Calibration: Goals, Priorities, and Plans

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On behalf of the Chandra Calibration Team

Chandra Users Committee meeting — Nov 10, 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 gain loss in the ACIS CCDs observed since mid-2022
3. Monitoring the buildup of the molecular contamination on the ACIS filters and developing a new contamination model

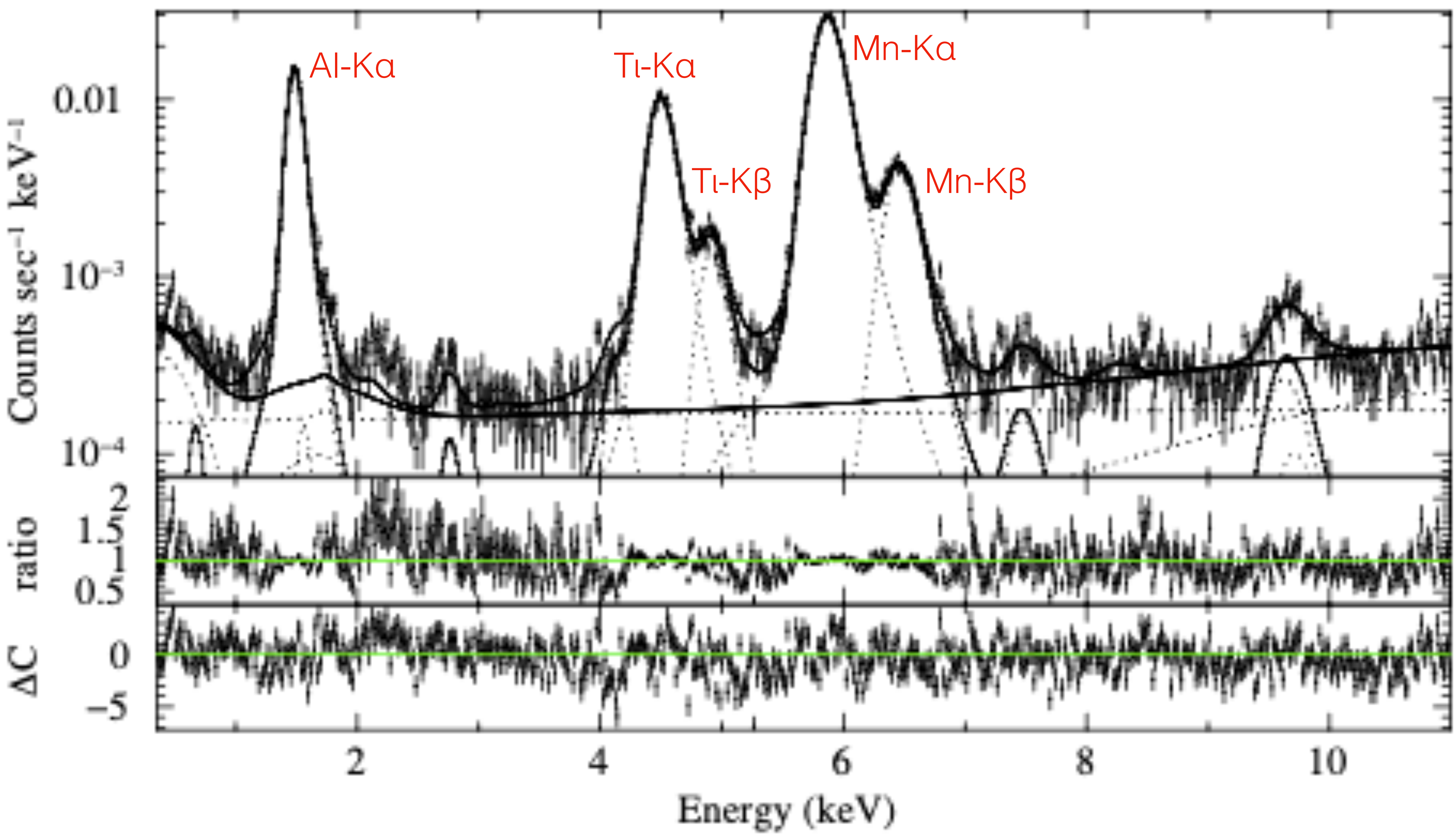
Generated ACIS response files at a range of focal plane temperatures (-120 C to -105 C) for the primary FI CCDs used for imaging (I0, I1, I2, I3, and S2)

Procedure:

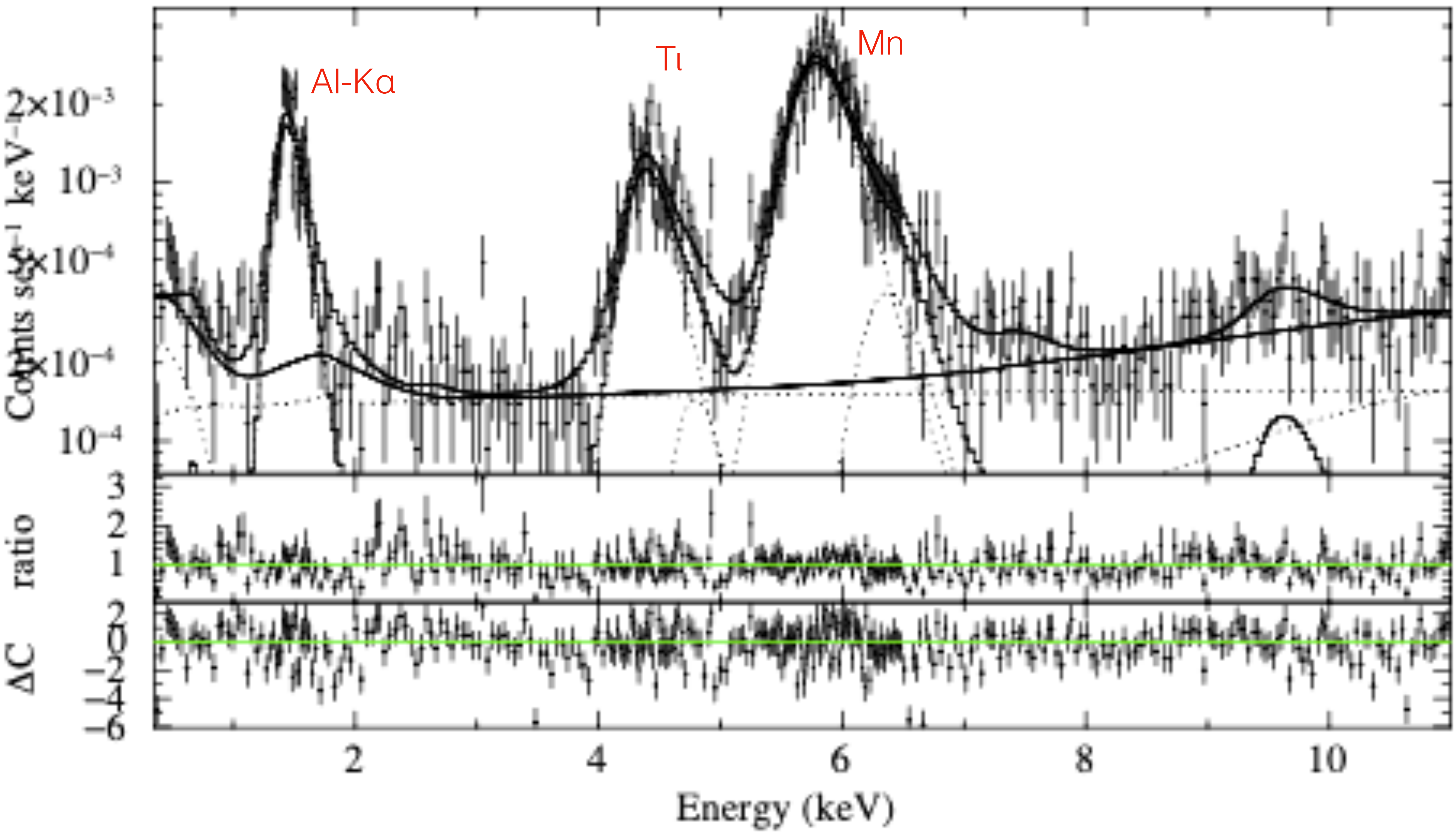
- Co-add ECS data from epochs 40-91 (approximately 13 years of data)
- Divide ECS data into 8 FP temperature intervals between -120 C and -105 C
- Bin data into 32 by 32 pixel regions
- Fit widths of Al, Ti, and Mn lines in each spatial region and temperature bin
- Released as 8 CALDB files (one for each temperature band) in CALDB release 4.12.0

Example of cold ECS data (FP Temps -120 C to -119 C) fit with the N0009 temperature-dependent response files

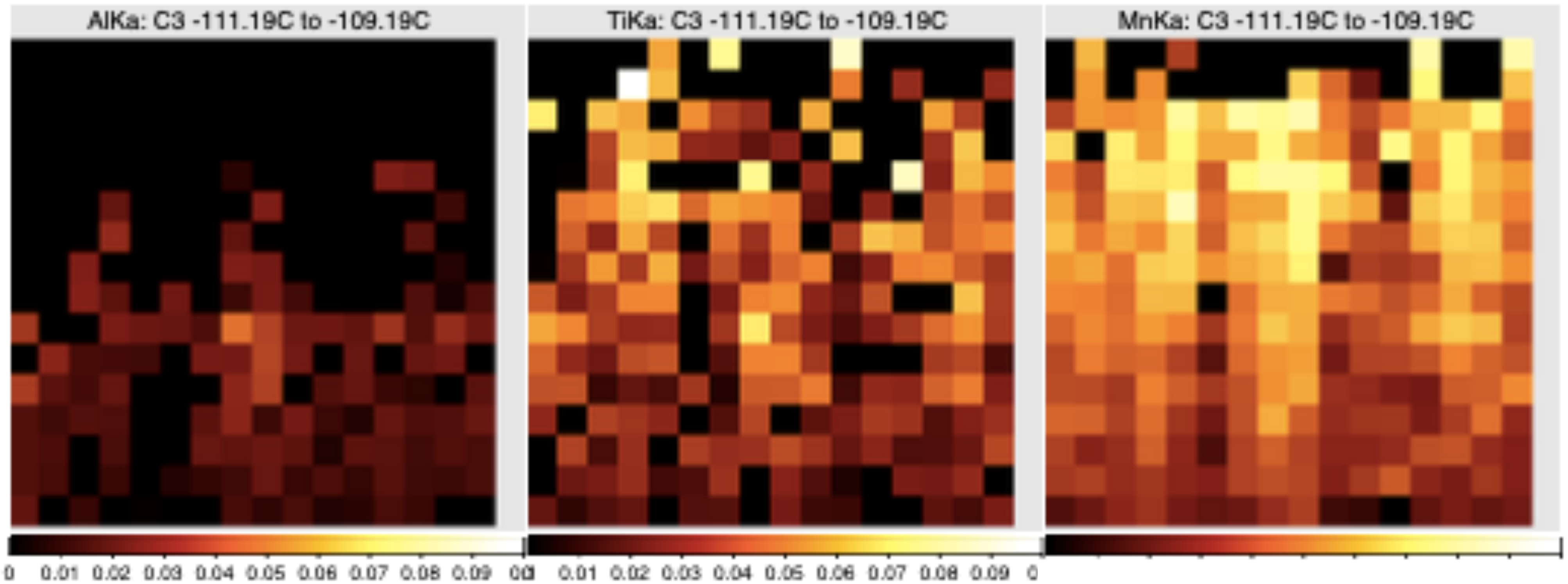
I3 aim-point



Example of warm ECS data (FP Temps -111 C to -109 C) fit with the N0009 temperature-dependent response files



Residuals in the FWHM with the N0009 temperature-dependent ACIS response files for warm ECS data (FP Temps -111 C to -109 C)

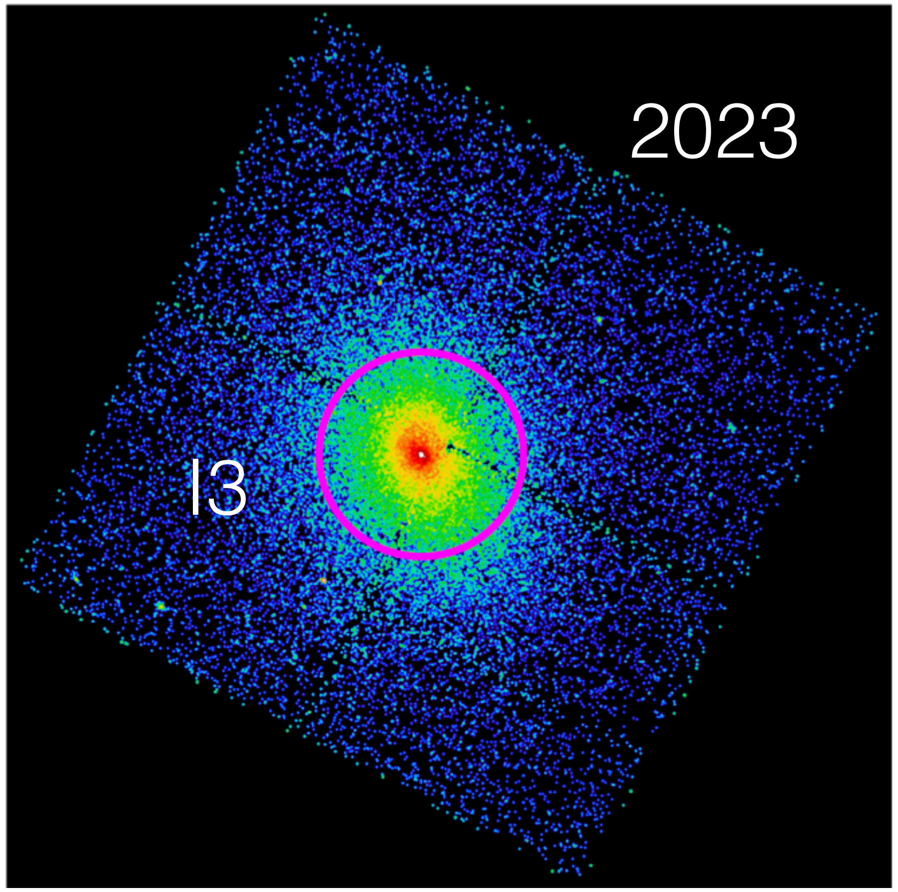


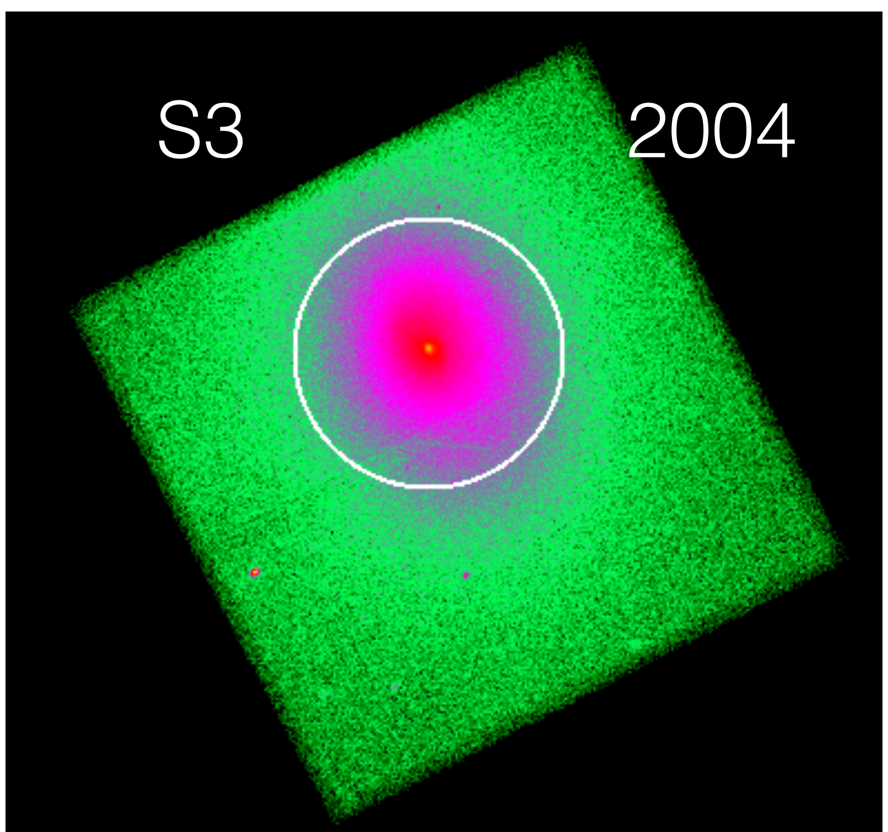
Line	max σ	σ / E_{line}
AlKα	44 [eV]	3.0%
TiKα	97 [eV]	2.1%
MnKα	83 [eV]	1.4%

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 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.

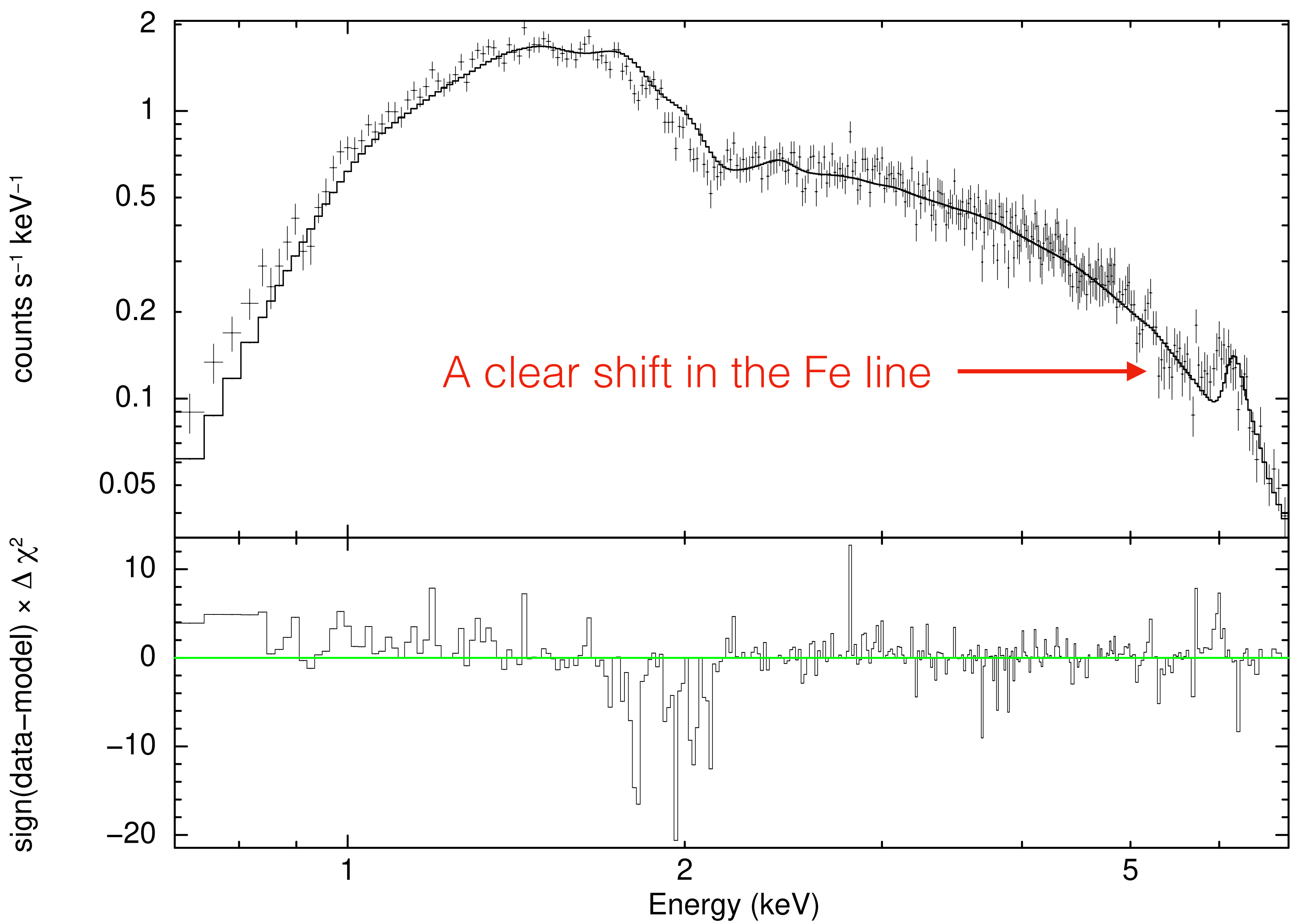
Investigating the gain loss in the ACIS CCDs



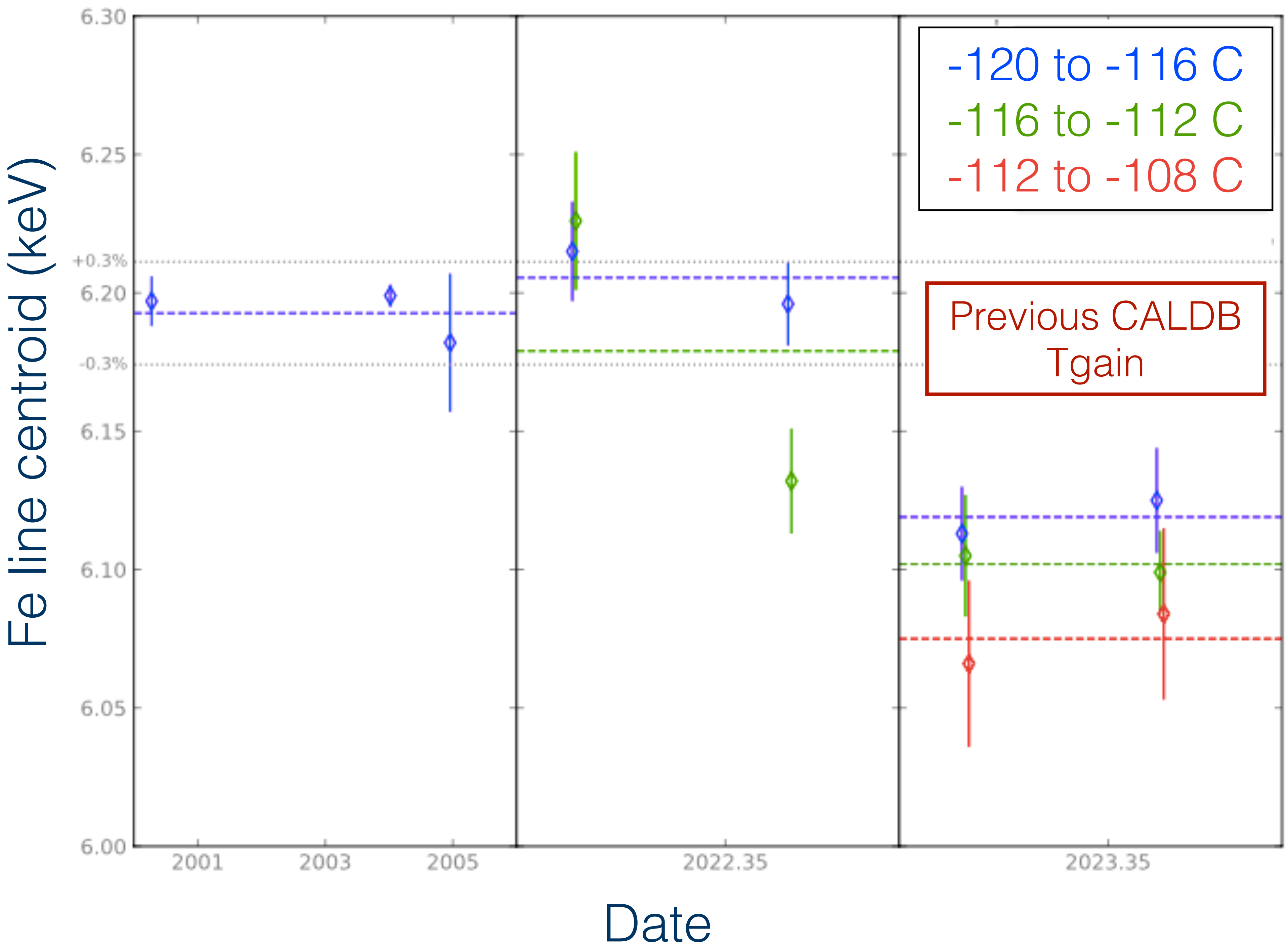


This issue was first reported in a 2023 ACIS-I observation of the Abell 2029 galaxy cluster

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

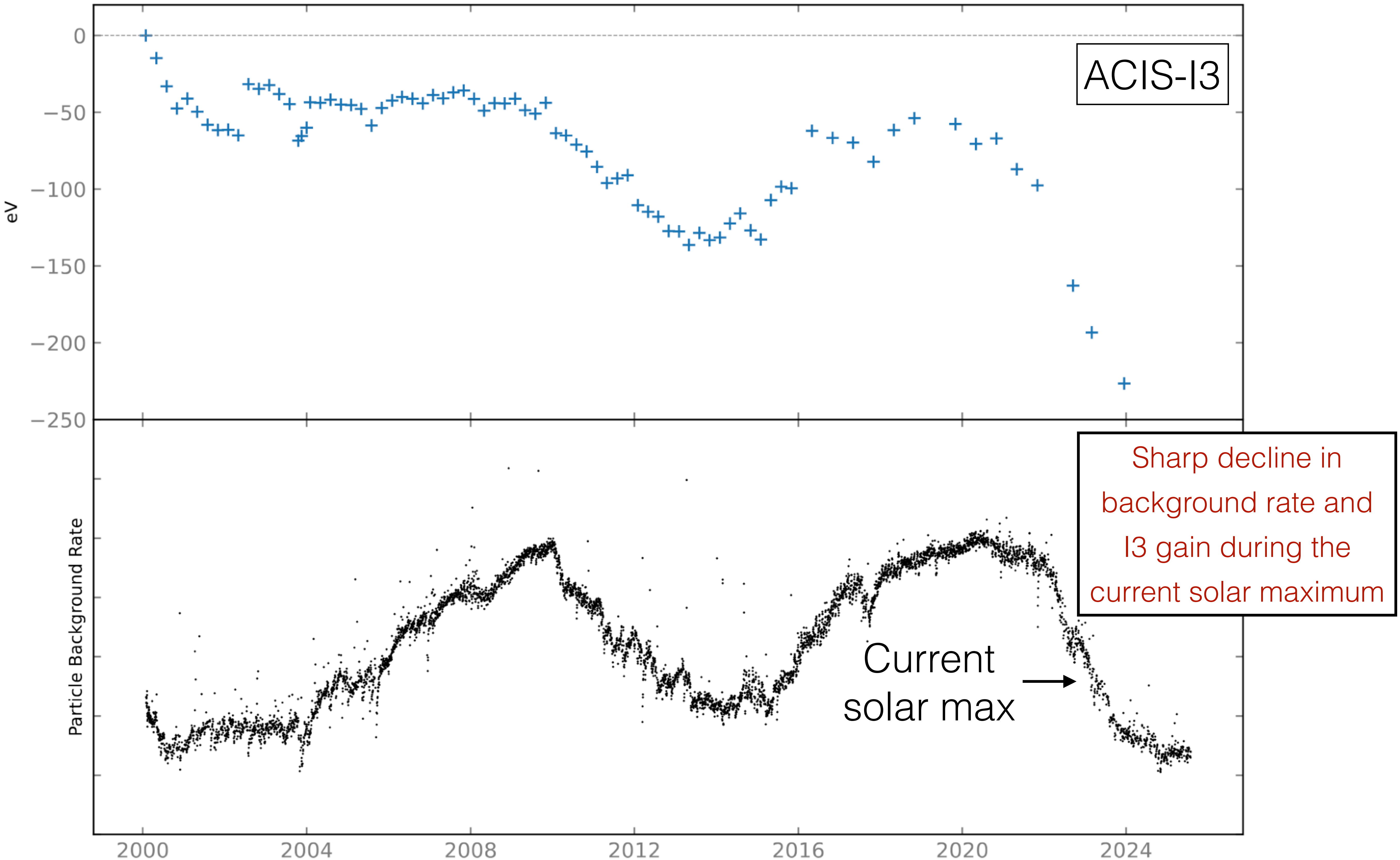


Time-dependent changes to the ACIS gain are mainly driven by the solar cycle and are calibrated through a set of time-tagged gain correction files (tgain) in the CALDB. During periods of high background, the traps in the CCDs are partially filled, which reduces the CTI. During periods of low background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

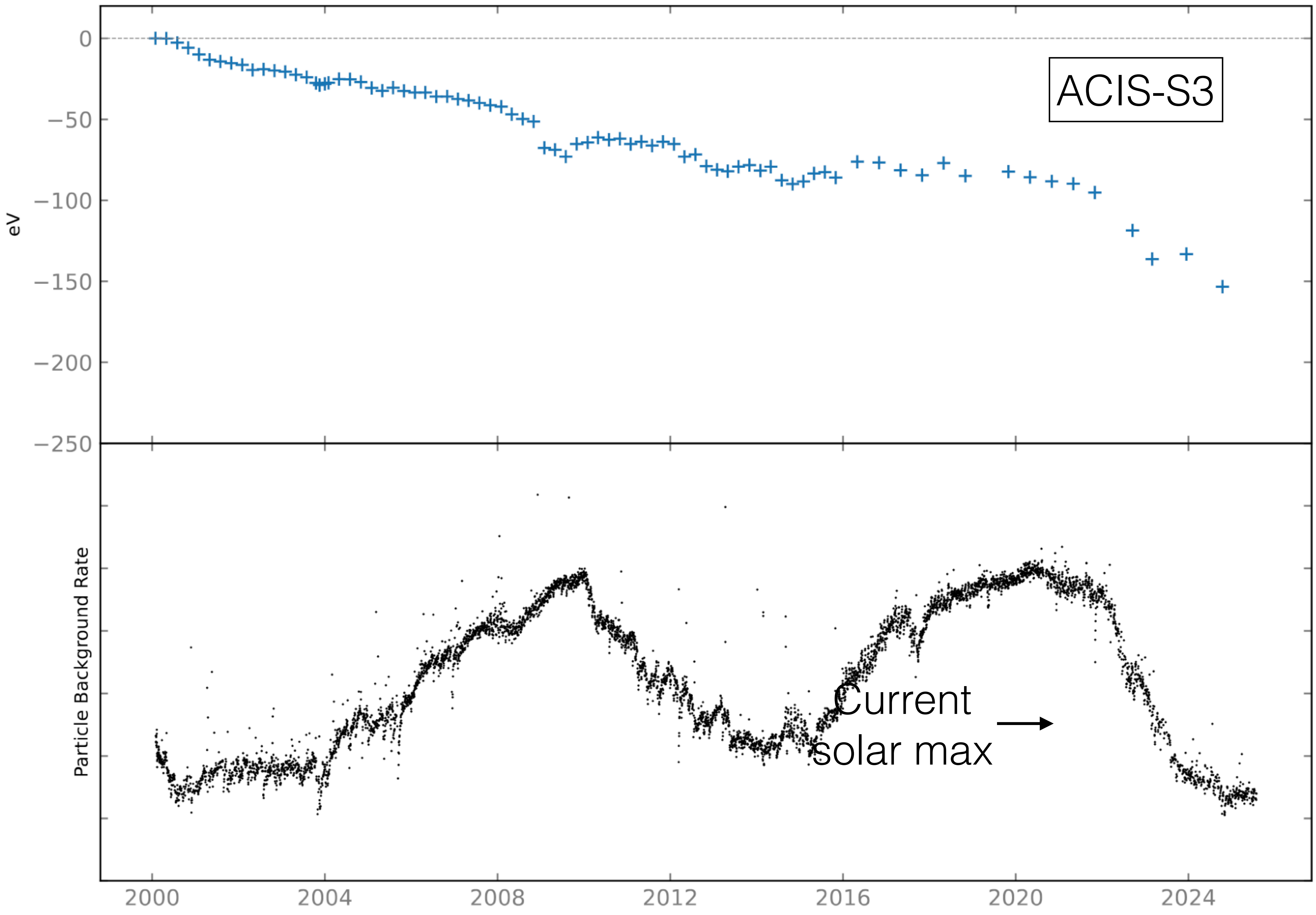


Decline in the Fe line centroid in A2029 observations beginning in 2022 using the current CALDB

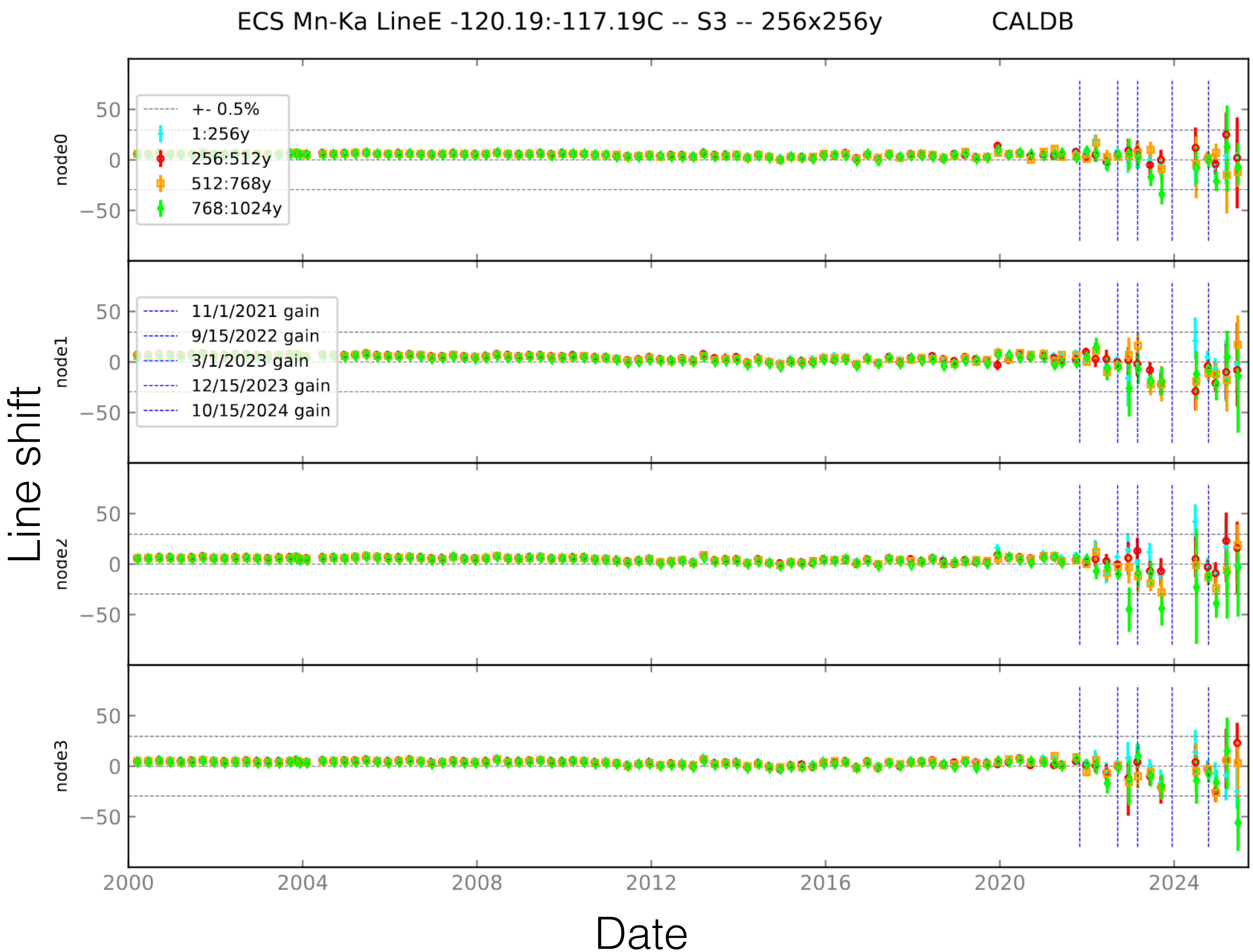
Comparison between the charged particle background rate and the I3 gain over the course of the Chandra mission. The effect of the solar cycle is clearly seen.



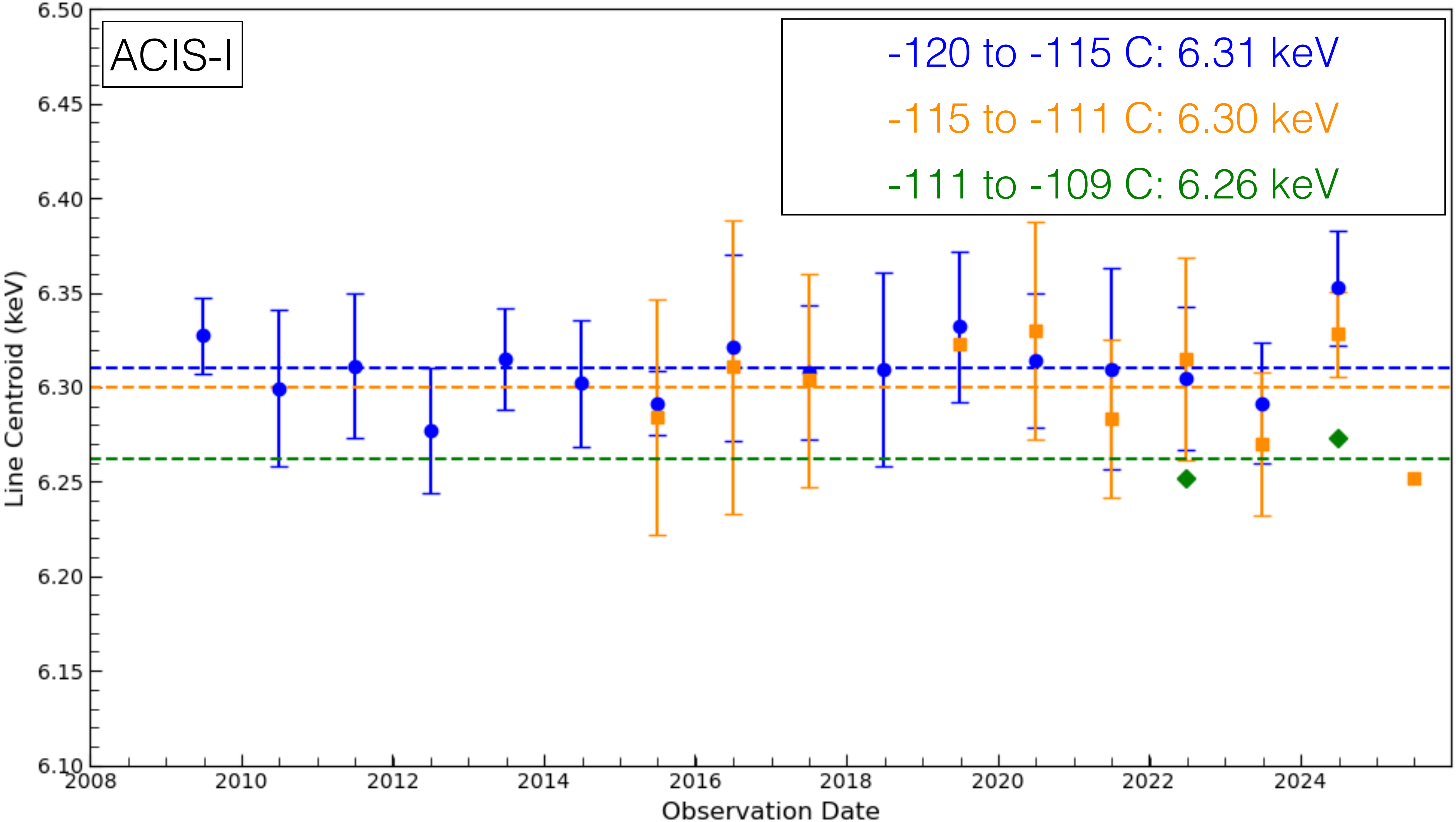
Gain loss in the S3 CCD is about one-half of that for the I3 CCD



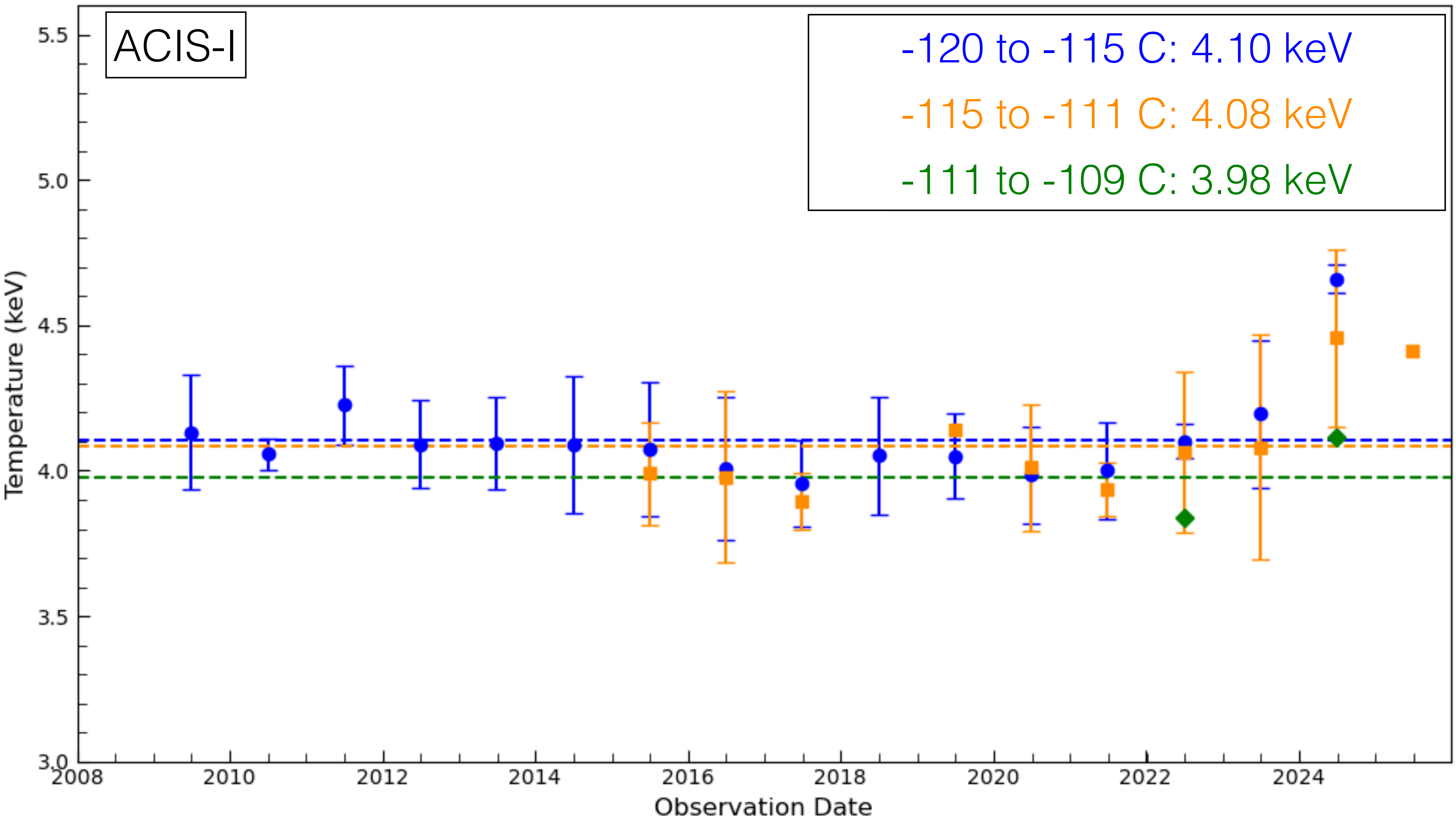
A set of tgain files were developed and released in CALDB 4.12.2 for observations taken during the period of 01 Feb 2022 through 2025



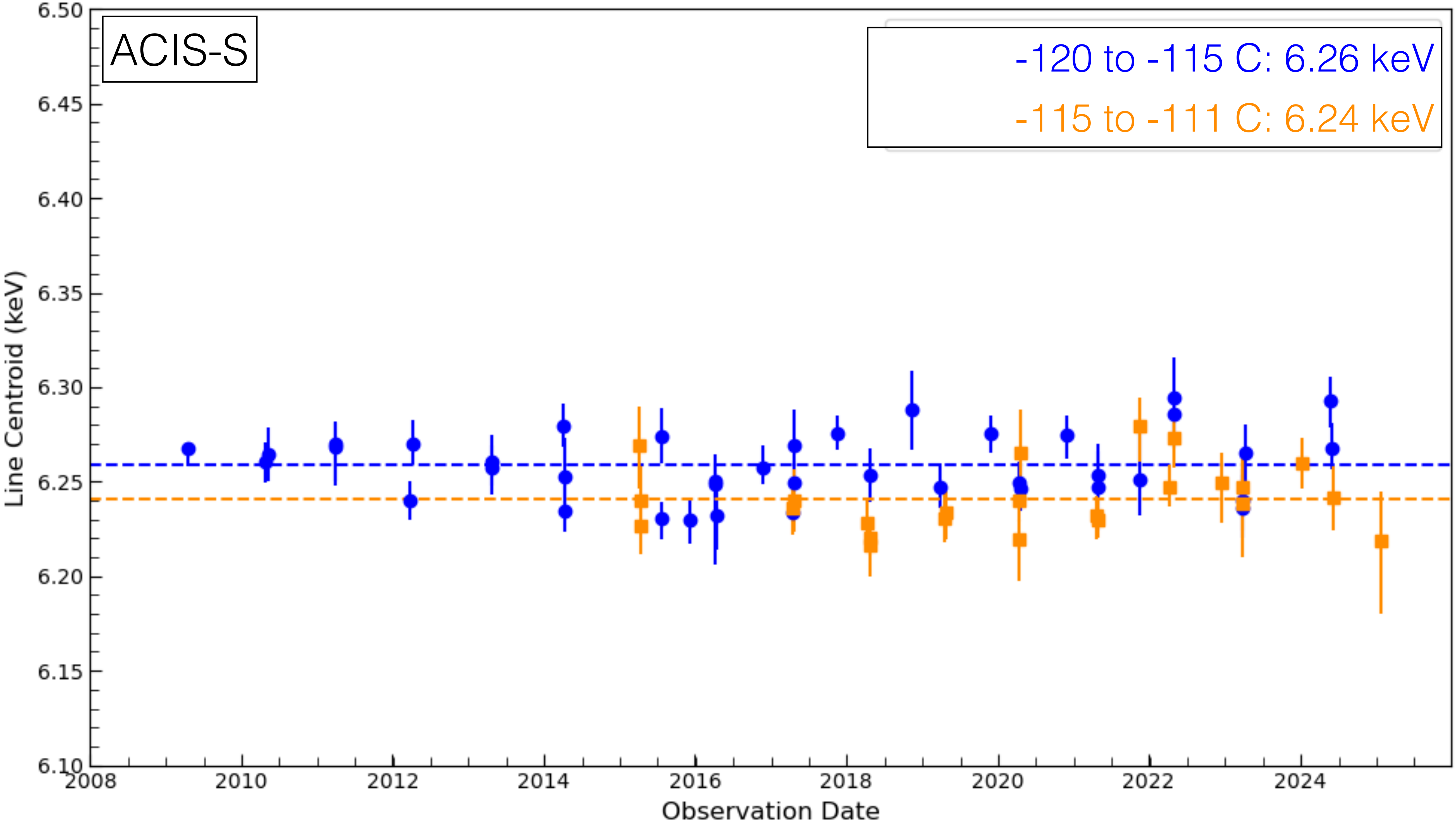
The Fe line in the A1795 spectrum can be used to monitor the ACIS gain. Fe line centroid in the ACIS-I observations of A1795 using the new CALDB tgain file.



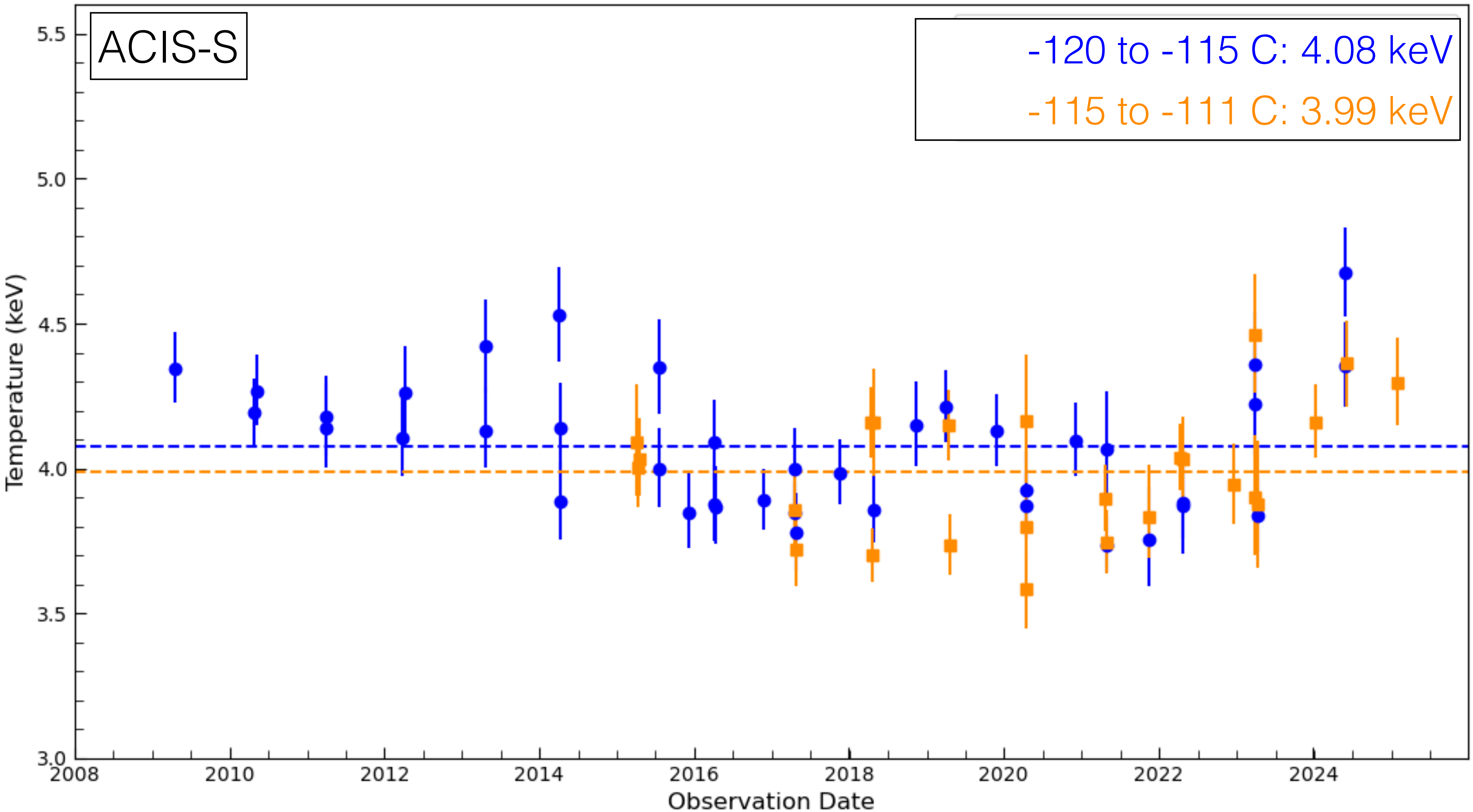
The Fe line in the A1795 spectrum can be used to monitor the ACIS gain. Best fit APEC temperatures in the ACIS-I observations of A1795 using the new CALDB tgain file.



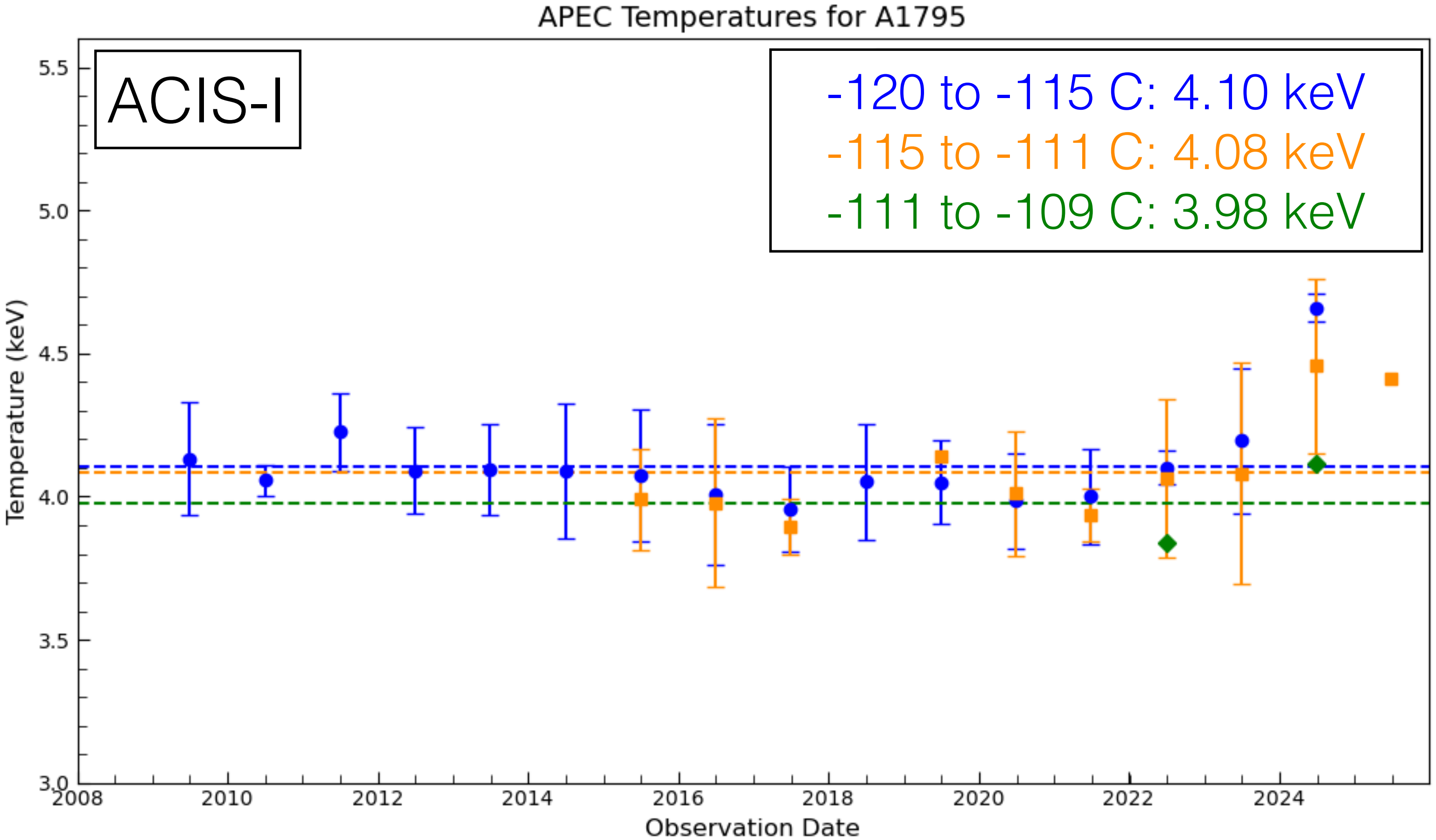
The Fe line in the A1795 spectrum can be used to monitor the ACIS gain. Fe line centroid in the ACIS-S observations of A1795 using the new CALDB tgain file.



The Fe line in the A1795 spectrum can be used to monitor the ACIS gain. Best fit APEC temperatures in the ACIS-S observations of A1795 using the new CALDB tgain file.

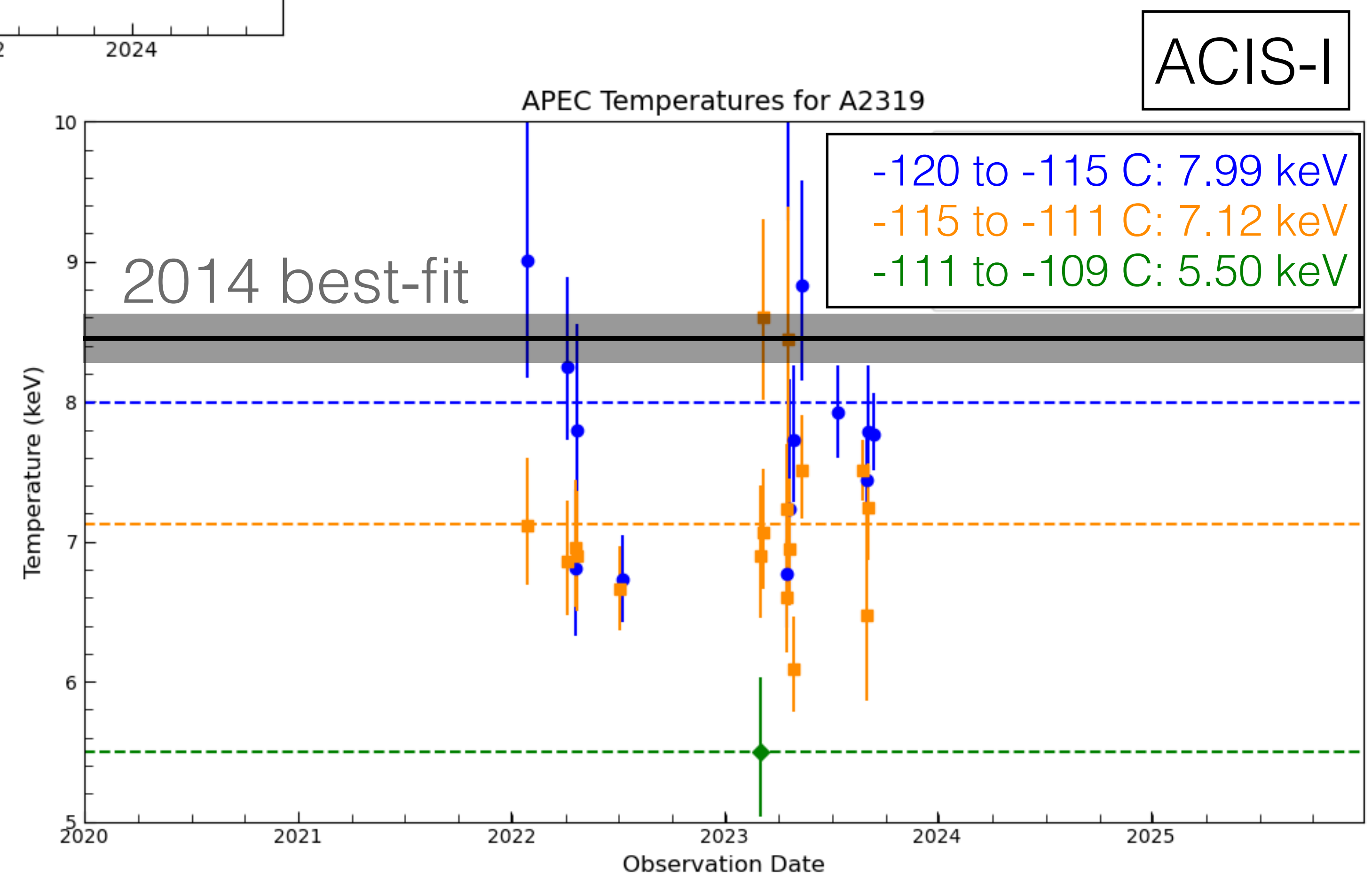


However, there are still some issues regarding the derived spectral parameters when fitting broad band spectra of hot clusters



A1795: Moderate temperate cluster provides good fits

A2319: Hot cluster provides too low temperatures

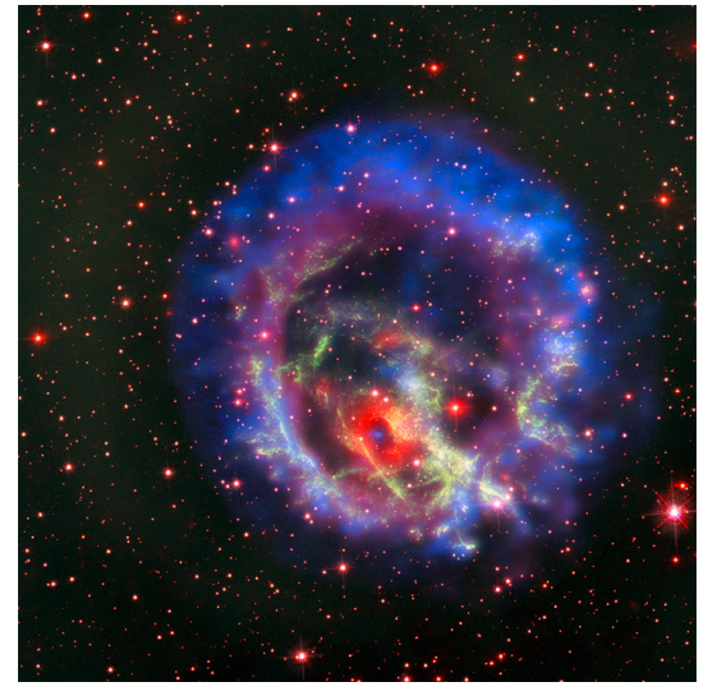


Updating the high-energy tgain and the tgain for observations taken from mid-2024 to 2025 is in progress

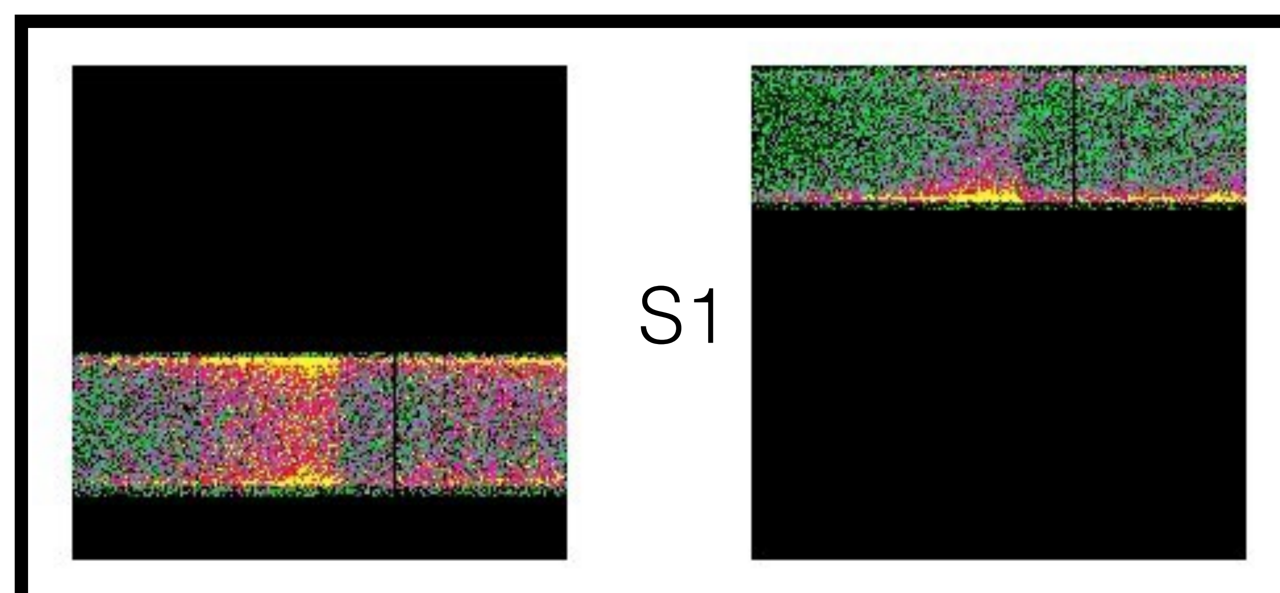
Monitoring the ACIS contamination and developing a new model

Abell 1795 galaxy cluster

E0102-72 supernova remnant



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



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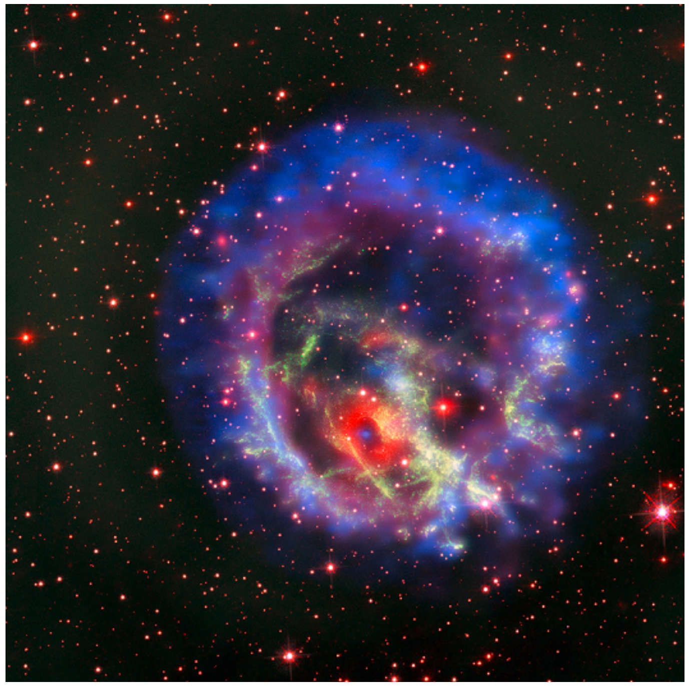
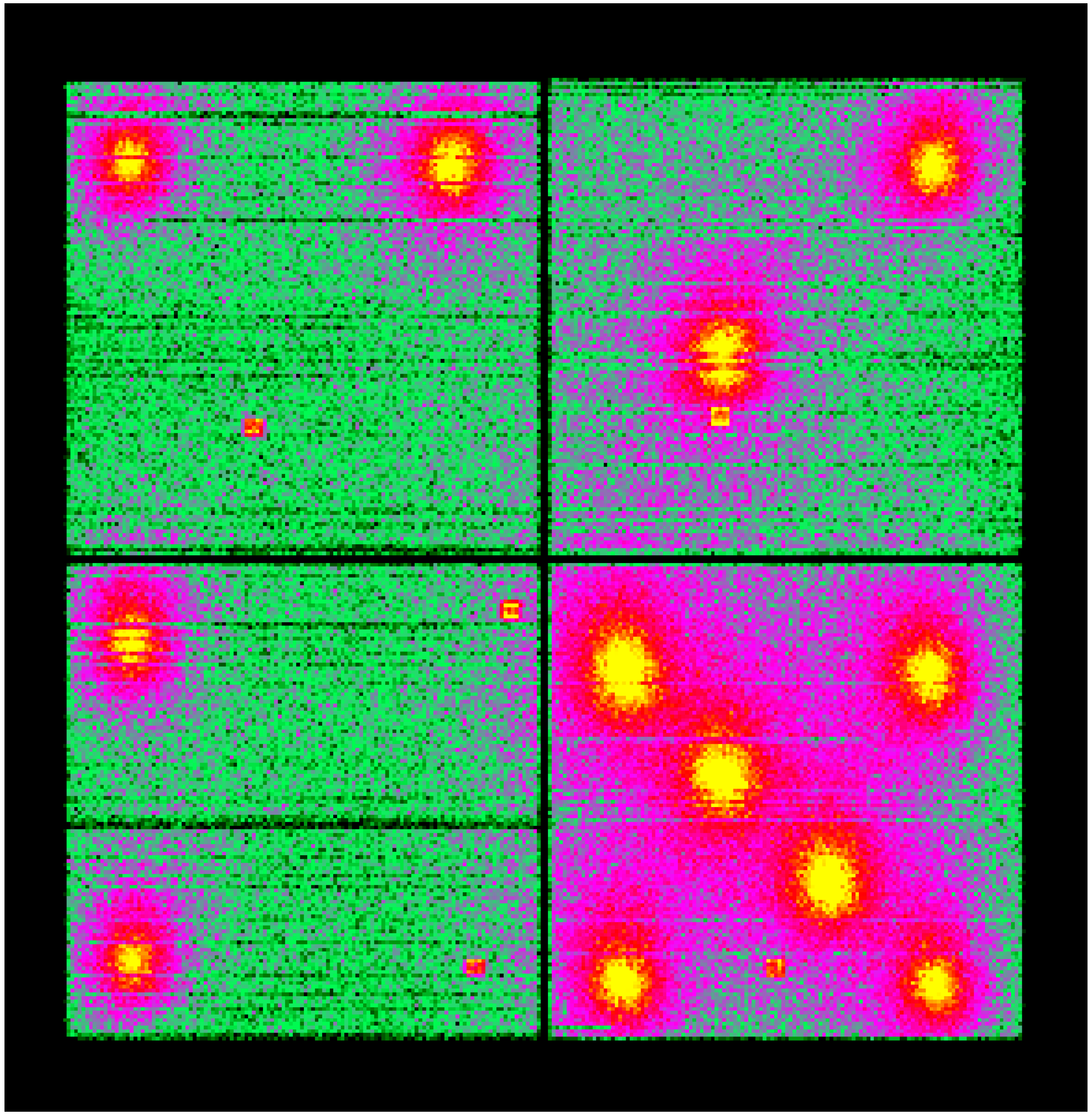
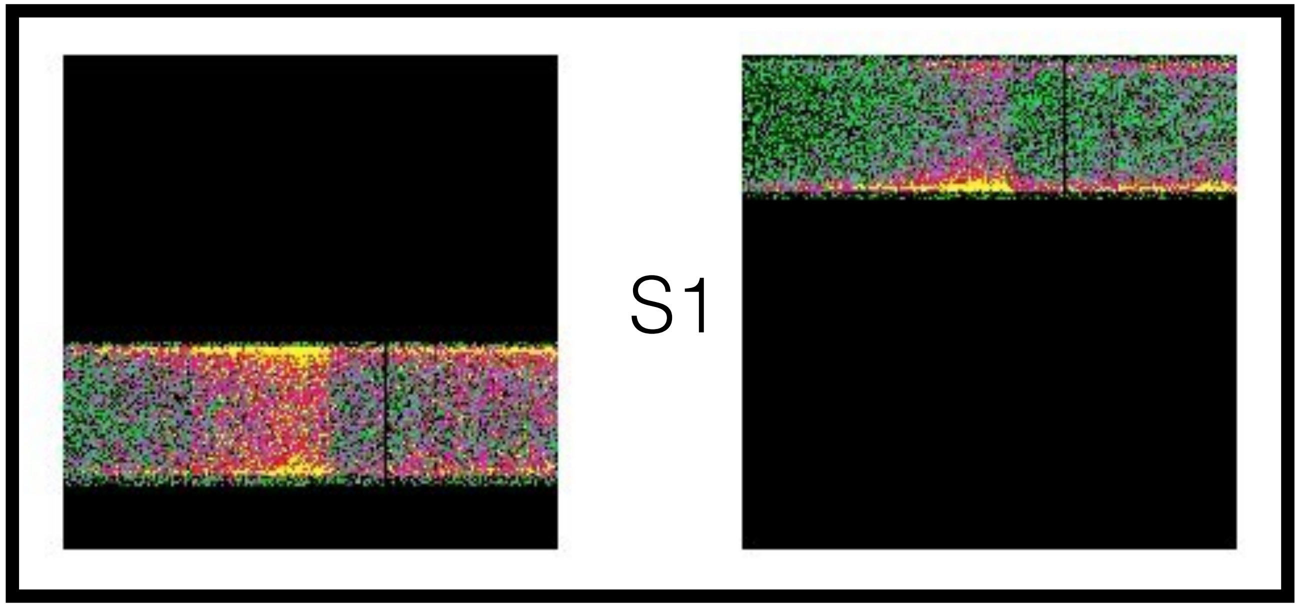
E0102-72 supernova remnant



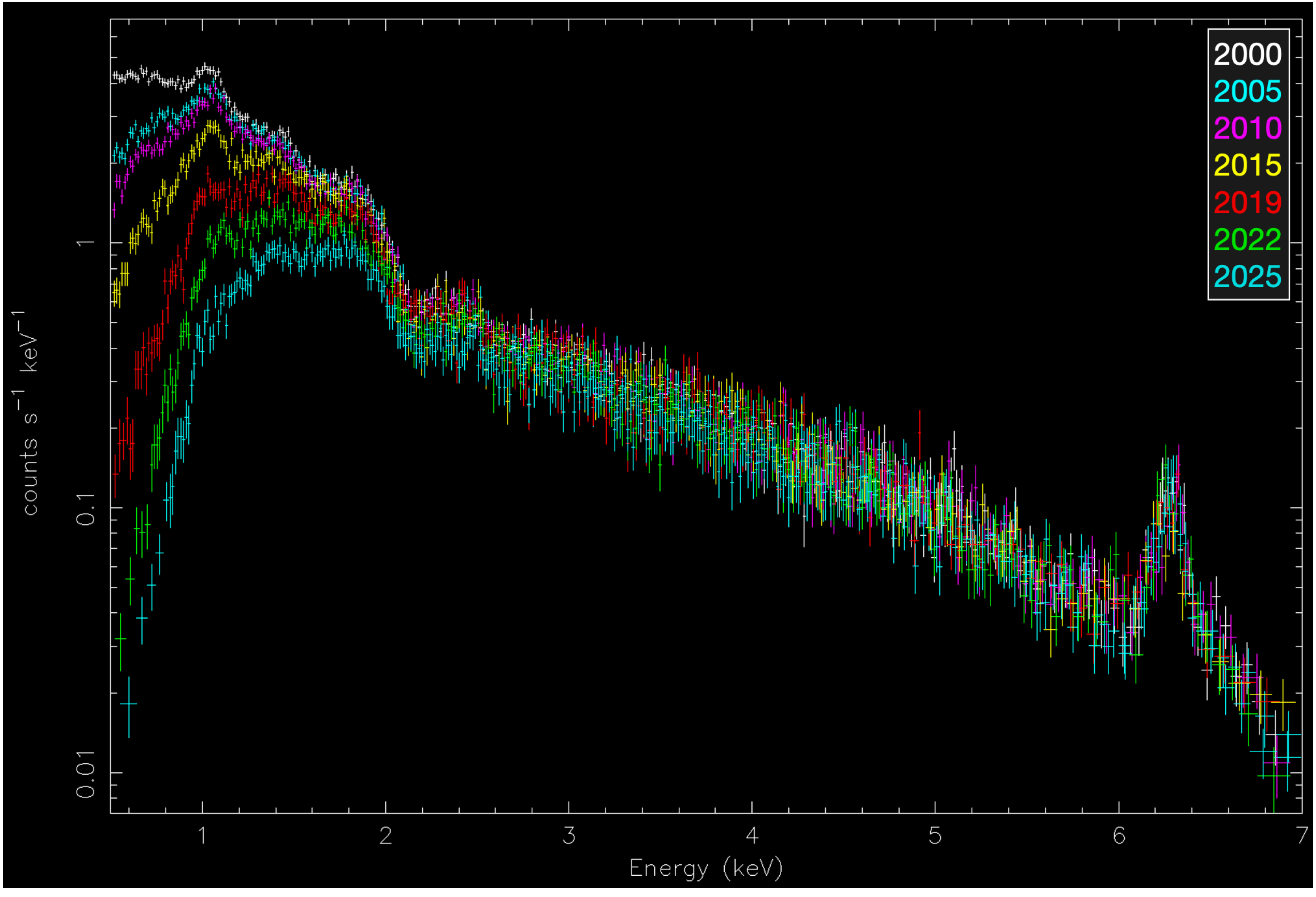
Abell 1795 Raster Scan on ACIS-I



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

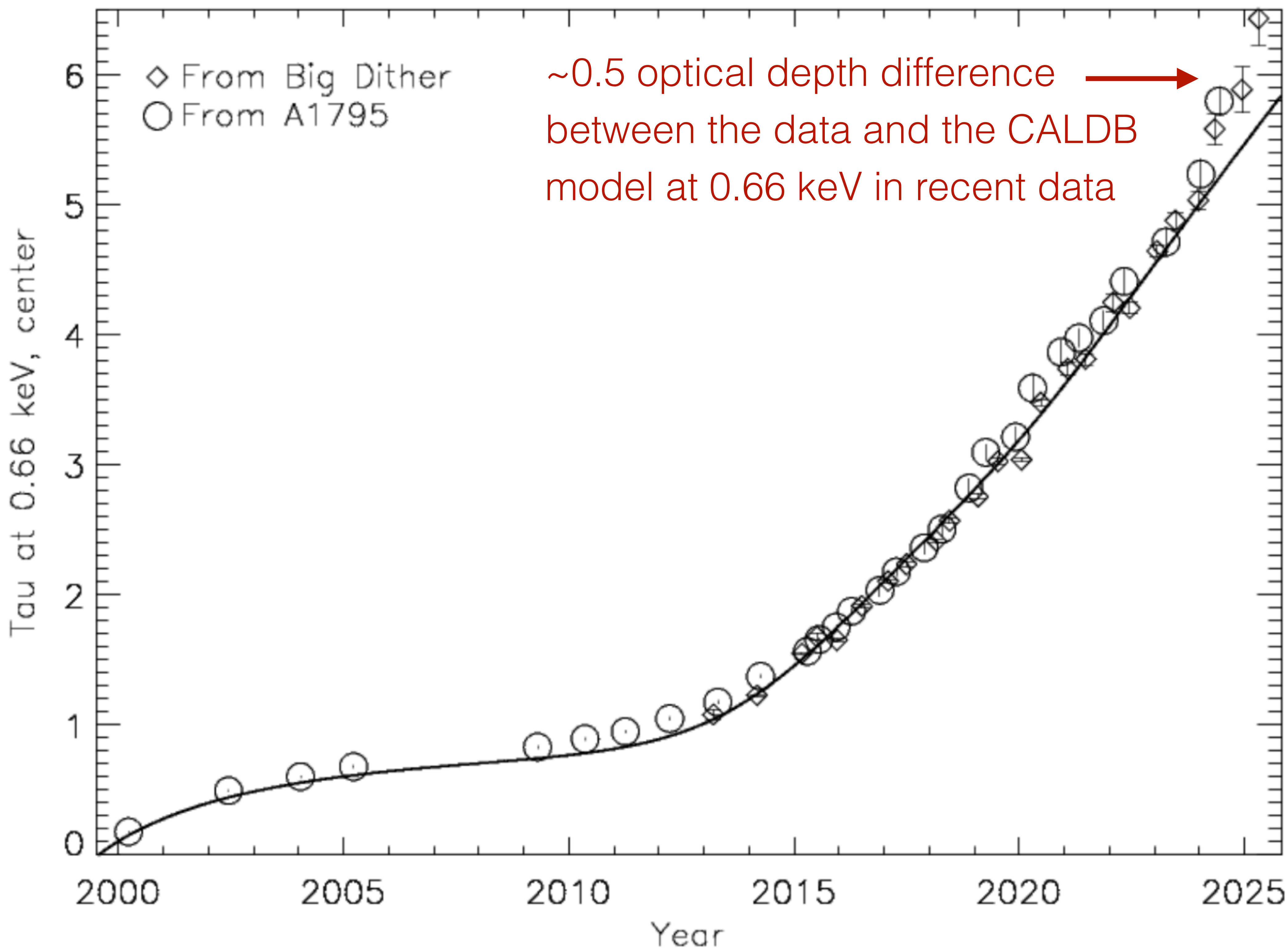


ACIS-S3 spectra of Abell 1795 over the course of the mission

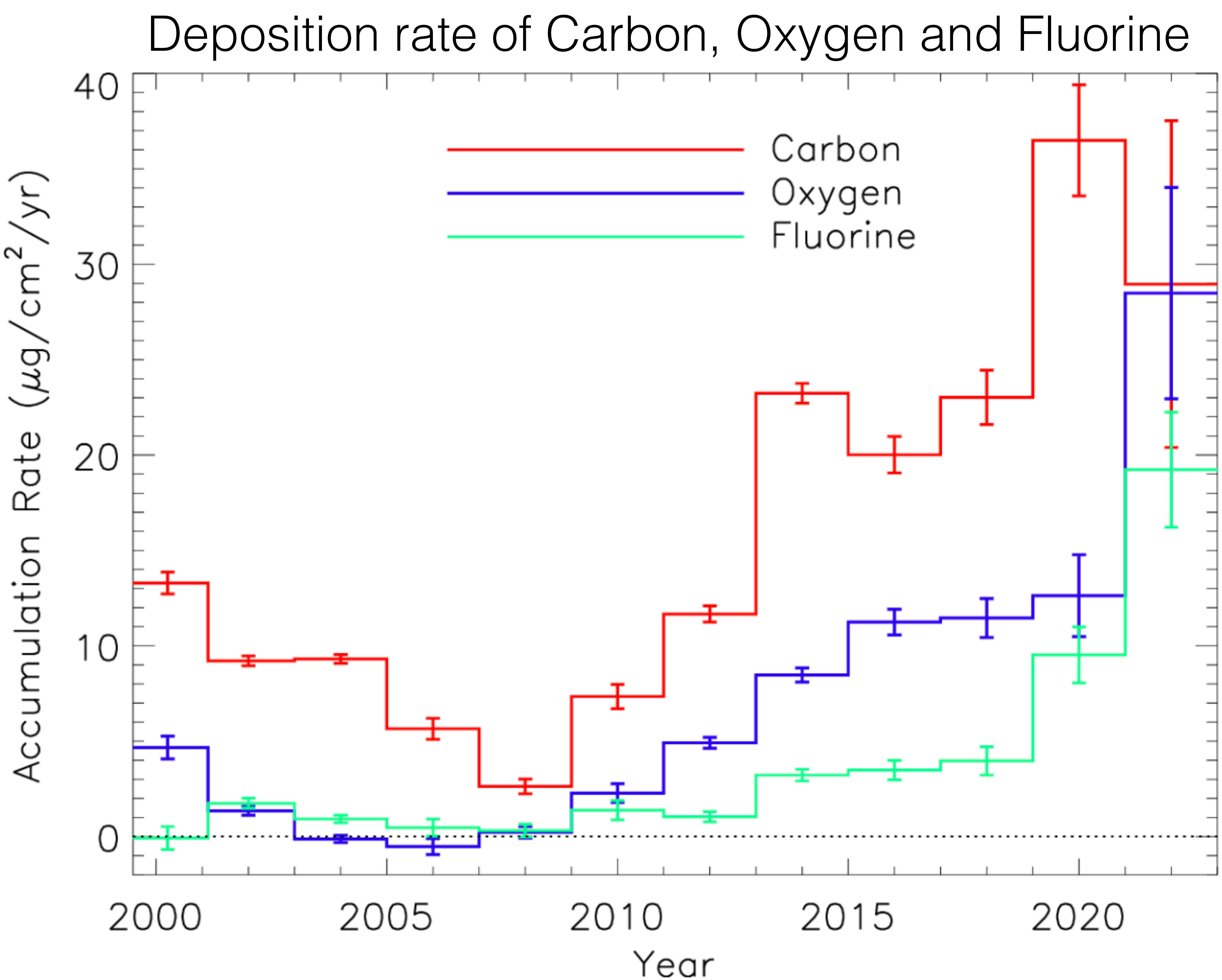


Optical depth of the contaminant at 0.66 on the ACIS-S array as measured from “Big Dither” LETG/ACIS-S observations of Mkn 421 and imaging observations of Abell 1795

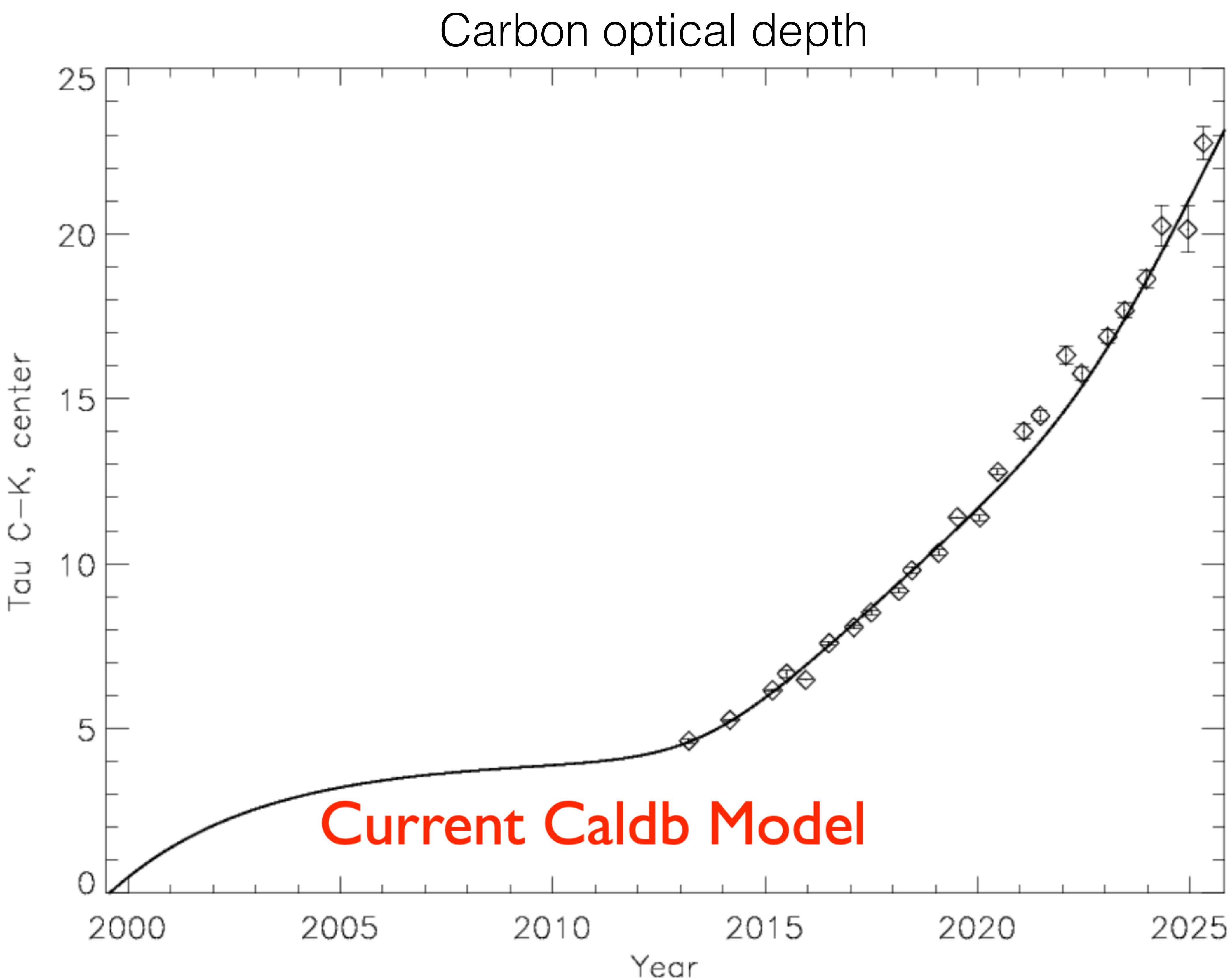
Current CALDB model



The contaminant is composed of carbon, oxygen and fluorine. The oxygen-to-carbon ratio of the material condensing onto the ACIS filters has varied significantly during the mission



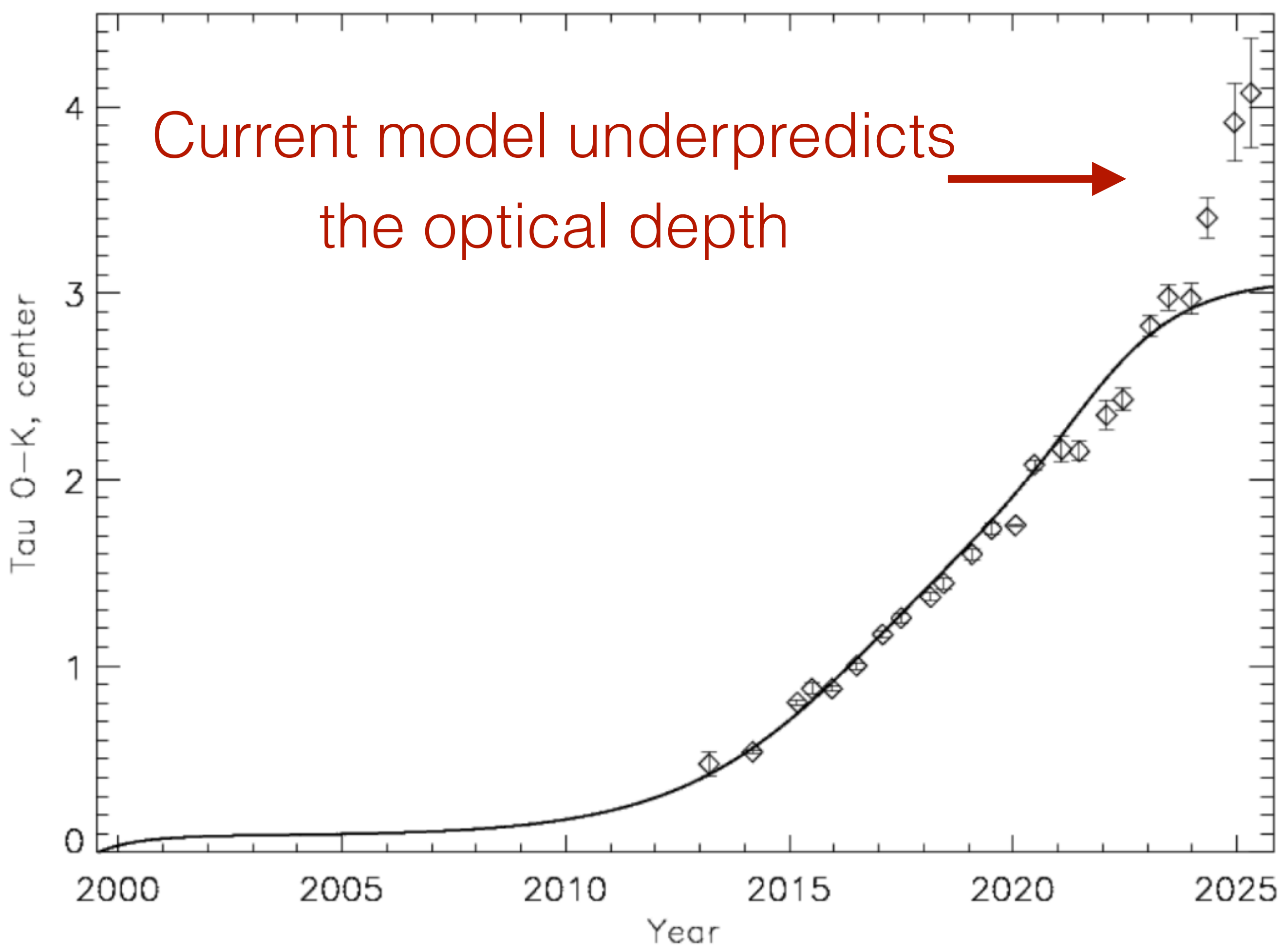
The evolution of the carbon optical depth is well described by the current contamination model



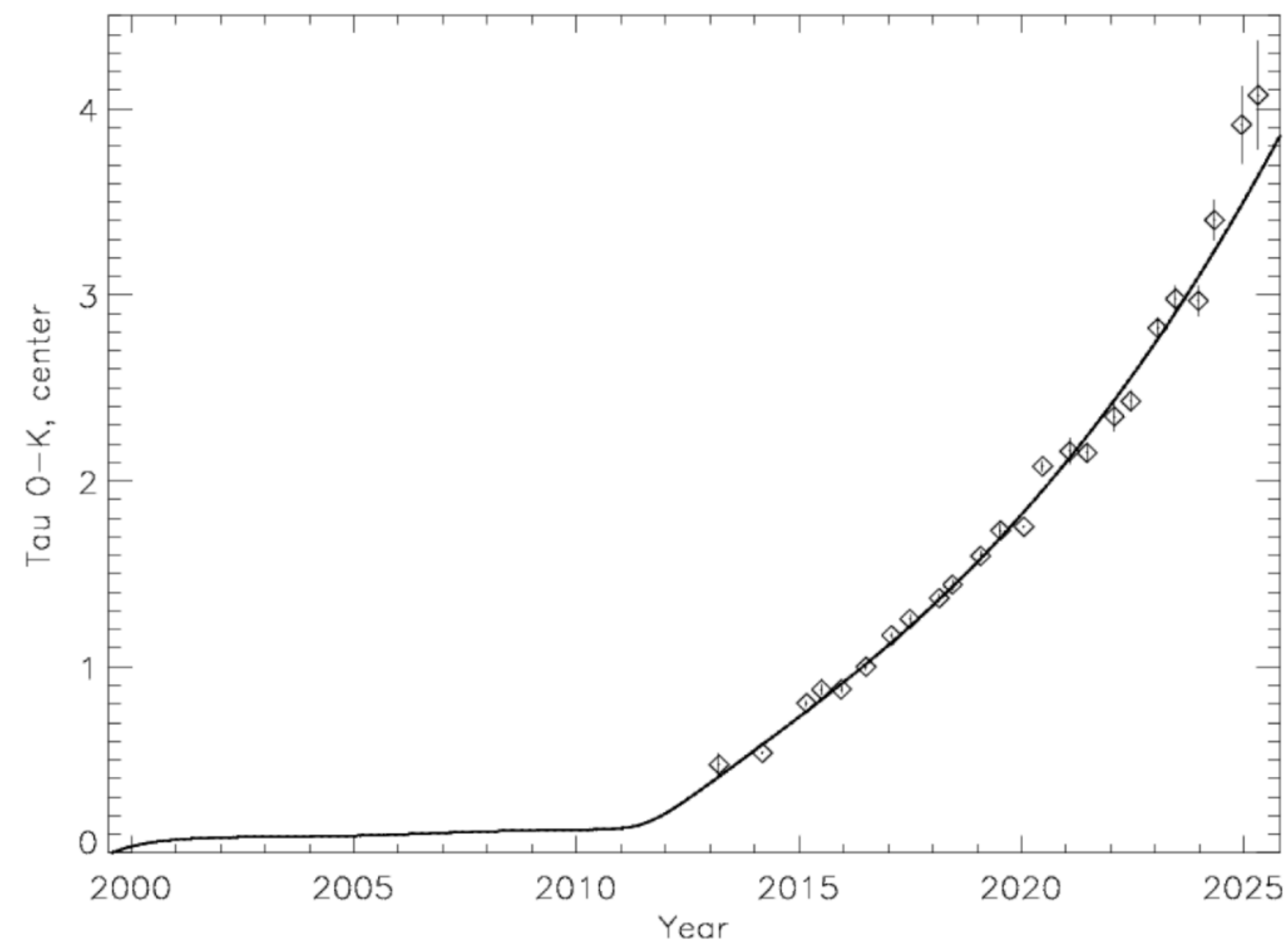
The evolution of the oxygen optical depth is under-estimated by the CALDB contamination model. The test contamination model provides a better fit to the Big Dither data

Oxygen optical depth

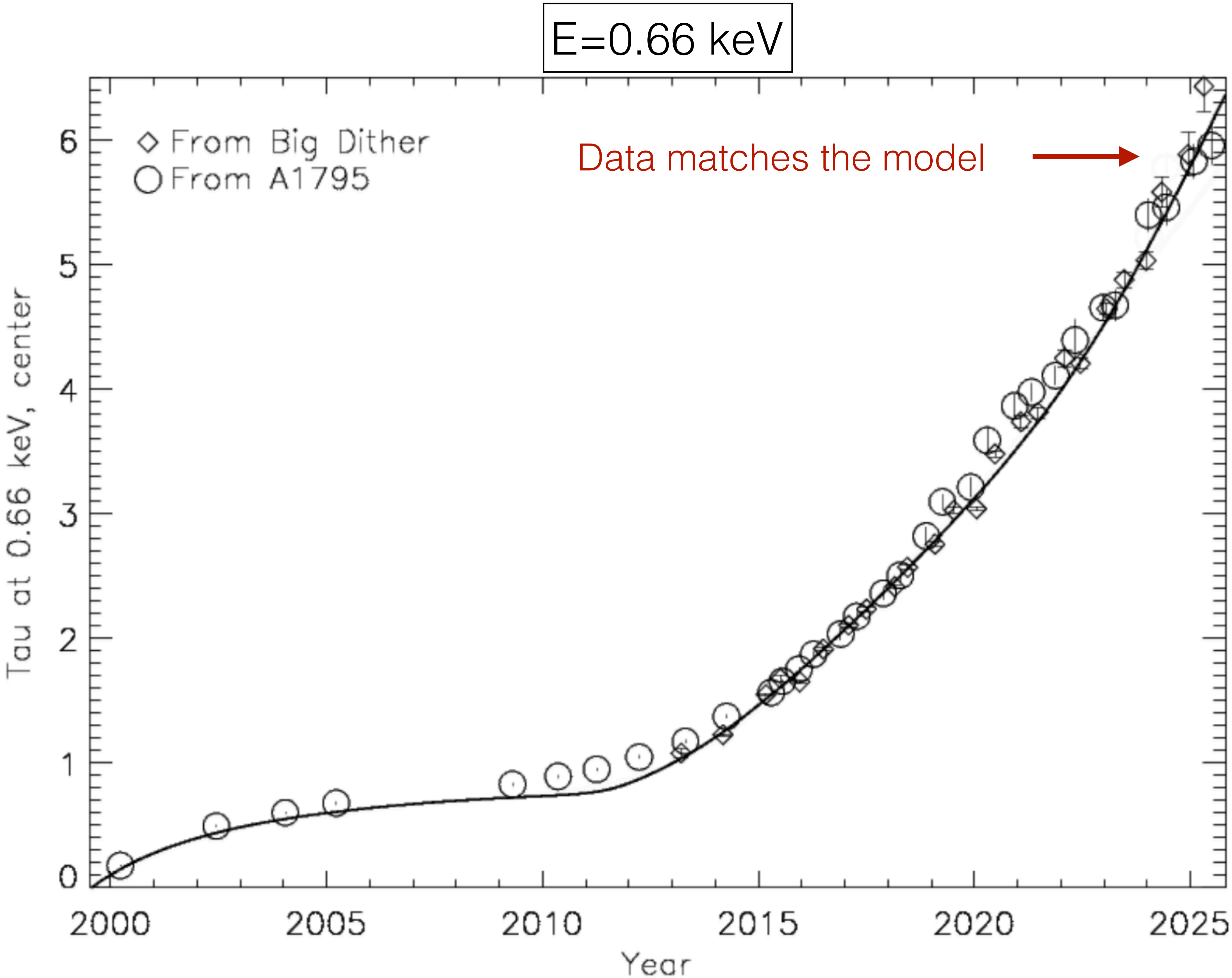
Current CALDB model



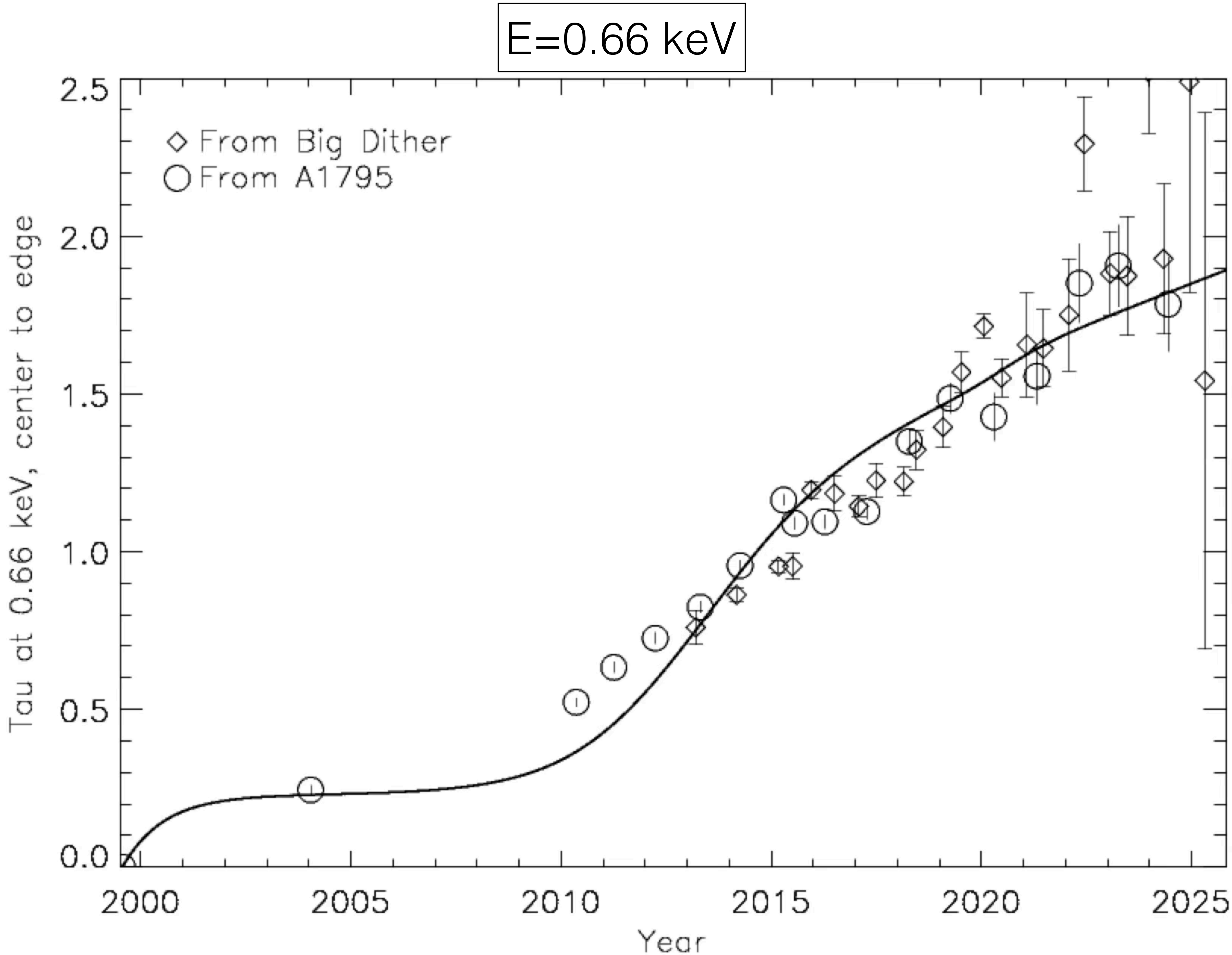
Test contamination model



A new model contamination model has been developed, which model well describes the optical depth at 0.66 keV on the ACIS-S array

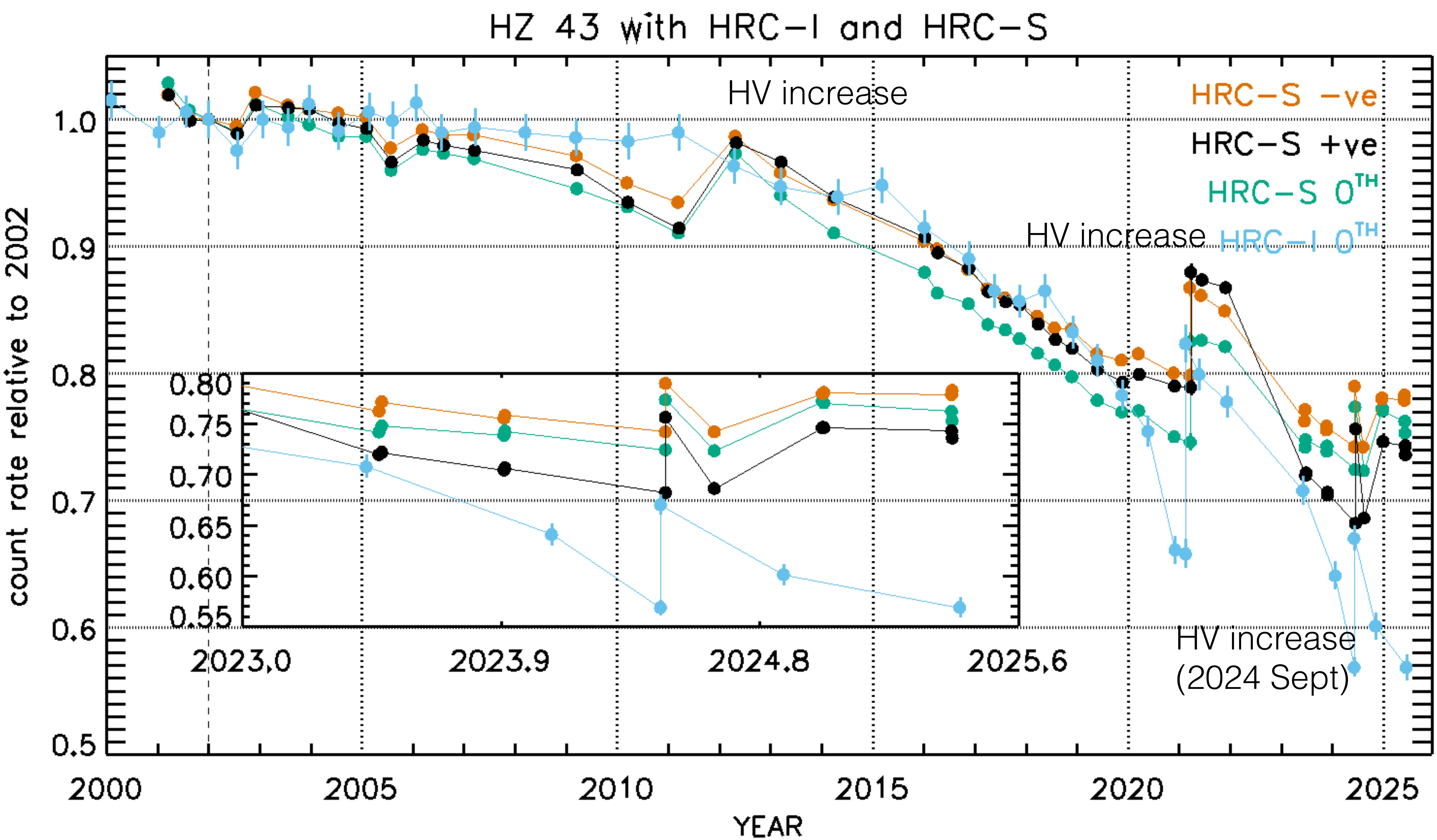


Difference in the optical depth between the edge to center of the ACIS-S array is well described by the current CALDB model

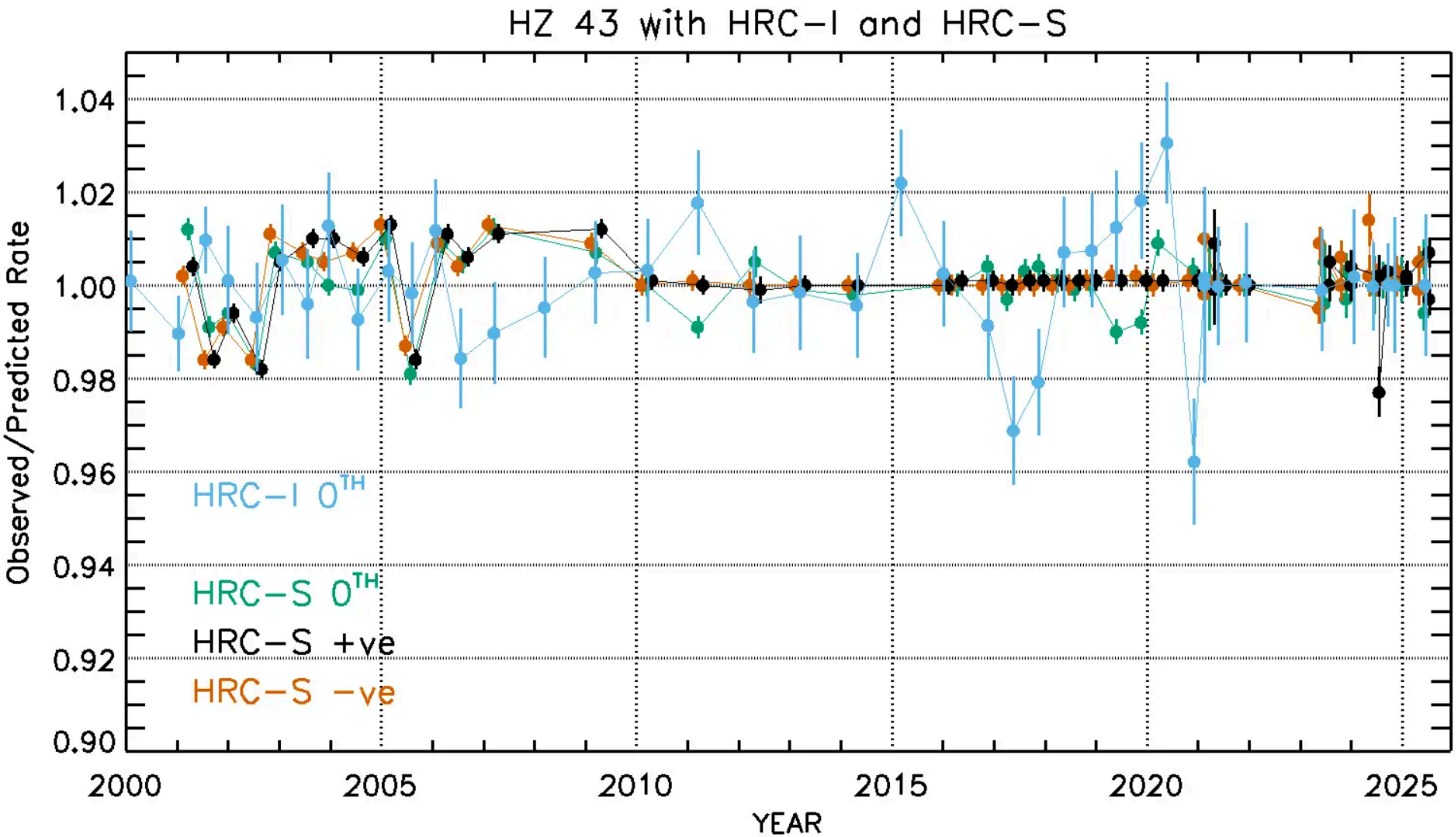


HRC Calibration

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



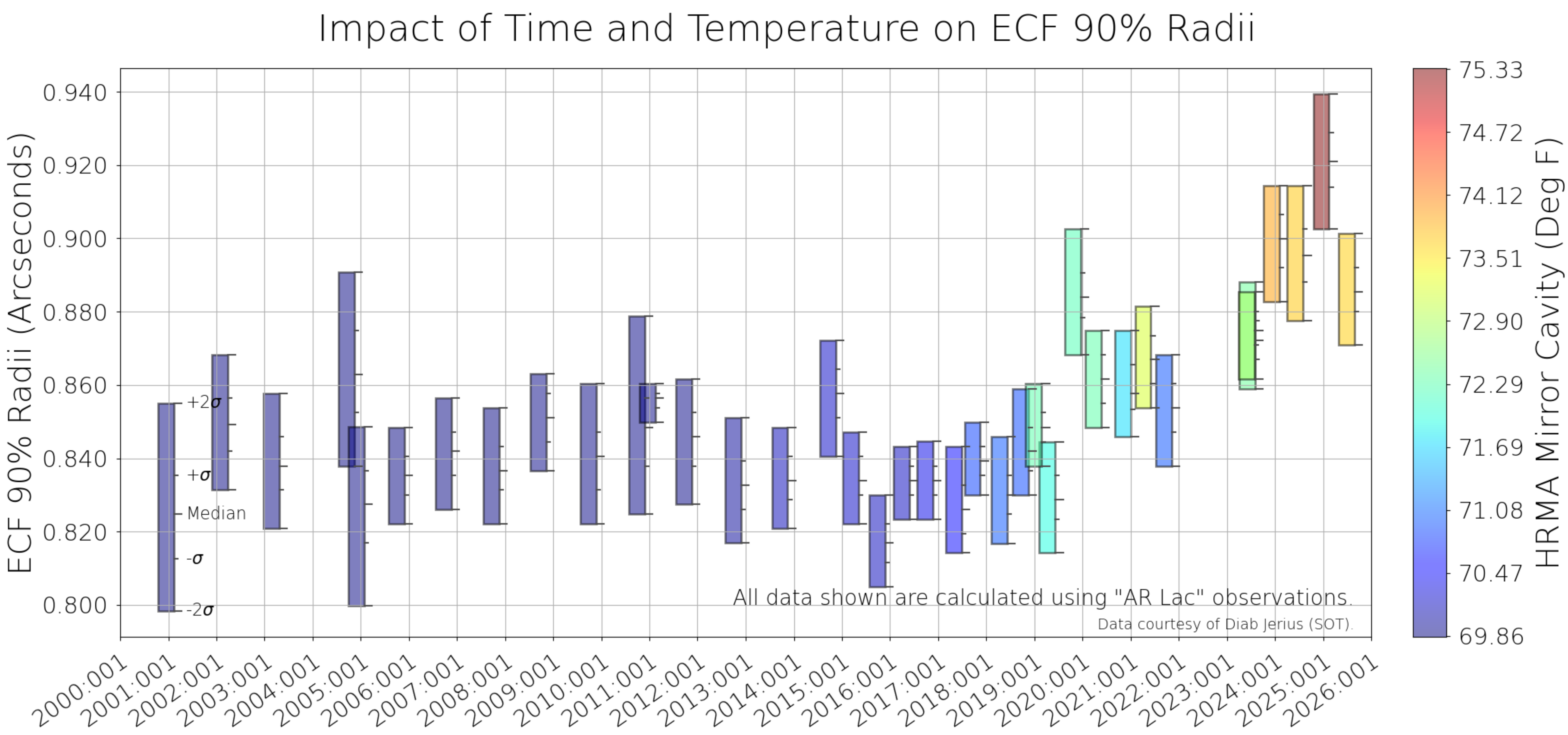
Corrected LETG/HRC-I and LETG/HRC-S HZ43 count rates with the current CALDB.



The final HRC-I QE and HRC-S QEU (QE map) with the old HV settings were released in the CALDB in June 2024 and updated HRC-I QE and HRC-S QEU files with the new HV settings were released in the CALDB in January 2025

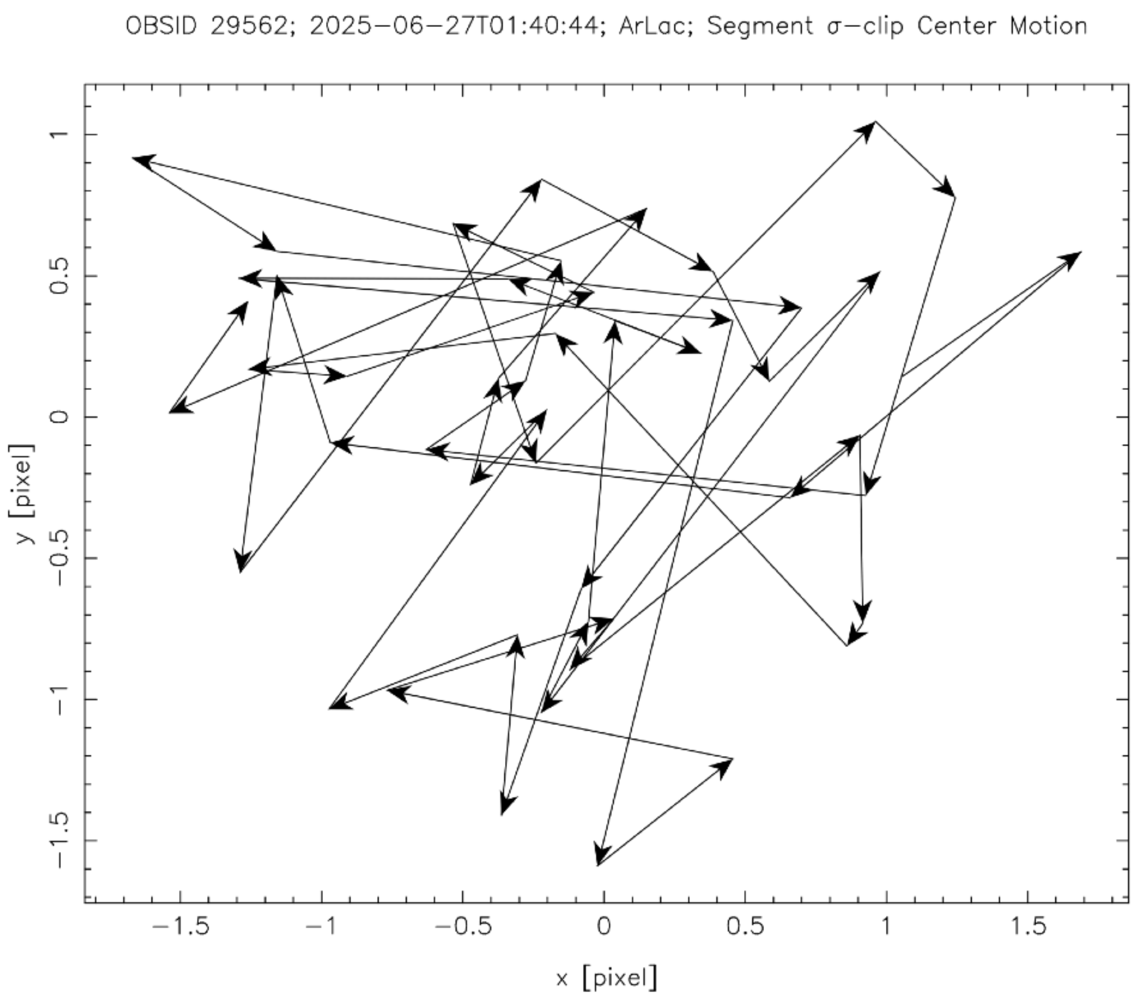
HRMA PSF monitoring

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



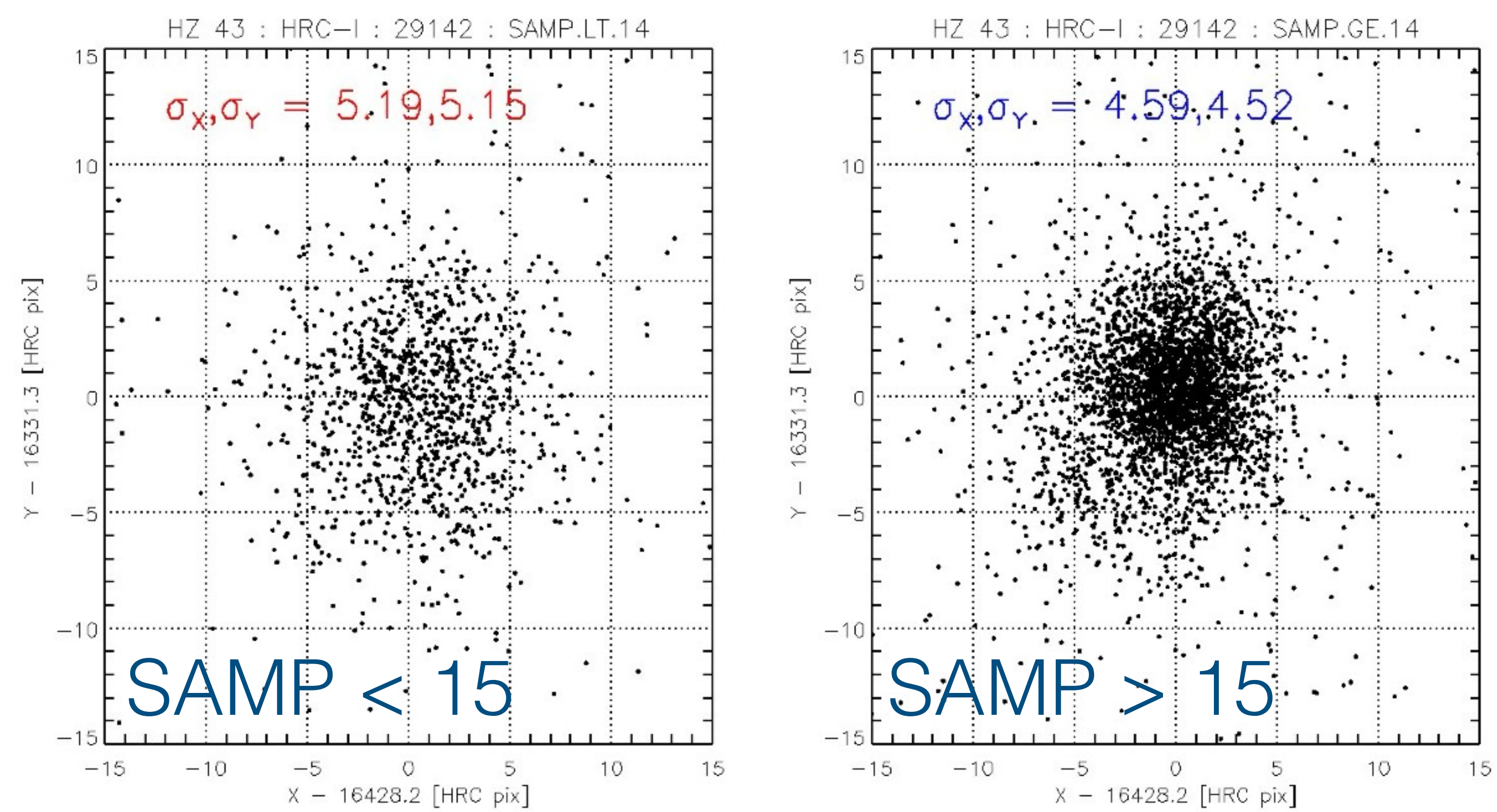
A slight increase of ~0.01” per year over the past four years

Jitter motion and low Pulse Height Events



- Jitter motion is fine-scale motion of the observatory's aim point
- Correction for this effect are applied and removed

Low SAMP events have a broader PSF



- Steady decline in the mean SAMP with time
- Recent observations show a low SAMP peak
- Low SAMP events were removed

Future Calibration Plans

ACIS

- Release a set of temperature-dependent S3 response files
- Update the tgain files for data taken in the 2024-2025 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
- Perform a focus calibration measurement with HRC-I Ar Lac observations