Optimization of LETG/HRC-S Spectral Extractions

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Abstract

We describe our analysis of the wavelength-dependent cross-dispersion profile of Chandra LETG/HRC-S which allows the use of a narrow spectral extraction region. Background is reduced by 25% with negligible loss of X-ray signal. Some features of this work are: improved 1st order platelets, expressed as a function of the 0th order plate, time-dependent tilts and slight time-dependent shifts in dispersed spectra, and an updated calibration of the cross-dispersion profile.

1. Helpful Terms and Numbers

- Transmission Gating scan running along (tg) and perpendicular to (crsv) the dispersion axis. All angles are measured in degrees.
- HRC pixels are 6.4294 µm.
- 1 tap = 4.09555 degrees (tg coordinate).
- 1 tap = 2.765 pixels, 1.88893 Å in the dispersion direction.
- Coarse tap axis scan along (crsu) and perpendicular to (crsv) the dispersion axis.
- The active region of the HRC-S cuts from crsu = 0 to 194.
- Low cross corresponds to HRC-S plate+1 and positive wavelengths. High cross corresponds to plate-1 and negative wavelengths.
- For on-axis sources, LETG/HRC-S spans about -30 to +175 Å.

2. Introduction

The LETG/HRC-S spectral extraction regions have a 'bow tie' shape, narrow in the midlength and widening beyond -60 Å to accommodate the inherent astigmatism of the LETG's Rowland circle geometry. The current extraction region is based on precise simulations (see Figure 1) and is somewhat conservative in order to allow for deviations from the idealized model. Our work aims to quantify and, where possible, correct these deviations so that a narrower extraction region can be used, preserving the X-ray extraction efficiency while reducing the number of included background events. We use high, frequently observed continuum sources to provide complete wavelength coverage with high signal, primarily Mkn421 and PKS2155 for short wavelengths (< 6 Å) and tidal for longer wavelengths. We find that:

- Pipeline determinations of zeroth order may have errors up to ~0.5 pixel. (An improved algorithm is now used in the Pipeline.)
- The cross-dispersion profile (along the tg axis) is symmetric.
- Spectral line intensity is dependent on (tg) but not (crsv) axis.
- Spectra have a slight (< 0.5 pixel) time-dependent curvature.
- In addition to 0th order, time-dependent tilts and wiggles have a time-independent pattern of (tg offsets) (~0.5 pixels peak-to-peak 'wiggles') as a function of position on the detector.
- Even when 0th order is well positioned and tilt and wiggles have been removed, spectra may be slightly (~0.5 pixel) offset in tg, particularly on the outer plates.

3. Time-Dependent Tilts

After applying pulse-height (PH) background filtering to each observation and removing periods of background filtering we do the data in the dispersion direction by tap (TP), plate (194 pixels, 1.88893 Å) and in the cross-dispersion direction (tg) by 0.00055 to 0.00010 degrees over 2 to 3 pixels, depending on wavelength. We then determine the median of the cross-dispersion profile. Results are plotted in Figure 2. As can be seen, many spectra are slightly tilted. These tilts, along with those from Capella data, are plotted versus time in Figure 3.

4. Time-Independent Wiggles

Spectra may be slightly (~0.5 pixel) offset in tg, particularly on the outer plates.

5. Profile Asymmetry

After correcting for spectral tilt and wiggles we studied the cross-dispersion profiles of the complete spectra. Figures 5 and 6 provide different illustrations of these profiles, which are obviously asymmetric. We are currently calibrating these profiles in order to derive improved enclosed energy fractions (EEFRAC) and define a new, improved optimal extraction region. Our hope is to name the region by 25–25%, reducing the included background by the same amount, with only a tiny change (<1%) in X-ray extraction efficiency. Preliminary EEFRACs results (normalized to the total flux on the detector, rather than 25–25% will be needed for the CALDB EEFRAC tables) are shown in Figure 7.

Figure 1: MARX simulation of a flat spectrum and the current spectral extraction region. Note that the vertical axis is tightly stretched. The fact that the vertical 'whiskers' in the middle are cross-dispersion orders from the LETG flat support structures. About 10% of the total dispersed flux lies in cross-dispersion orders with another ~5% lost to scattering or the extreme wings of the cross-dispersed line spread function, so that the net spectral extraction efficiency of the region is ~85%.

Figure 2: Median tg versus time, after subtracting the average tg median for each source. These are therefore relative to the average tilt for each source. For continuum sources, only points with errors of less than 0.005681 degrees (about 0.5 pixel) are plotted. Errors for Capella's linear 'residues' are explicitly shown.

Figure 3: Spectral tilt versus time. Uncertainties on each point (other than for Capella) are small, so the observed scatter is real and probably caused by observation-specific thermal conditions. There is no apparent correlation with aim-point jumps. The solid black line can be used to estimate the tilt in any observation, and the gray band denotes the degree of uncertainty that would cause a 1-pixel error at 170 Å.

Figure 4: Median tg values for combined spectra, with tilt and offset adjustments to make the wiggles symmetric about tg=0. This set of spectra are multiplied by 1.0001 for convenience and crsv axes are degrees. Ticks are in units of degrees per tap, also multiplied by 1.0001. Example data points are for 16 combined HZ43 spectra, with a tilt correction of 0.00059 and global offset of 0.045. The composite wiggles curve is shown in black, same data points for 17 tap and 24 tap and the end of the outer plate were adjusted by hand because the true errors are larger than indicated by the purely data-derived error bars. Data points around 170 Å are caused by higher orders in Mkn421 and PKS2155 spectra, which broaden the observed (1st plus higher orders) profile.

Figure 5: tg profile for HZ43 ObsID59, with tilt A-binning.

Figure 6: Image of combined HZ43 spectra, after removal of tilts and wiggles. Nonzero sais is denoted 200 times more than the vertical. The white horizontal line marks the median of the cross-dispersion profile.

Figure 7: Cumulative count fractions of corrected data from combined Mkn421 and combined HZ43 observations. The cross-dispersion 1st order is shown in light gray, plus seen with 2nd order as the faint 'whiskers' in Fig 1). Solid black line is the current spectral extraction region.

As noted above, improvements to the determination of the 0th order position have already been implemented in the processing pipeline. We are currently reworking combined software for the other corrections, and are working to implement them in CALDB and CIAO. Corrections for time-dependent tilt can be made by adjusting a geometry parameter and wiggle corrections can be made immediately after degapping using a lookup table. Current EEFRAC tables imply a symmetric cross-dispersion profile and modifying the CALDB for use with an optimized (asymmetric) extraction region will require some effort. We will, in any case, provide a contributed software workaround.