

Temperature-Dependent ACIS Response

Terry Gaetz

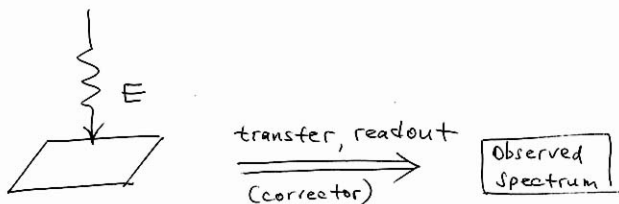
Chandra X-ray Center/Smithsonian Astrophysical Observatory

IACHEC 2026, Seeblic, Pelham

ACIS CCD Response Factored

Alexey Vikhlinin, 2002, Chandra Calibration Review, 2002.26

Separating response into two components



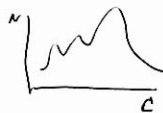
$$R_{\text{ideal}}(C_0 | E) \otimes P(c | C_0) = R_{\text{obs}}(c | E)$$



pre-CTI



effect of CTI, corrector



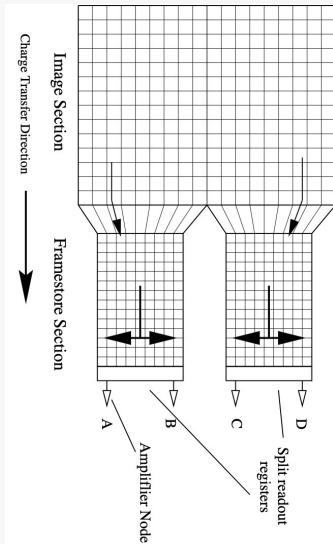
result

ACIS-S3 - backside-illuminated CCD

- ACIS-I and the other ACIS-S CCDs (except S1 and S3) are frontside-illuminated (FI) CCDs
 - FI CCDs started with very little CTI, but have much larger CTI after radiation damage.
 - framestore covered - essentially pristine - very little CTI in framestore
- ACIS S3 and S1 are backside-illuminated (BI) CCDs - higher CTI than initial FI CTI
 - framestore covered - but BI CTI in the framestore
 - characteristic “W” broadening with chipx because of serial readout directions to output amplifiers
- CTI increases with higher Focal Plane Temperatures (FPTs)
 - FI chips *much* more affected
 - BI chips (e.g., S3) affected, maybe a factor ~ 1.5 at warm FPT and high chipy (furthest from framestore)

ACIS-S3 CTI Response Width Broadening

Imaging array: increases top to bottom; Framestore: characteristic “W” shape



ACIS-S3 Response Broadening with Increasing FPT

- External Cal Source (ECS): 3 month “epochs” - later 6 months
- combine later ECS epochs - more higher temperature data
 - merge ECS epochs 040..097; filter on FPT: 2C-wide bins starting at -119.19C
 - -120.19C to -119.19C: merged epochs e040..e049 (revised p2resp to use current CALDB for -120.19C to -119.19C)
- FP Temperature bins (C):
 - 120.19:-119.19 C -119.19:-117.19 C -117.19:-115.19 C
 - 115.19:-113.19 C -113.19:-111.19 C -111.19:-109.19 C
 - 111.19:-109.19 C -109.19:-107.19 C
- ACIS-S3:
 - bin to $\Delta_{\text{chip}x}=64$, $\Delta_{\text{chip}y}=64$
 - main ECS $K\alpha$ lines:
 - Al- $K\alpha$ (1.49 keV), Ti- $K\alpha$ (4.51 keV), Mn- $K\alpha$ (5.89 keV)

Planned Workflow: ECS Width Fits

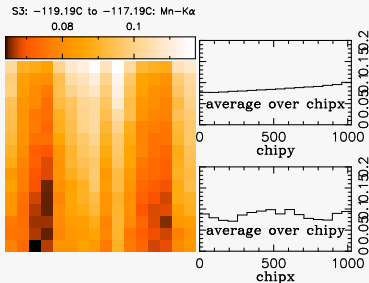
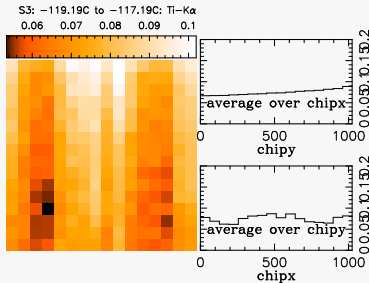
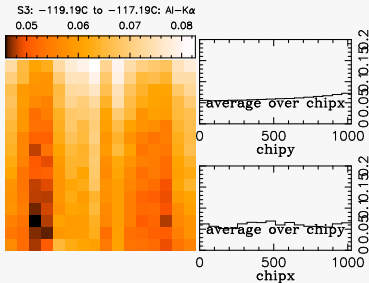
- detgain: Gain: $pha(E_g)$:
 - fixed energy grid: 30 energies: 0.1 keV to 12.0 keV (log spacing)
- p2resp [BI] Response Width:
 - BI response width W : gaussian FWHM
 - fixed pha grid: 20 phas: 40 ADU to 3100 ADU (log spacing)
- $W_{BI,FPT_j}(chipx, chipy, pha) \equiv W_{BI,-120C}$ [current CALDB]
- generate “0-CTI-width” response width:
 $W_0(chipx, chipy, pha) = 1 \times 10^{-6} keV$

Planned Workflow: Xspec Fits ECS

- External Cal Source (ECS): For a given bin FPT_j :
 - extract spectrum: $spec_{FPT}(chipx, chipy, pi)$
 $pi \equiv \text{floor}(E/14.6 \text{ eV}) + 1$
 - generate $RMF_0(chipx, chipy, pi)$ using $W_0(chipx, chipy, pha)$
“0-CTI-width” RMFs
- Al-K α , Ti-K α , Mn-K α : widths, energies allowed to vary
 - Ti-K β and Mn-K β widths tied to the α lines
 - Ti-K β and Mn-K β energies scaled from the α lines
- Xspec fits
 - Xspec: fit Al-K α (1.49 keV), Ti-K α (4.51 keV), Mn-K α (5.89 keV)
 - $\sigma(chipx, chipy, E_{ECS,j}) \times 2.3548 =$
 $fwhm(chipx, chipy, response E_{ECS,j})$
 - $W_{ECS,j}(chipx, chipy, E_{ECS,j})$

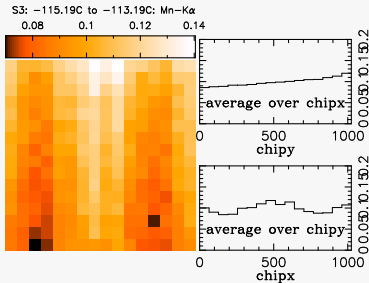
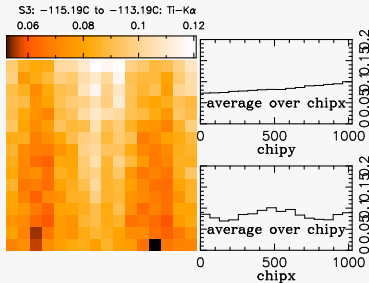
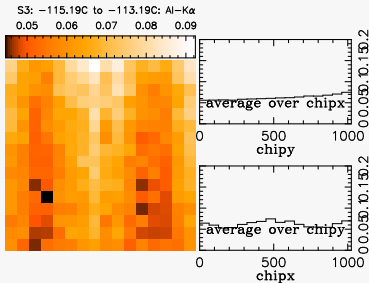
Fits: FWHM

-119.19C to -117.19C: Al-K α (ul), Ti-K α (ur), Mn-K α (ll)



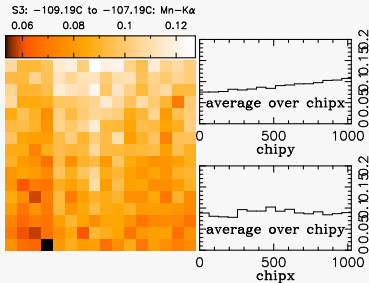
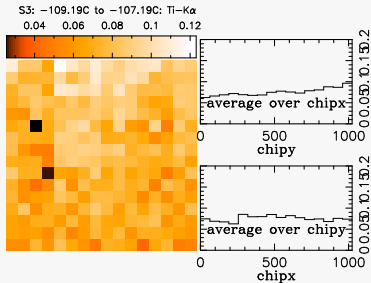
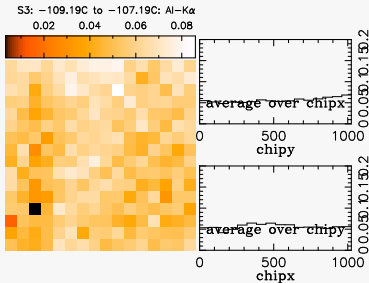
Fits: FWHM

-115.19C to -113.19C: Al-K α (ul), Ti-K α (ur), Mn-K α (ll)



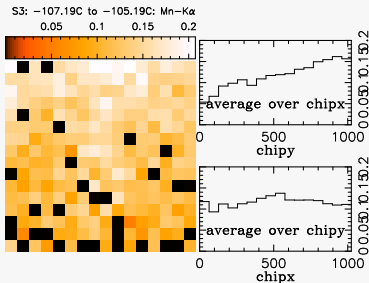
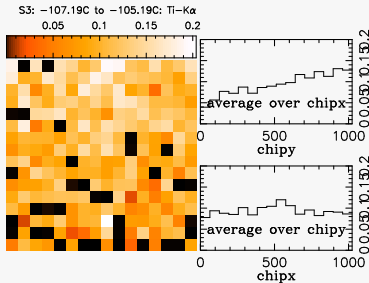
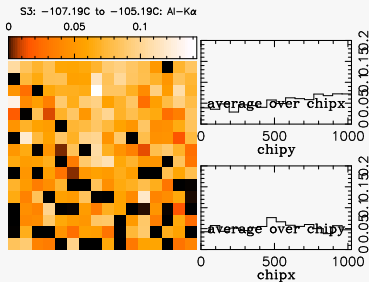
Fits: FWHM

-109.19C to -107.19C: Al-K α (ul), Ti-K α (ur), Mn-K α (ll)



Fits: FWHM

-107.19C to -105.19C: Al-K α (ul), Ti-K α (ur), Mn-K α (ll)



Fitting the FWHM - First Try - chipy variation only

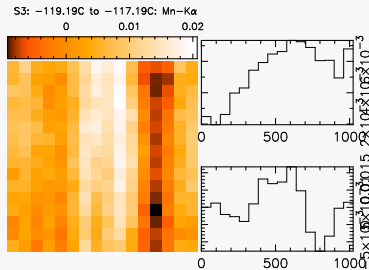
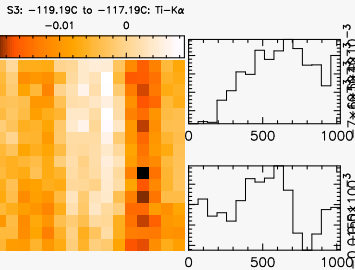
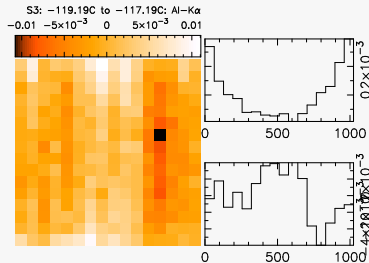
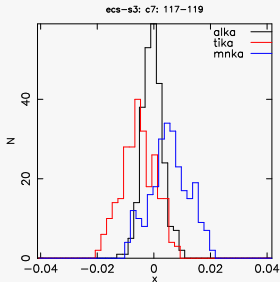
- initial fitting function (matrix form) - *chipy variation only*

$$W = s + a_1(Y - y_1) + a_2(Y - y_2)^2$$

- set y_1 and y_2 to zero for now.
- evaluate residuals: *Data - Fit*

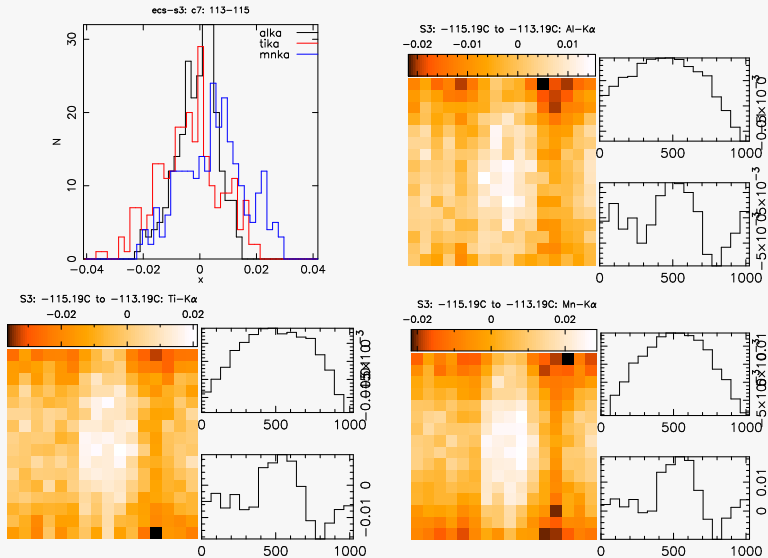
-119.19C to -117.19C Fit Residuals: Data - Fit)

(ul) Histogram; (ur) Al-K α , (ul) Ti-K α , (ur) Mn-K α



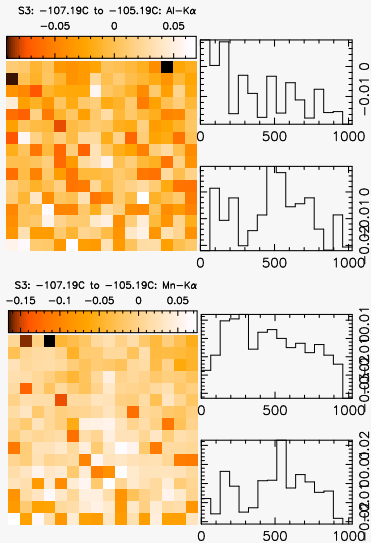
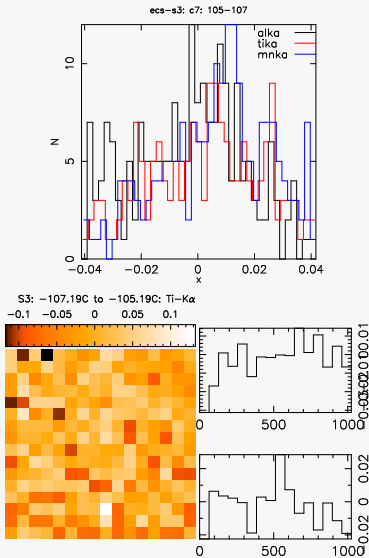
-115.19C to -113.19C Fit Residuals: Data - Fit)

(ul) Histogram; (ur) Al-K α , (ul) Ti-K α , (ur) Mn-K α



-105.19C to -107.19C Fit Residuals: Data - Fit

(ul) Histogram; (ur) Al-K α , (ul) Ti-K α , (ur) Mn-K α



Next Steps

- chipx variation needs to be reduced;
 - try average (projection) along chipy
 - try fitting chipx variation with "W" piecewise linear fit
 - combine with chipy variation: outer-product chipy \otimes chipx
 - IF necessary, consider chipx-chipy cross-terms
- try combining -109.19C..-107.19C and -107.19C..-105.19C FPT bins for better statistics
- iterate: generate p2resp response files, remake RMFs, refit, examine residuals

Planned Workflow: ECS Width Fits to a New p2resp

Once reasonable $W_{ECS}(chipx, chipy, E_{ECS,j})$ models found:

- map: $W_{caldb,S3,0}(chipx, chipy, pha \Rightarrow E_g)$
using detgain $pha(E_g)$
- generate scaling factor scl from
 - $W_{ECS,j}(chipx, chipy, E_{ECS,j})$ vs. $W_{caldb,S3,0}(chipx, chipy, E_g) \Rightarrow scl$
 - consider $scl(E_g)$: powerlaw energy scaling: E^γ for $\gamma \sim 0.5 - 1.0$;
 - limit extrapolation much below $E = 1.49$ keV or above $E = 5.9$ keV
 - $W_{new,S3}(chipx, chipy, E_g) = scl \times W_{caldb,S3,0}(chipx, chipy, E_g)$
- map: $W_{new,S3}(chipx, chipy, E_g \Rightarrow pha)$
using detgain $pha(E_g)$
- inject $W_{new,S3}(chipx, chipy, pha)$ into $p2resp_{new}(FPT_j)$