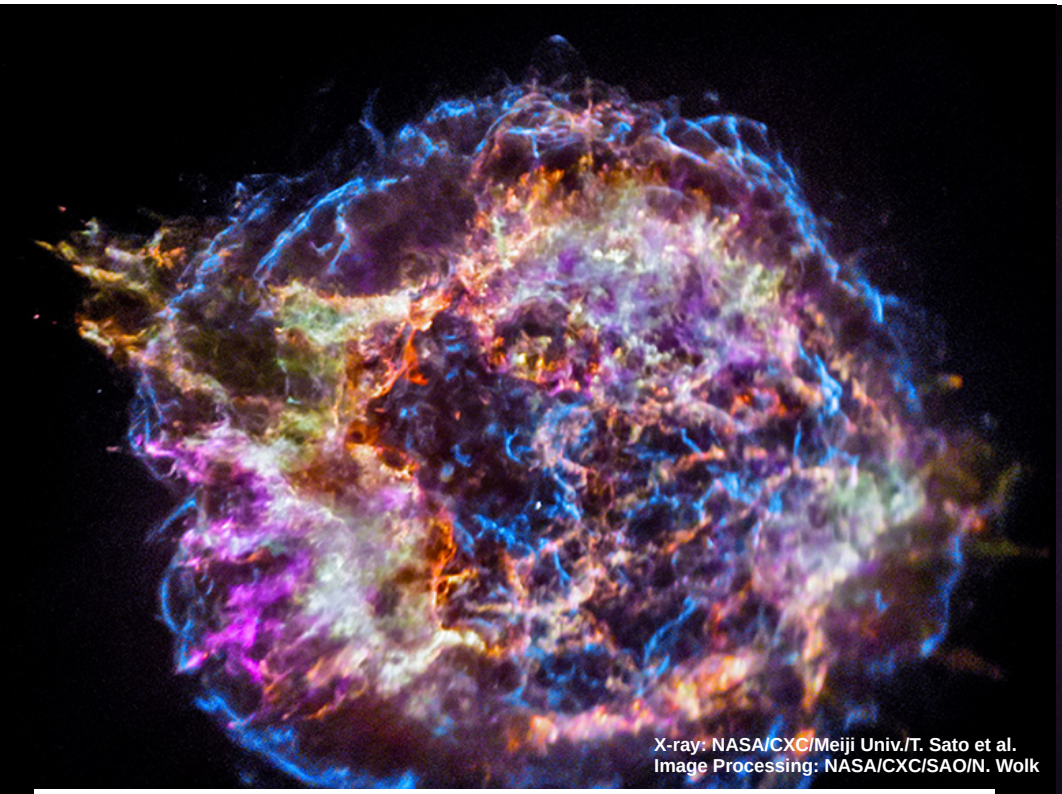
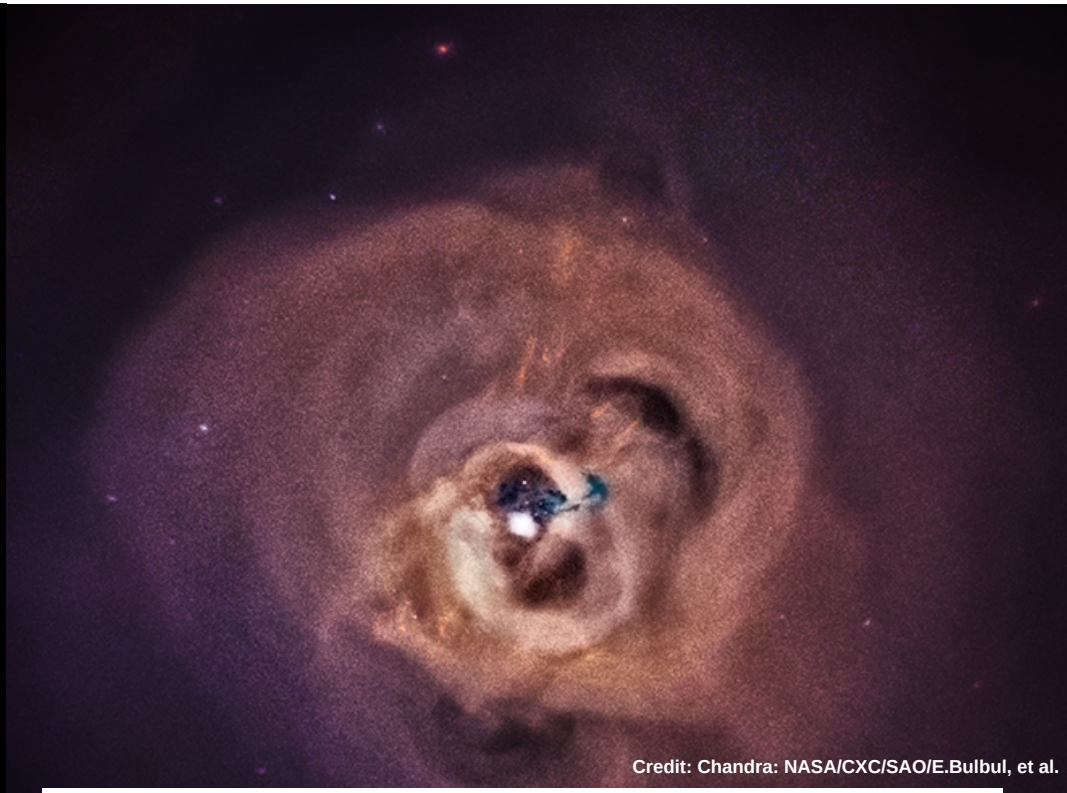
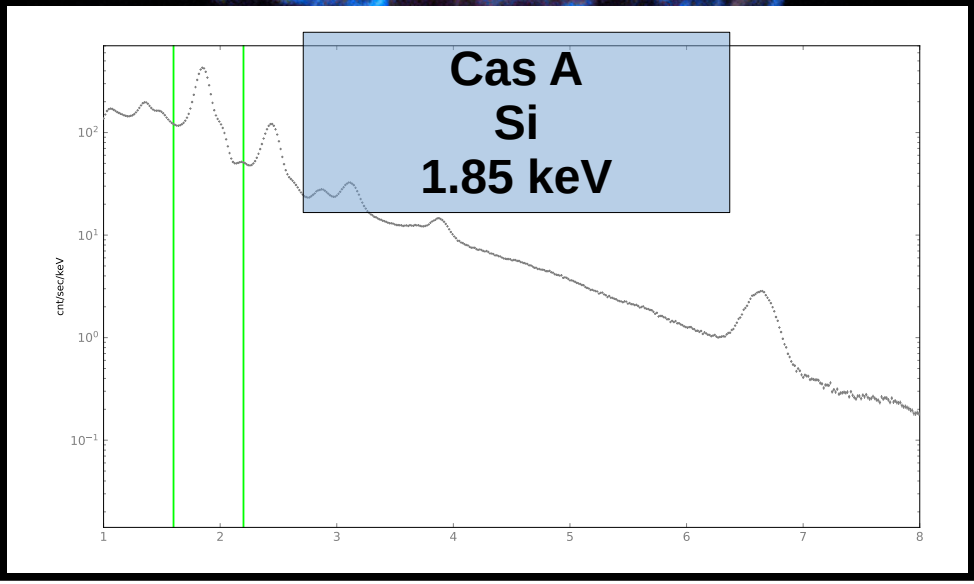
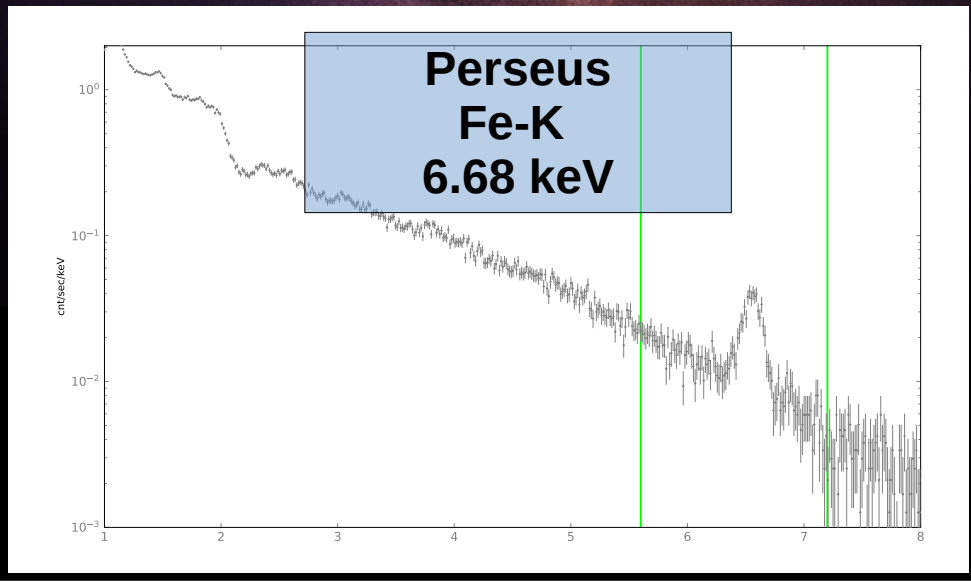
ACIS Gain ~~Results Using~~ Including Astrophysical Sources









ACIS Gain ~~Results~~ ~~Using~~ Including Astrophysical Sources

Why Does the Gain Vary?

April 2025 Gain Accuracy (CALDB 4.12.0)

August 2025 Update (CALDB 4.12.2)

Where We Are Now

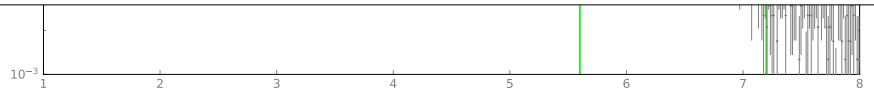
Latest Gain Tracking

Astrophysical Source Program & Challenges

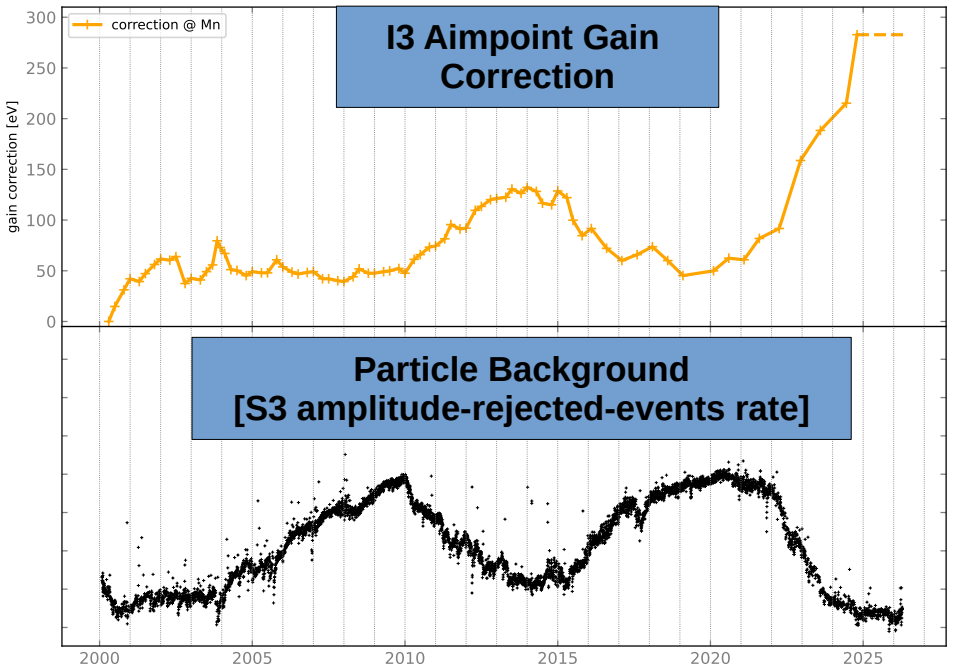
Where We Are Going

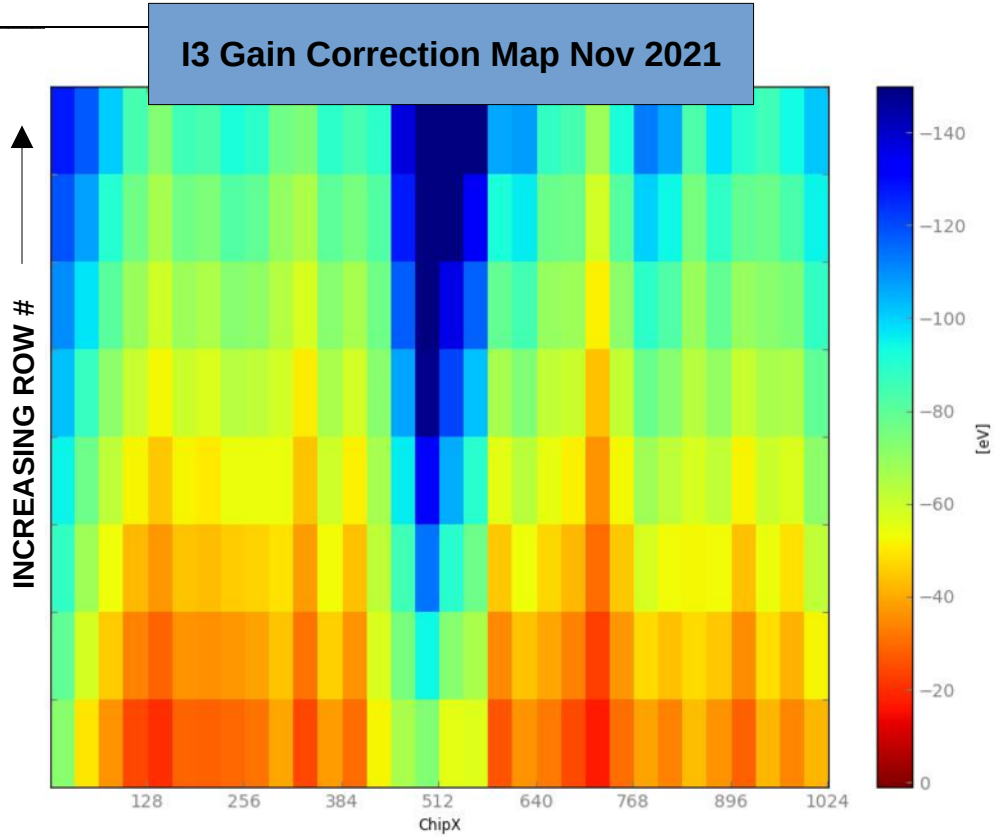
Warm Temperatures

et al.



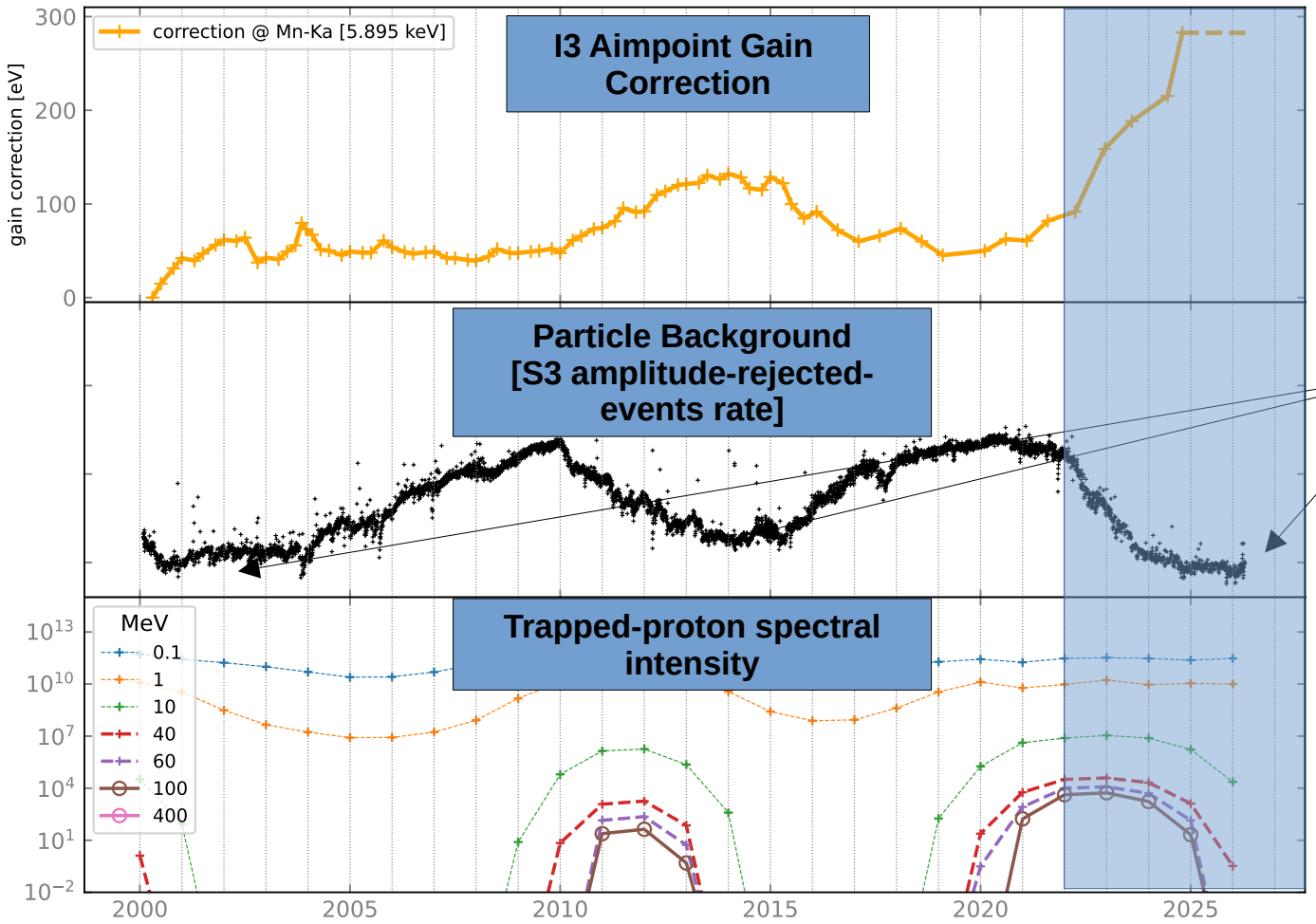
Why Does ACIS Gain Vary?
CTI: Strongly Dependent On Solar Cycle





- Photon-induced charge packet can be trapped within a pixel on short timescales
  - Decreases pulse height of event to shift energy
    - 0 < energy shift < 100+++ eV
- Effect increases with:
  - row# of event
  - total charge of event
- Re-emitted charge typically recorded as a bad grade and filtered out of event list
- Solar Cycle Effect:
  - Particle background provides “sacrificial charge” to traps

2023-2025 Unexpectedly Large CTI Increase
Solar Cycle (Max) + Radiation Belt Crossing Fluence ?

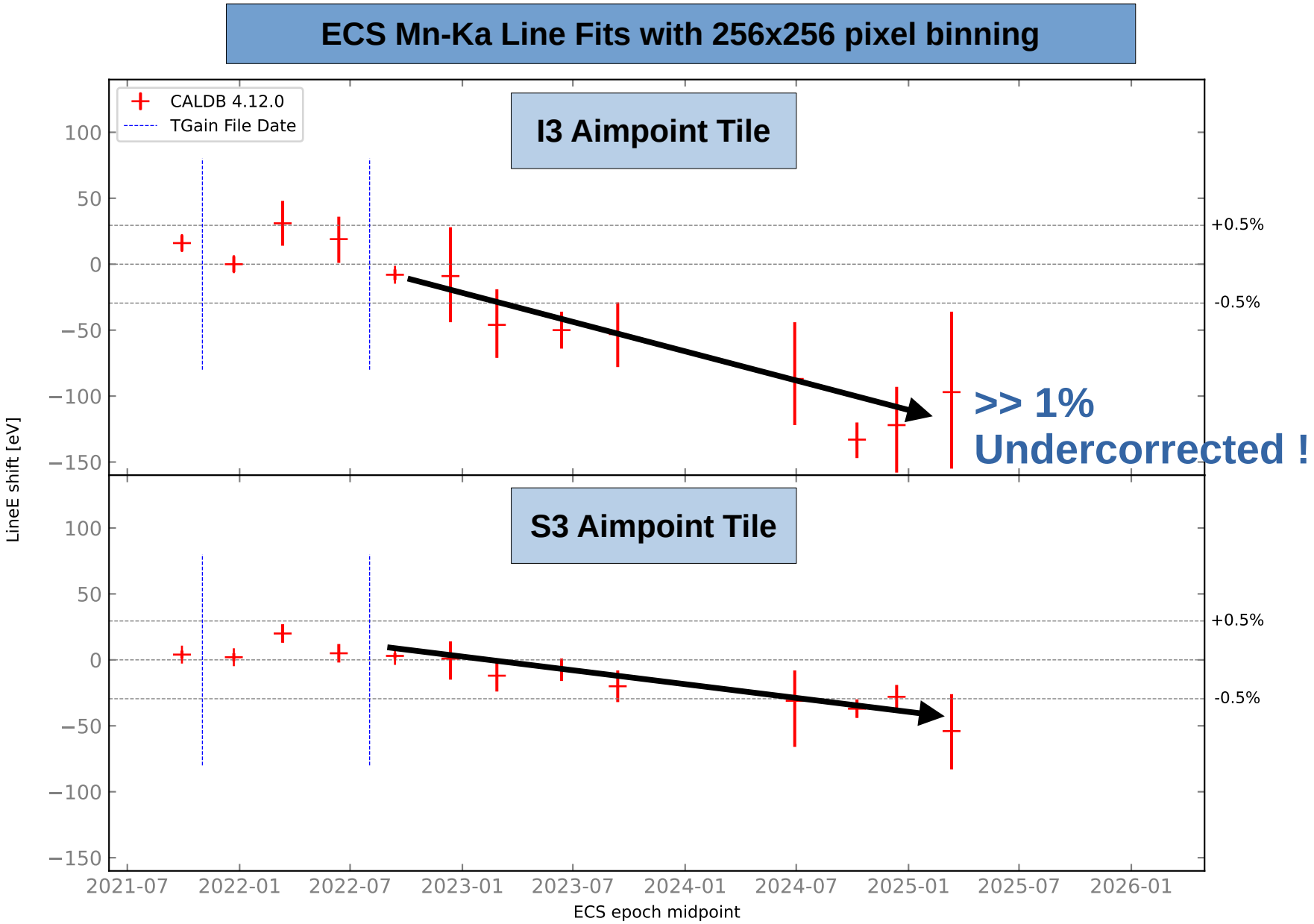


BI CCDs (S1 + S3) Trending As Normal
- ✔ Solar Max Particle Damage (FI chips)
- ✔ Solar Max sacrificial charge deficit (FI chips)
- ?? Radiation belt fluence damage (ALL chips)

Managing radiation degradation of CCDs on the Chandra X-ray Observatory

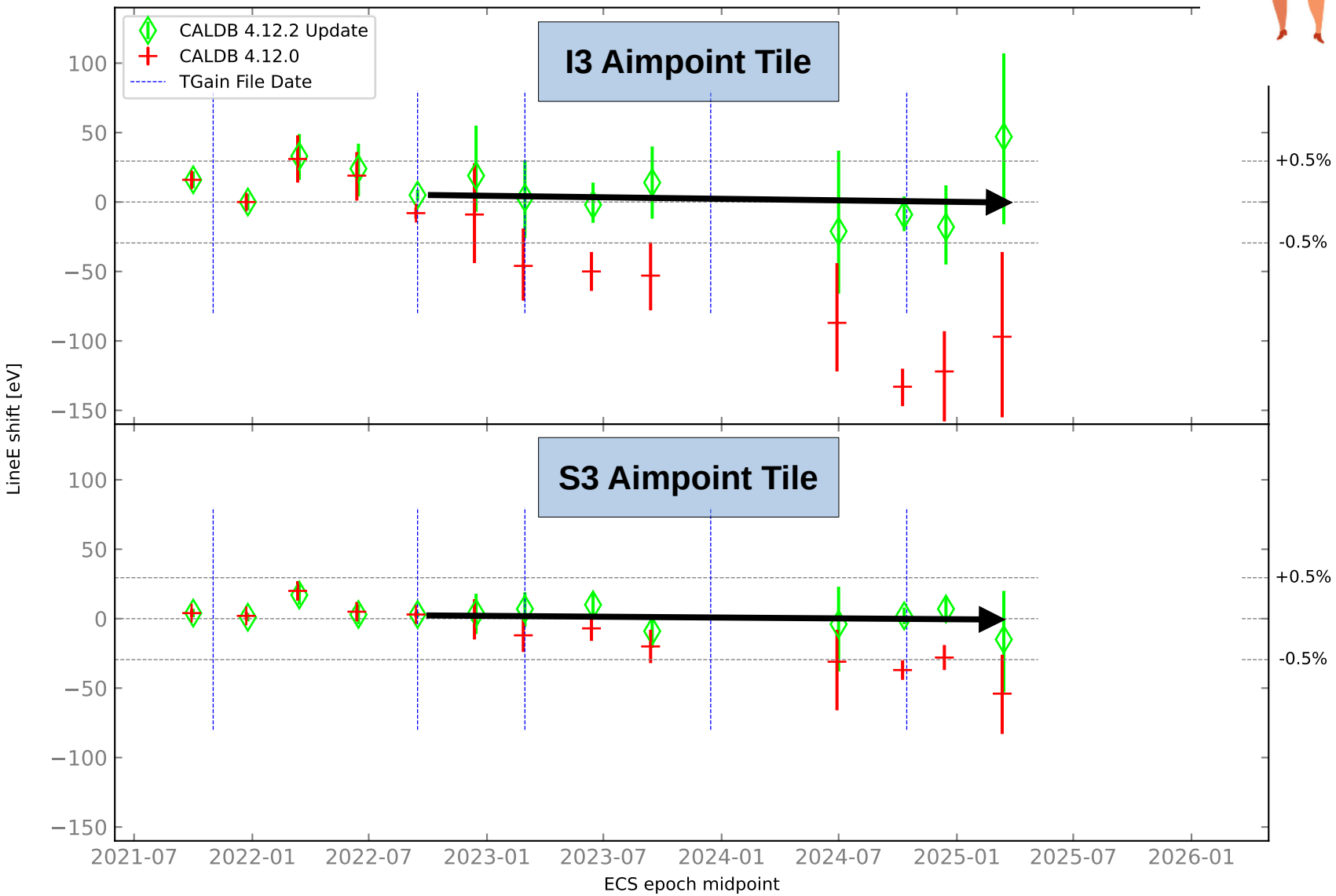
Stephen L. O'Dell[a], William C. Blackwell[b], Robert A. Cameron[c], Joseph I. Minow[b], David C. Morris[c,d], Bradley J. Spitzbart[c], Douglas A. Swartz[e], Shanil N. Virani[c], and Scott J. Wolk[c]

CALDB 4.12.0 April 2025



CALDB 4.12.2 Released August 2025

ECS Mn-Ka Line Fits with 256x256 pixel binning



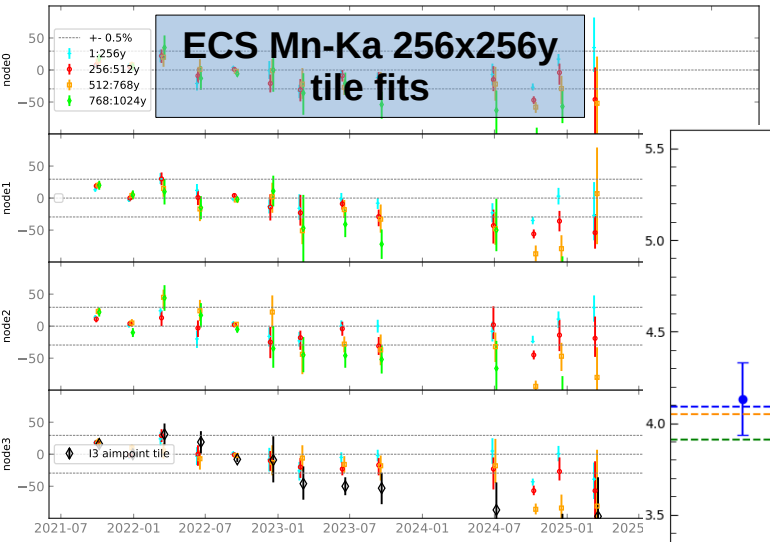
CALDB 4.12.2 Update

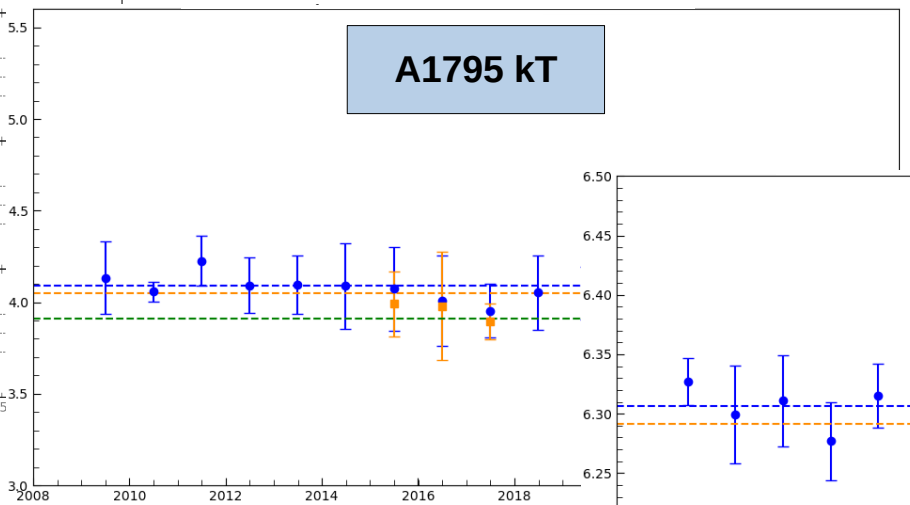
4x New Gain Correction Files
September 2022
March 2023
December 2023
October 2024

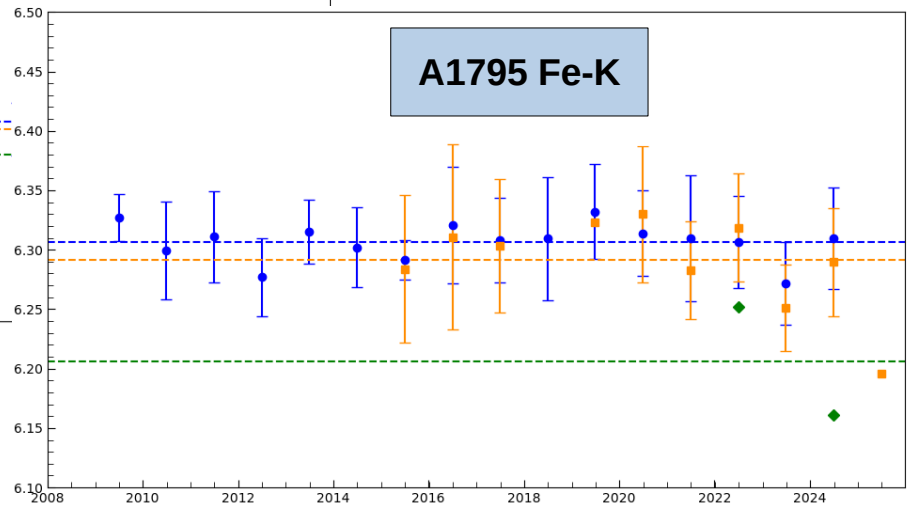
ECS Mn-Ka at low spatial resolution: 256x256 pixel tiles
(target Gain Resolution: 32x128 pixel tiles, dither = 64 pix)
Fe55 fluoresced Al, Ti, Mn lines are too dim after 26 years for target 32x128 pix resolution
Mn still viable using 16x larger spatial binning

Abell 1795 Fe + kT measurements

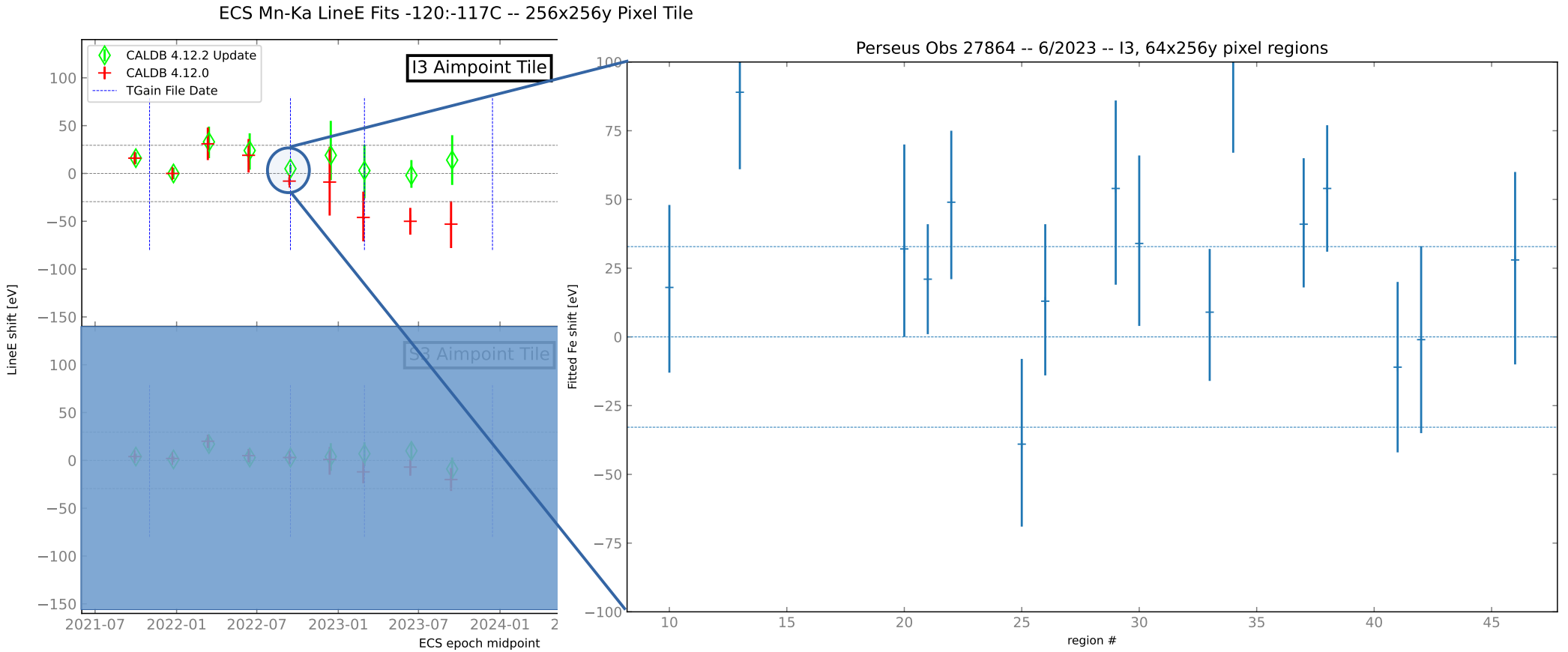
All the above used to scale the spatial structure of the gain maps that is well described by 5x vector basis components (principle component analysis)







CALDB 4.12.2 Update – Not Without Issue



Coarse binned ECS Mn-Ka + Gain Map scaling cannot account for smaller scale deviations.

Perseus Fe-K fits analyzed after CALDB update show >0.5% deviations

Perseus as a Calibration Source

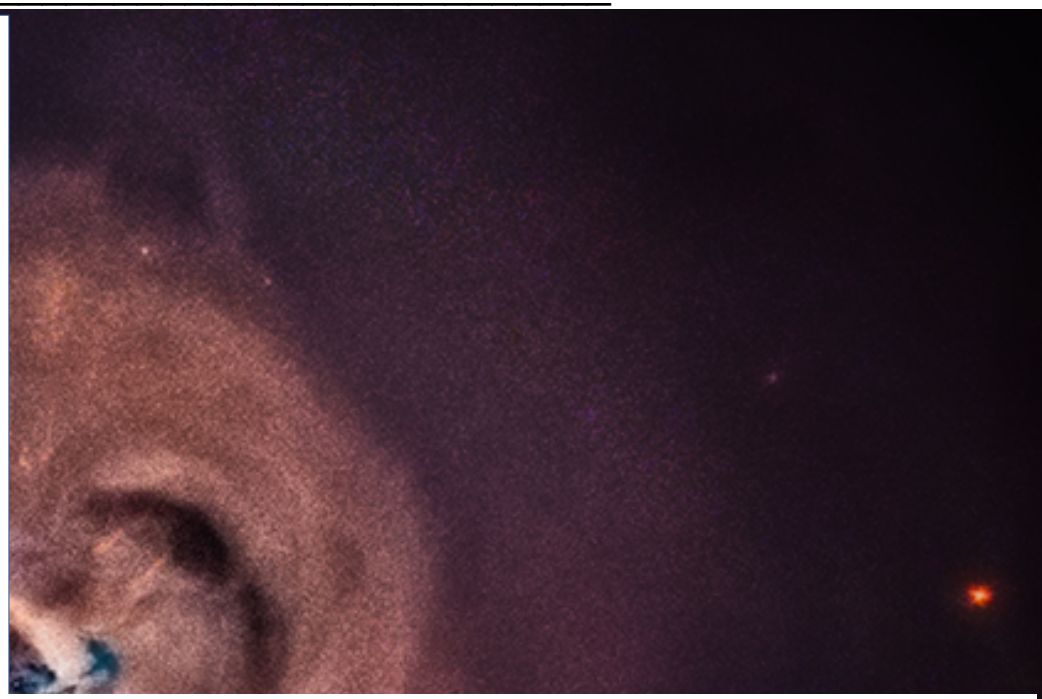
- Isolated Fe-K
- 10 ksec provides enough line counts to measure gain for ~25% of CCD to better than 0.5%

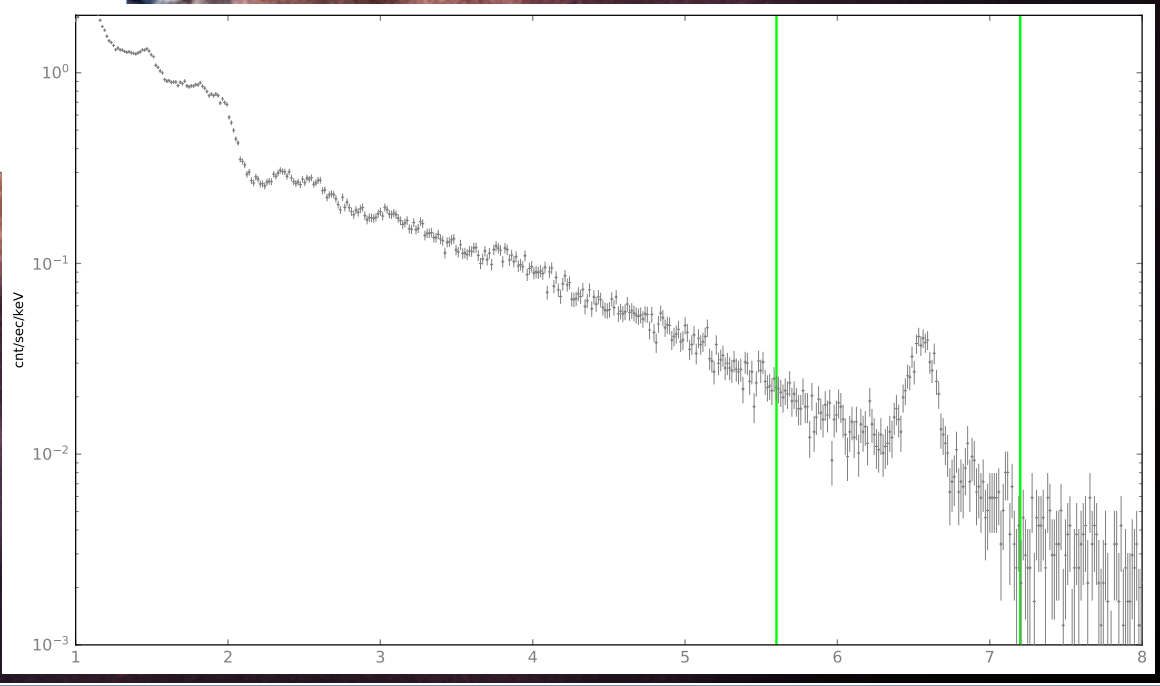
- PCA method used to predict remaining 75% gain shifts

- Observing Plan
  - 10 ksec on each: I0, I1, I2, I3, S2, S3
  - Annually

- Current observation epochs:
  - June 2023
  - June 2024
  - June 2025
  - + GO Observations on I3

EASY





Cas A as a Calibration Source

- Bright
- 2 ksec provides enough line counts to measure gain for >65% of CCD

- PCA method used to predict remaining 35% gain shifts

- Observing Plan
  2 ksec on each: I0, I1, I2, I3, S2, S3
  ~ 3-month intervals

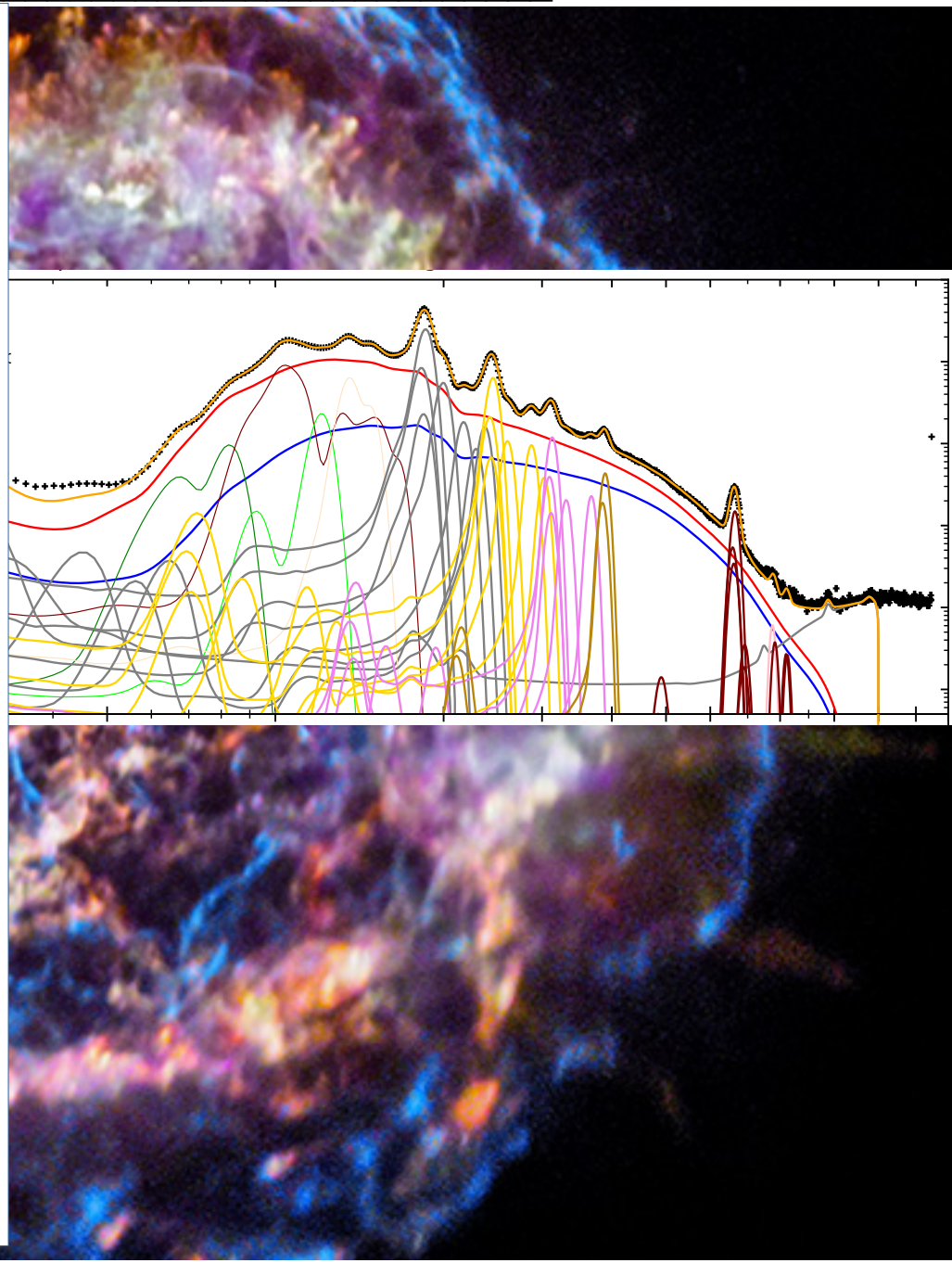
- Current observation epochs:
  ~every 3 months beginning 2022
  + Earlier CAL and GO Obs

VERY COMPLICATED SPECTRUM

~ -15:+40 eV Doppler Velocity @ Si 1.85 keV with small scale spatial variations
= 1-2% line shifts
Accounting for spatial dependence creates additional uncertainty due to sky chip coordinate transformations

Overlapping and blended line features which also vary by location.

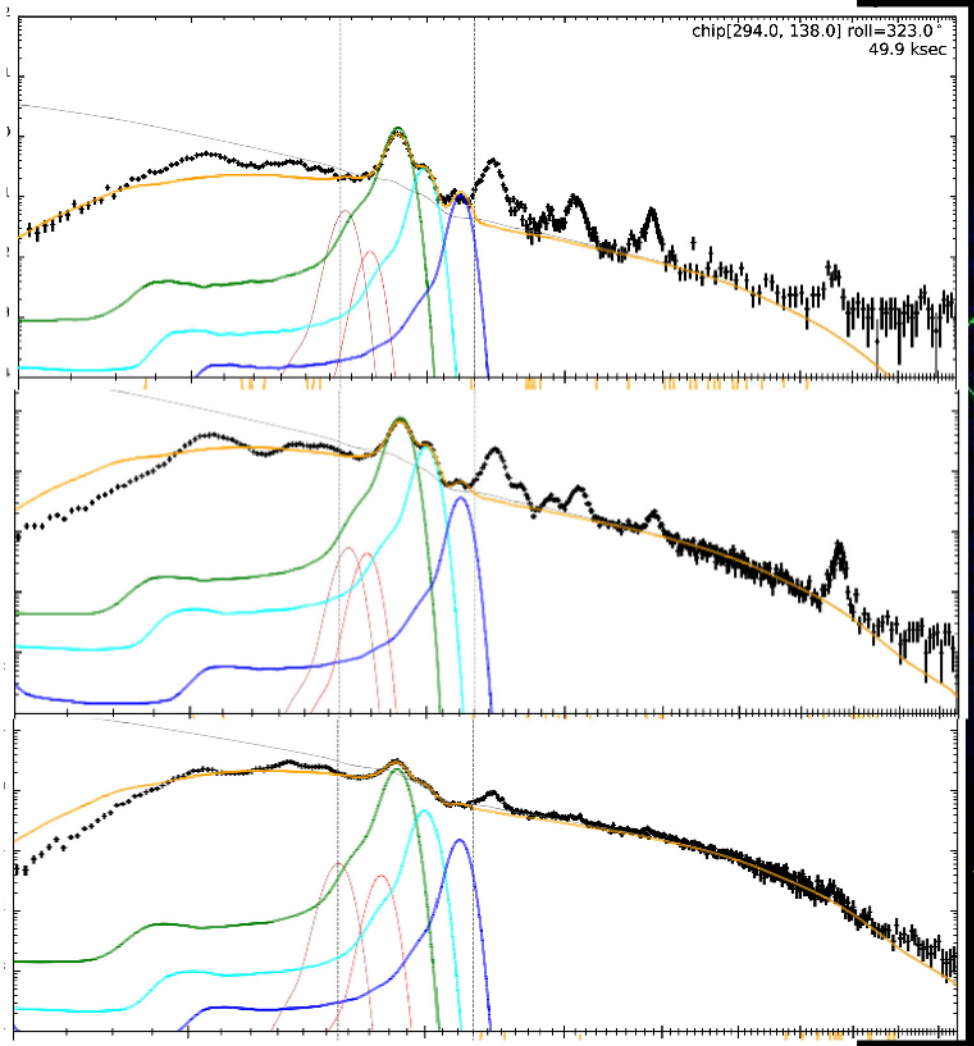
High count rate provides its own sacrificial charge which must be filtered out of event list.

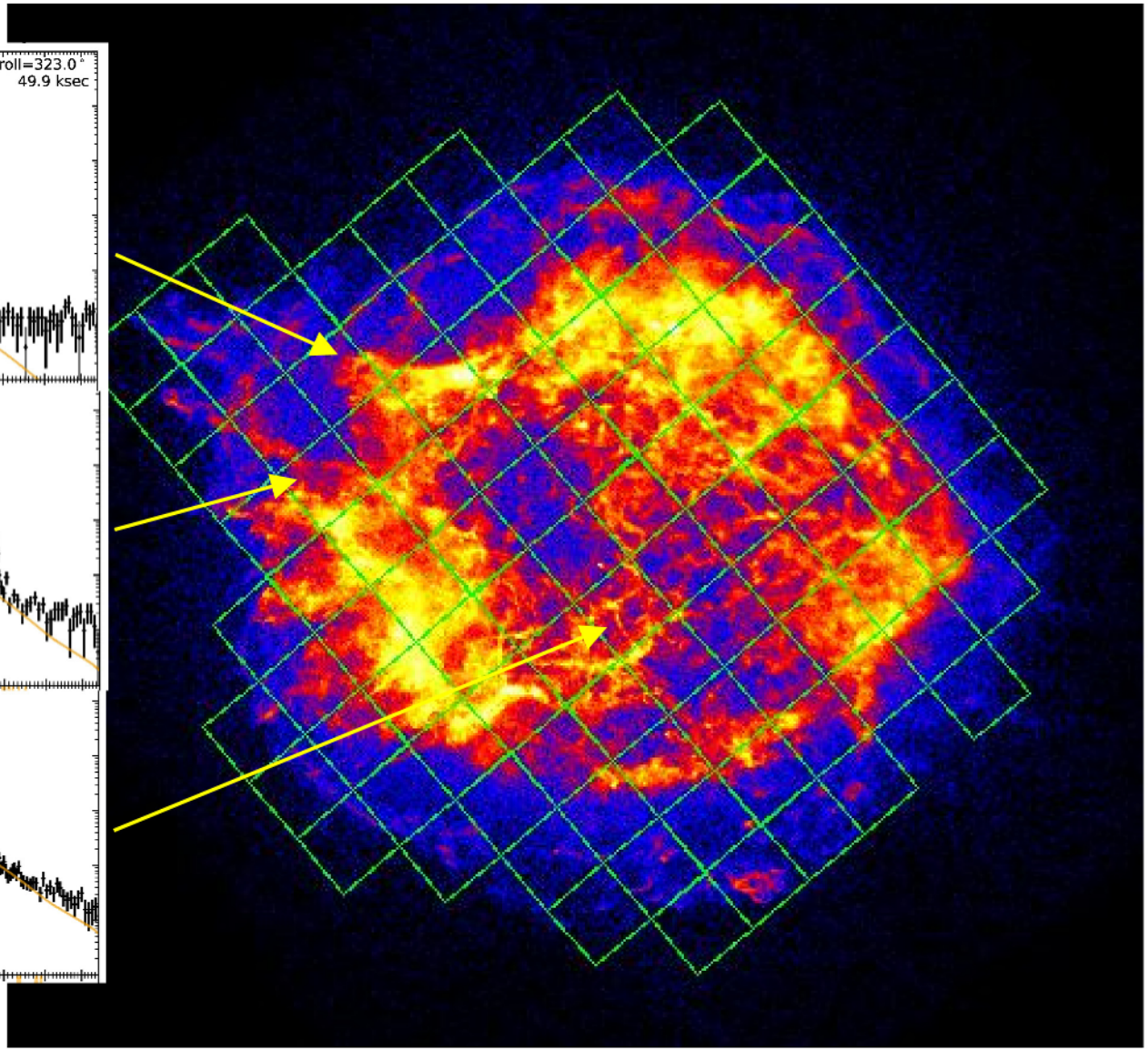


ACIS Cas A “Little” Model(s) ~ 1.5-2.3keV

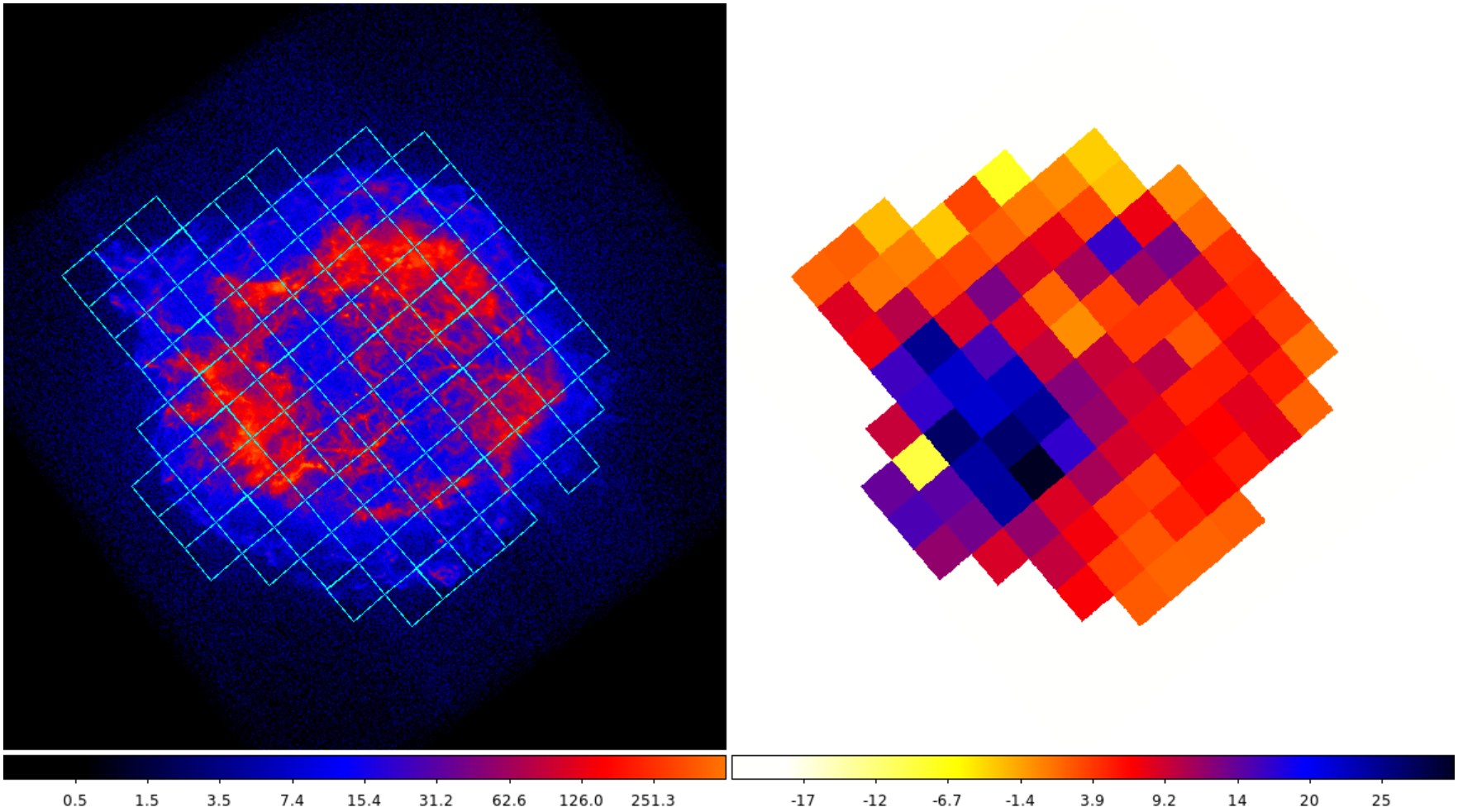
64x64 pixels (~32x32 arcsec) x101 regions

tbabs * (powlaw + 5 gaussians)





Cas A Si-XIII Velocity Shift

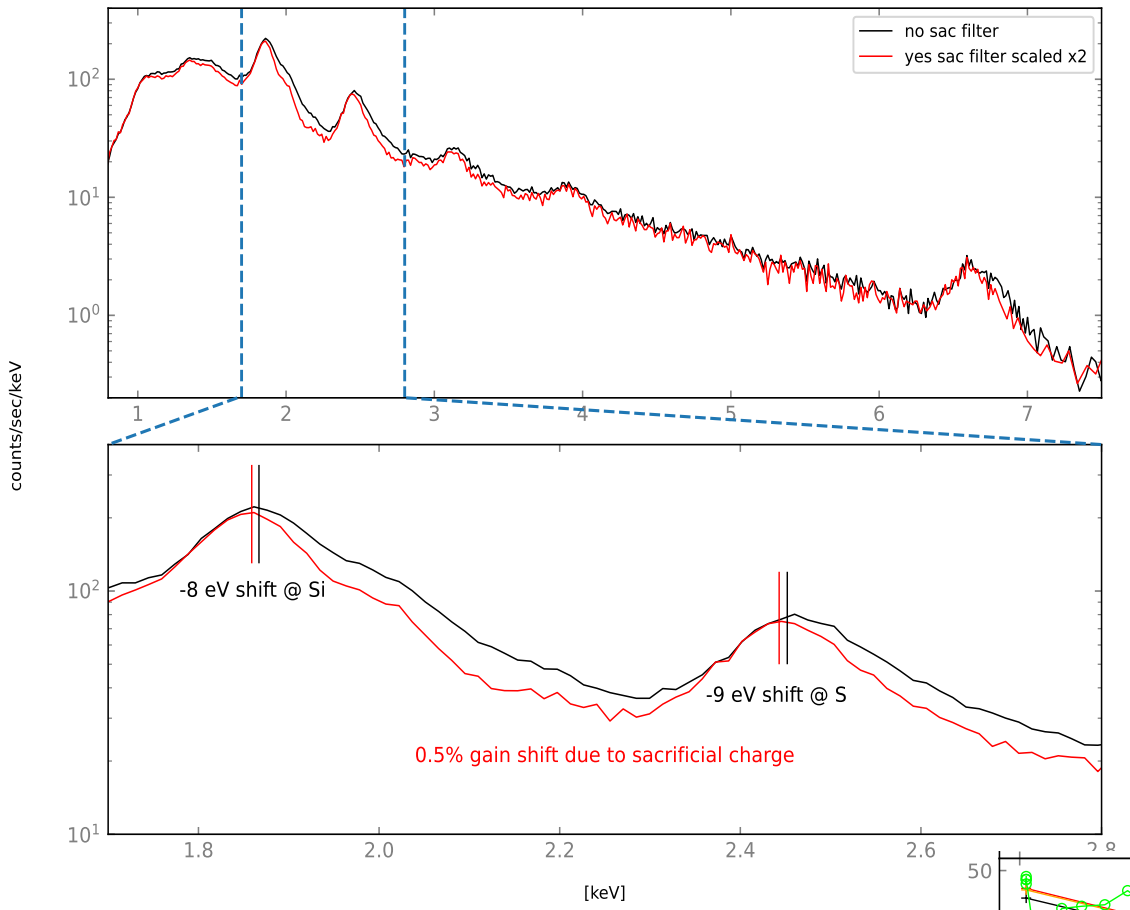


Si velocity map is used to shift pulse height of each event according to sky(x,y) position. This removes structure do to doppler shift.

Si line is then fitted in 32x128 pixel regions in chip(x,y) coordinates to measure gain shift and map onto gain correction location

Bright Source Sacrificial Charge

Before & After SacCharge Filter

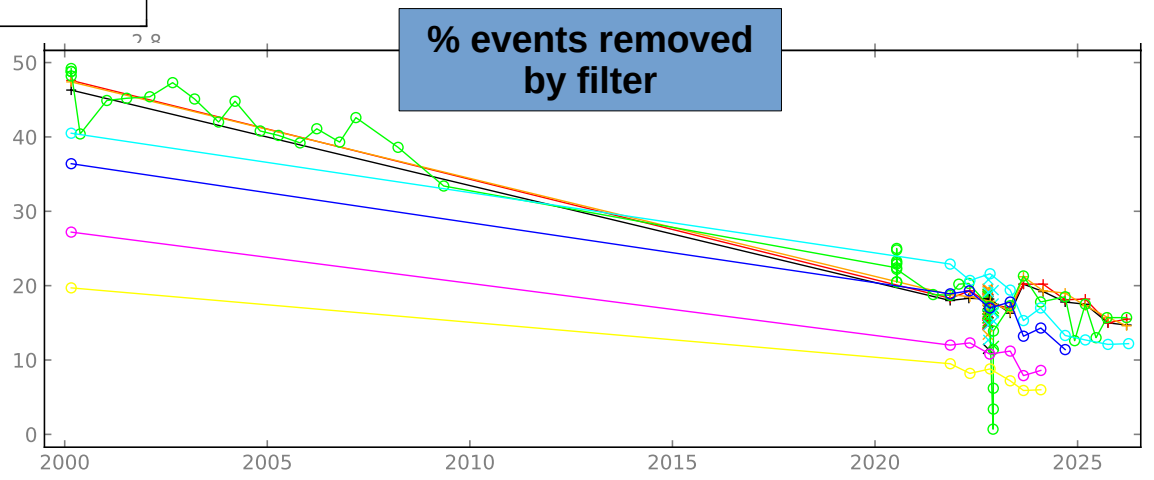


Filter discards events if there are 3 or more per column per frame

This effect is not seen on Perseus with count rates ~65 cts/s

Up to 0.5% gain shift due to source sacrificial charge

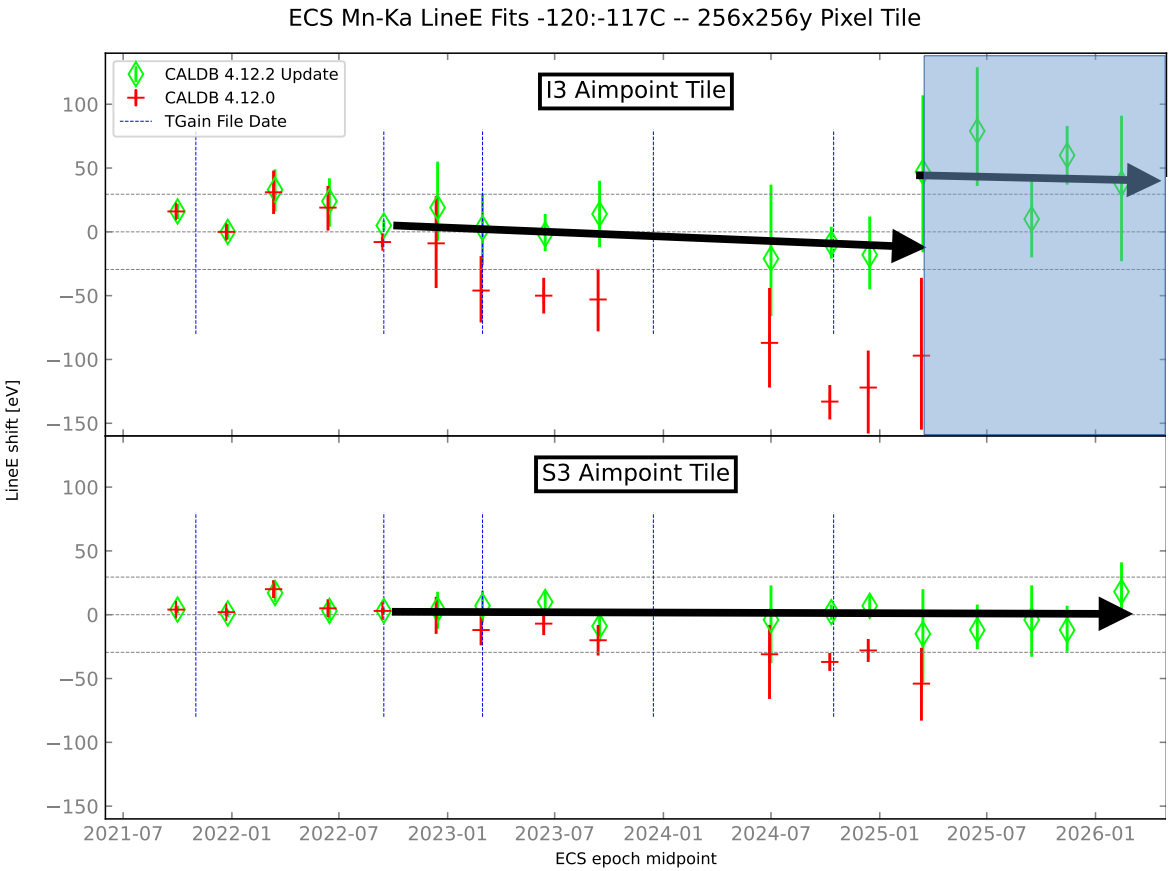
% events removed by filter

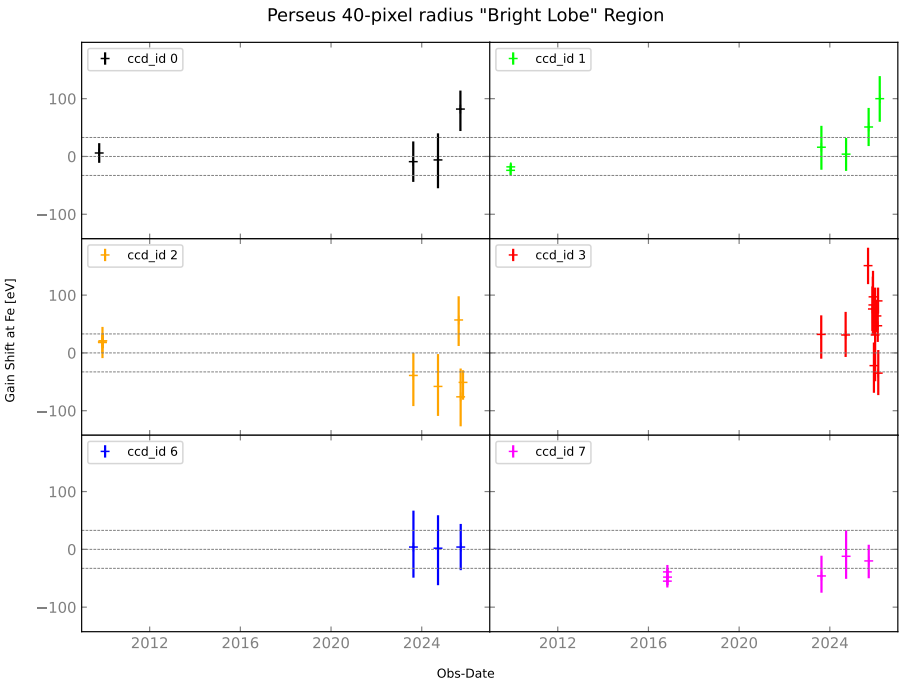


Up to 50% of events are filtered

Contamination mitigates the amount of sacrificial source charge by reducing count rates

Coming Next...





Latest gain calibration over-corrects for 2025-onward for FI CCDs

Coming Next…
Focal Plane Temperature Based Gain Corrections