HRC–I Gain Correction

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We study the gain variations in the HRC-I over the duration of the Chandra mission. We analyze calibration observations of AR Lac obtained yearly at the nominal aimpoint and at 20 offset locations on the detector. We show that the gain is declining, and that the time dependence of the gain can be modeled generally as a linear decrease in PHAs. We describe the spatial and temporal characteristics of the gain decline and discuss the creation of time-dependent gain correction maps. These maps are used to correct PHAs to PI channels, thereby removing spatial and temporal dependence, and allowing source pulse-height distributions to be compared directly regardless of observation date or location on the detector.

Data

- Yearly calibration observations of AR Lac (Table 1) at 21 locations on the detector (Δy, Δx) = (0, 0), (0, ±2), (±2, 0), (±2, ±2), (0, ±4), (±4, 0), (±6, ±5). Each observation nominally 1 ks.
- Monitor gain response by tracking the median PHA over time at each of the 21 observation locations.
- Data reduced with CIAO v3.3 CALDB v3.3, following the CIAO HRC Data Preparation analysis guide; analyzed with pre-packaged and custom-built IDL routines (e.g., PINTofALE).
- Background subtracted, median PHA values (and errors) estimated using Monte Carlo simulations.

Characteristics of PHA Decline

- Gain decreases steadily and monotonically over time at all monitored locations (see Figure 1).
- Linear decrease in median PHAs (except aimpoint; linear after Dec 2000).
- Best-fit slopes roughly equal for all cases (excluding four pointings at 14.14 off-axis), indicating that rate of gain decline is relatively uniform across detector (see Figure 2).

Spatial Corrections

1. For each epoch, compute set of spatial correction factors γ by a direct comparison of PHA spectra at each of 21 pointings to aimpoint PHA spectrum (see Figure 3).
2. Use γ to interpolate minimum curvature surface at all locations on detector to obtain corrective surface γ(x,y). This is multiplied by high-resolution gain map g(x,y) to obtain gain correction map g'(x,y) for the epoch.
3. Test gain correction maps by independently applying g'(x,y) to PHA(x,y) values and comparing median PHA spectrum at each of 21 pointings to aimpoint PHA spectrum, with updates based on AR Lac observations, are shown chronologically in clockwise order.

Temporal Corrections

To find TC(t):
1. Fit lines to medians of spatially-corrected PHA, i.e., medianPHA(0,0)(t) = m + b
separately for each observation location, excluding Oct and Dec 1999 data because of non-linear drop between Dec 1999 and 2000. Result is set of 21 slopes m and intercepts b.
2. Find average slope m and average intercept b.
3. T corresponds to expected value of median PI for Oct 1999 if non-linear drop had not occurred. To account for non-linear drop we define Δ = medianPHA(0,0)(t) – b
4. Finally, define TC(t) = 1 +(Δ – m)/b

Summary

- Final Chandra HRC-I gain correction maps shown in Figure 5.
- Maps successfully remove spatial and temporal dependence in PHA as shown by AR Lac PI in Figure 6. Maps also tested with calibration sources G143 and G143.5-9.
- We continue to monitor gain and investigate correlation with X-ray dosage.

References


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