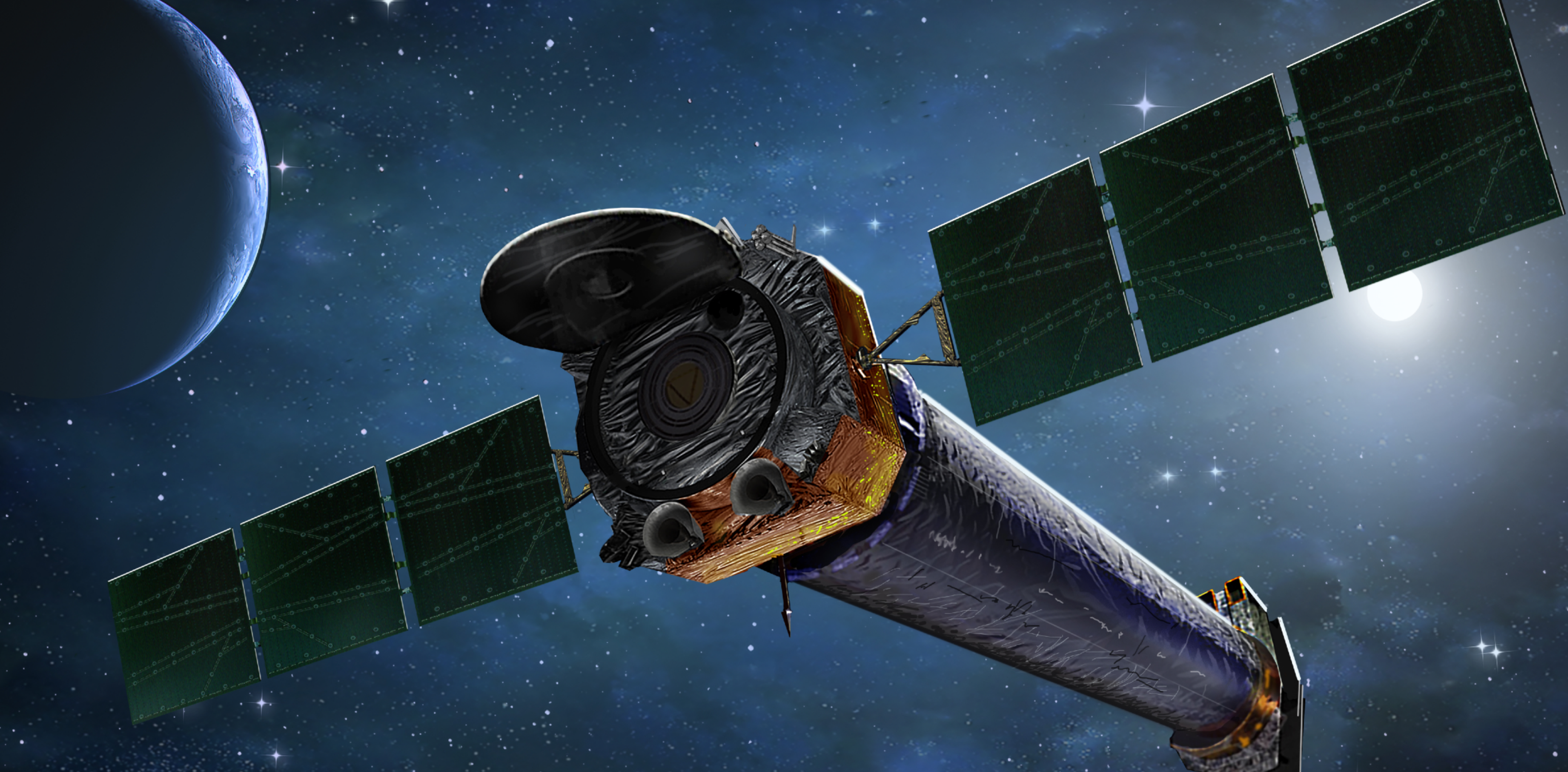
Chandra Calibration Status



Akos Bogdan

On behalf of the Chandra Calibration Team

17th IACHEC — May 12, 2025

ACIS Calibration

Over the past year the Chandra calibration team has investigated three primary aspects of ACIS calibration:

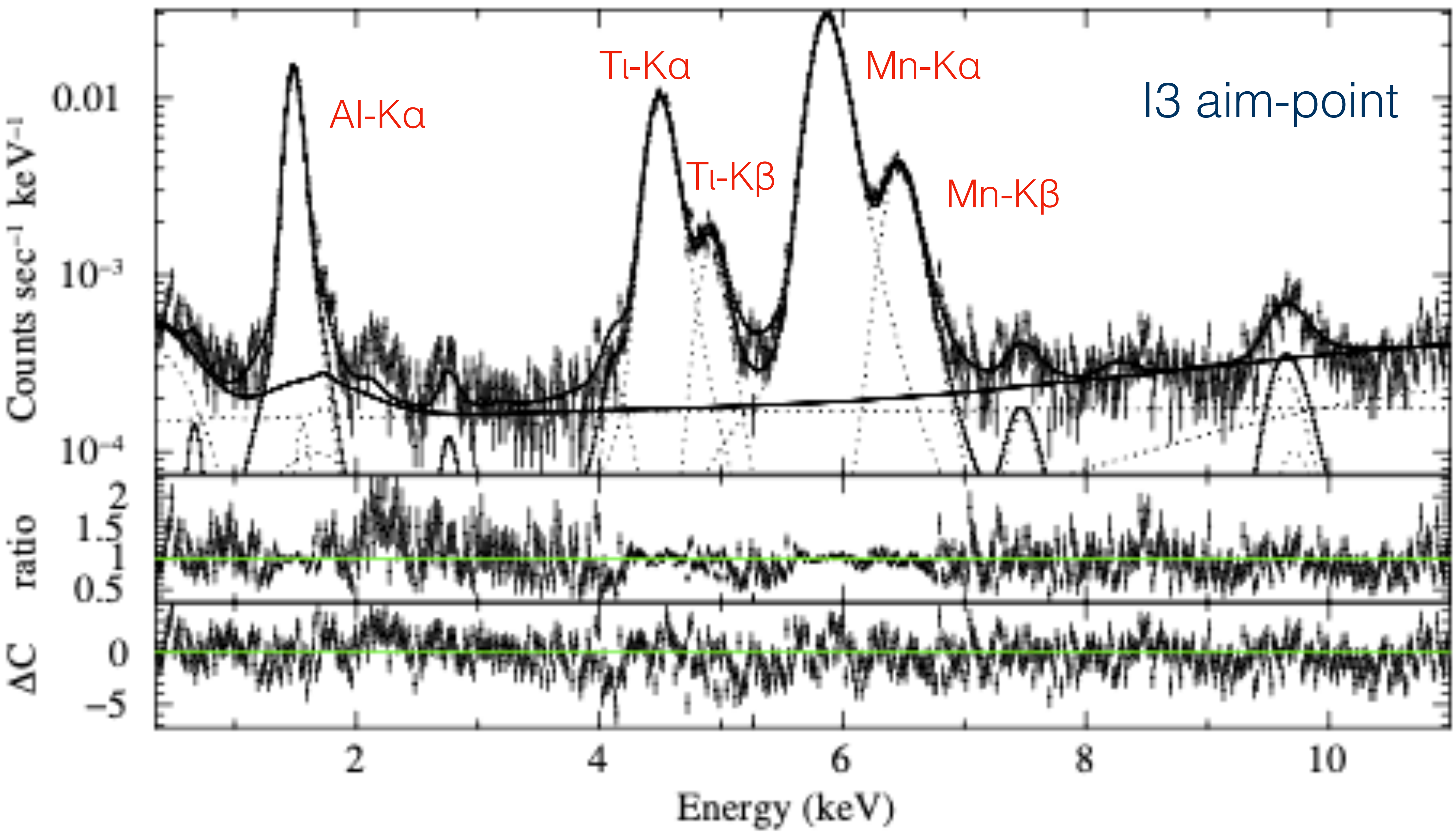
1. Releasing a set of temperature-dependent response files for ACIS
2. Investigating the recent gain loss in the ACIS CCDs (starting in mid-2022)
3. The continued monitoring of contamination building up on the ACIS filters

Generate ACIS response files at a range of focal plane temperatures (-120 C to -105 C) for the primary CCDs used for imaging (I0, I1, I2, I3, S2, and S3)

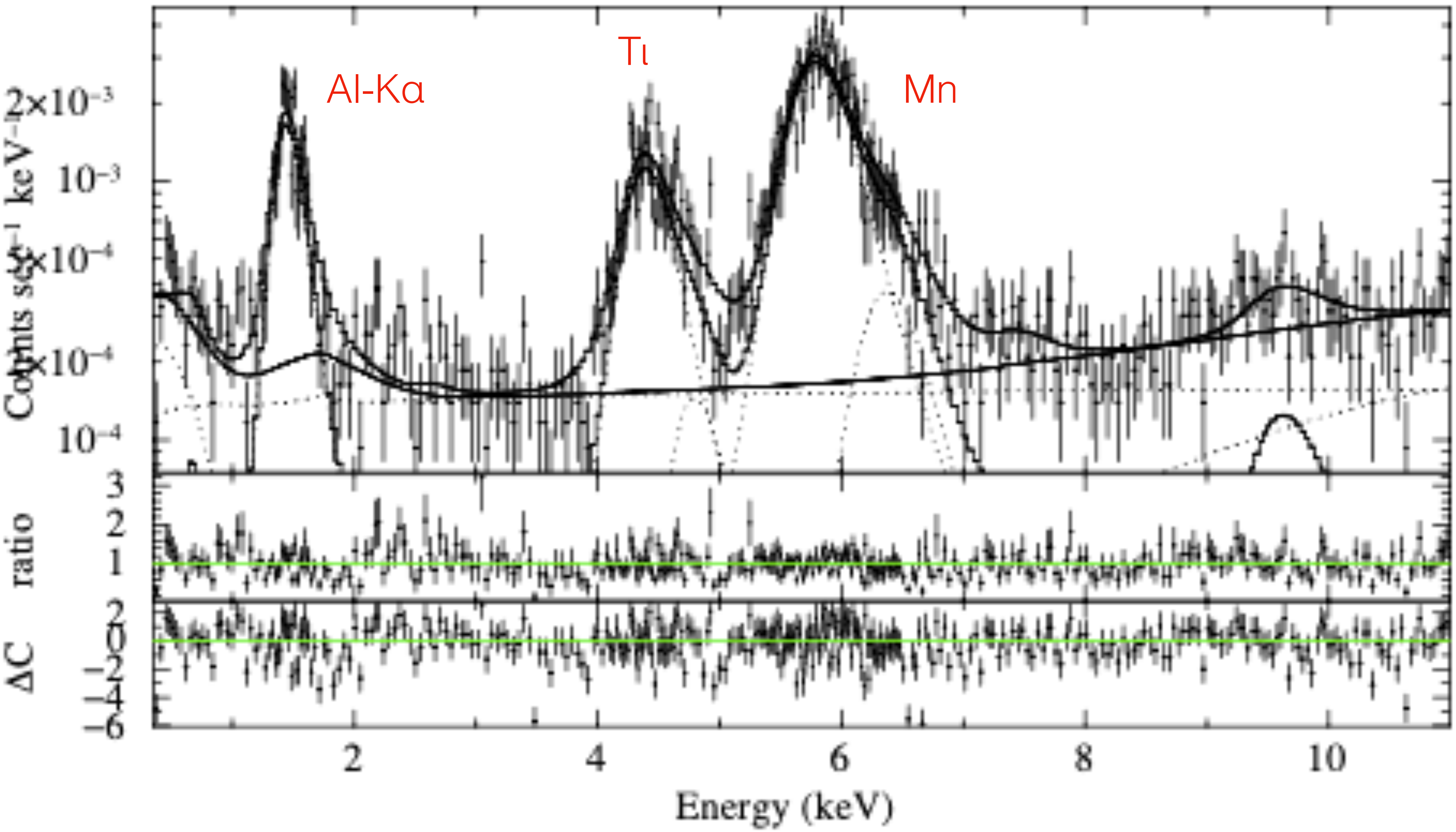
Procedure:

- Co-add ECS data from epochs 40-91 (approximately 13 years of data)
- Divide ECS data into 8 FP temperature intervals between -120 C and -105 C
- Bin data into 32 by 32 pixel regions
- Fit widths of Al, Ti, and Mn lines in each spatial region and temperature bin

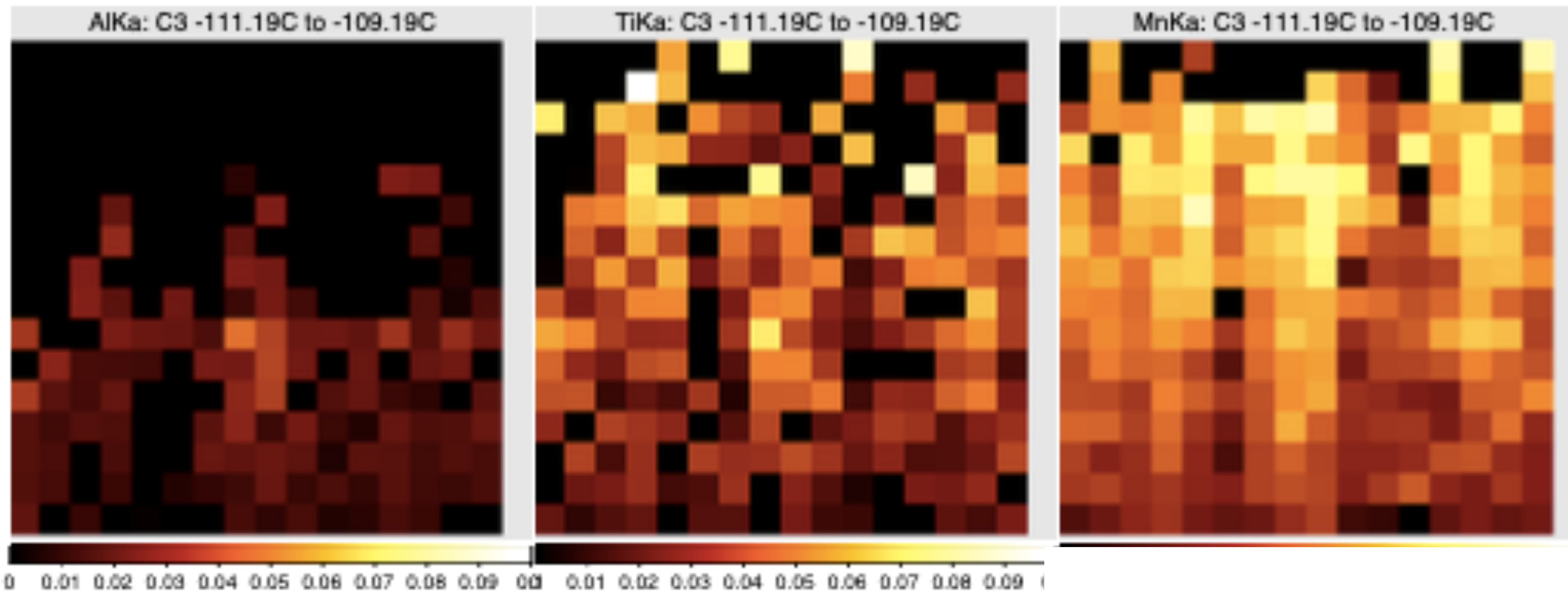
Example of cold ECS data (FP Temps -120 C to -119 C) fit with the newly released temperature-dependent response files



Example of warm ECS data (FP Temps -111 C to -109 C) fit with the newly released temperature-dependent response files



Residuals in the FWHM with the newly released temperature-dependent ACIS response files for warm ECS data (FP Temps -111 C to -109 C)

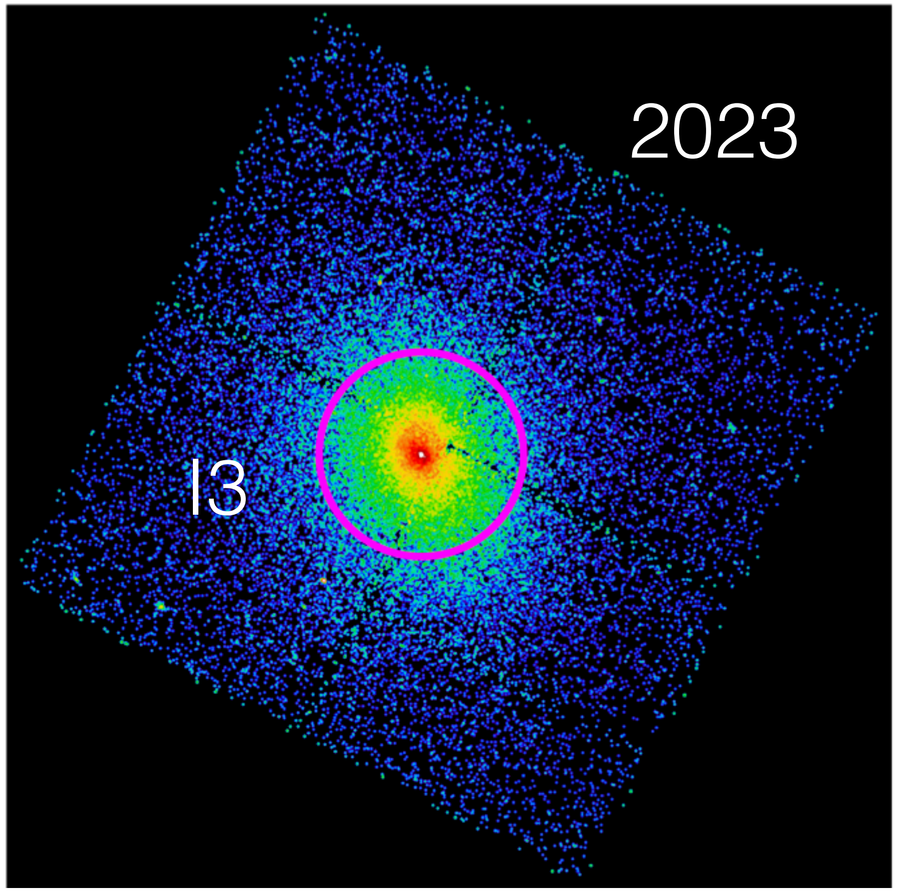


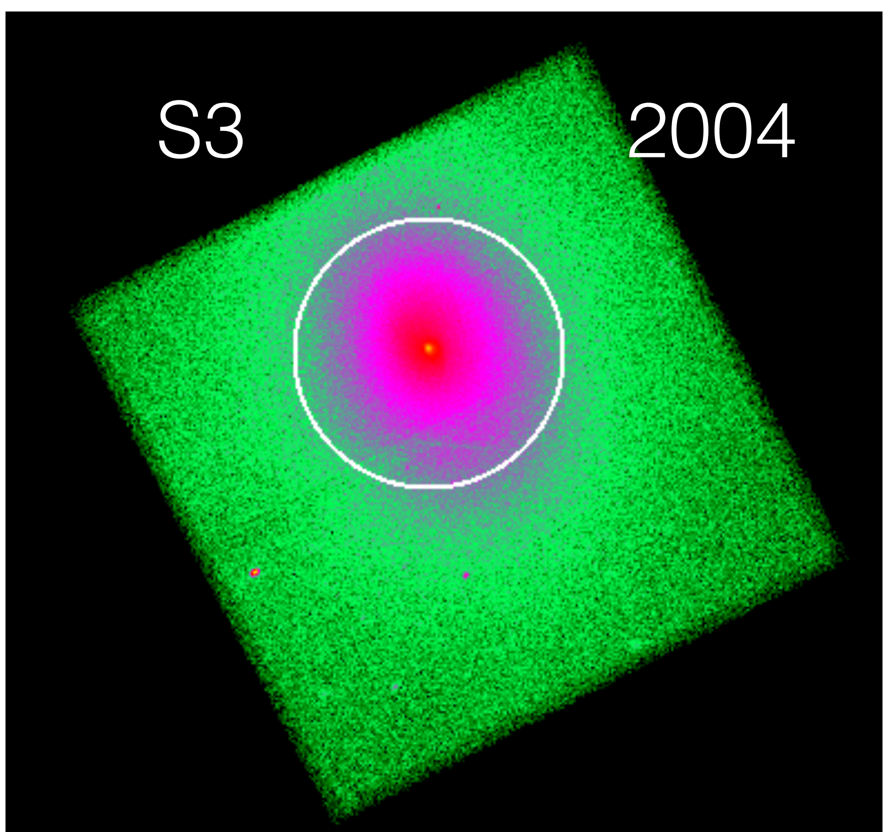
Line	max σ	σ / E_{line}
Al$K\alpha$	44 [eV]	3.0%
Ti$K\alpha$	97 [eV]	2.1%
Mn$K\alpha$	83 [eV]	1.4%

Residuals in the FWHM are less than 3% even at warm focal plane temperatures

Note: A set of 8 temperature-dependent response files (covering a focal plane temperature range from -120 C to -105 C) was released in CALDB 4.12.0 (January 2025) for the primary FI CCDs used for imaging (I0, I1, I2, I3, S2). Work continues on a set of temperature-dependent response files for S3.

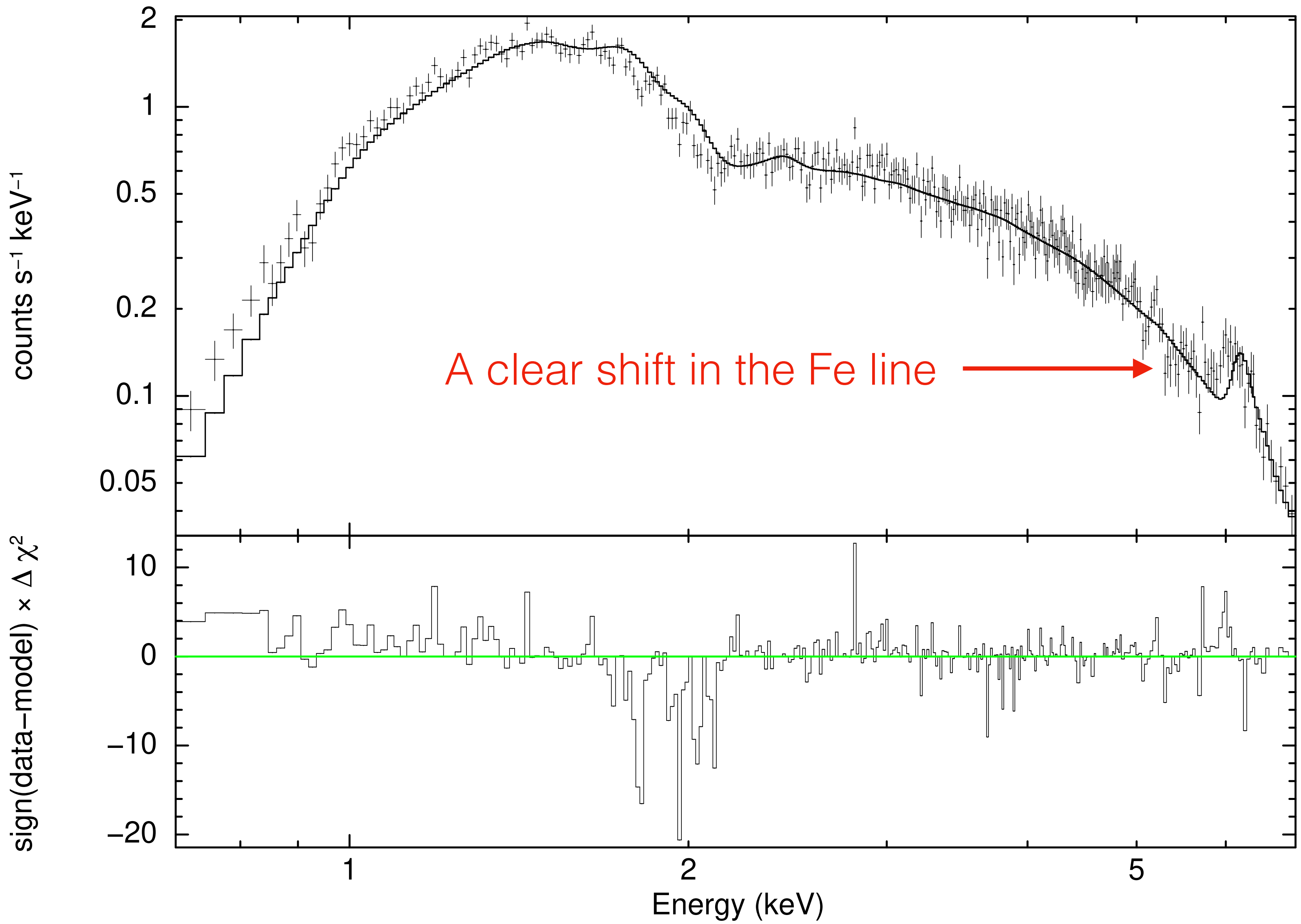
Investigating the recent gain loss in the ACIS CCDs



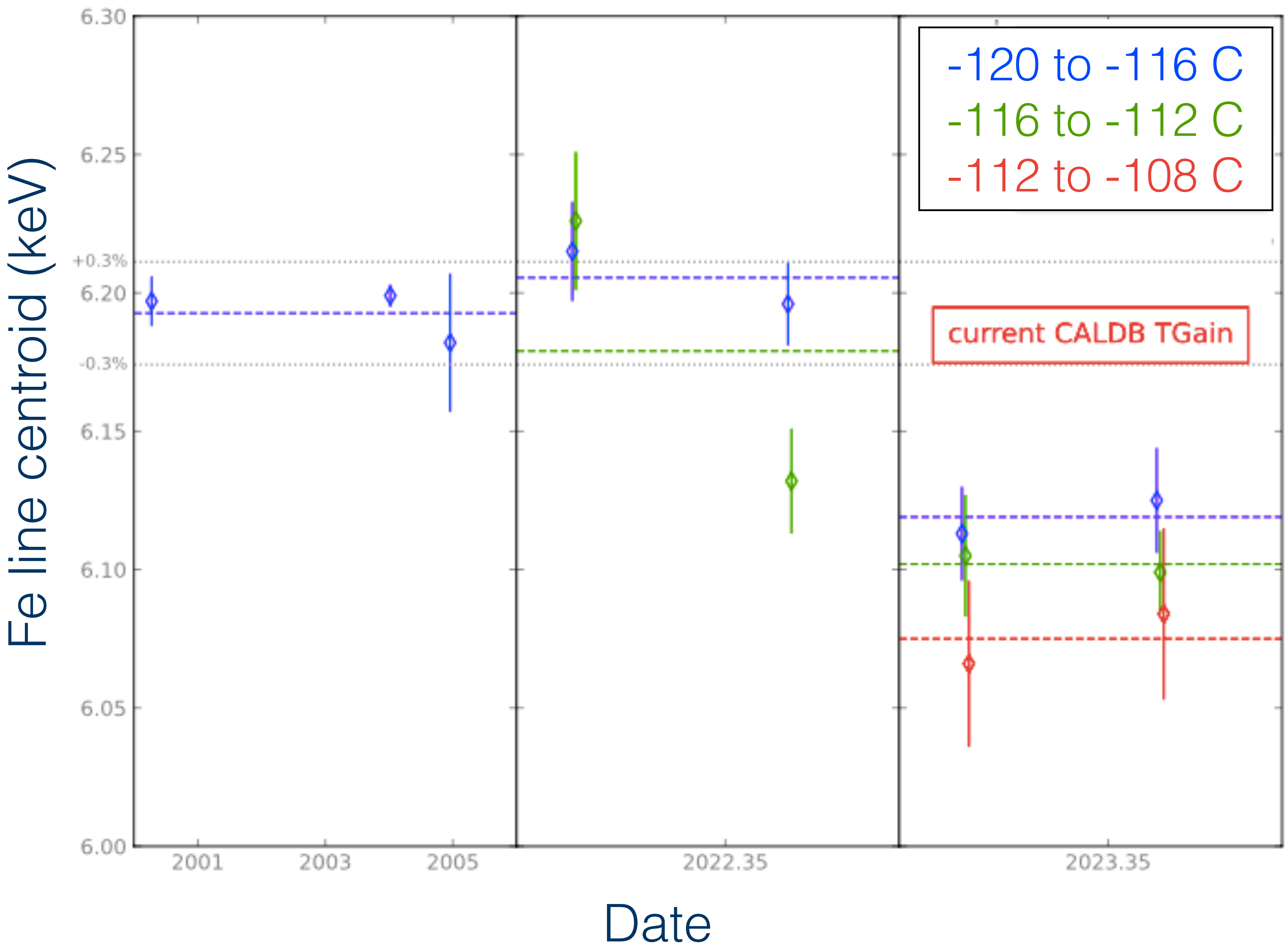


This issue was first reported in a 2023 ACIS-I observation of the rich cluster Abell 2029

Best-fit model to the early ACIS-S data shown with the 2023 ACIS-I data

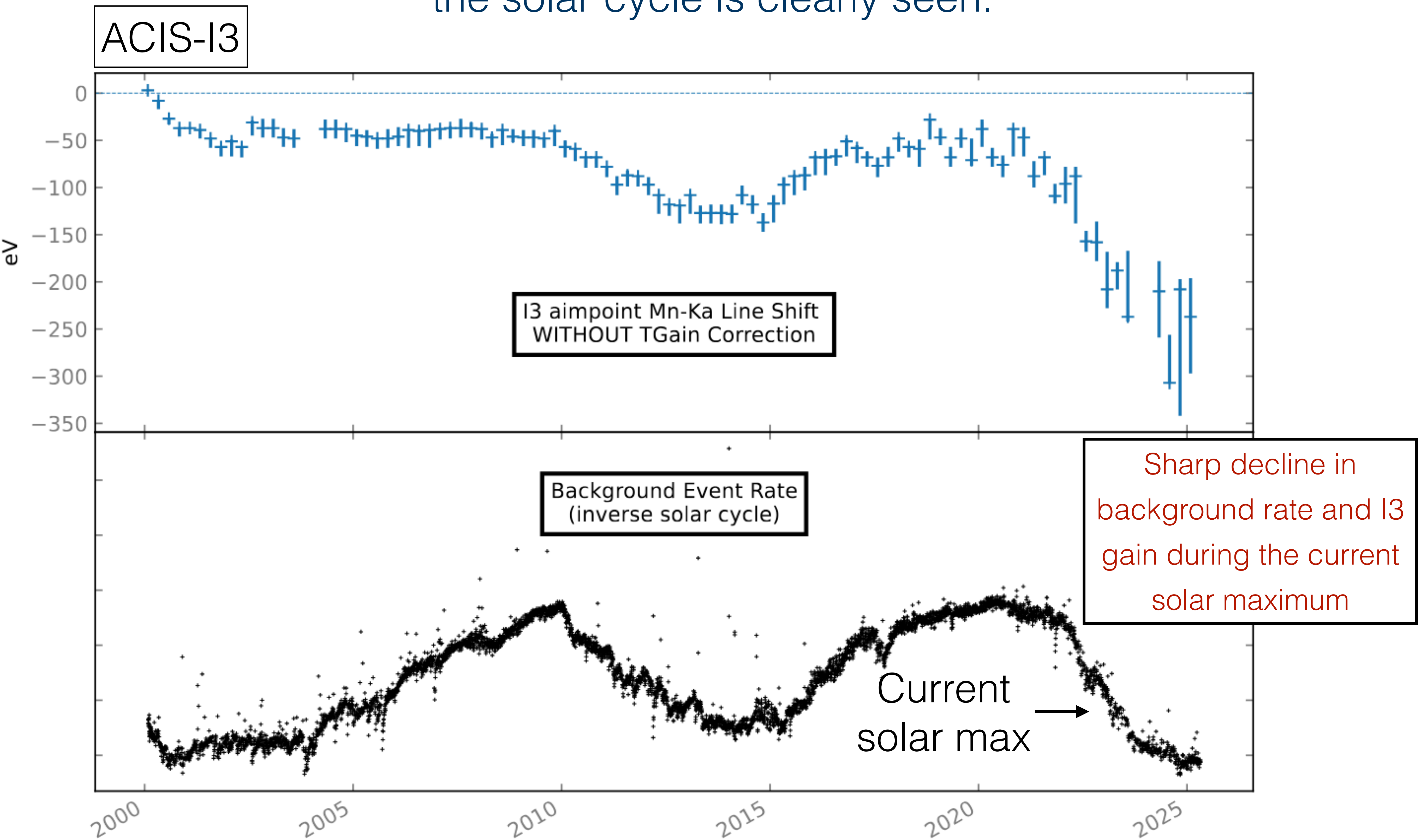


Time-dependent changes to the ACIS gain are mainly driven by the solar cycle and are calibrated through a set of time-tagged gain correction files (tgain) in the CALDB. During periods of high background, the traps in the CCDs are partially filled, which reduces the CTI. During periods of low background (as in the current solar maximum), the CTI increases and reduces the gain.

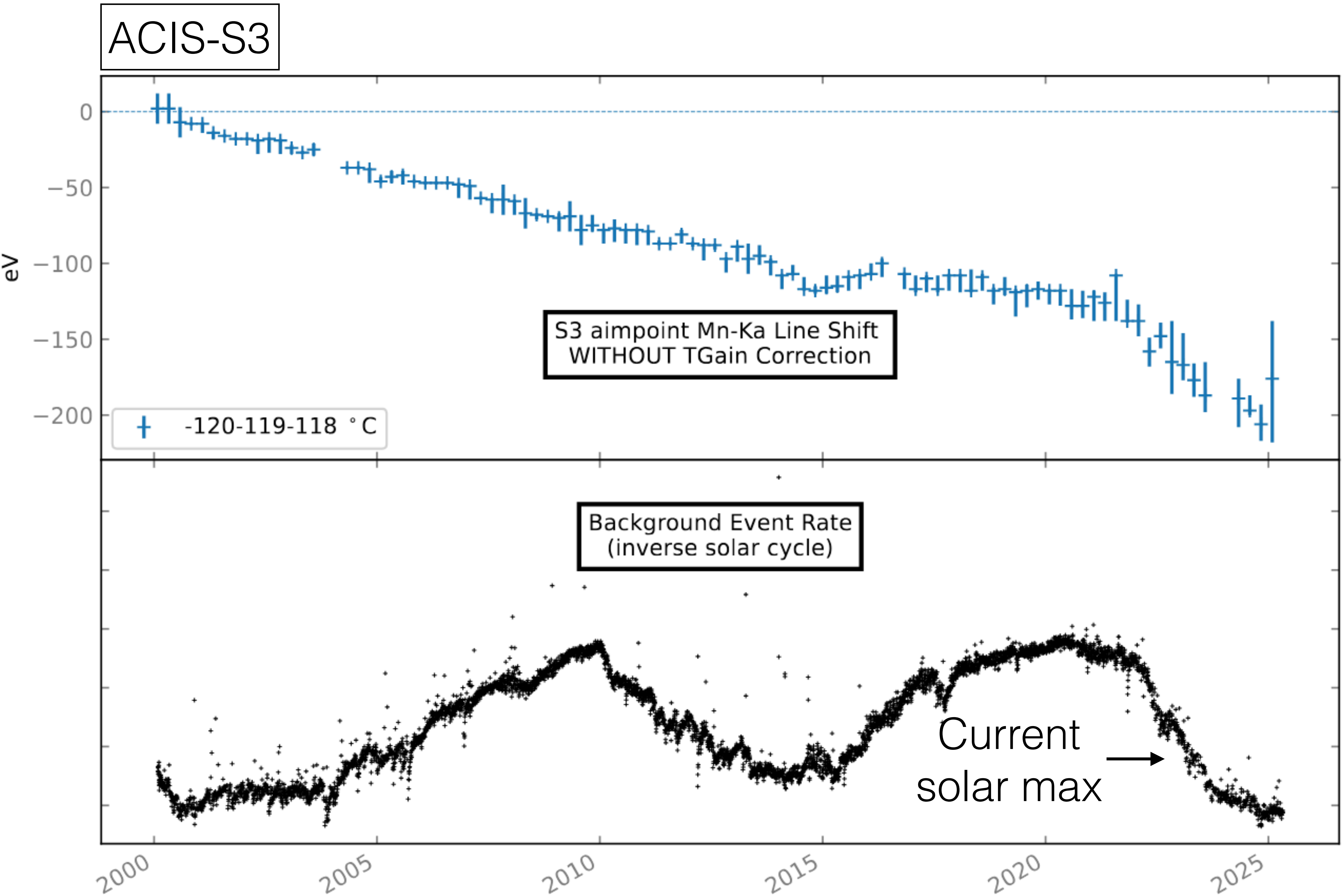


Decline in the Fe line centroid in A2029 observations beginning in 2022 using the current CALDB

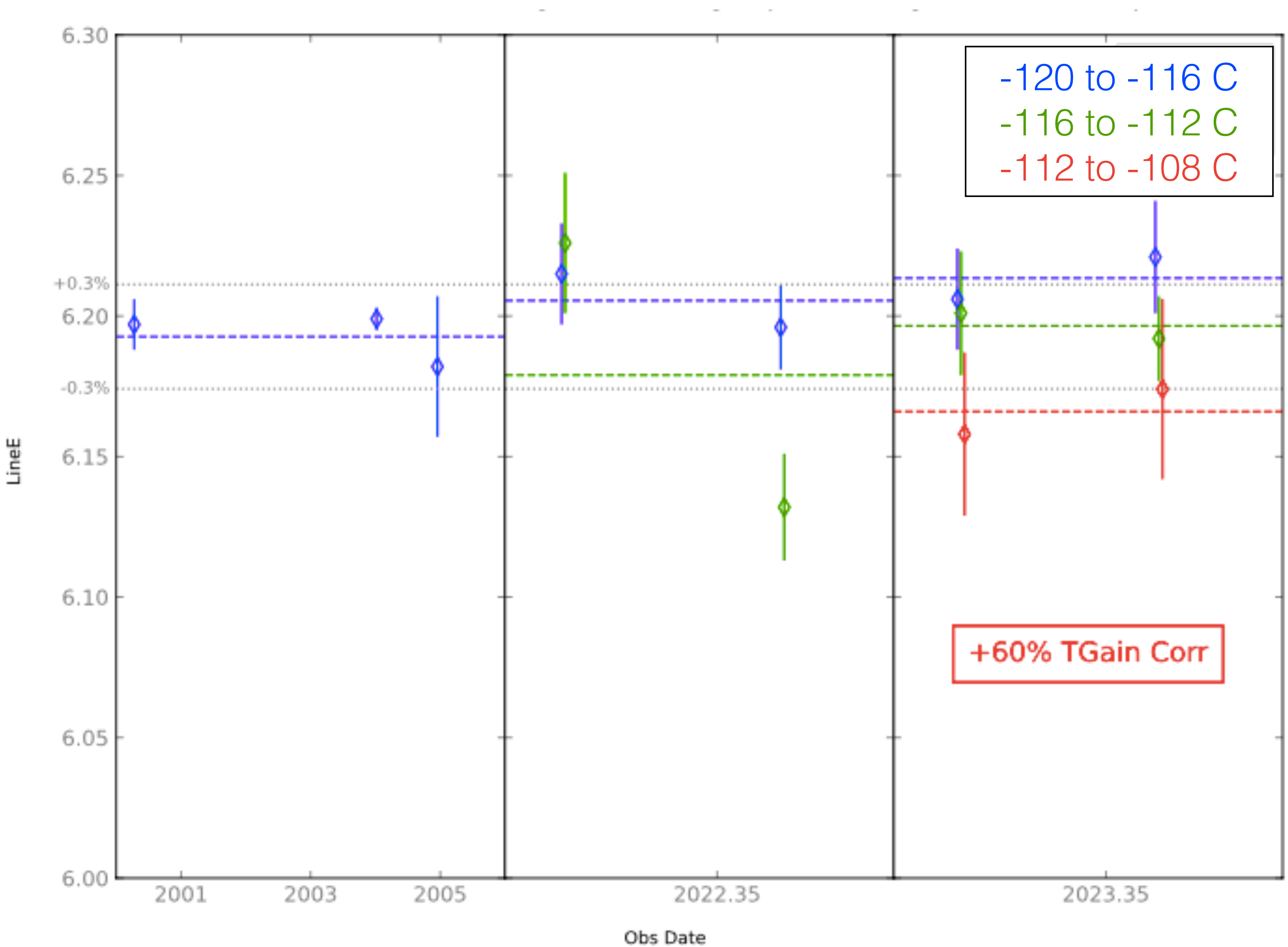
Comparison between the charged particle background rate and the I3 gain over the course of the Chandra mission. The effect of the solar cycle is clearly seen.



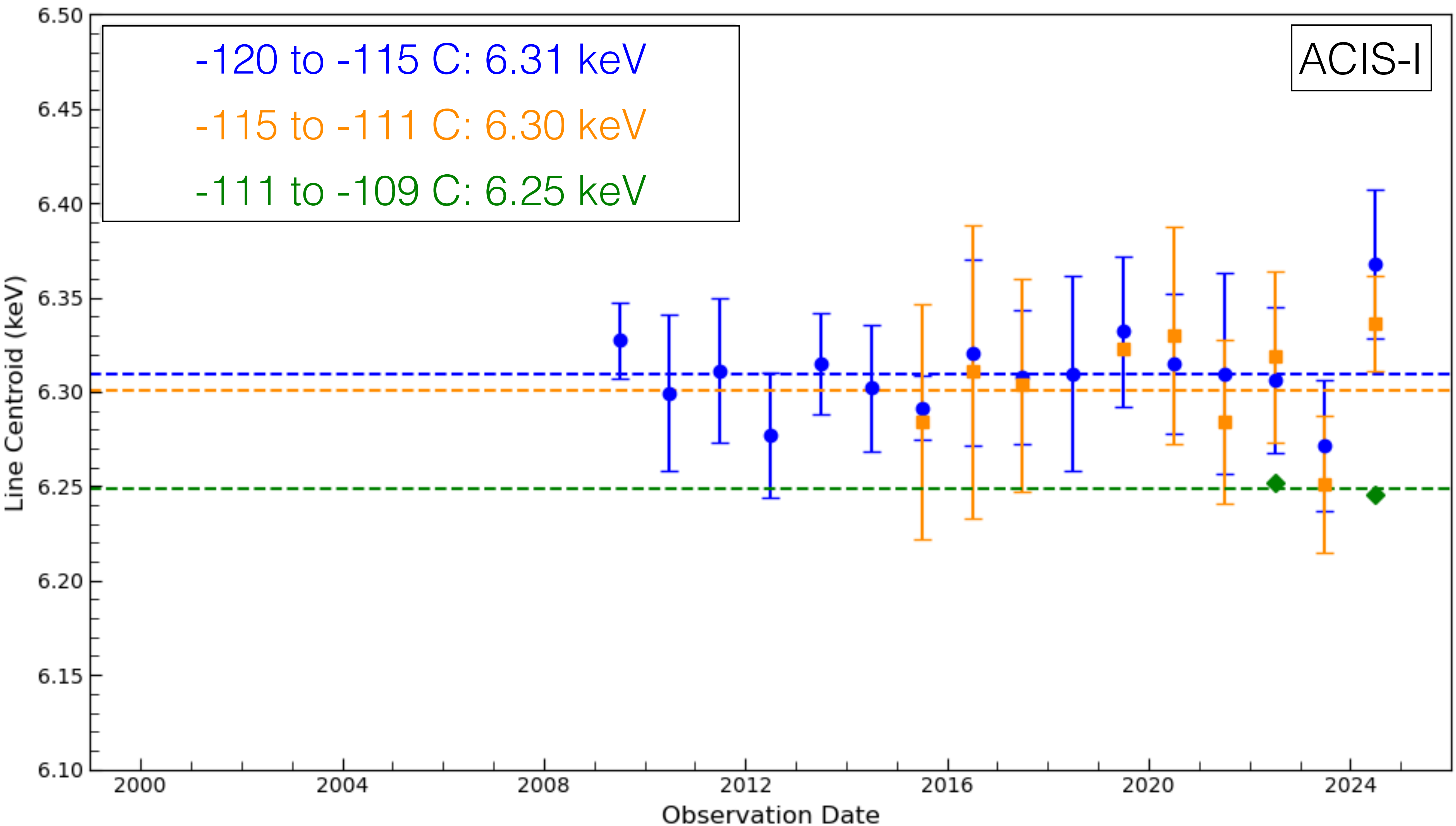
Recent Gain loss in the S3 CCD is about one-half of that for the I3 CCD



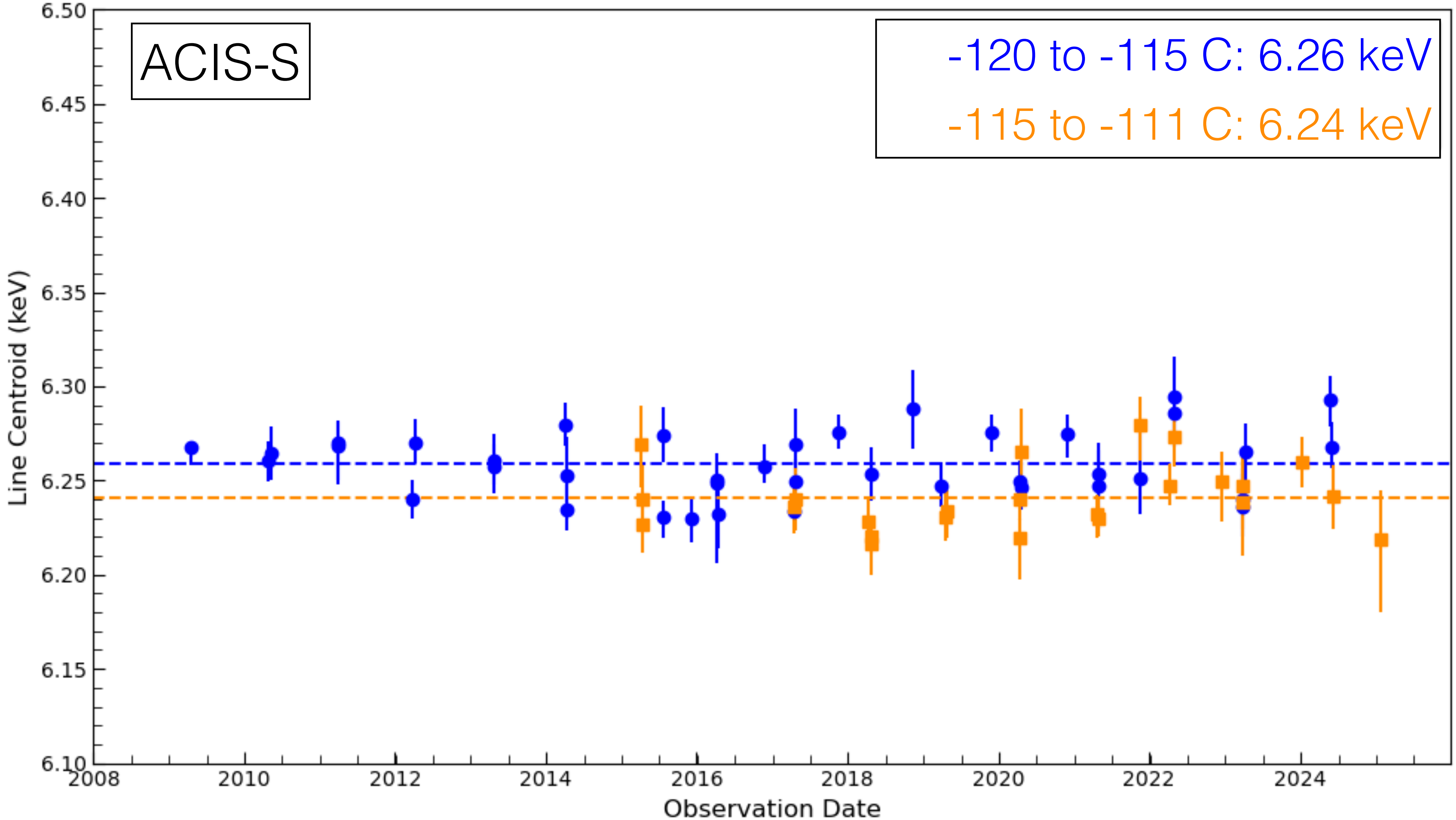
Corrected A2029 Fe line centroid using the latest test version of the tgain file



Raster scans of A1795 are completed on ACIS-I and S3 every year, primarily to monitor the build-up of contamination on the ACIS filters. The Fe line in the A1795 spectrum can also be used to monitor the ACIS gain. This plot shows the Fe line centroid in the ACIS-I observations of A1795 using the latest test version of the tgain file.

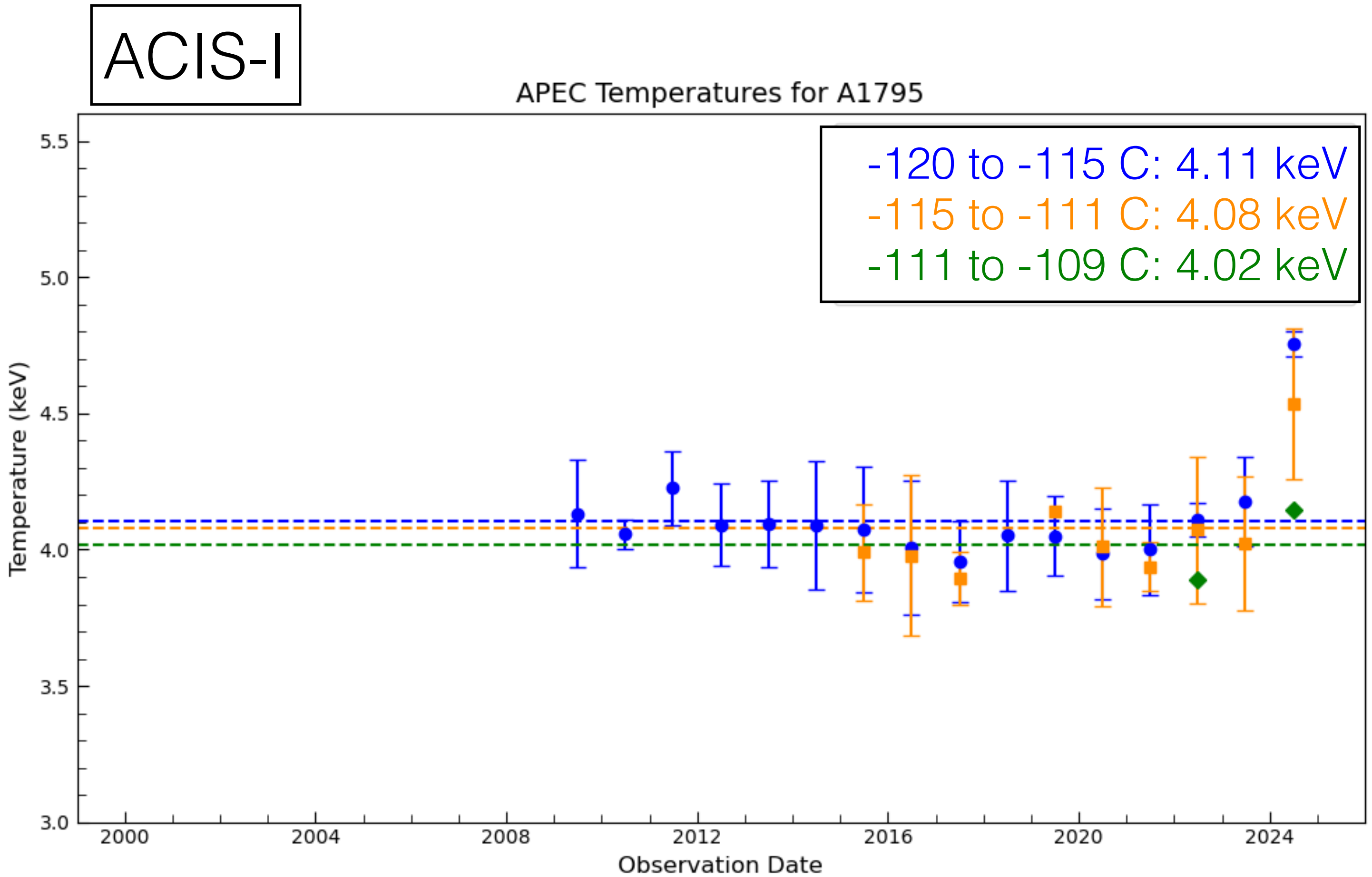


The Fe line centroid in the ACIS-S observations of A1795 using the latest test version of the tgain file.



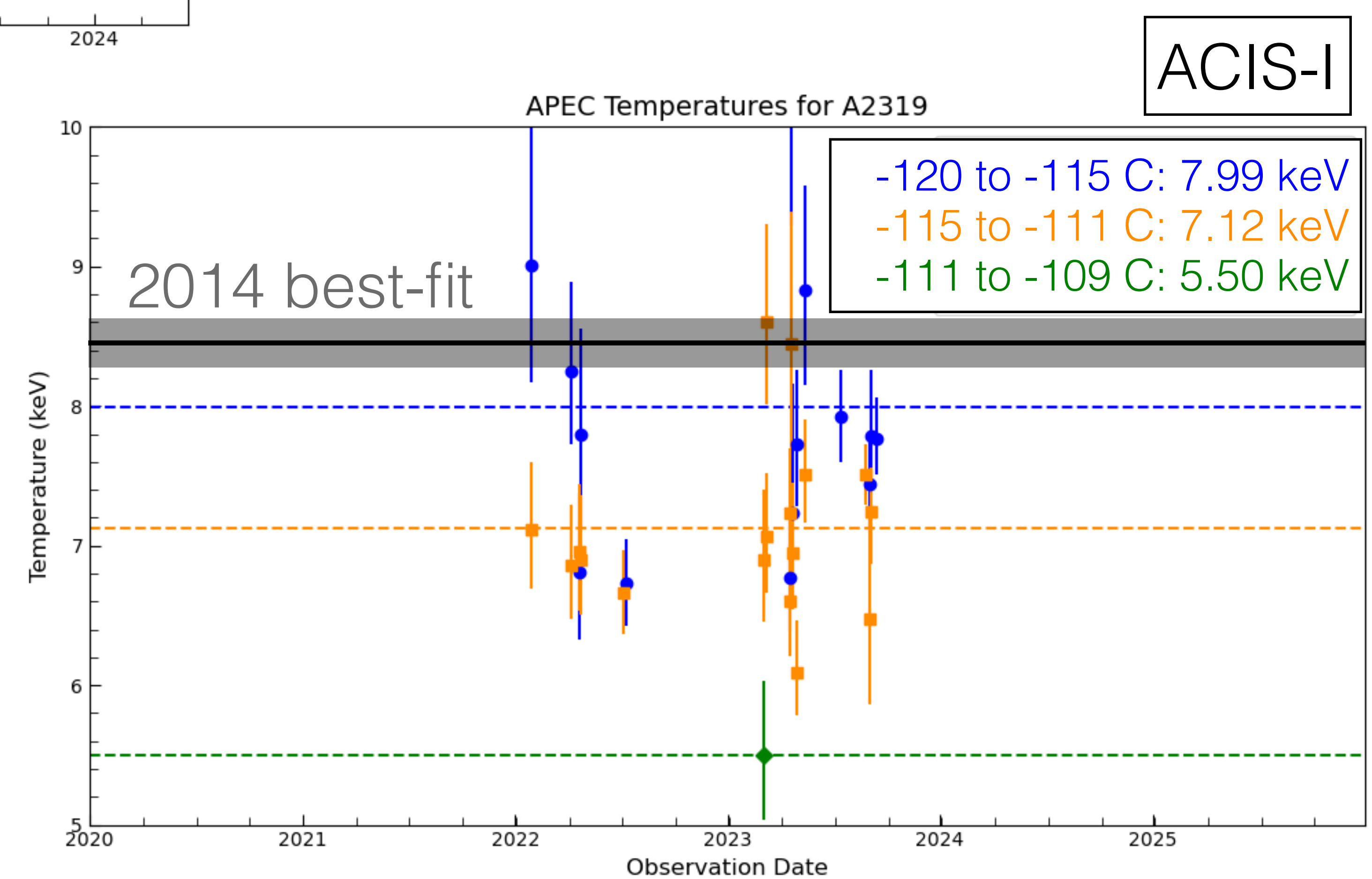
The latest test version of the tgain file provides accurate gain calibration at the Fe line

However, there are still some issues regarding the derived spectral parameters when fitting broad band spectra.



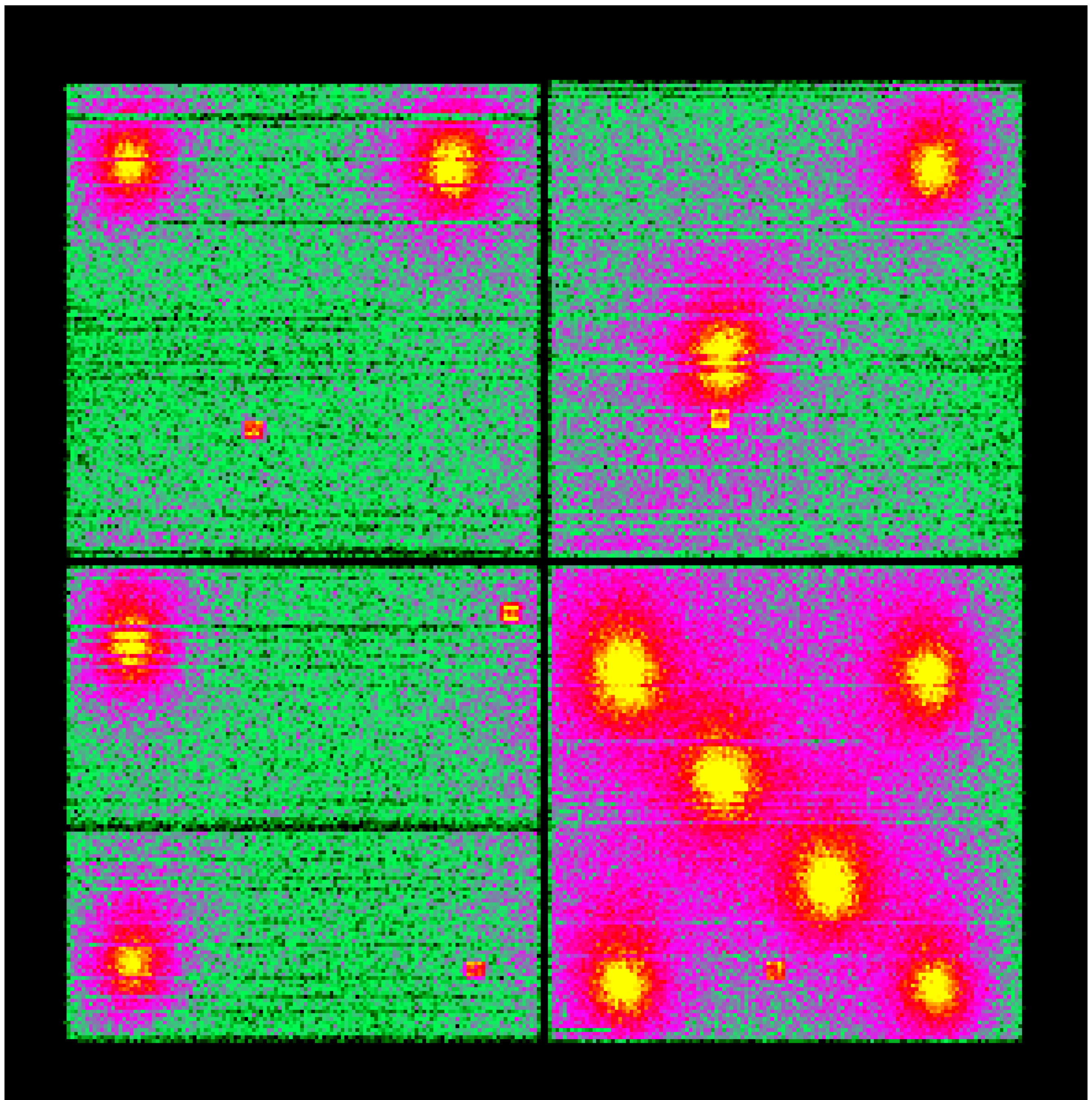
A1795: Moderate temperate cluster provides good fits

A2319: Hot cluster provides too low temperatures



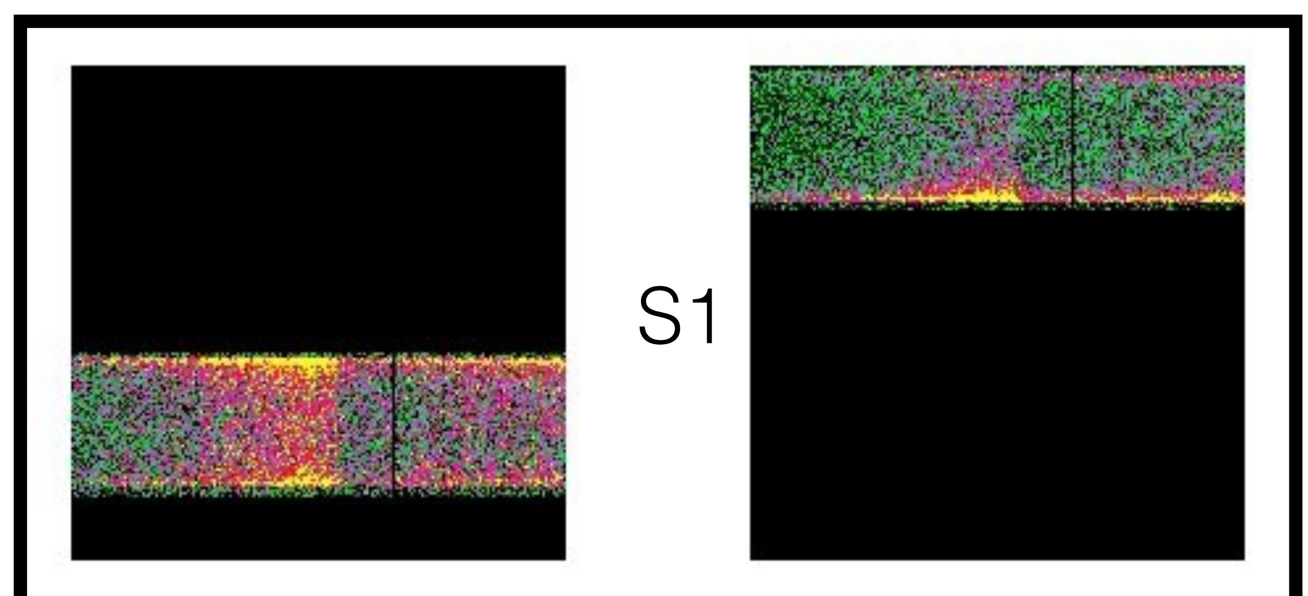
Monitoring the ACIS Contamination

A1795 Raster Scan on ACIS-I

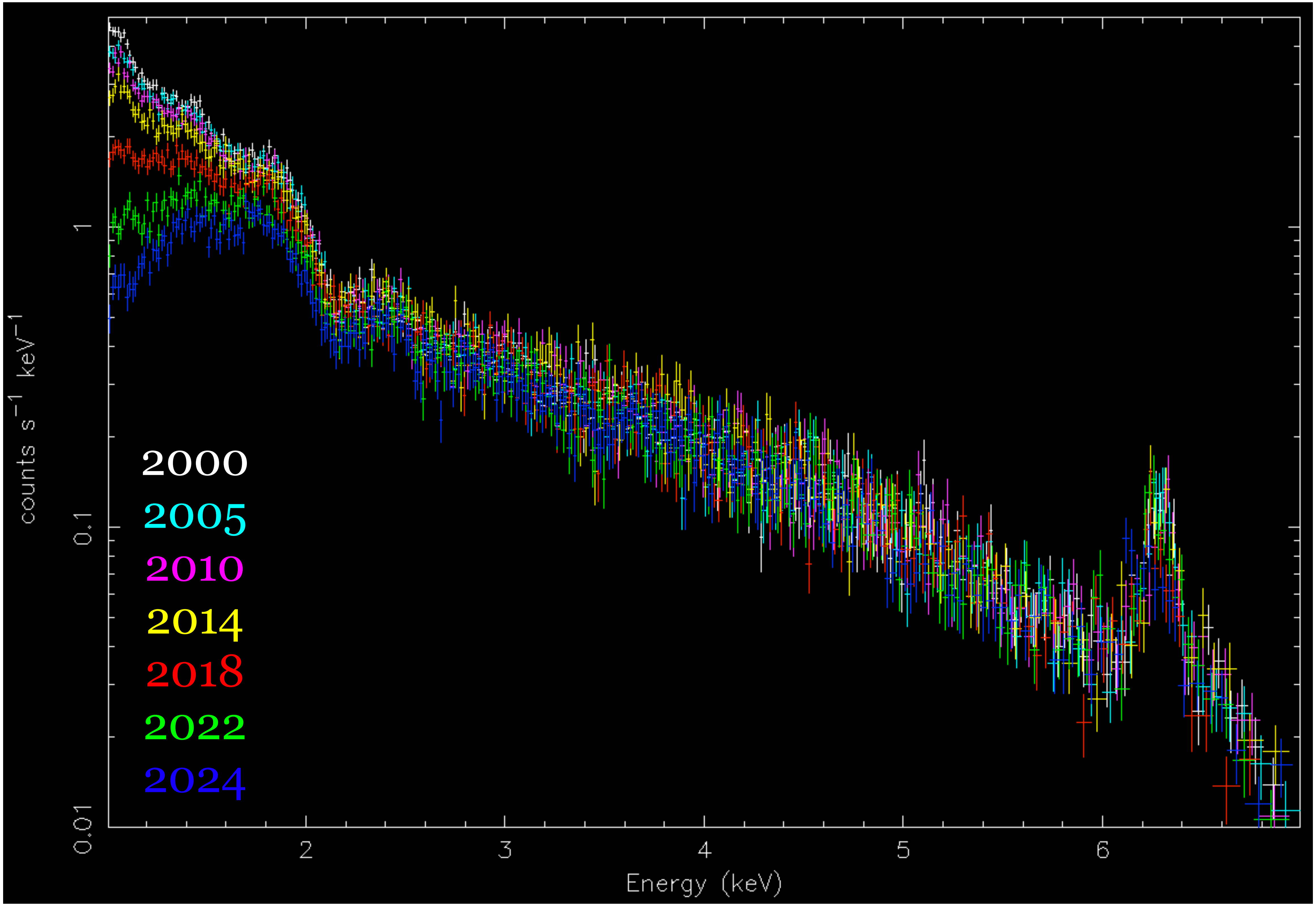


E0102-72

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

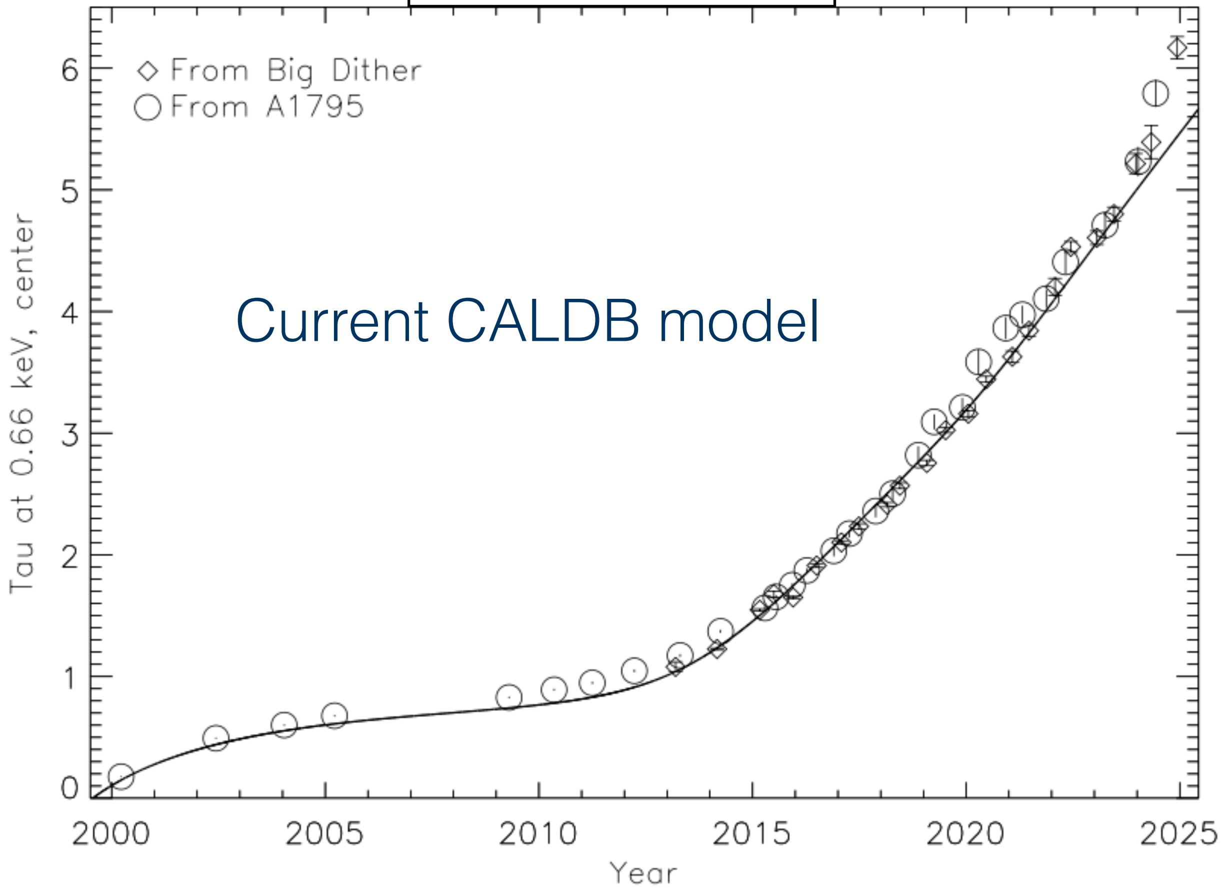


ACIS-S3 spectra of Abell 1795



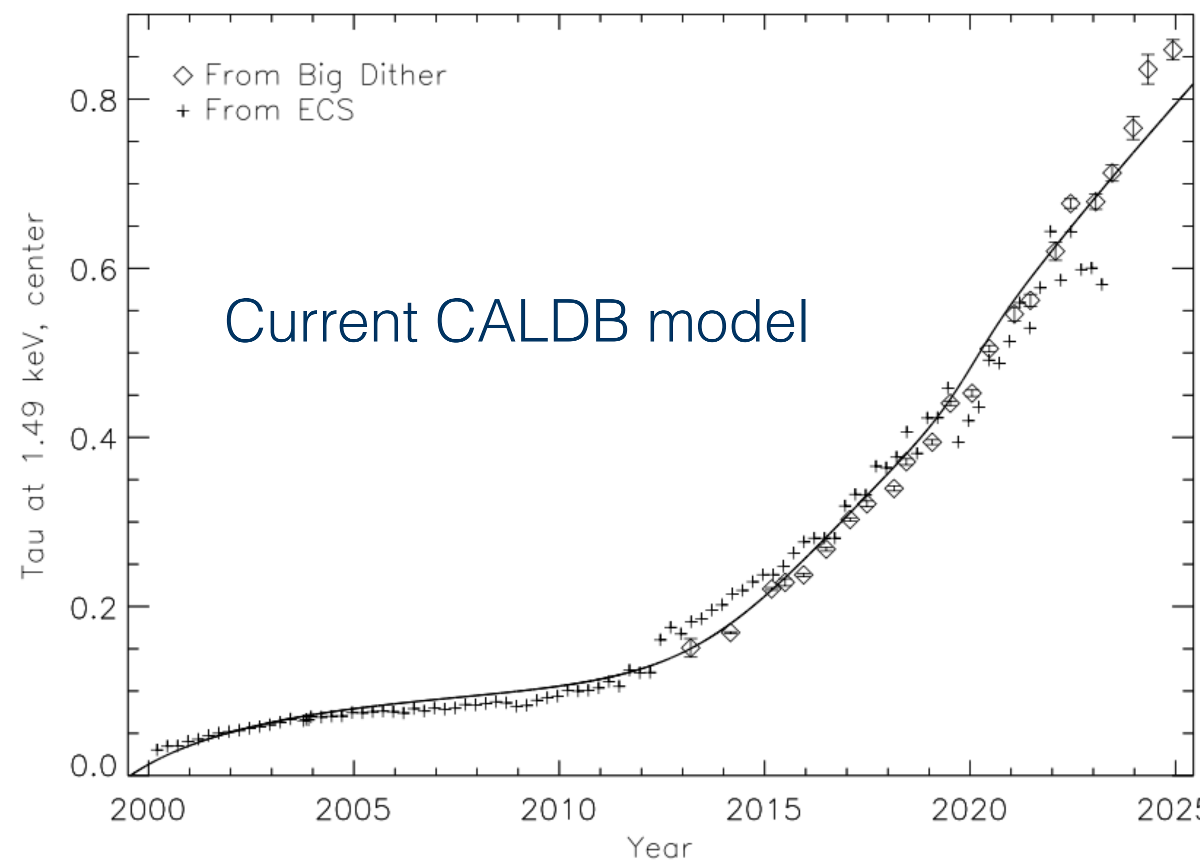
Optical depth of the contaminant at 0.66 and 1.49 keV on the ACIS-S array as measured from “Big Dither” LETG/ACIS-S observations of Mkn 421, imaging observations of A1795, and the Al line in the ECS

E=0.66 keV



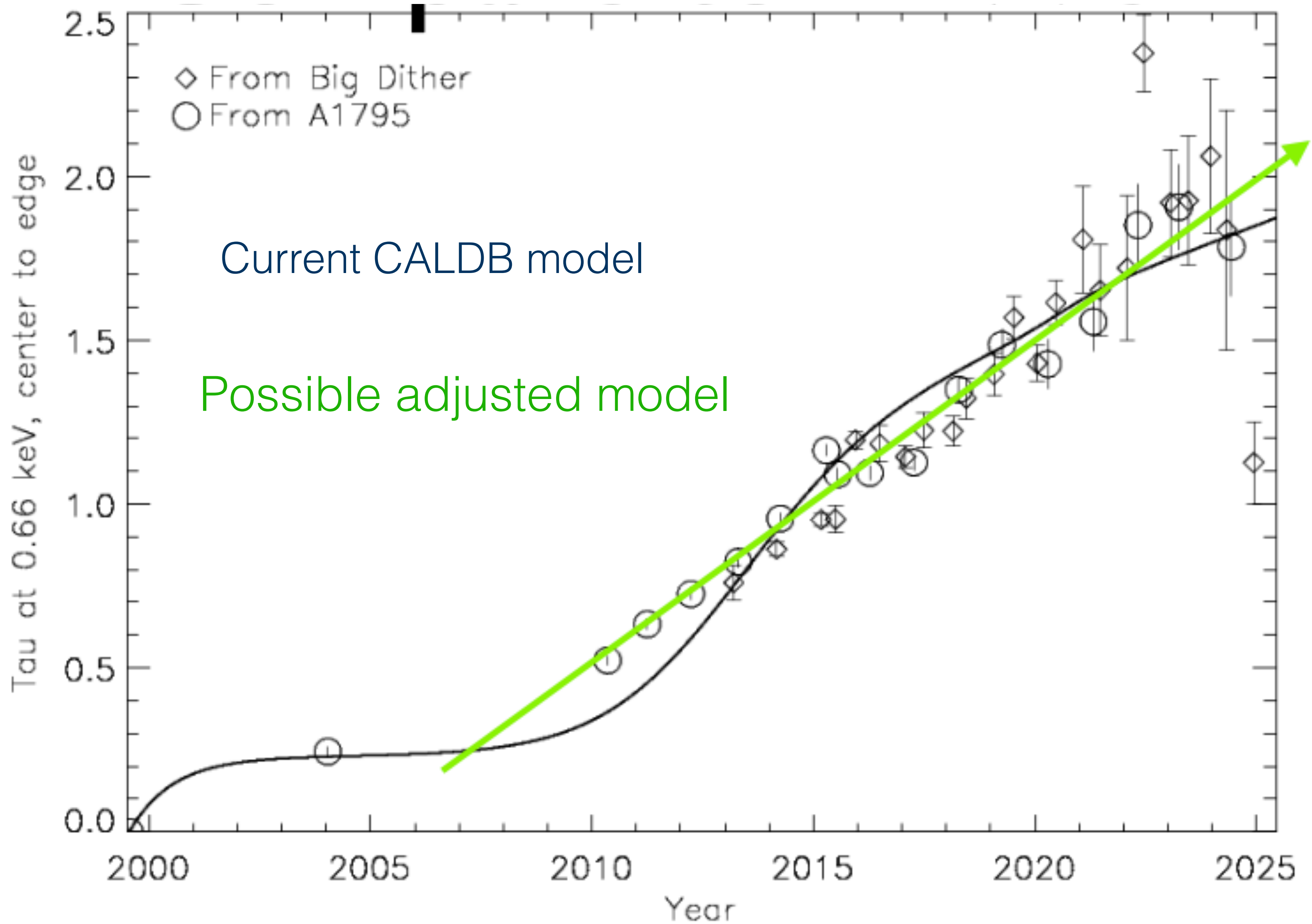
~0.5 optical depth difference between the data and the CALDB model at 0.66 keV in recent data

E=1.49 keV



~0.05 optical depth difference between the data and the CALDB model at 1.49 keV in recent data

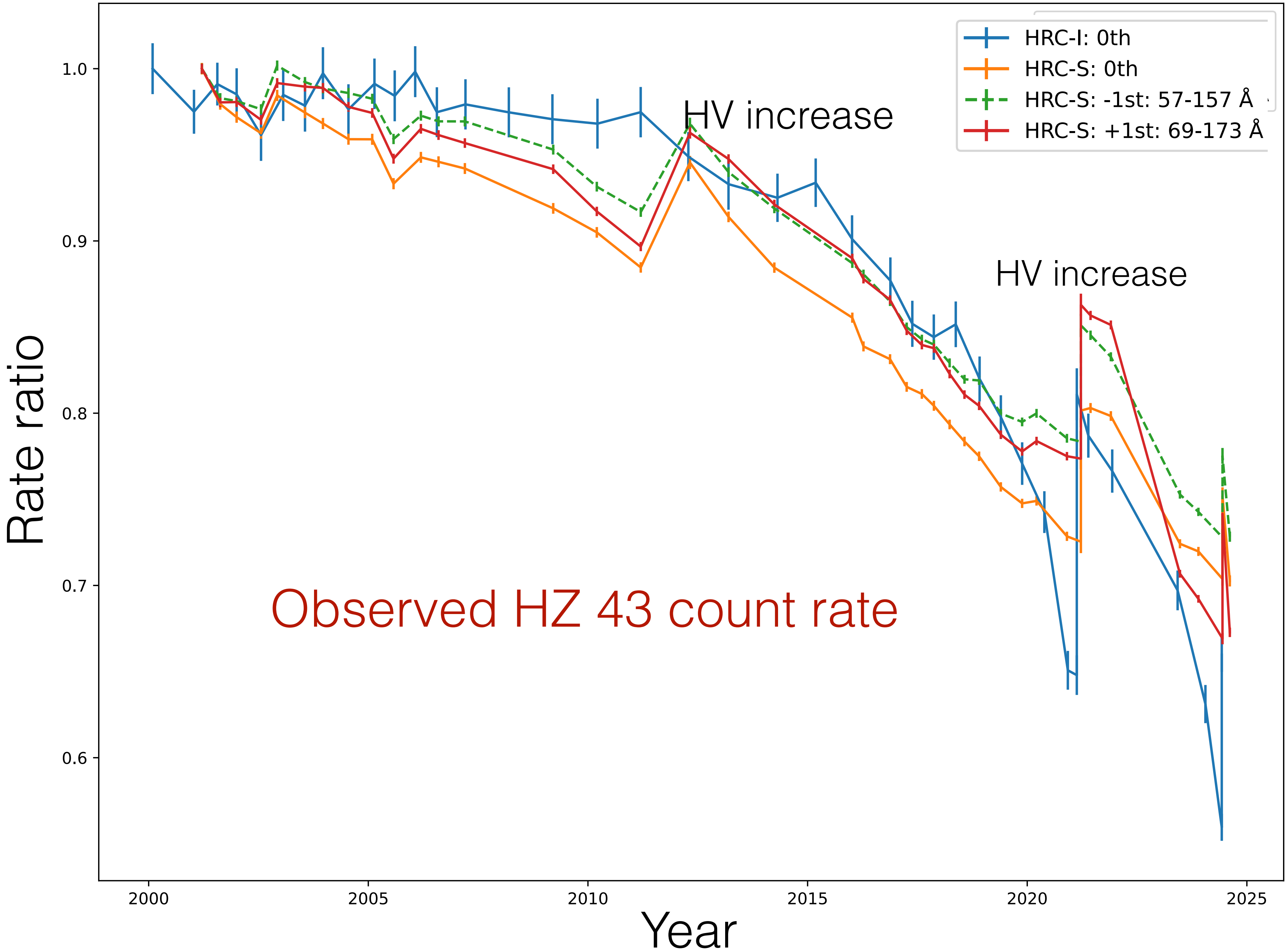
Difference in the optical depth between the edge and middle of the ACIS-S array at 0.66 keV



Note: These results indicate indicate that some modifications to the current ACIS contamination model are required regarding the build-up of contamination over the past ~2 years.

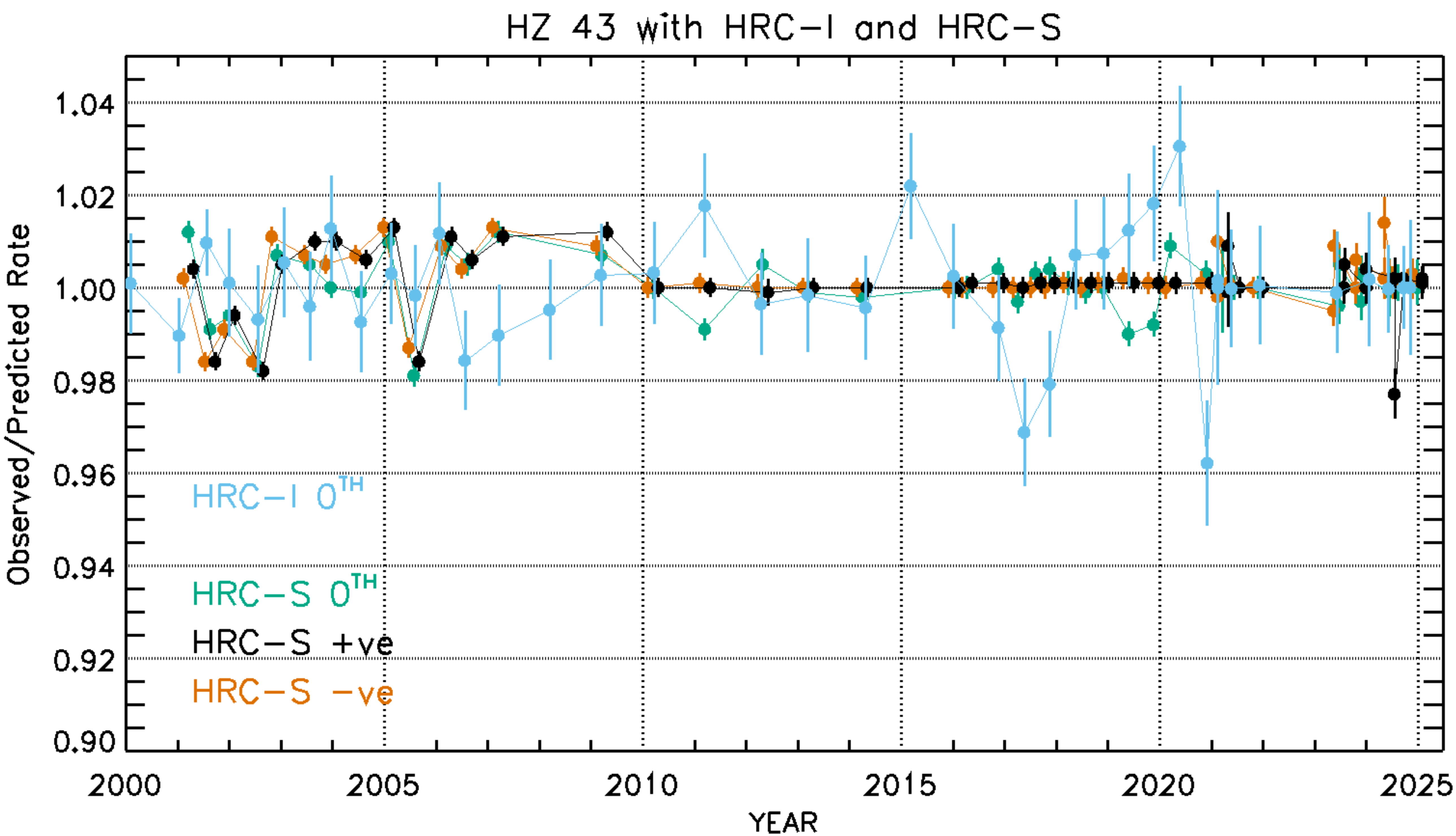
HRC Calibration

The QE of the HRC detectors has declined by ~2% per year over the course of the Chandra mission, which requires periodic increases in the operating high voltage of the HRC detectors. The latest increase in the HV occurred in Sep. 2024. The low energy QE of the HRC detectors has been monitored with LETG observations of HZ 43

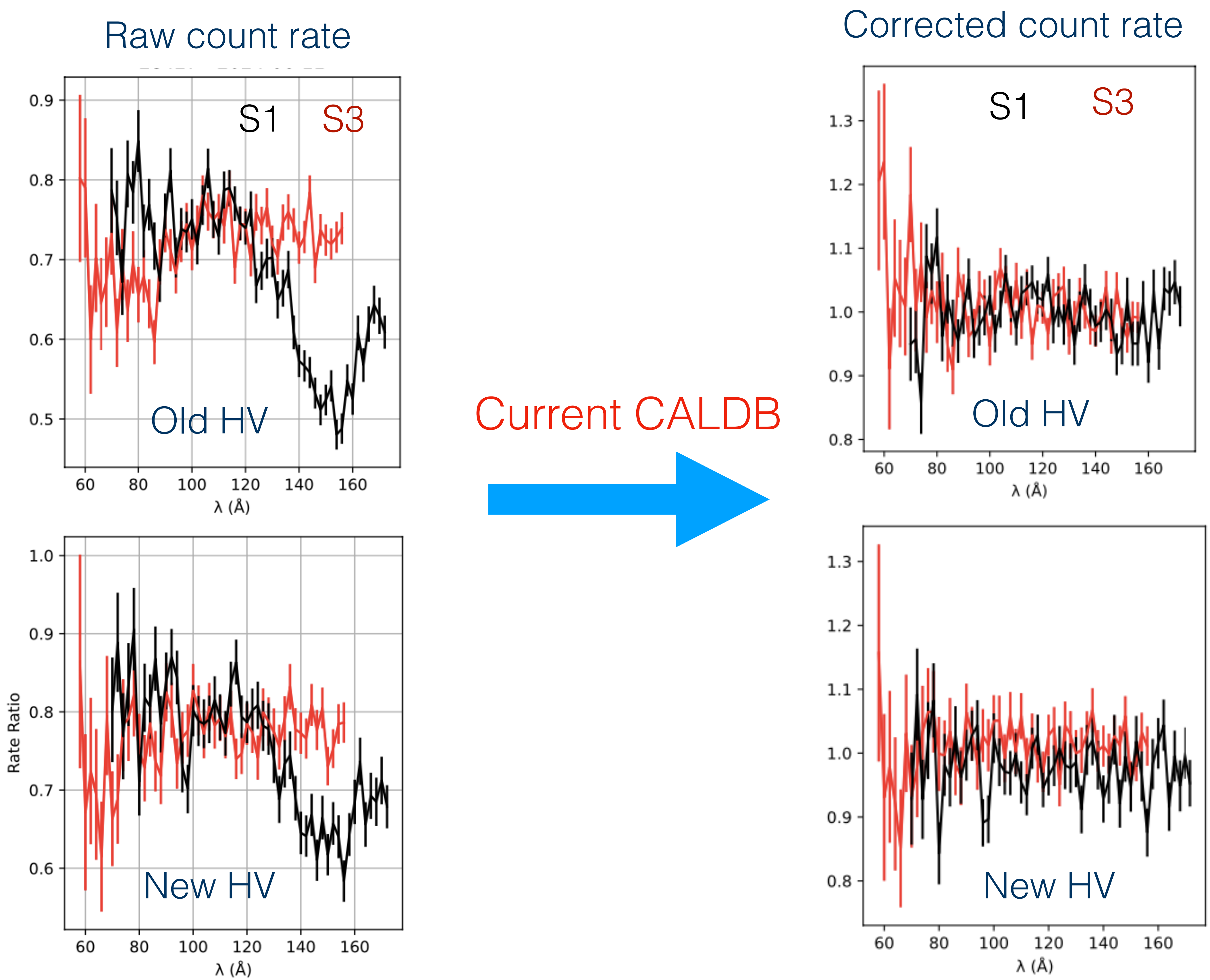


HV increase
(Sep. 20, 2024)

Corrected (with the current CALDB) LETG/HRC-I and LETG/HRC-S HZ43 count rates

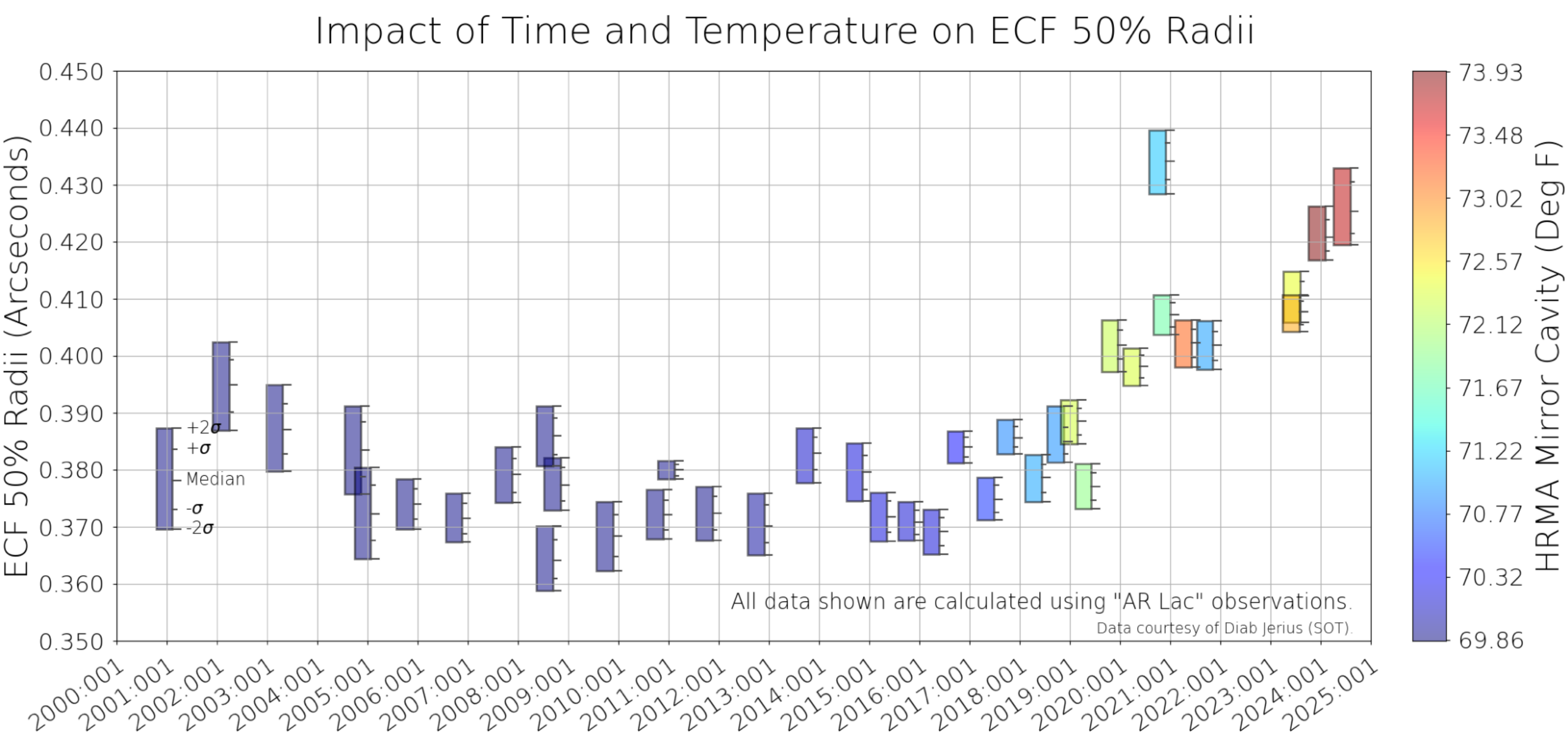


Dispersed LETG spectra of HZ43 on the outer plates of the HRC-S



HRMA PSF monitoring

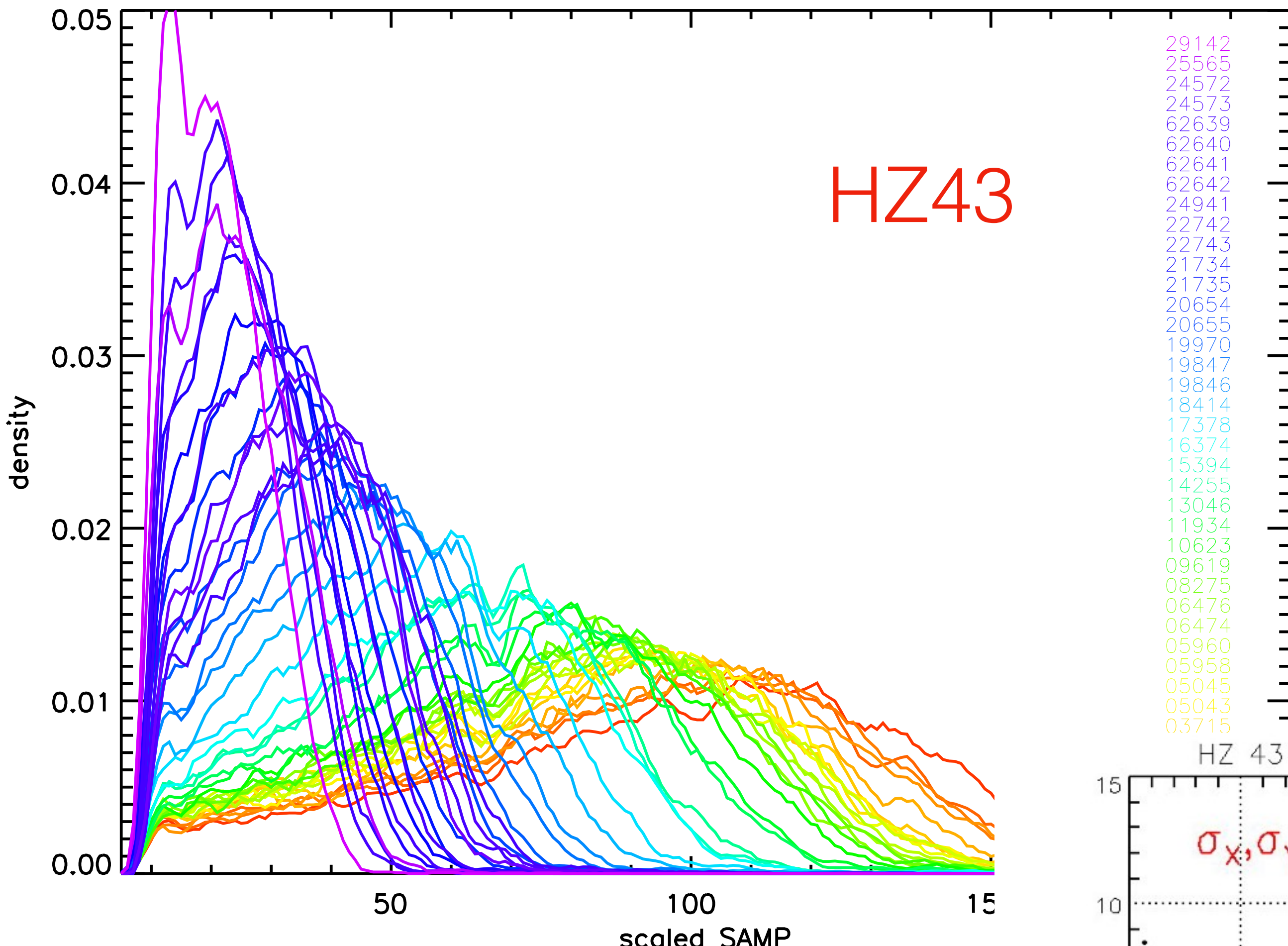
AR Lac has been observed at least once per year on-axis with the HRC-I since launch.



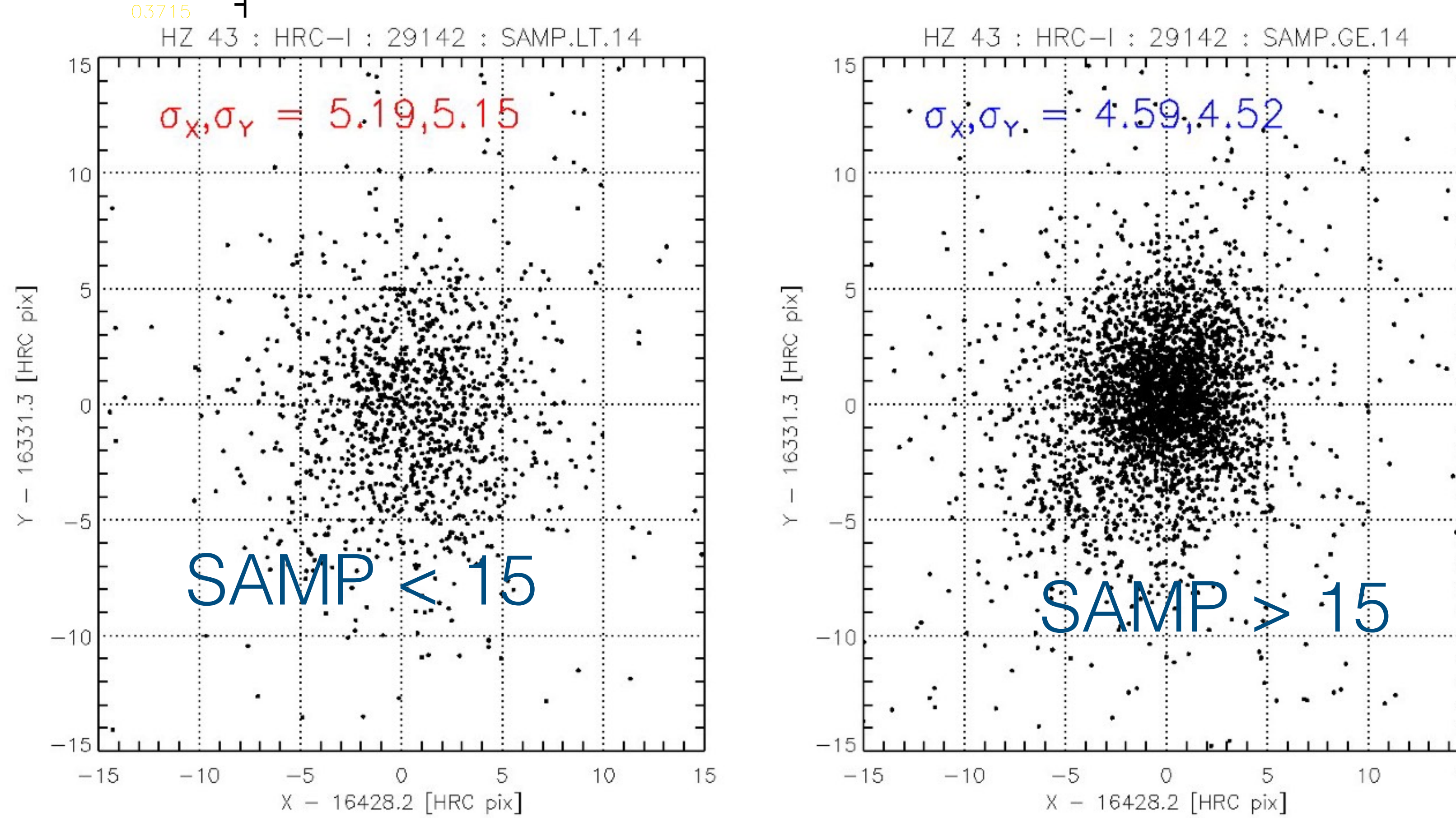
A slight increase of 0.01” per year over the past four years.

Broadening of the PSF due to low Pulse Height Events

- Steady decline in the mean SAMP with time
- Recent observations show a low SAMP peak



Low SAMP events have a broader PSF



Note: This work indicates that the declining HRC gain is partially responsible for the broadening of the PSF.

Future Calibration Plans

ACIS

- Release a set of temperature-dependent S3 response files
- Release updated tgain files for data taken in the 2023-2025 timeframe.
- Release an updated ACIS contamination model.
- Generate a stet of ACIS blank sky observations by co-adding data accumulated data over the past four years.

HRC

- Continue to Monitor the QE and gain of the HRC-I and HRC-S and release updated files as needed.

Optics

- Continue to monitor the PSF
- Improve the statistics in the ACIS empirical PSF