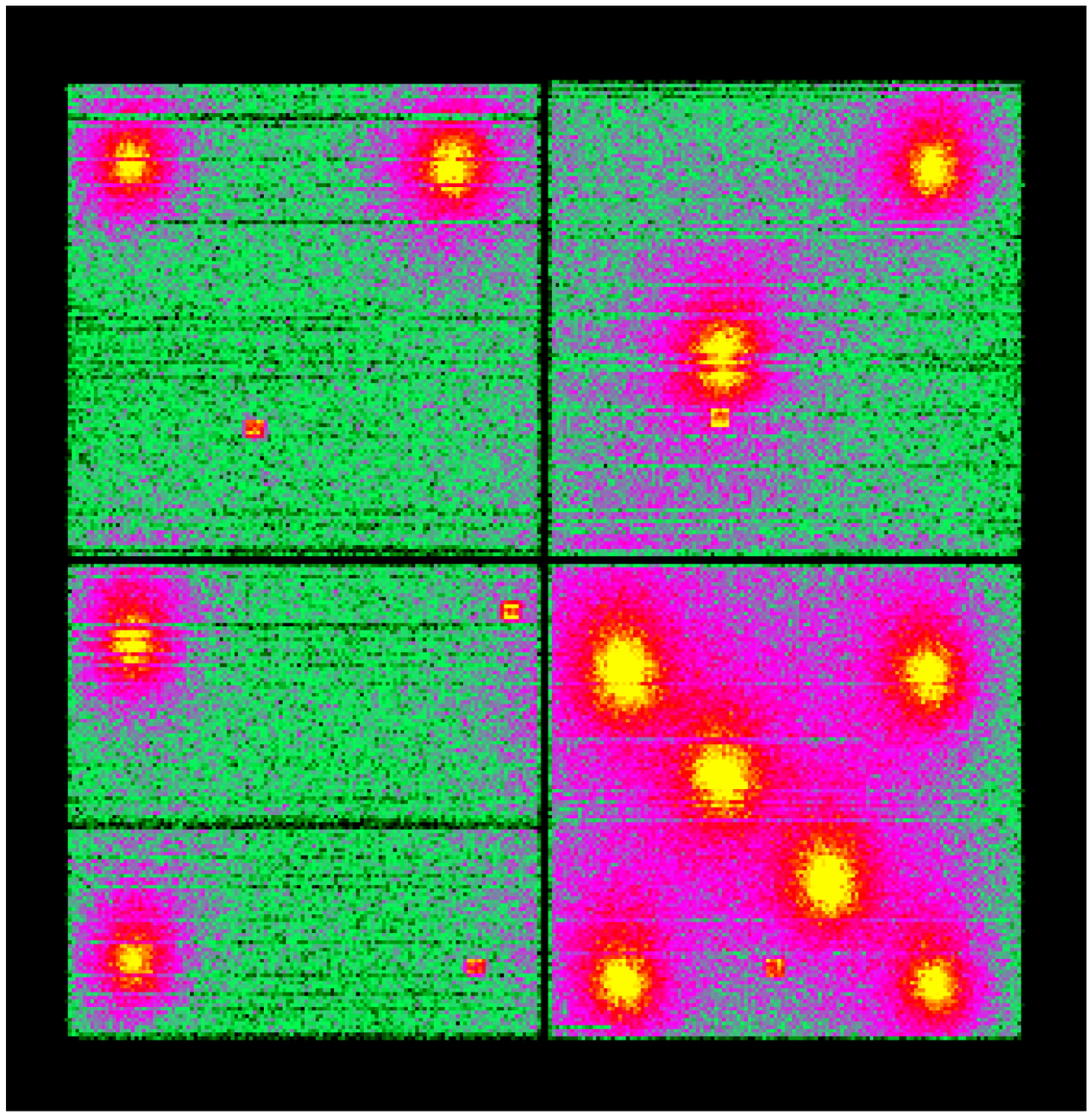
Chandra Calibration Status

CUC Meeting - September 28, 2023

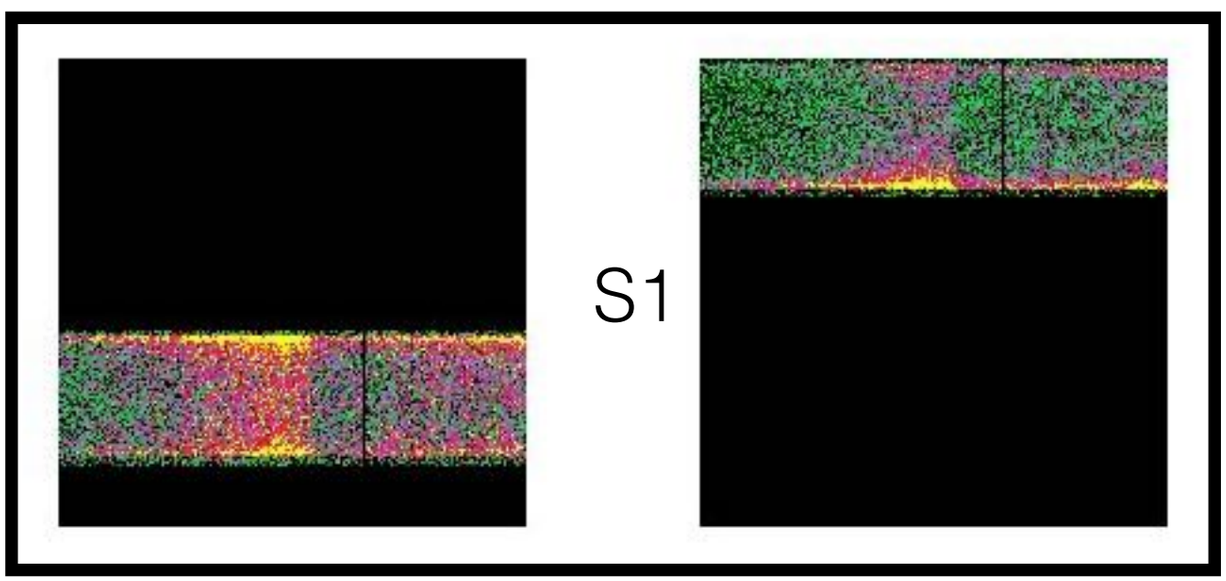
Monitoring the ACIS Contamination

A1795 Raster Scan on ACIS-I

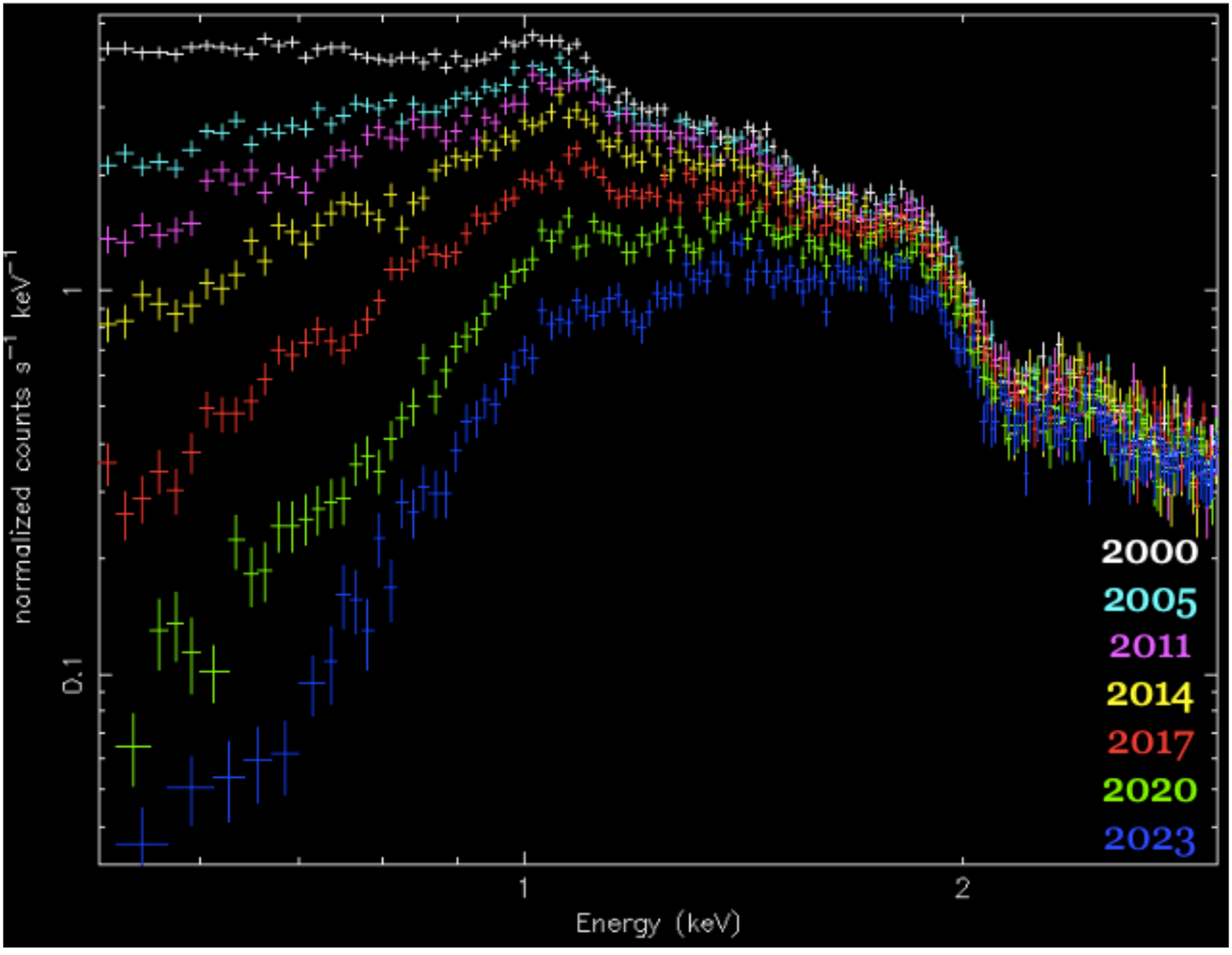


E0102-72

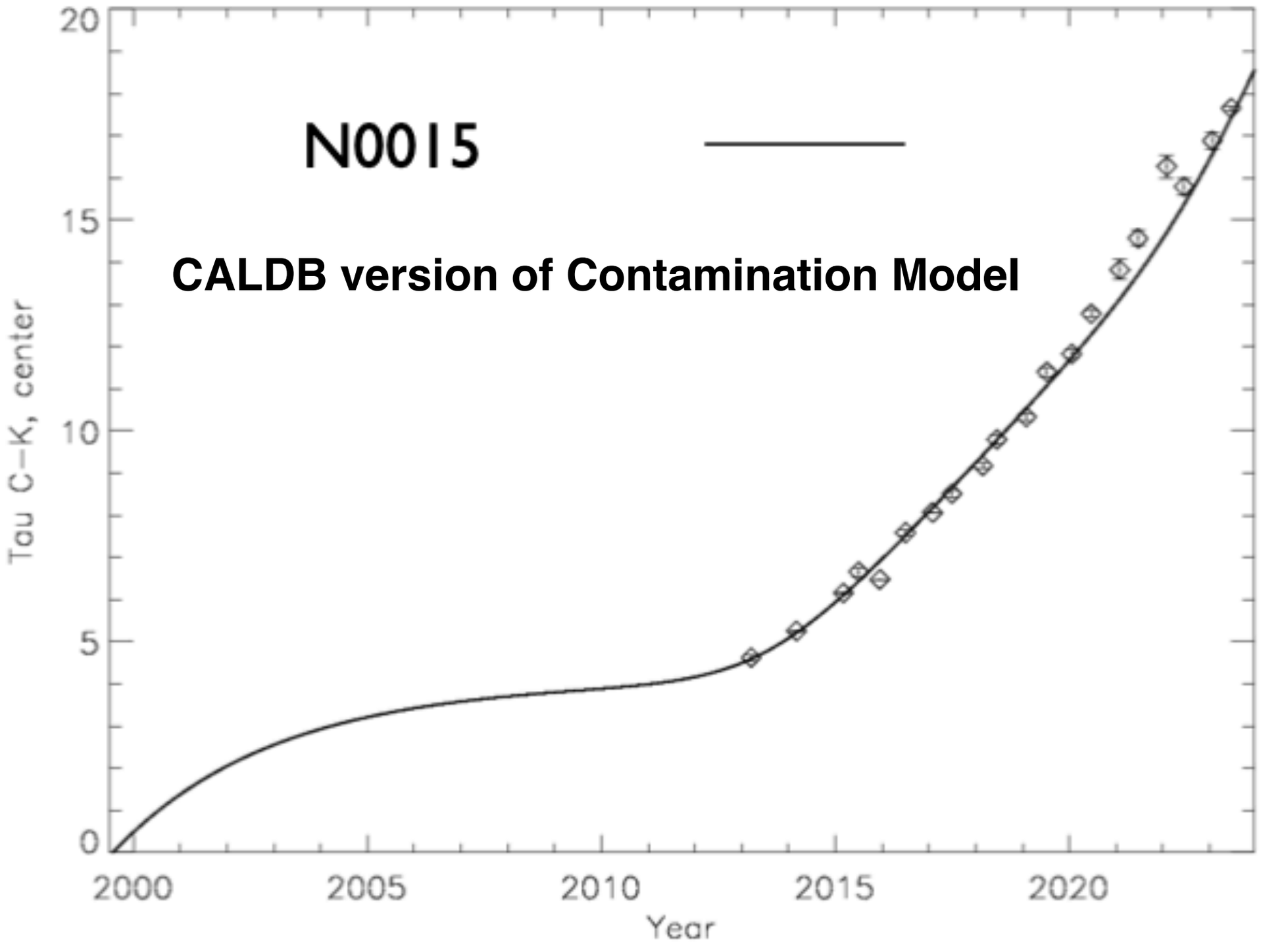
Big Dither LETG/ACIS-S observations of Mkn 421 - measures the optical depth at the K shell edges of C, O, and F



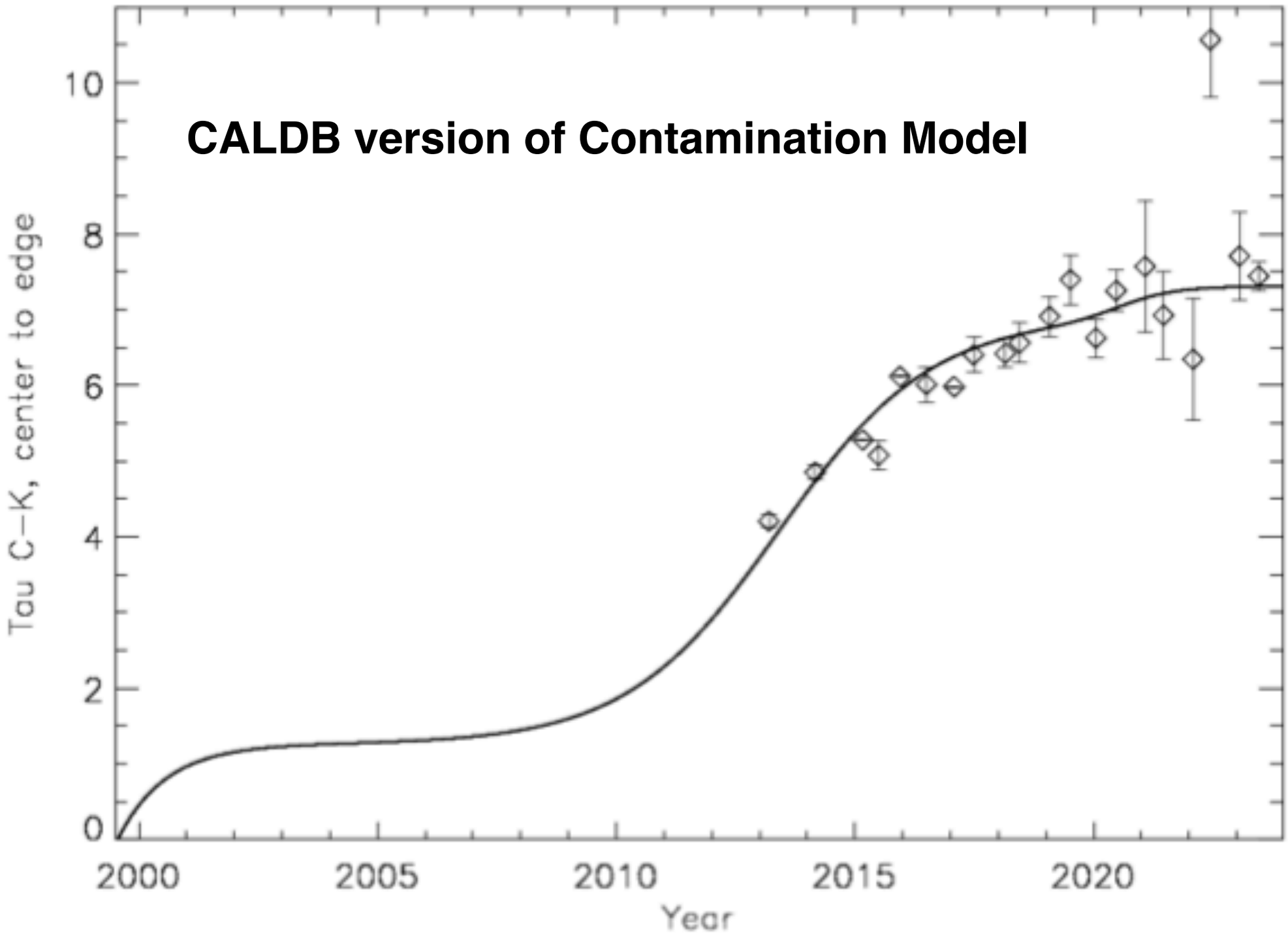
Observations of Abell 1795 Over the Course of Mission



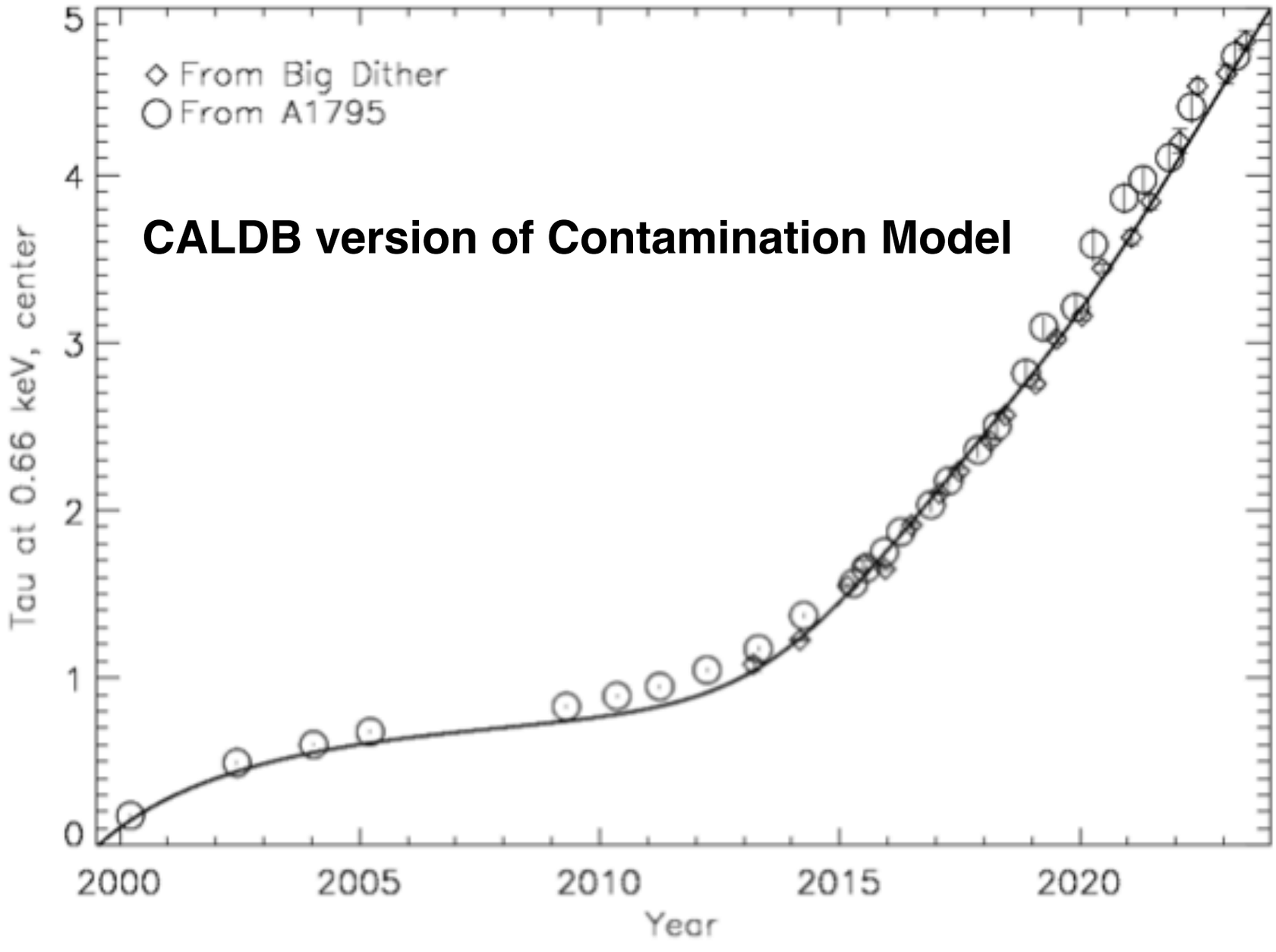
Optical Depth at the C-K edge for the ACIS-S array from the LETG/ACIS-S Big Dither Observations of Mkn421



Difference in Optical Depth at the C-K edge between the bottom and middle of the ACIS-S array from the Big Dither Observations

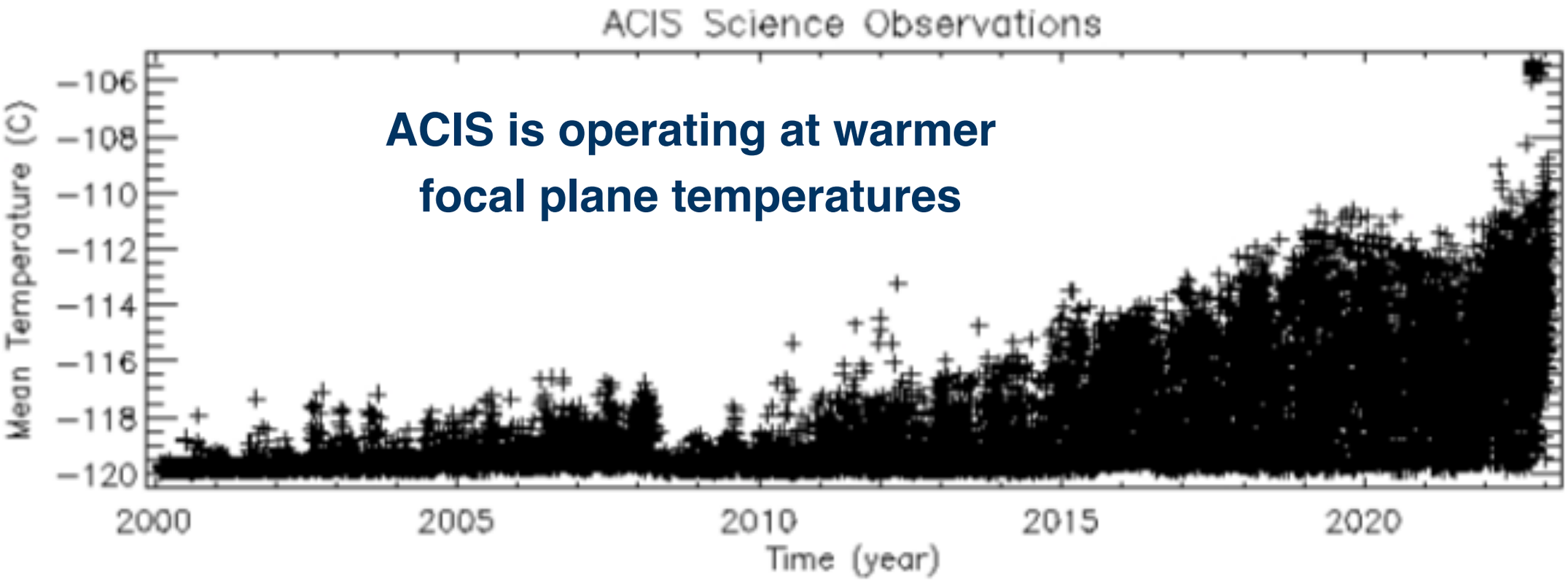


Optical Depth at 0.66 keV for the ACIS-S array from Big Dither and A1795 Observations



Conclusion: No need to update the ACIS contamination model at the present time.

Improving the ACIS CTI Correction at Warm Focal Plane Temperatures



Charge Transfer Inefficiency (CTI) increases with temperature which affects the detector gain and energy resolution

Current FP limits

- ACIS-I FP Temp < -112 C
- ACIS-S FP Temp < -111 C
- Low S/N observations up to -109 C

The ACIS CTI Correction Procedure

CTI correction ~ (temperature)(energy)(spatial)
All chips are calibrated separately

1) Temperature-dependence: Calibrated using the Mn line in the ECS data

Old Method: Uses a linear function of temperature.
New Method: Uses a quadratic function of temperature

2) Energy-dependence: Initially calibrated with ECS data.

Old Method: Uses a single power-law for the energy-dependence at all temperatures (i.e. $\Delta Q \sim PHA^{a}$).
New Method: Uses different power-law indices at different temperatures (i.e., a=f(T)).

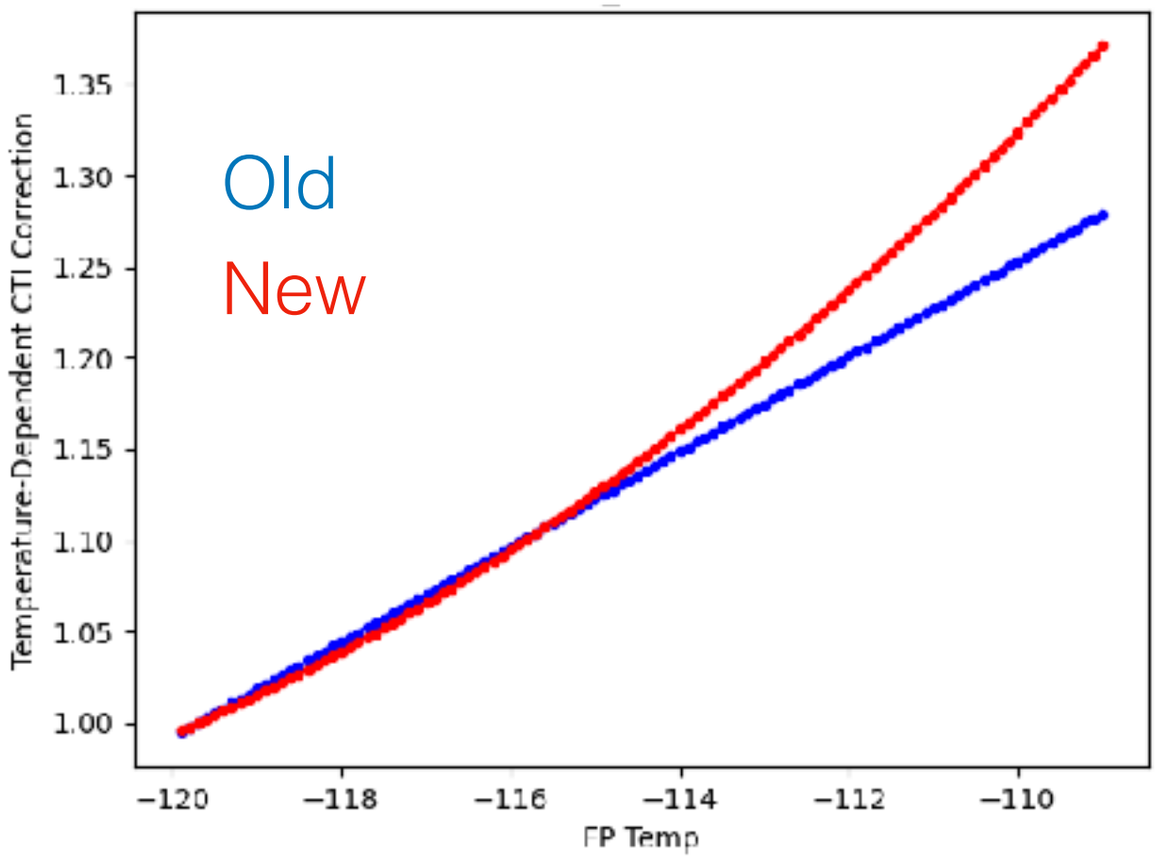
3) Spatial-dependence: Based on trap maps generated from ECS data

Old Method: Applies the same trap map at all temperatures.
New Method: Applies different trap maps at different temperatures.

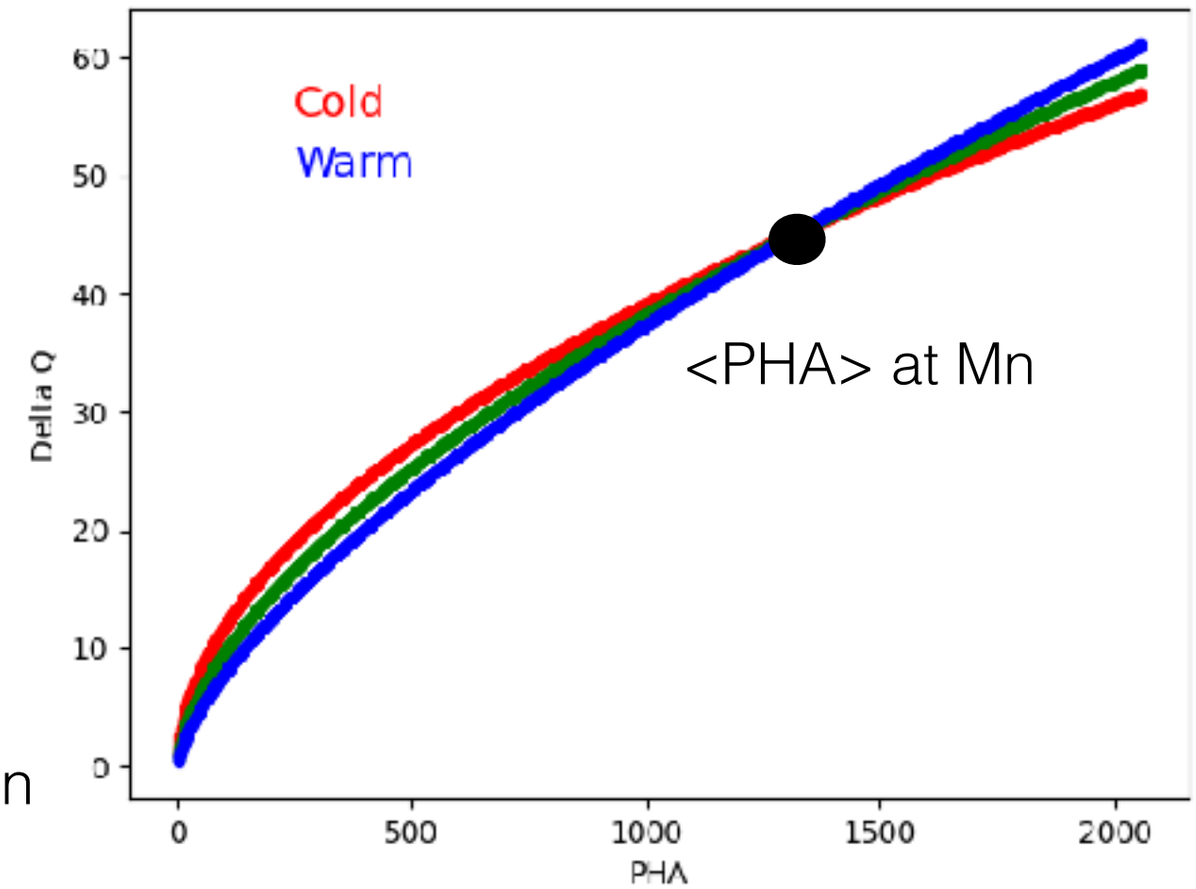
4) ECS data is used up to -107 C. Cas A observations are used at warmer FP temperatures for gain calibration.

ACIS CTI Correction

Temperature-Dependent Correction



Energy-Dependent Correction



- Since the temperature-dependence is calibrated at Mn, the energy-dependent corrections must pivot about the correction at Mn.

- Illustrative - actual energy-dependent corrections are more similar

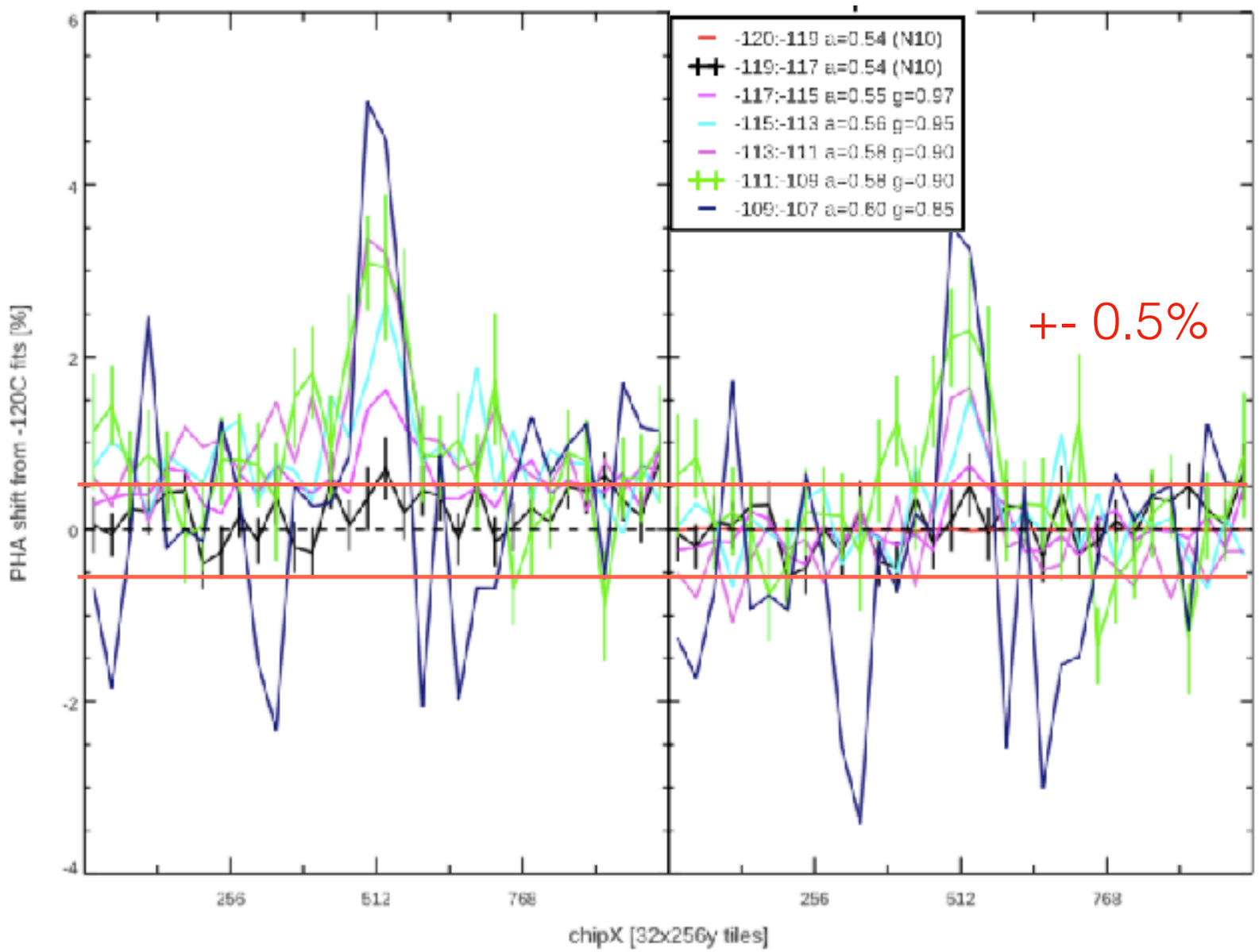
Results with new Temperature and Energy CTI corrections

I3 at Al-Ka and chipy=769:1024 (top 1/4 of chip)

- CALDB overcorrects the data at Al at warm temperatures.
- New method produces good agreement at warmer temperatures.
- The data is still overcorrected in the middle of the chip.
- The data in the warmest temperature bin has the poorest statistics.

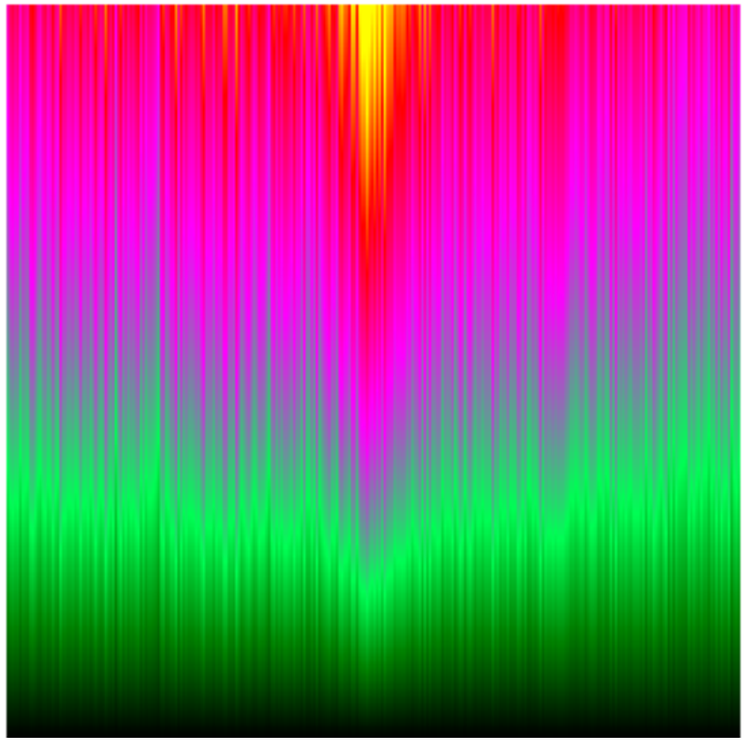
CALDB

New temperature- and energy-dependent CTI corrections



ACIS Trap Maps

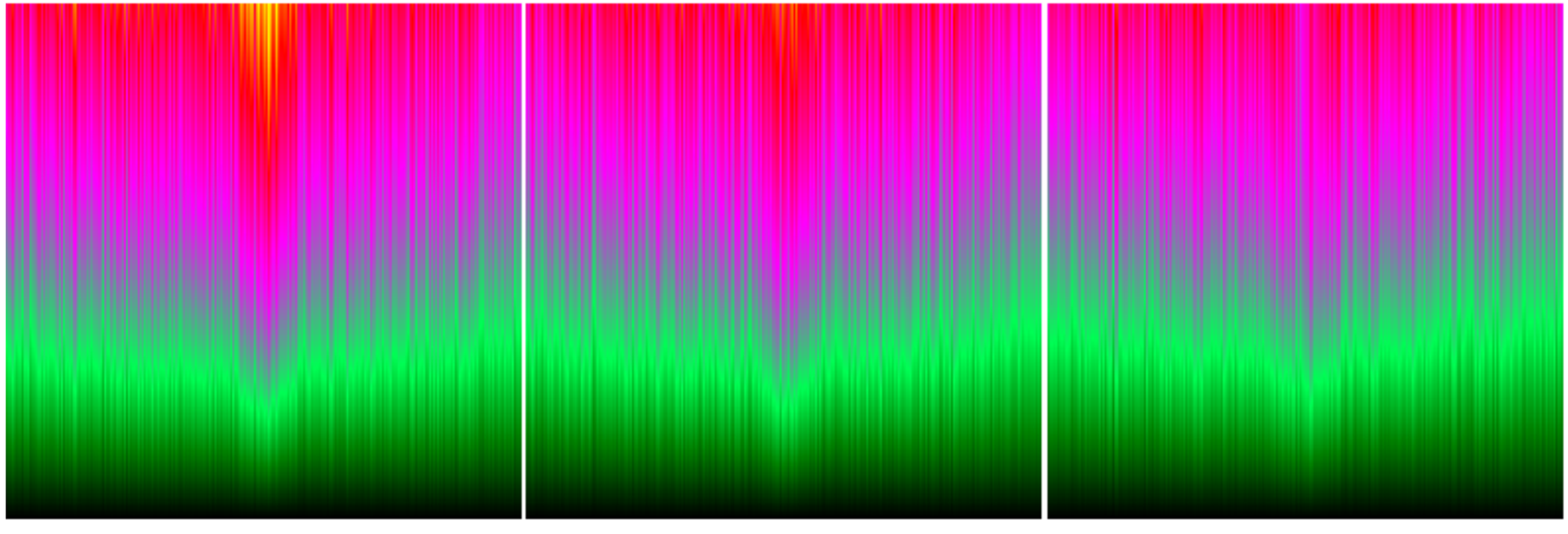
I3 trap map generated from ECS data taken at -120C early in the mission.



- To counter the gain overcorrection in the middle of the chips, a set of trap maps were created with reduced values in the middle of the trap maps.

- These images are for illustrative purposes. The actual trap maps used for different temperature data are much more similar.

Cold



Warm

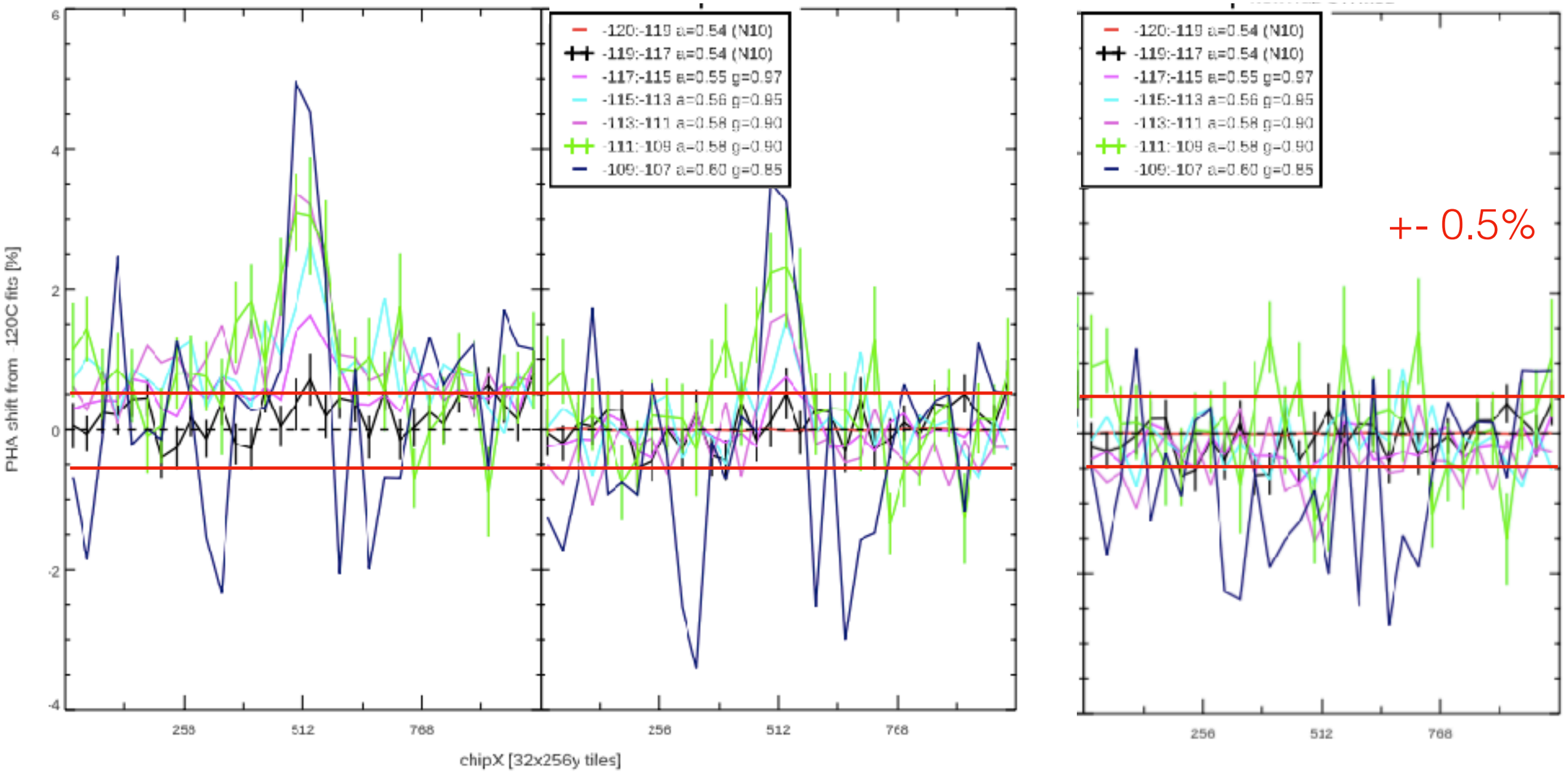
Including Different Trap Maps for Each Temperature Bin

I3 at Al-Ka and chipy=769:1024

CALDB

New temperature- and energy-dependent CTI corrections

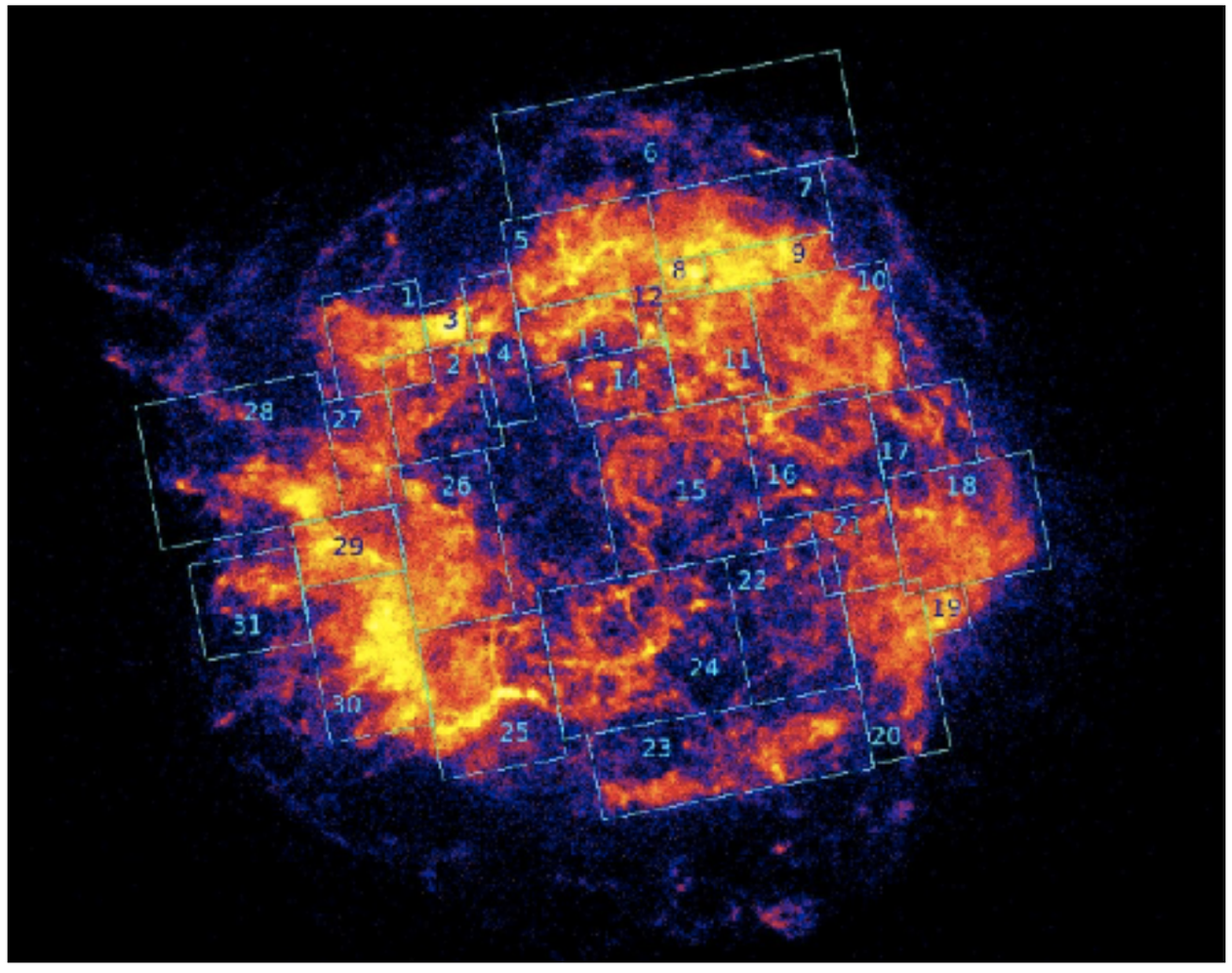
Plus adjusted trap maps for each temperature bin



Post ECS Gain Calibration

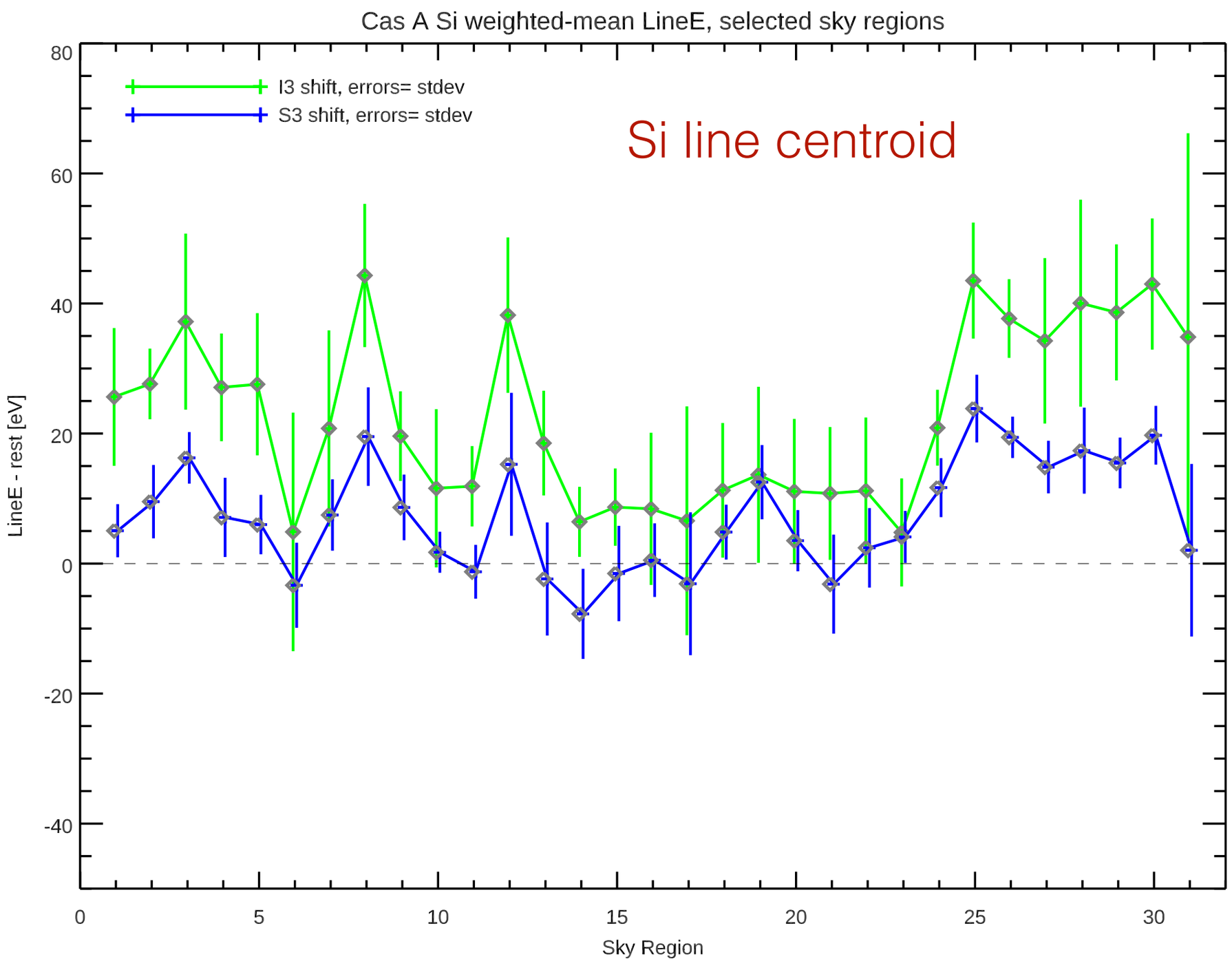
Two aspects of ACIS gain calibration

- Calibrate the temperature-dependence of the CTI correction for FP temperatures above -107 C.
- Monitor the time-dependent changes to the ACIS gain. In general, the ACIS gain has shown a slow decline with time modulated by the solar cycle.



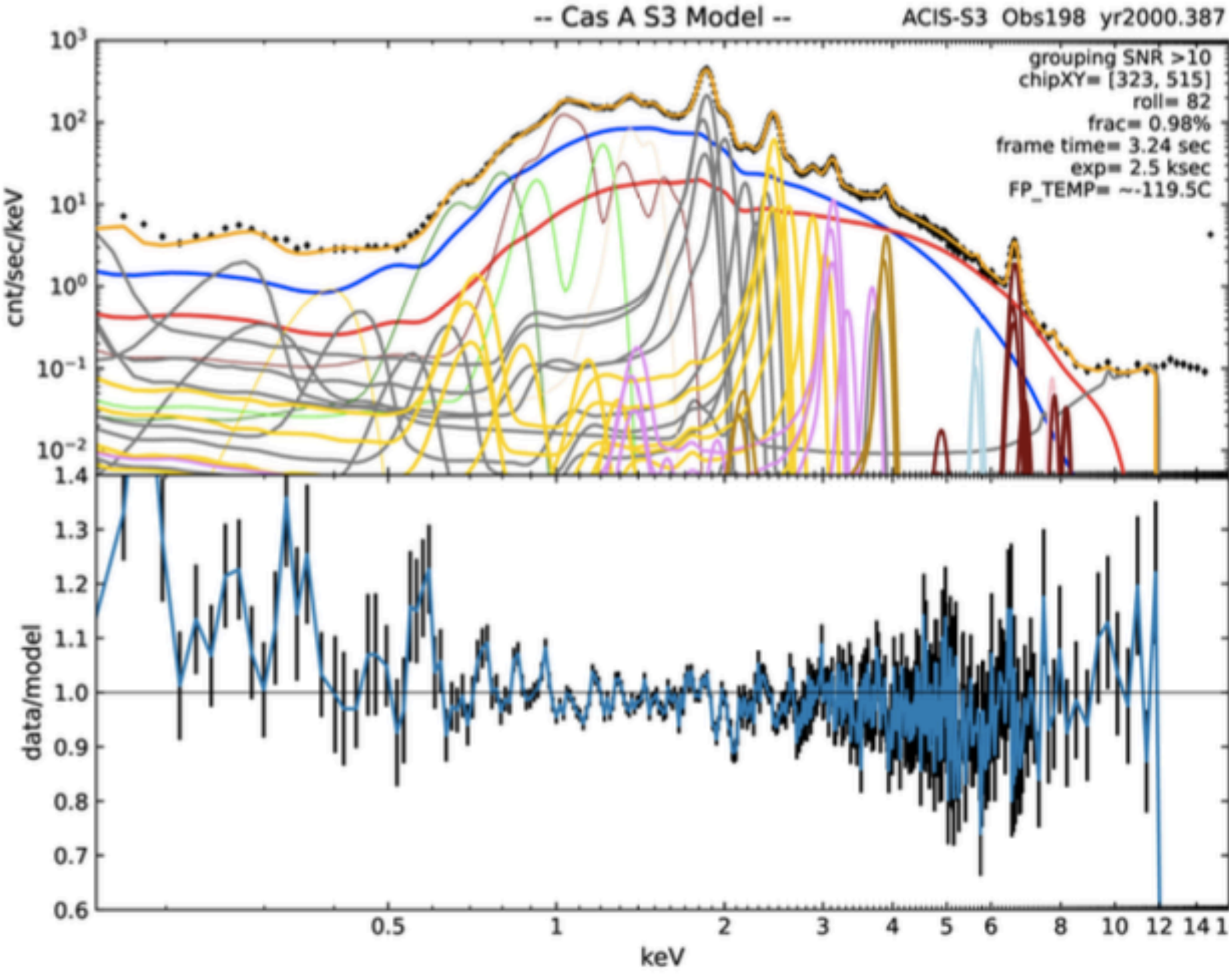
Cas A is now our primary target for gain calibration

S3 and I3 Velocity Maps for Cas A

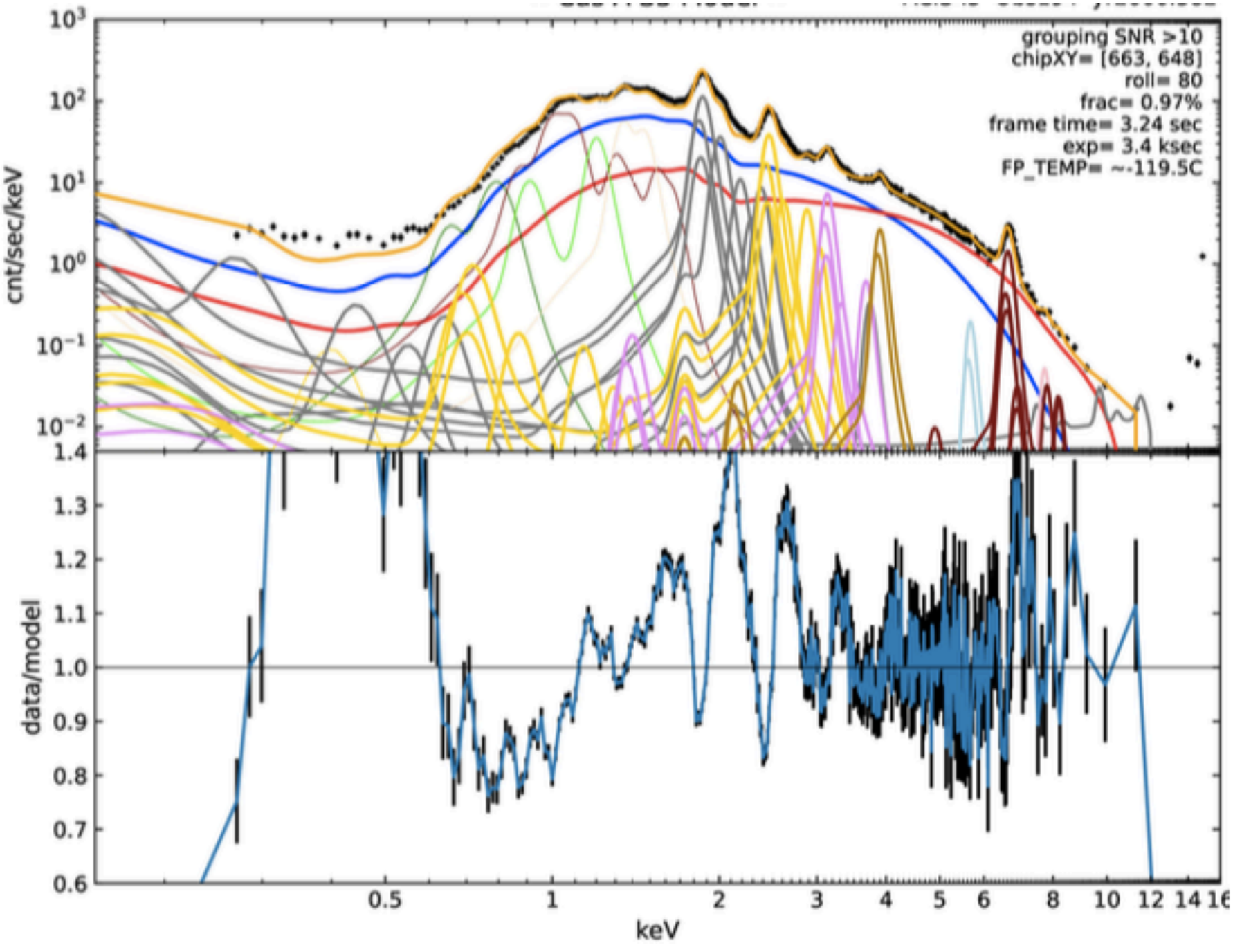


ΔE up to 1% (3,000 km/s)

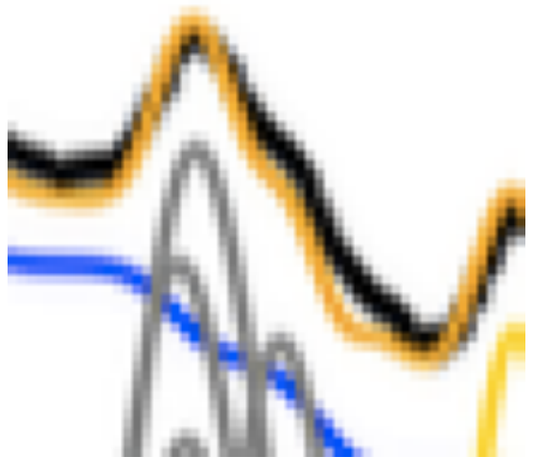
Early S3 Observation of Cas A



Early I3 Observation of Cas A



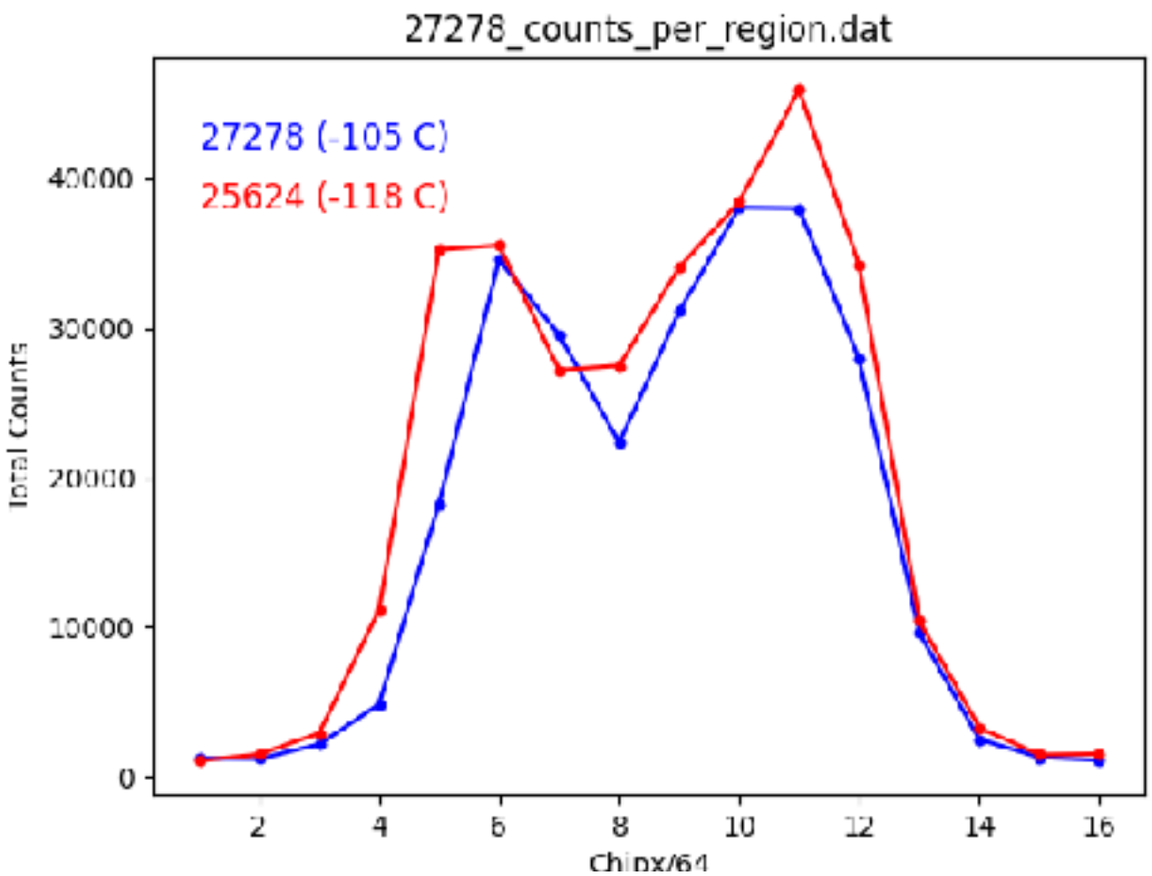
Si line

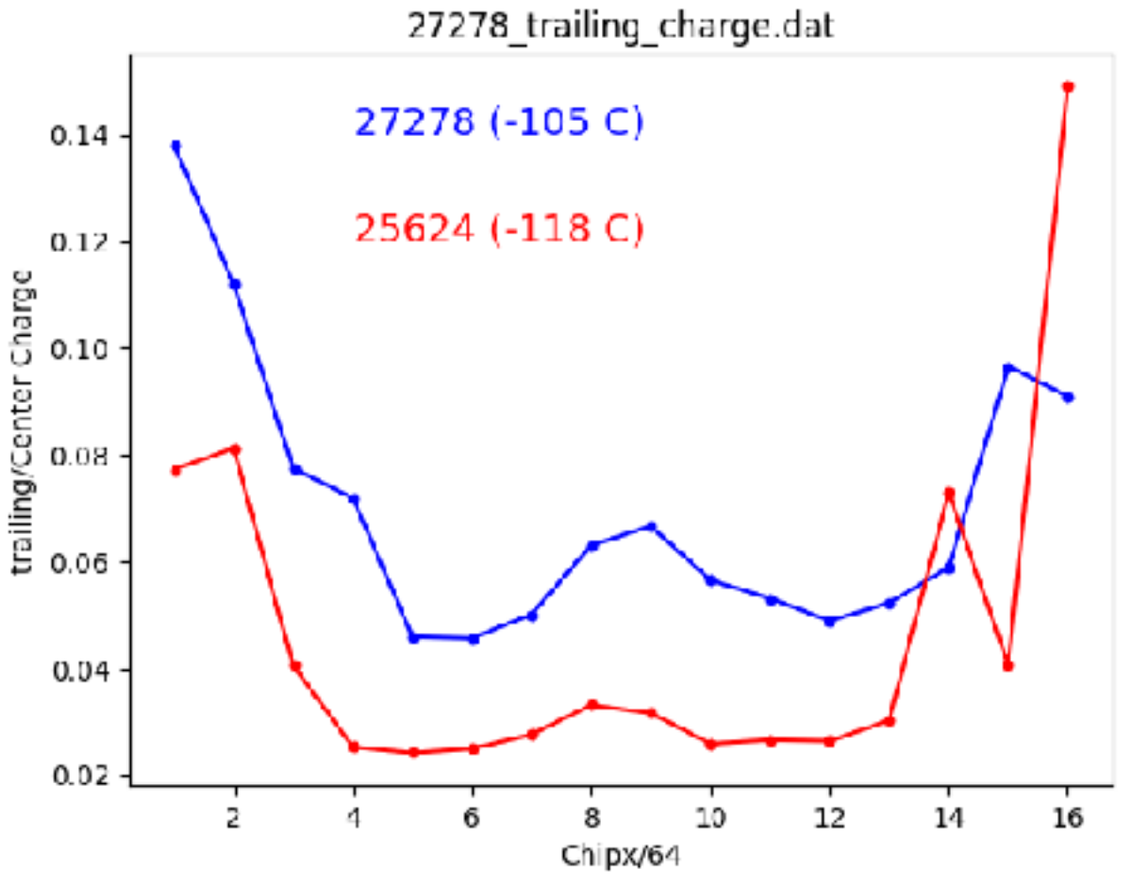


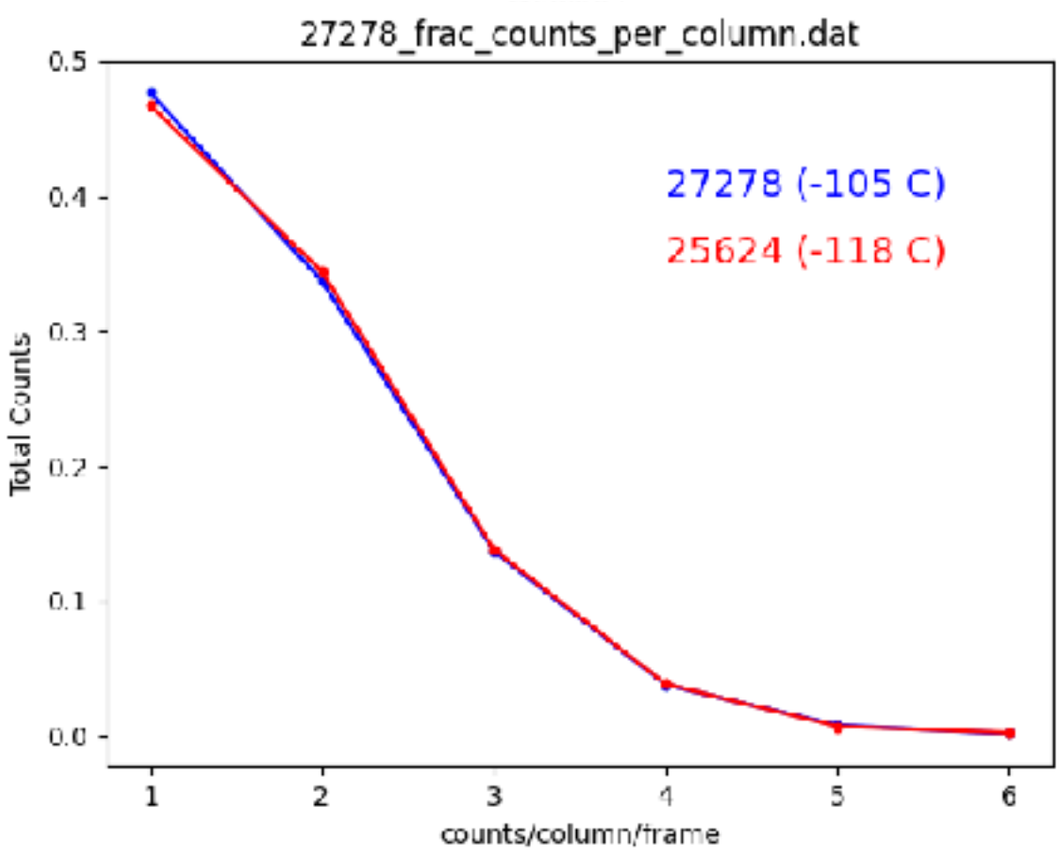
S3 Model

I3 data

Evidence for Sacrificial Charge in Cas A Observations



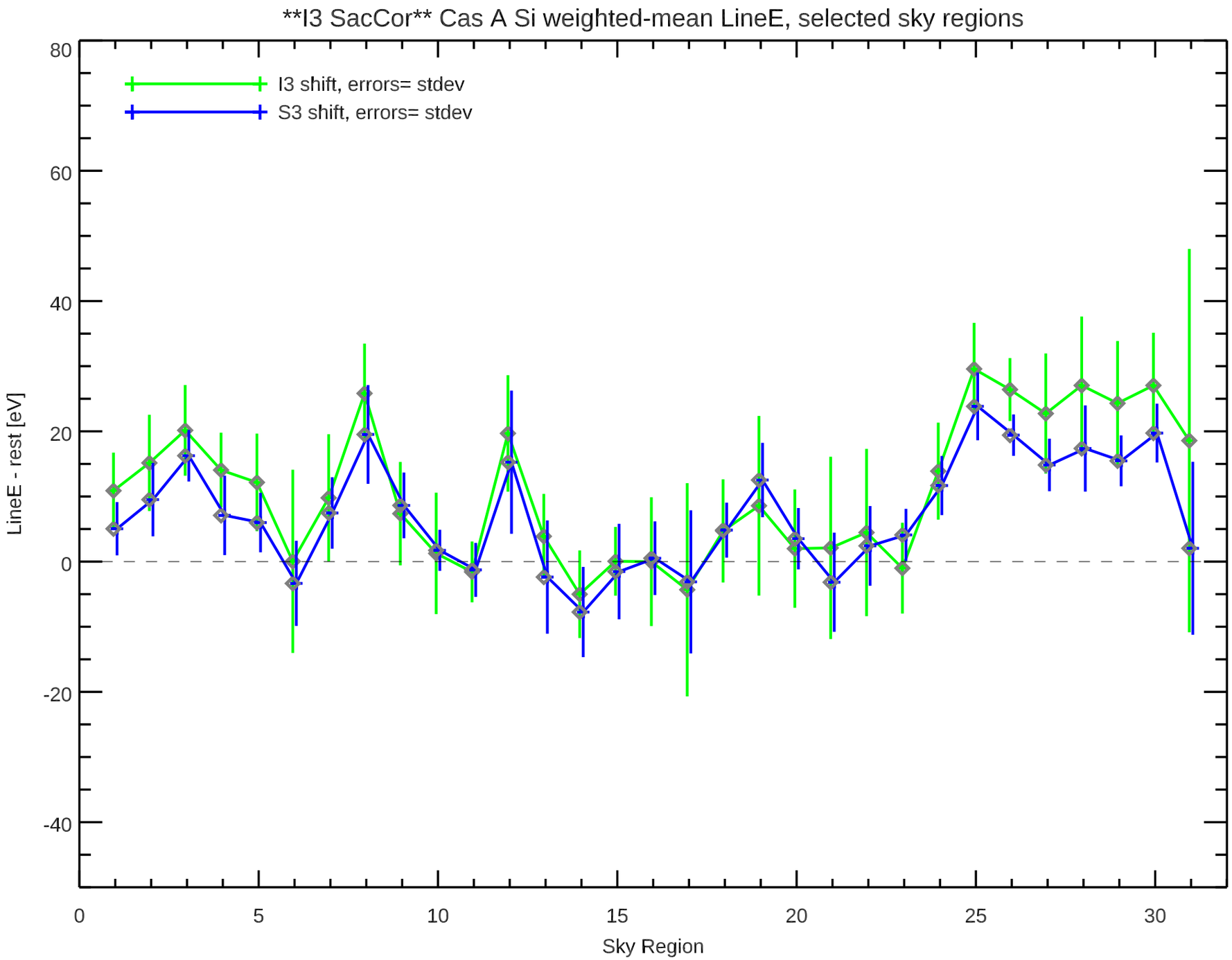




Solution to gain offset between BI and FI chips: Remove all events where there are three or more events per column per frame in FI observations.

After Correcting for Sacrificial Charge

Remove all events when there are more than 3 events per column per frame. This only removes ~15% of all events



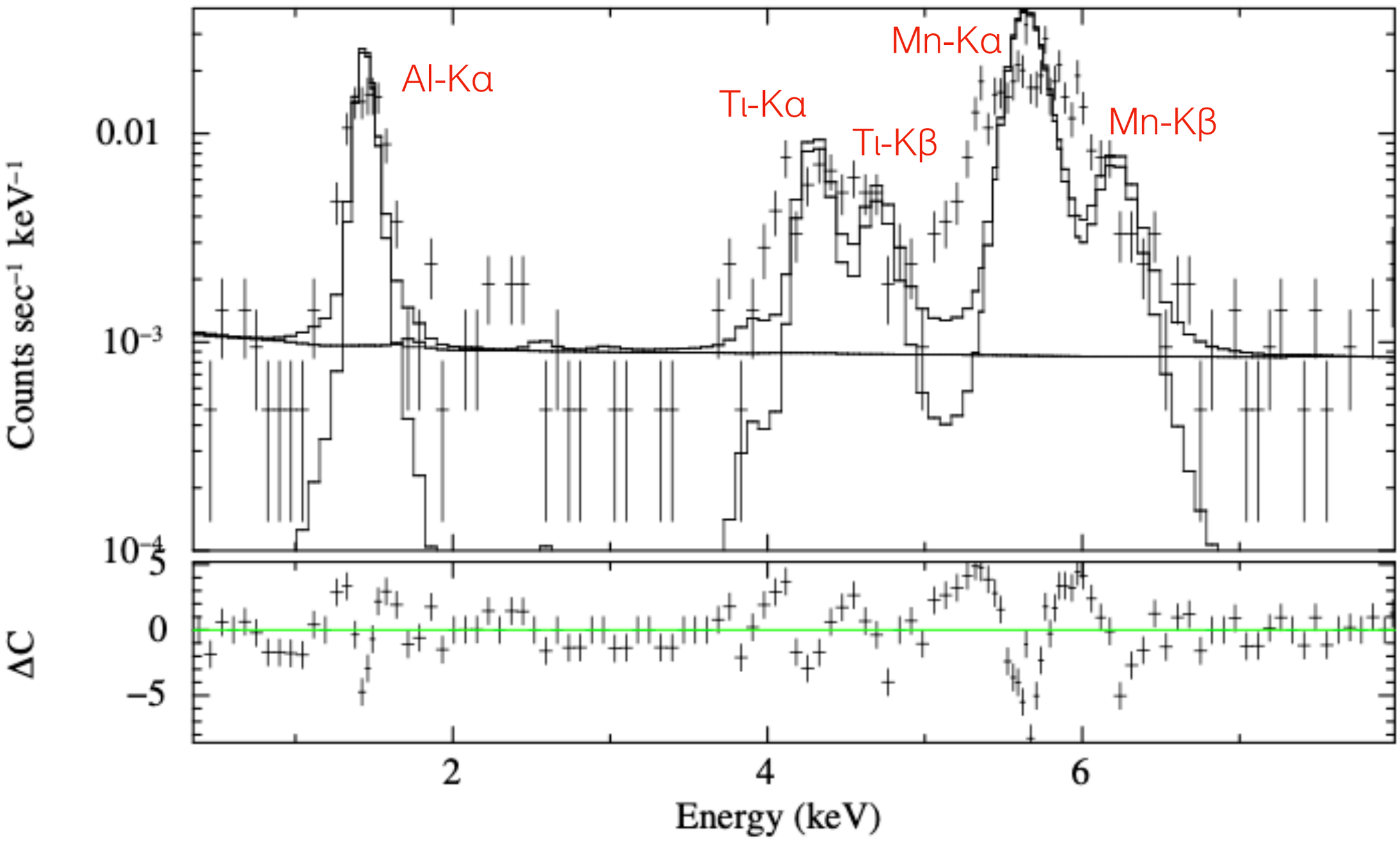
RMFs at warmer Focal Plane Temperatures

Procedure

- Co-add ECS data from epochs 40-91 (approximately 13 years of data)
- Divide ECS data into 7 FP temperature intervals between -120 and -107 C
- Bin data into 32 by 32 pixel regions
- Fit widths of Al, Ti, and Mn lines in each spatial region and temperature bin

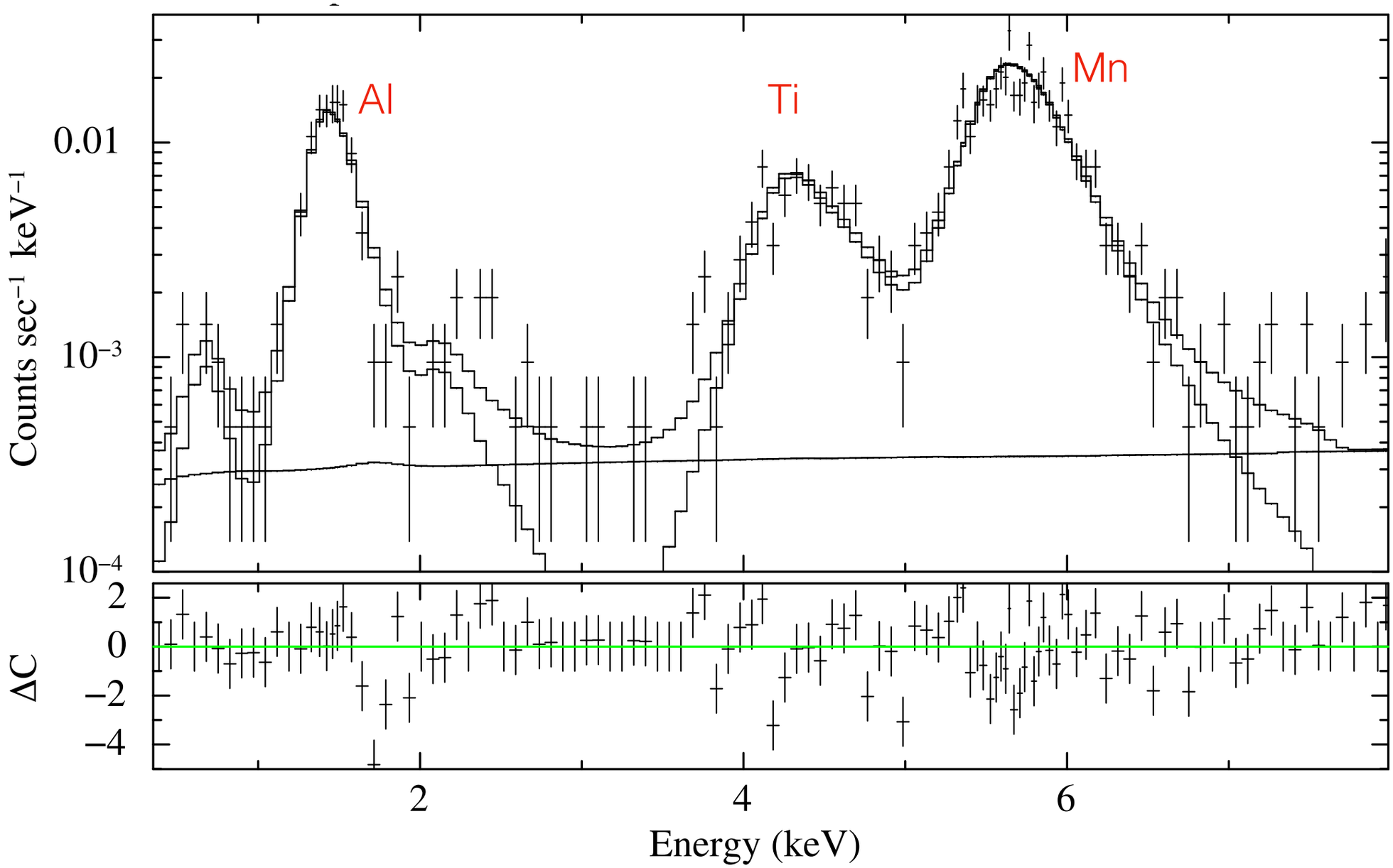
Warm ECS data (FP temps -109:-107C) fit with CALDB version of rmf file.

I3 aim-point

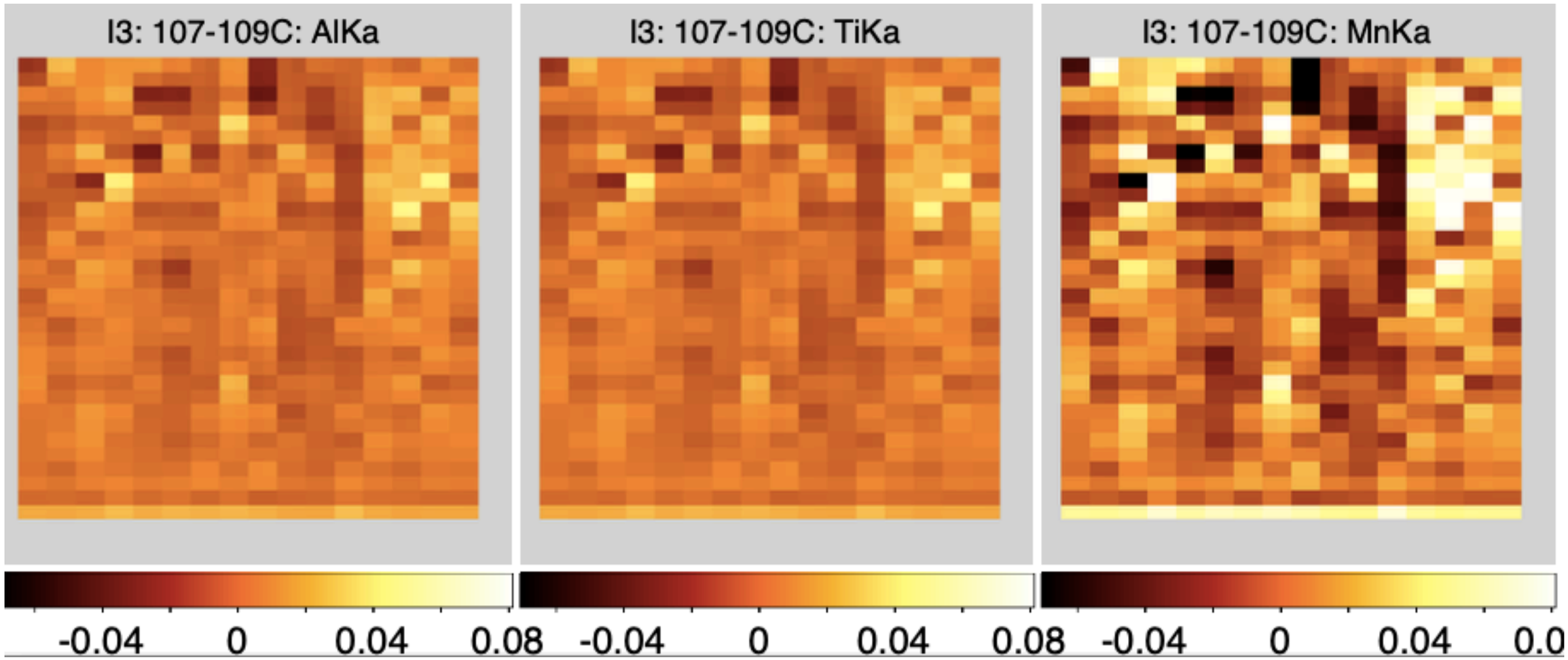


Warm ECS data (FP temps -109:-107C) fit with test version of rmf file.

I3 aim-point



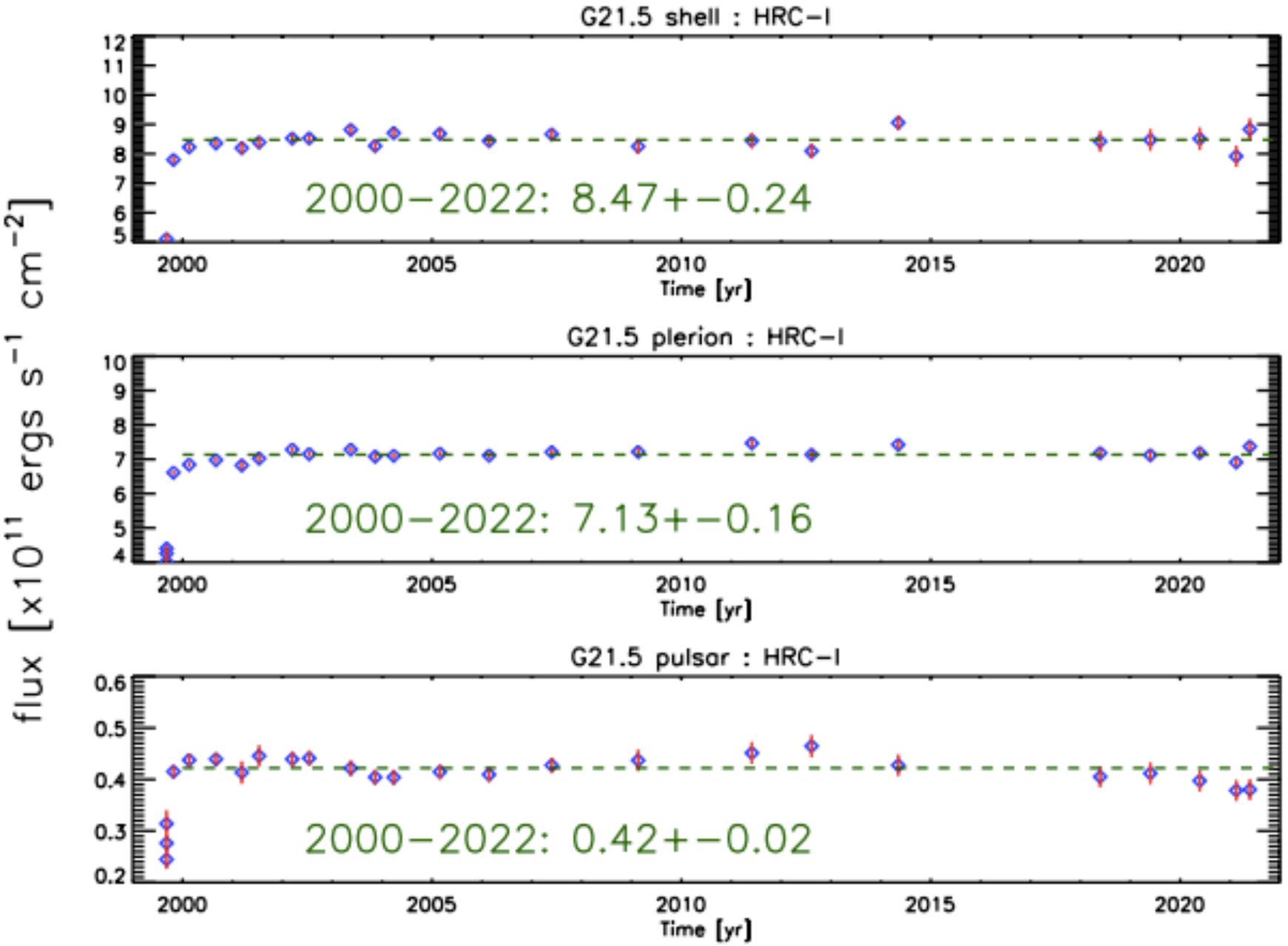
Residuals in the width of the ECS lines with FP temps -109:-107 C on I3.



Most residuals are within 4%.

HRC Return to Science

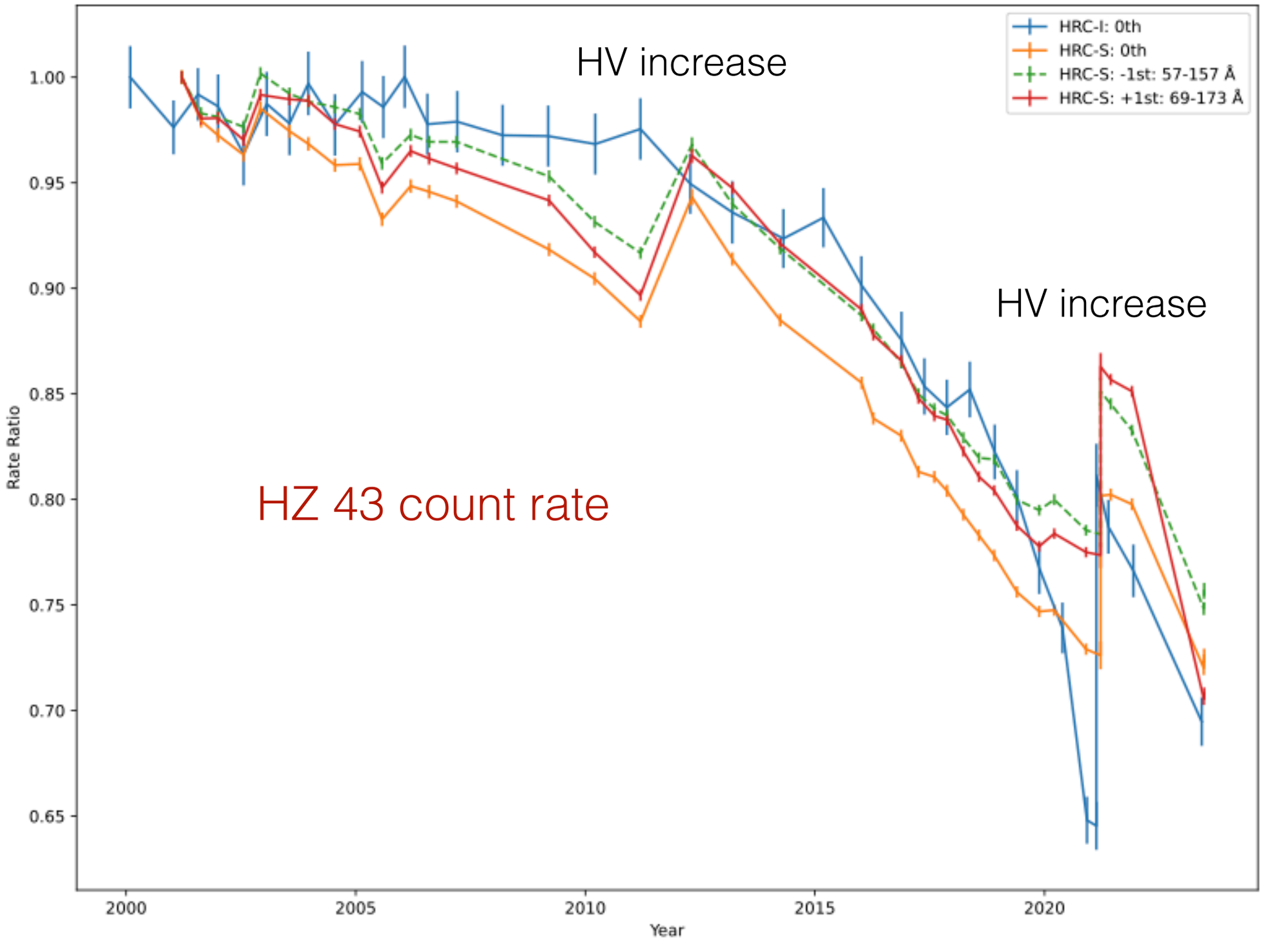
The SNR G21.5-09 has been observed in imaging mode with both the HRC-I and HRC-S every two years over the course of the mission. G21.5-09 is heavily absorbed with little flux below 2 keV.



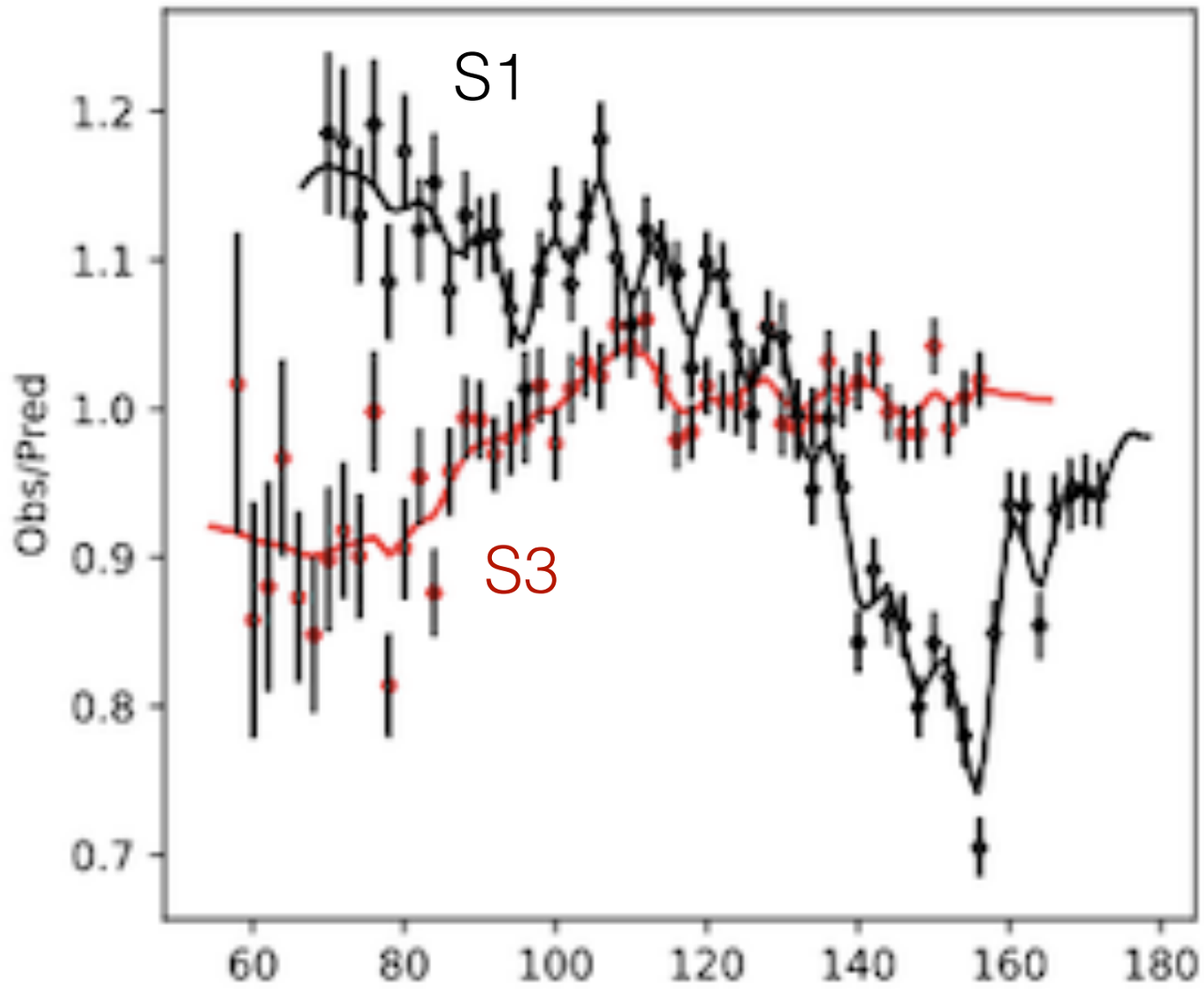
Flux computed with the CALDB version of the HRC-I QE

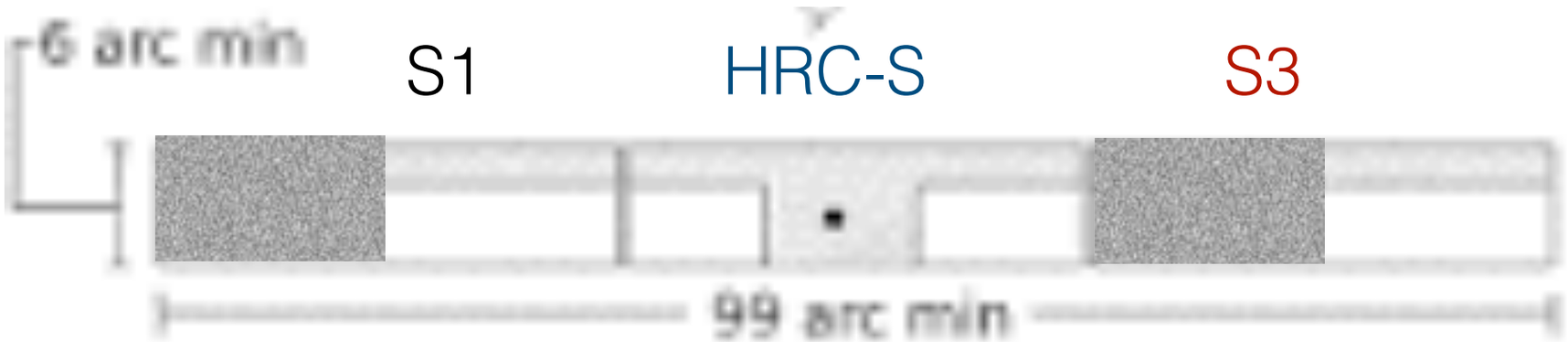
Low Energy Response of the HRC

LETG observations of HZ43 with the HRC-I and HRC-S have been performed annually over the course of the mission.

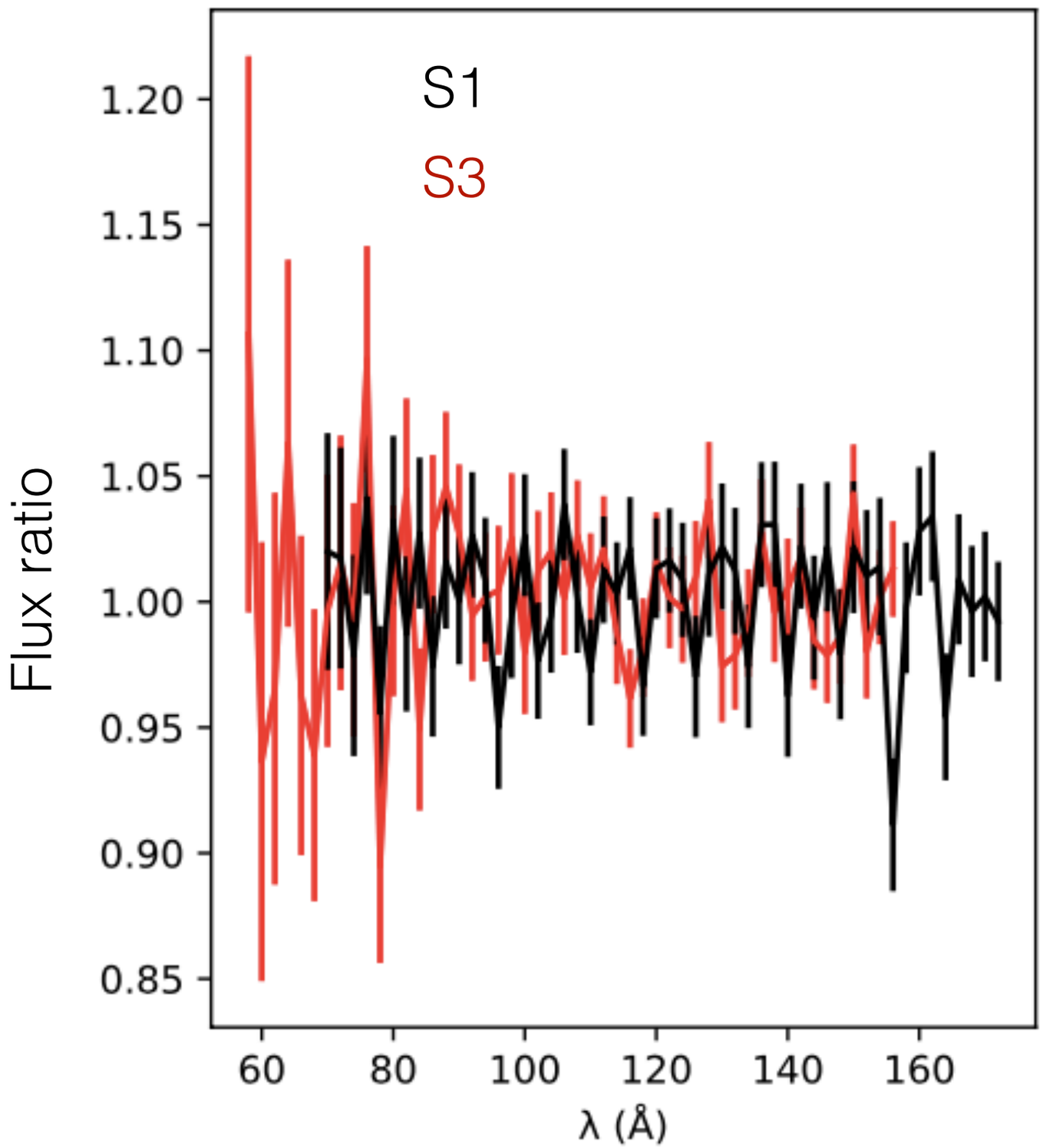


Dispersed LETG spectra of HZ43 on the outer plates of the HRC-S

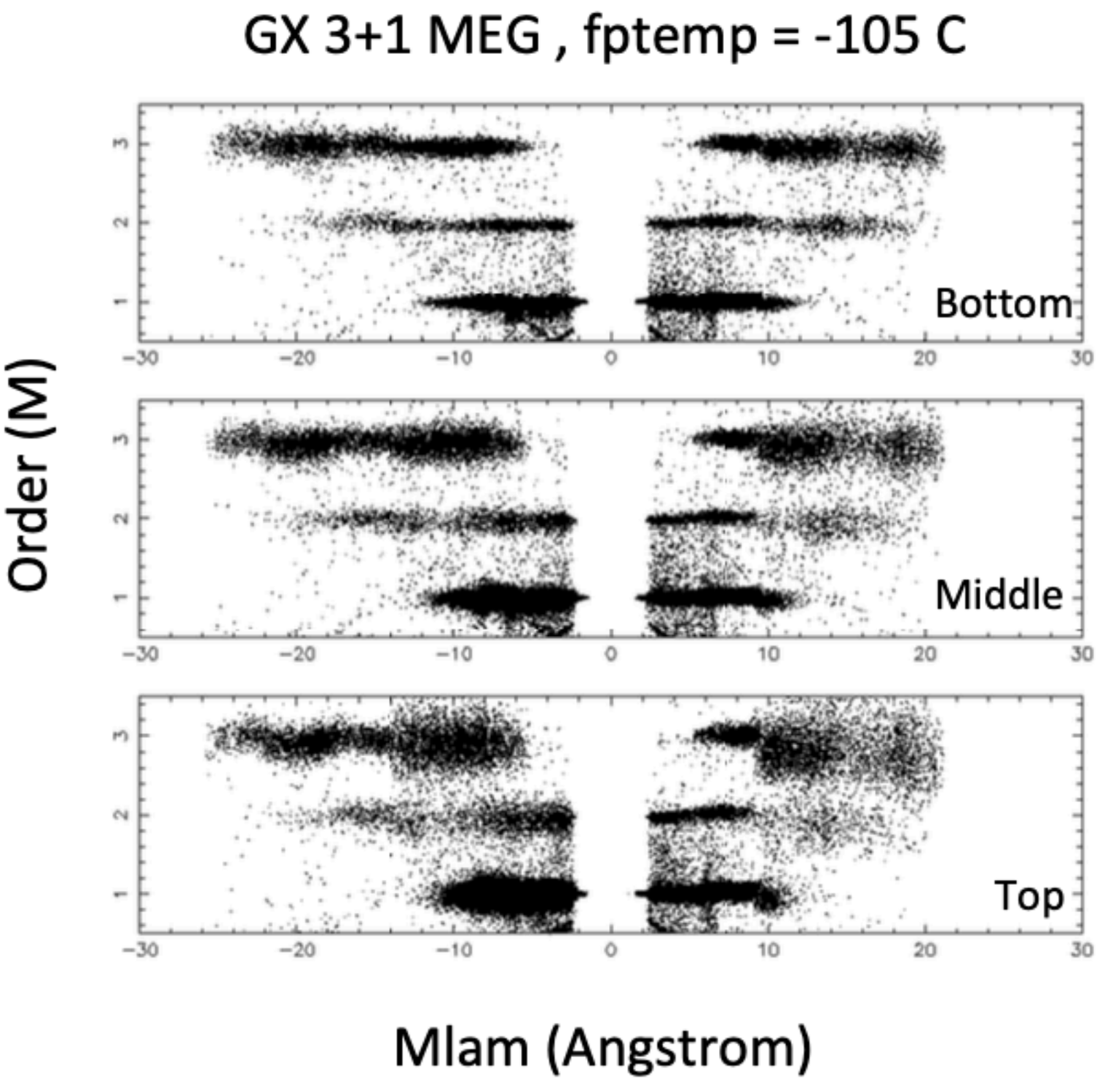




Fluxed LETG spectra of HZ43 on the outer plates of the HRC-S with the newly released HRC-S QEU file (CALDB 4.10.7)

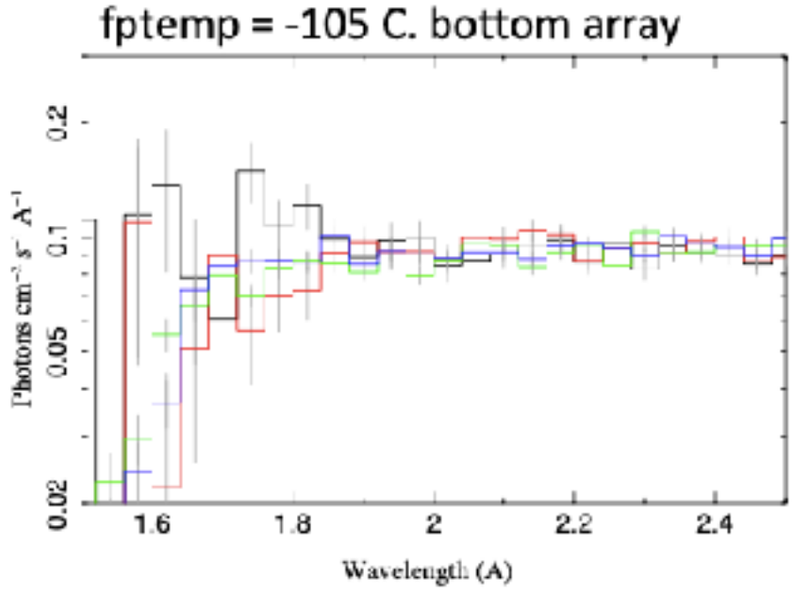


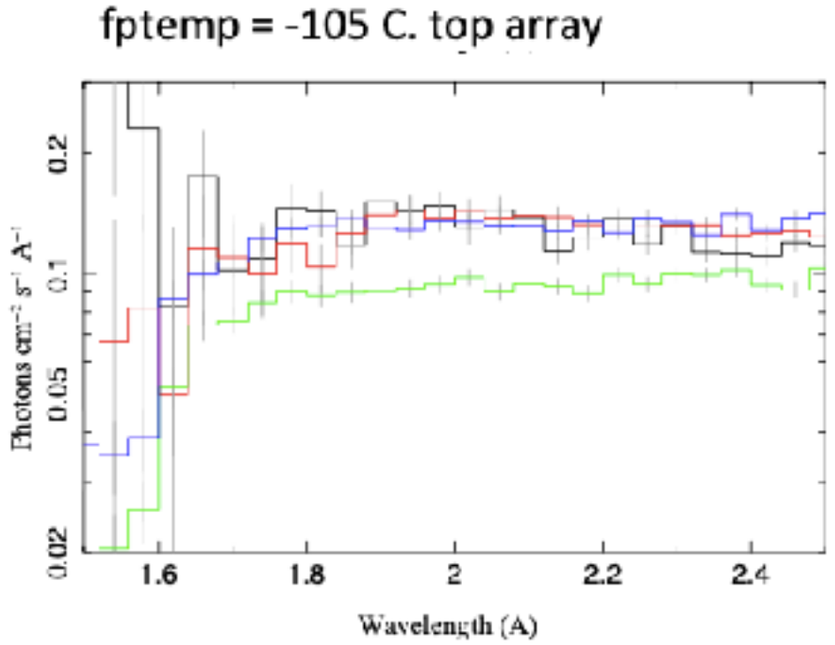
HETG/ACIS-S Observations of GX 3+1 at a FP Temperature of -105 C



Orders are cleanly sorted near the bottom of the ACIS-S array

HETG spectra of GX 3+1 near the bottom and top of the ACIS-S array at a FP temperature of -105 C

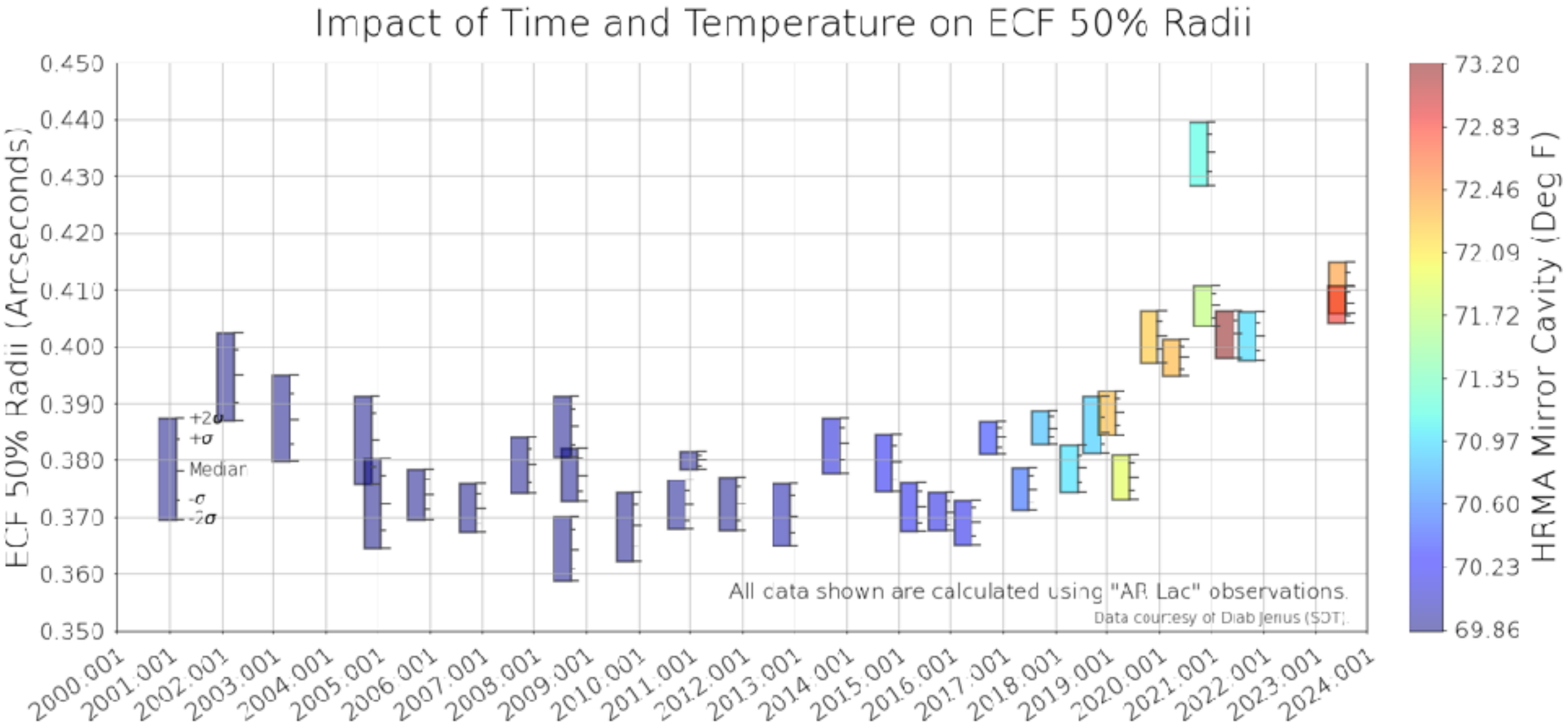




Recommendation: The HETG can be used up to a FP temperature of -105 C only if the zeroth-order location is moved beyond 6 mm in minus Sim Z direction, preferably associated with a sub-array.

HRMA PSF Monitoring

AR Lac has been observed at least once per year on-axis with the HRC-I since launch.



A slight increase of 0.03” (1/4 of a HRC pixel 1/16 of an ACIS pixel) over the past four years.

Future Calibration Plans

ACIS

- Finish testing and release updated CTI correction products for ACIS-I data taken up to -107 C
- Develop and release new CTI correction products for ACIS-S (S2 and S3) for data taken up to -107 C
- Develop CTI correction products for Cas A data taken at -105 C and append the new CTI correction products with an additional temperature bin from -107:-105C
- Finish work on the set of temperature-dependent rmfs for data up to -107 C.
- Develop a tgain file from the Cas A and Perseus data for 2023
- Continue to monitor the accumulation of contamination on the ACIS filters

Future Calibration Plans

HRC

- Continue to Monitor the QE and gain of the HRC-I and HRC-S
- Release updated QE for HRC-I for data taken since return to science
- Combine HRC-I and HRC-S data since return to science and release new background files for each detector

Optics

- Continue to monitor the PSF