CC-mode backgrounds and Si K edge modifications. In the MEG +1 st order the Si K edge is least affected since it falls on a BI (S3) device. The bottom spectra show all four HETG spectral arms on top of each other with respect to our actual points our source spectrum (dashed line). Here the HEG spectra, HEG -1st (green) and HEG +1st (blue) also appear systematically higher in the soft range because of MEG high order overlaps. The HEG -1st spectrum also is less modified at the Si K edge because it falls on a BI (S1) device.
Scattering halo effect and Si K edge
Si K edge at low and high absorption

Fig. 13.— Appearance of the Si K edge in all four spectral arms of the ±1st order in MEG (top panels) and HEG (bottom panels) for Cyg X-2 in CC mode, which has an absorption column of around $3 \times 10^{21}$ cm$^{-2}$. The blue line indicates how a fit to the MEG +1st data of S3 transposes on the other spectral arms.

Fig. 15.— Appearance of the Si K edge in all four spectral arms of the ±1st order in MEG (top panels) and HEG for 4U 1728-34 (bottom panels) in CC mode, which has an absorption column of around $2.5 \times 10^{22}$ cm$^{-2}$. Here the blue line indicates how a fit to the MEG +1st data of S3 transposes on the other spectral arms.
Instrumental Si K edge correction in front-illumination devices

Fig. 14.—Left: The Si K edge in Cyg X-2 on a FI device. Due to the edge fill of the scattering background the Si K instrument correction gets imprinted in to the residuals.

Right: The SiO$_2$ transmission function measured for FI devices in ground calibration.
Conclusions:

- Calibration of ACIS in CC-mode generally does not deviate from TE-mode
- The Si K edge in FI devices has Si O$_2$ XAFS imprints, BI devices have not
- The Si K edge is optical depth is affected by collapsed dispersed scattering halos
- The full collapsed dispersed imaged in CC-mode alters the original point sources spectrum and requires additional science modeling
- Higher order background overlaps can be avoided by moving two grating arms of the array
- CC-mode background is significant but can be dealt with in several ways

Problems in bright HETG spectra are not ACIS calibration related but require intensive additional modeling and data reduction depending on chosen configurations