# Calibration: Goals, Priorities, and Plans



## CUC Presentation - November 5, 2026

# Outline

## ACIS

1. Adjustments to the ACIS gain at warm focal plane temperatures

2. Status report on the contaminant on the ACIS filters

3. Adjustments to the S3 response at warm focal plane temperatures

## HRC-I

1. Updates to the QE

2. Change in the default aim-point

## Monitoring of the HRMA/HRC Point Spread Function

# ACIS Gain Corrections

1. Time-dependent gain correction:

   Traditionally calibrated from cold ECS data (T < 117 C) - currently supplemented with cold Cas A and Perseus data

2. Temperature-dependent gain correction:

   Traditionally calibrated using the ECS Mn line (5.9 keV) over a broad range of focal plane temperatures - currently supplemented with clusters of galaxies (I.e., the Fe-Kα near 6.5 keV). Expressed as a quadratic in the focal plane temp:

$$\Delta \text{PHAS} / \text{PHAS} = \underline{\mathbf{a_0}}(\text{FP_TEMP}-T_0) + a_1(\text{FP_TEMP}-T_0)^2$$

3. Energy-dependent gain correction:

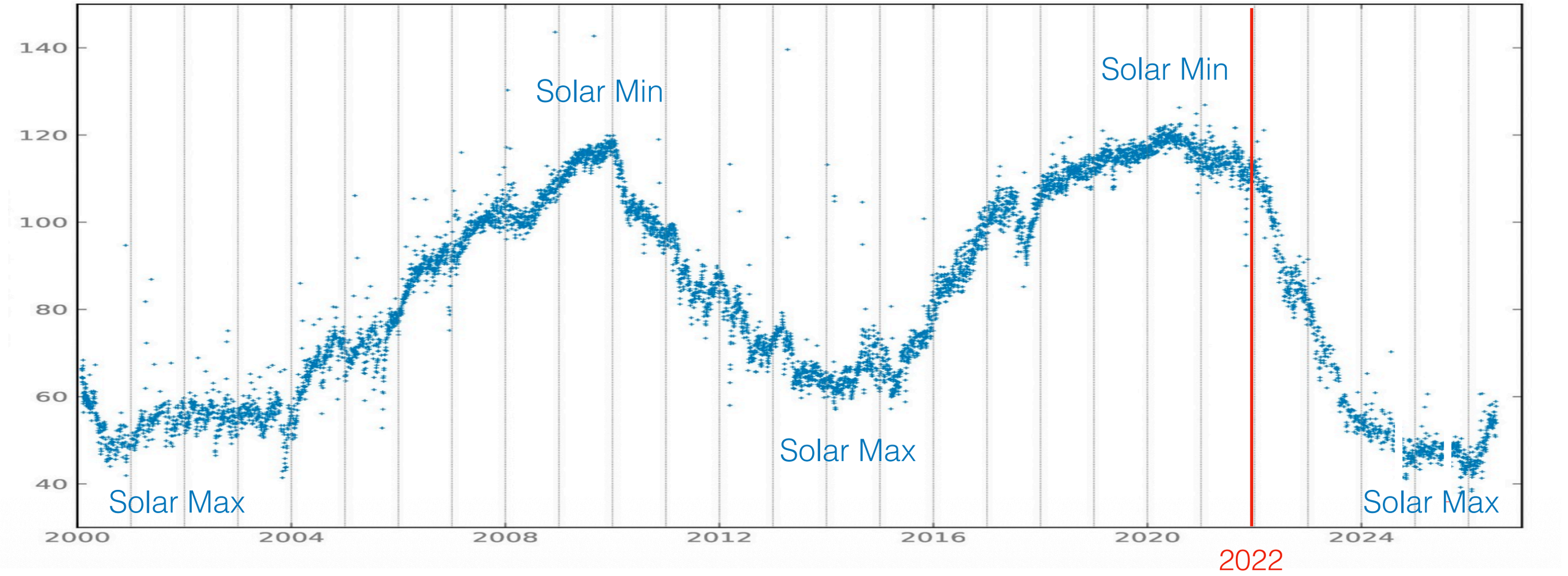
   Calibrated using ECS data over a broad range of focal plane temperatures.

   Expressed as a power-law in energy.

Two recent events have affected the ACIS gain:

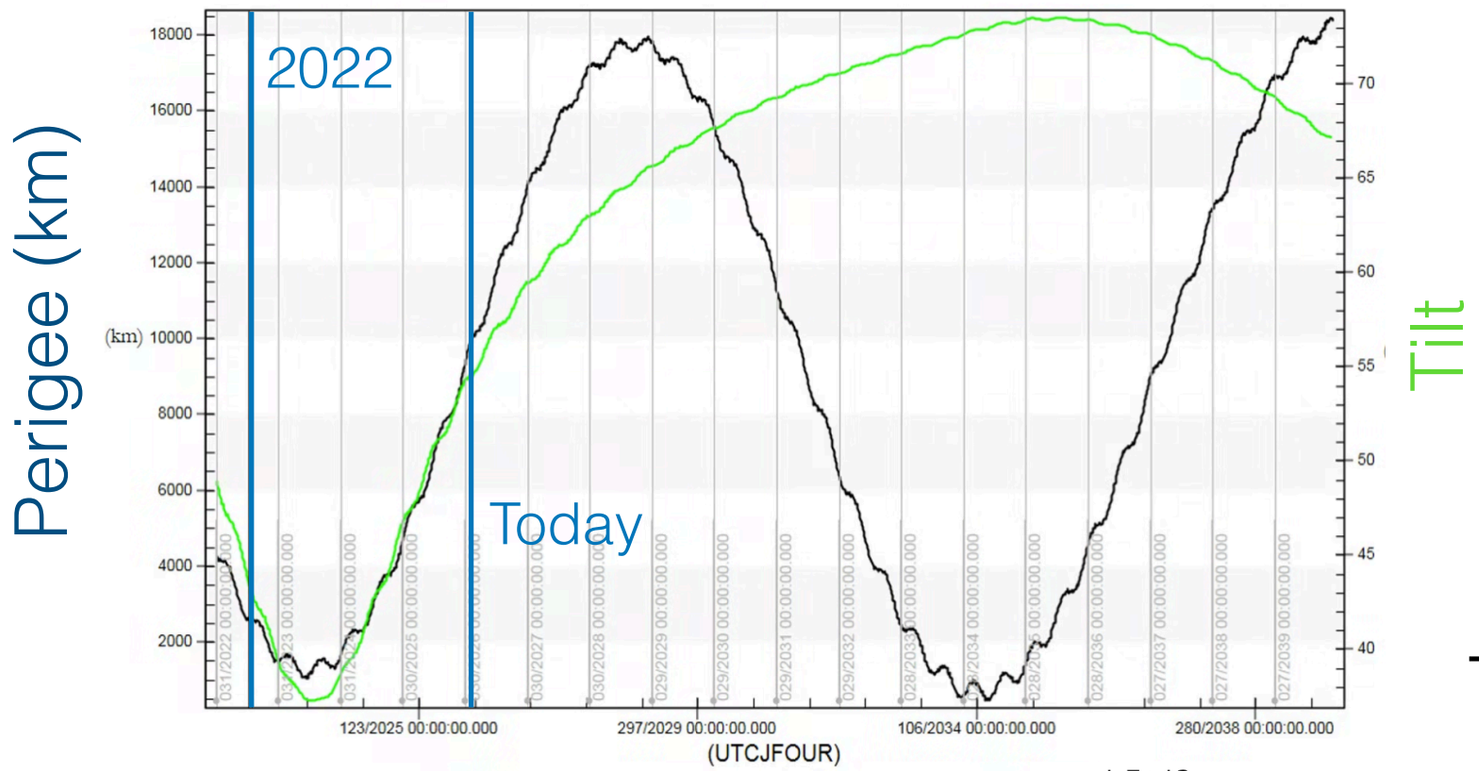
- Entering the recent solar maximum
- Chandra's orbit passing through its minimum perigee
- Both events happened around 2022-2023

# ACIS Background Light Curve




Note: High background rates fill in the radiation-induced traps and reduce CTI
Low background rates leave traps unfilled which increases CTI

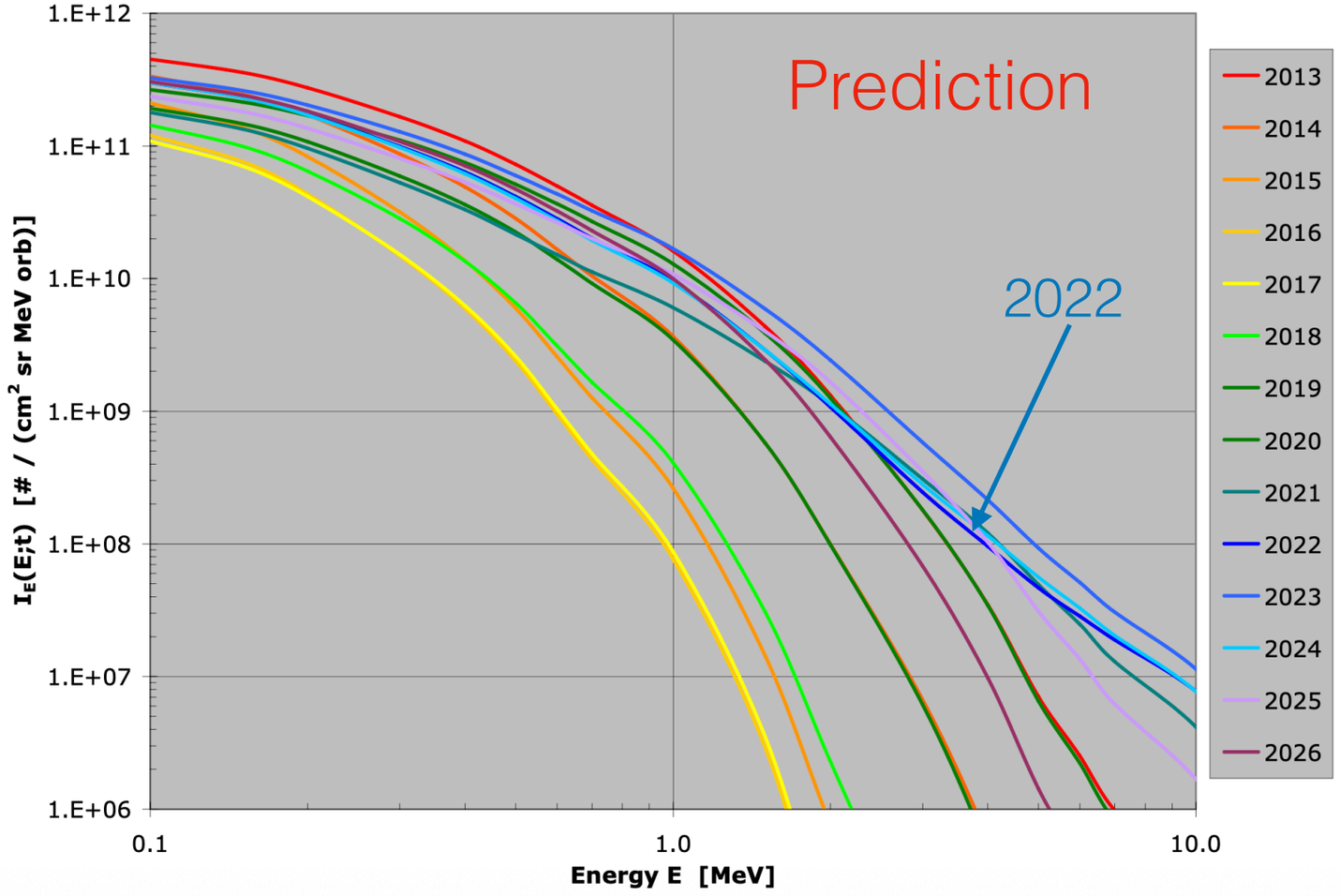
# Evolution in Chandra's Orbit





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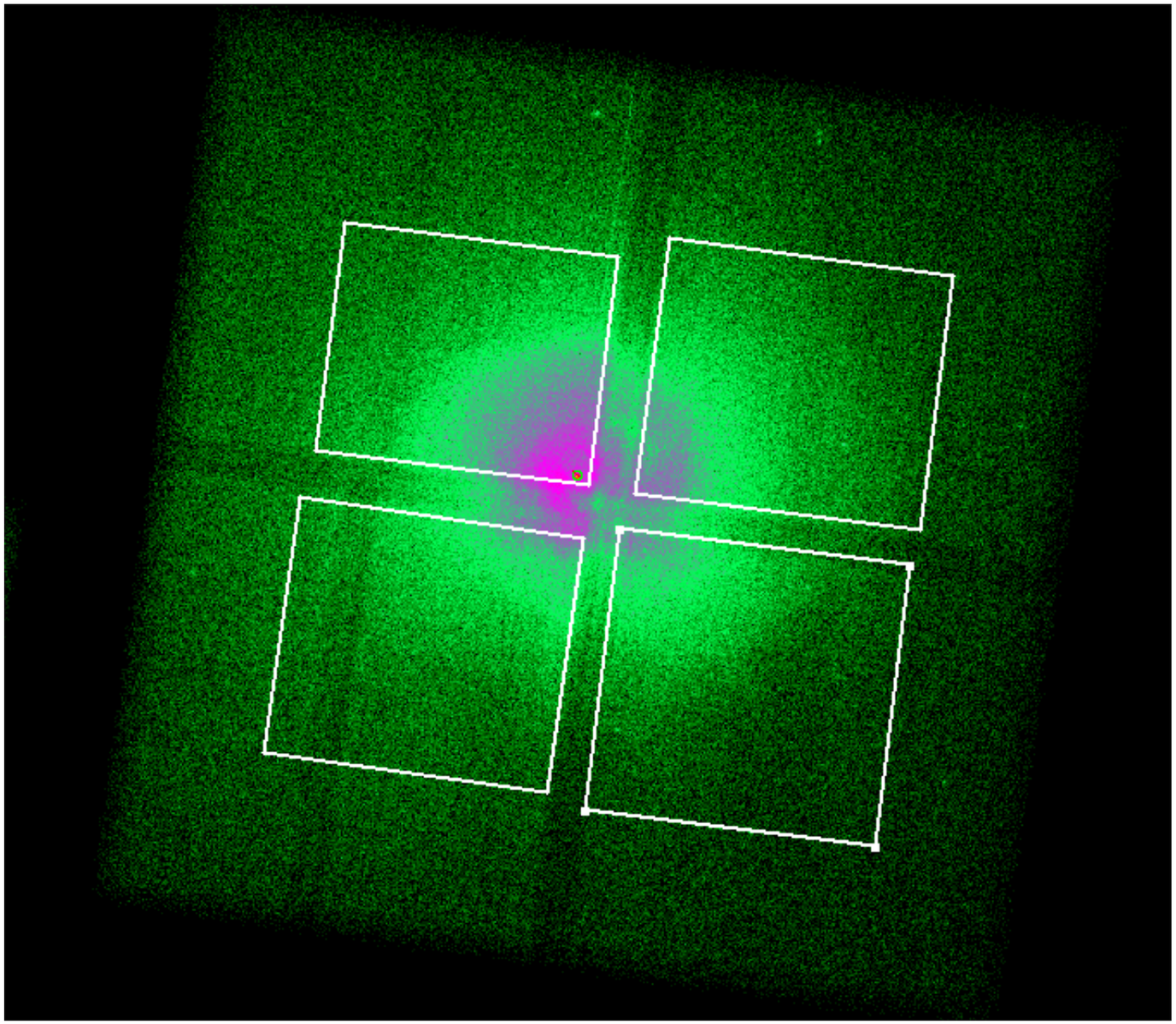

# Trapped Proton Spectrum

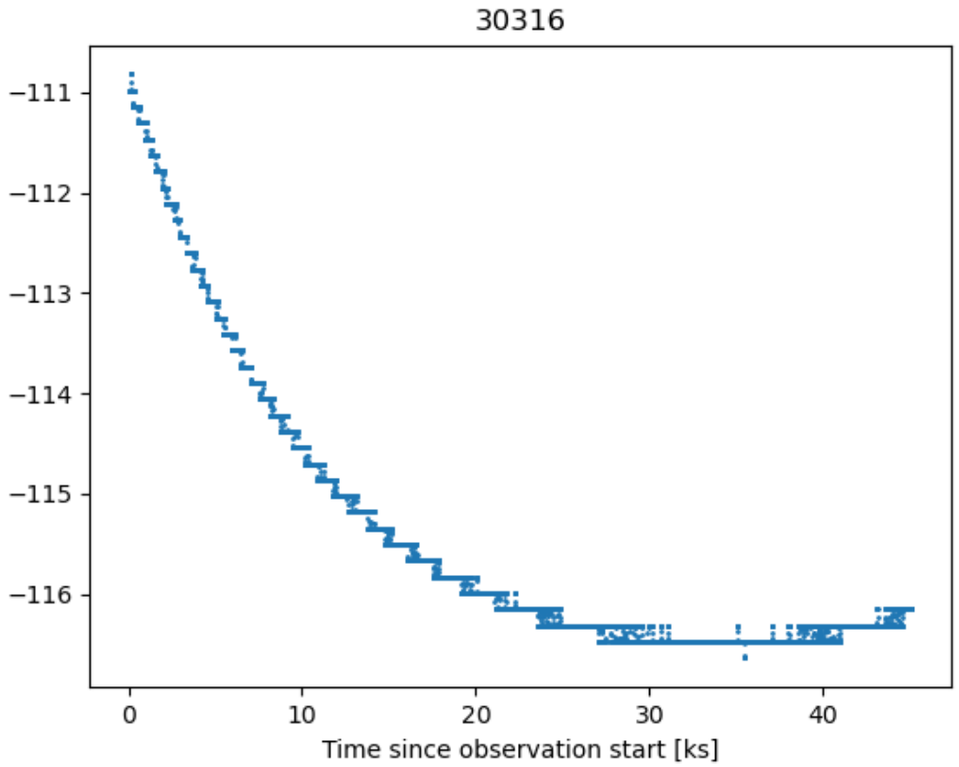


# Calibrating ACIS with data from the Perseus Legacy Project

Perseus covers all 4 CCDs on ACIS-I and
most observations span a range in focal plane temperatures

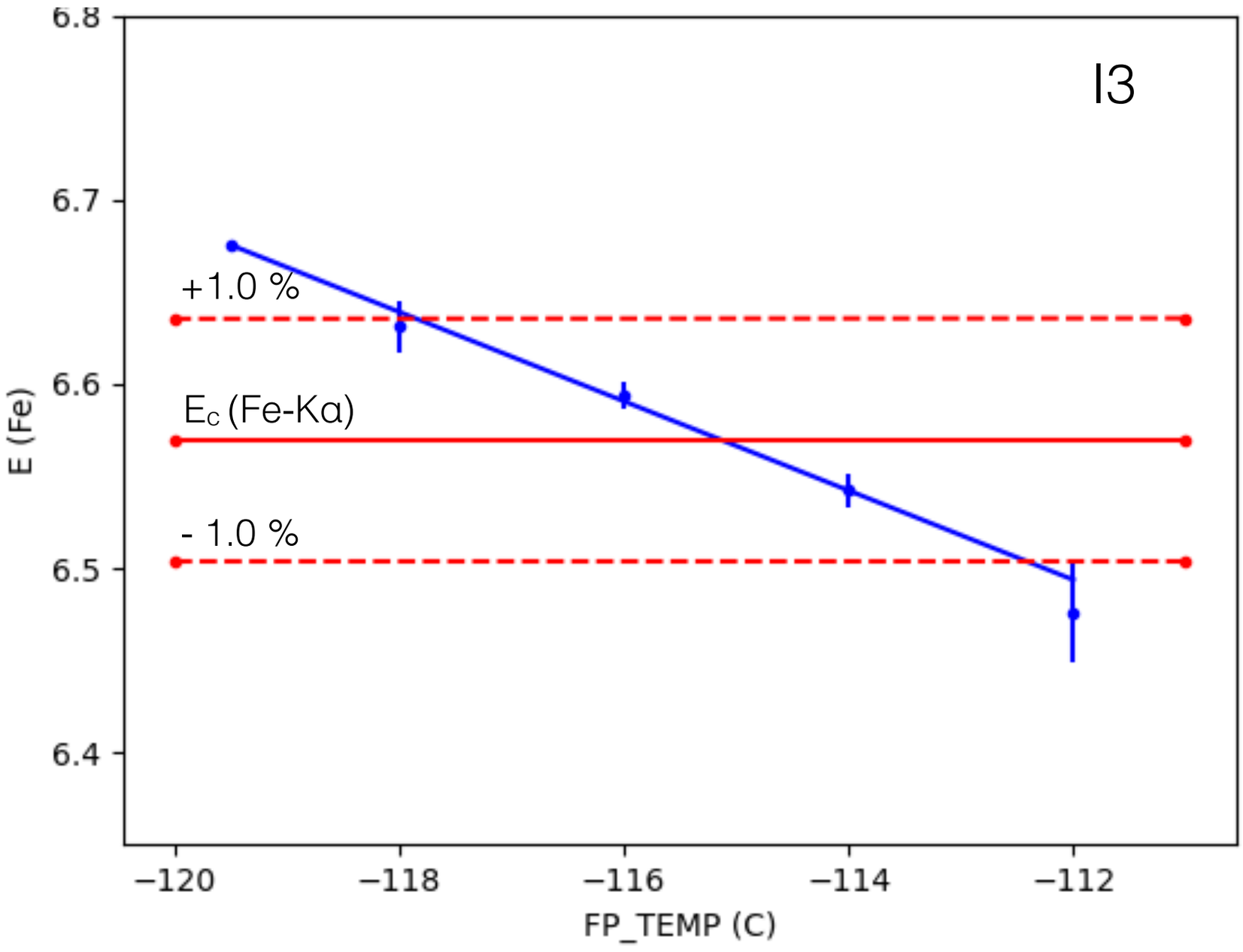
Z = 0.017



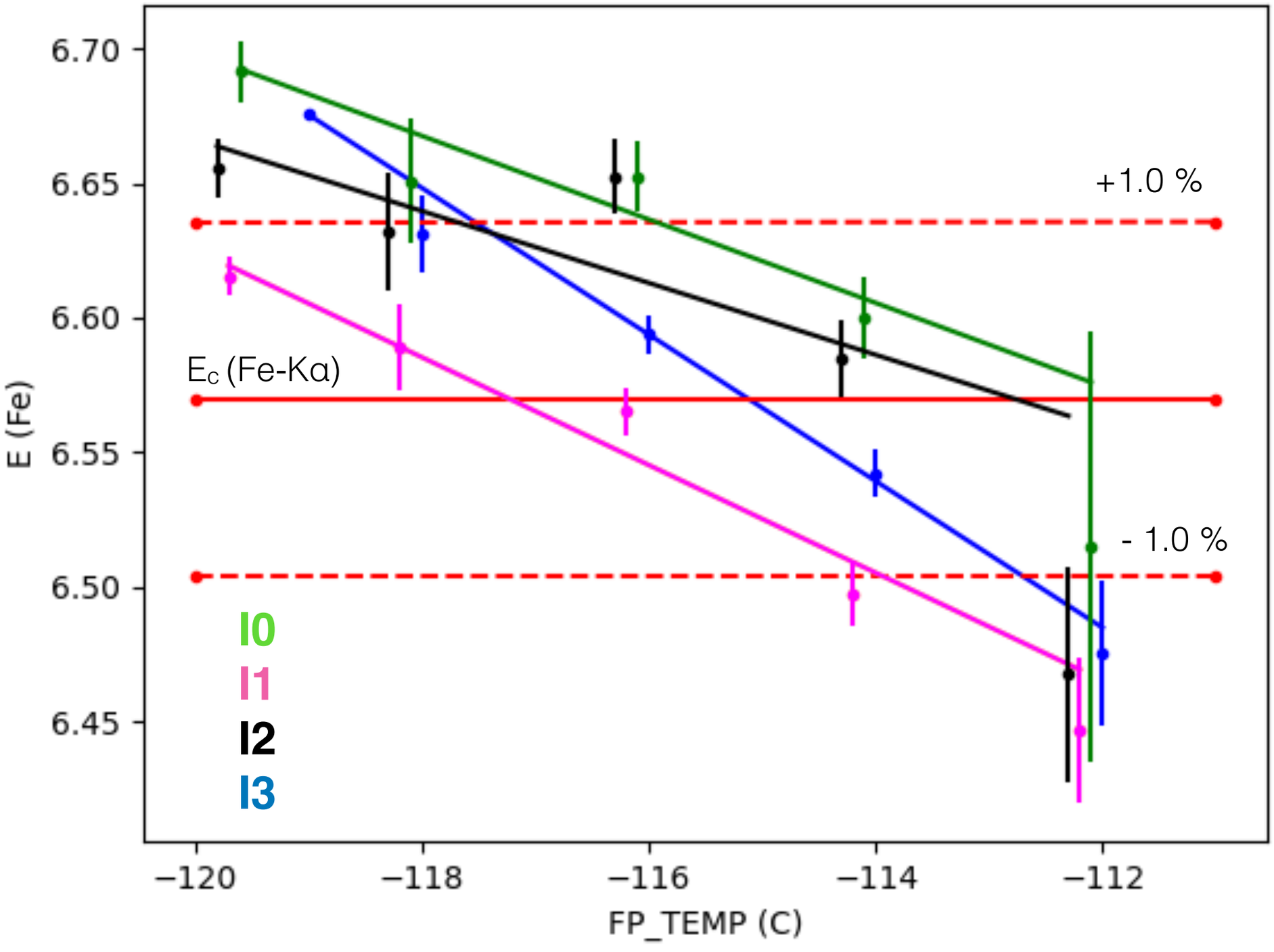


# Perseus data - Fe-Kα line centroid vs. focal plane temperature

- Extract spectra from 7 long ACIS-I observations of Perseus taken in 2026
- Split the data into 2 degree temperature bins in focal plane temperature
- Fit all spectra in each temperature bin simultaneously

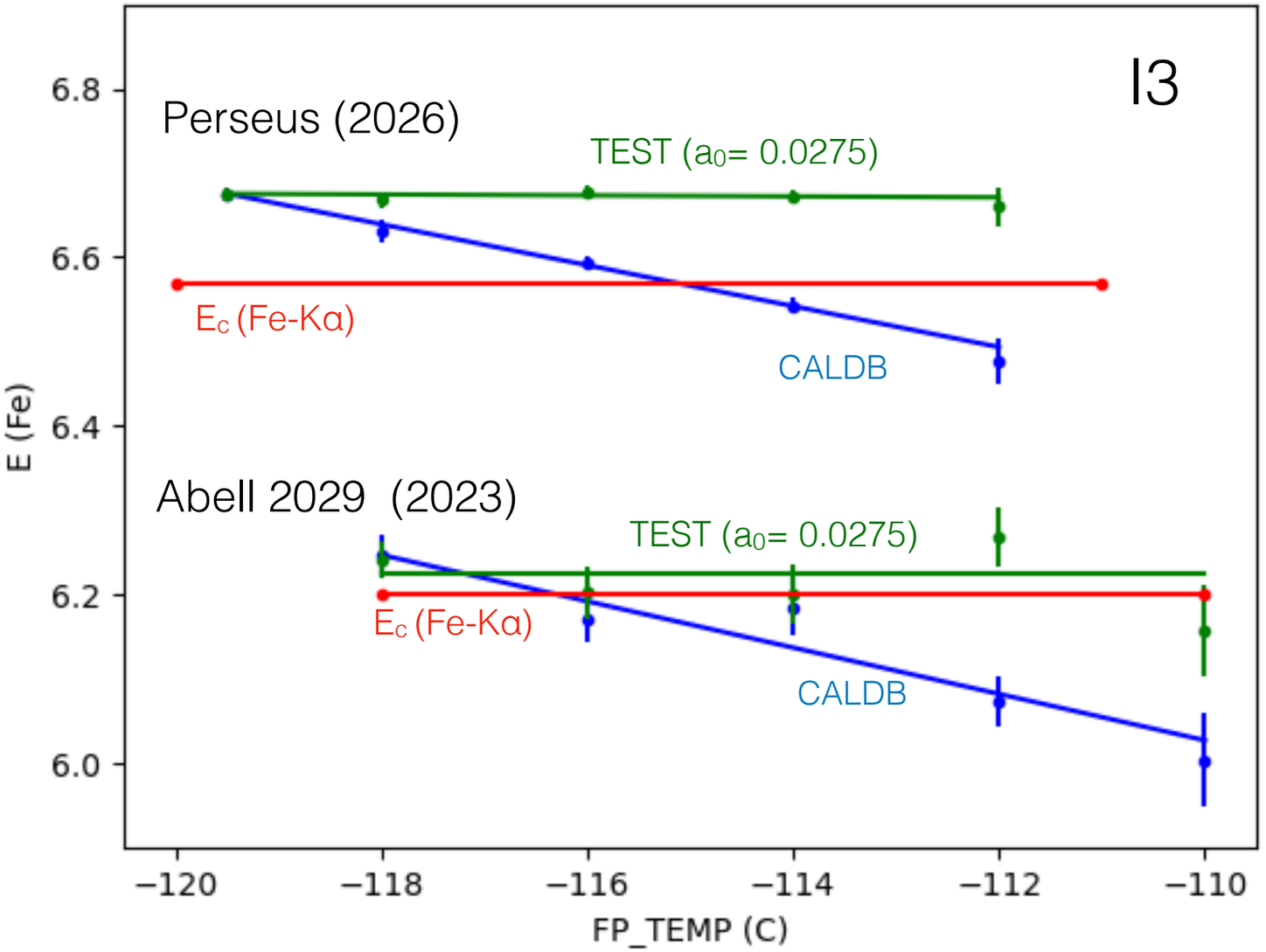


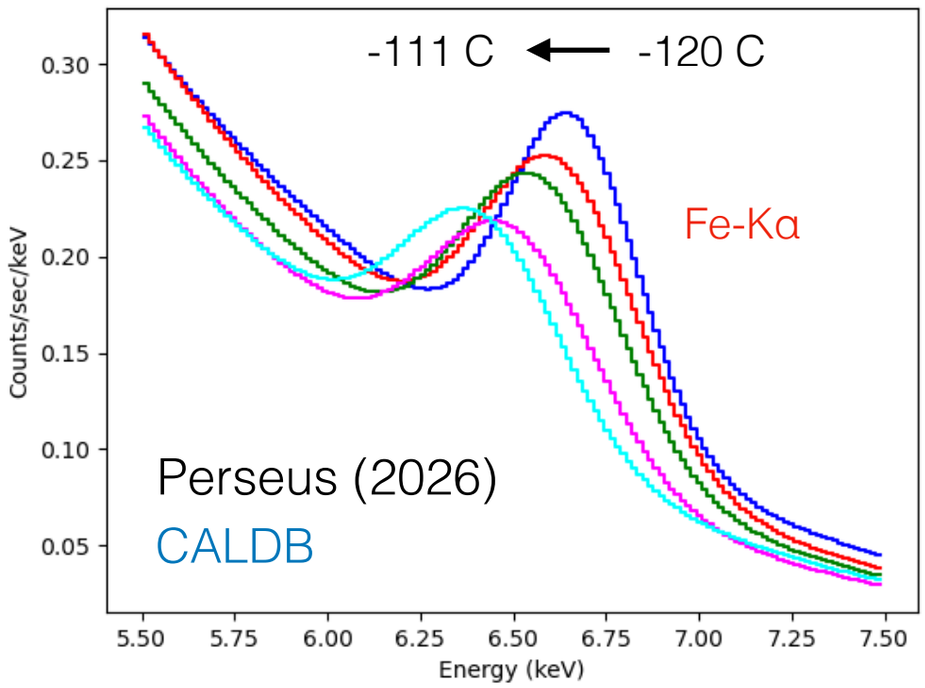
# Perseus data - Fe-Kα line centroid vs. focal plane temperature
# For all 4 CCDs on ACIS-I

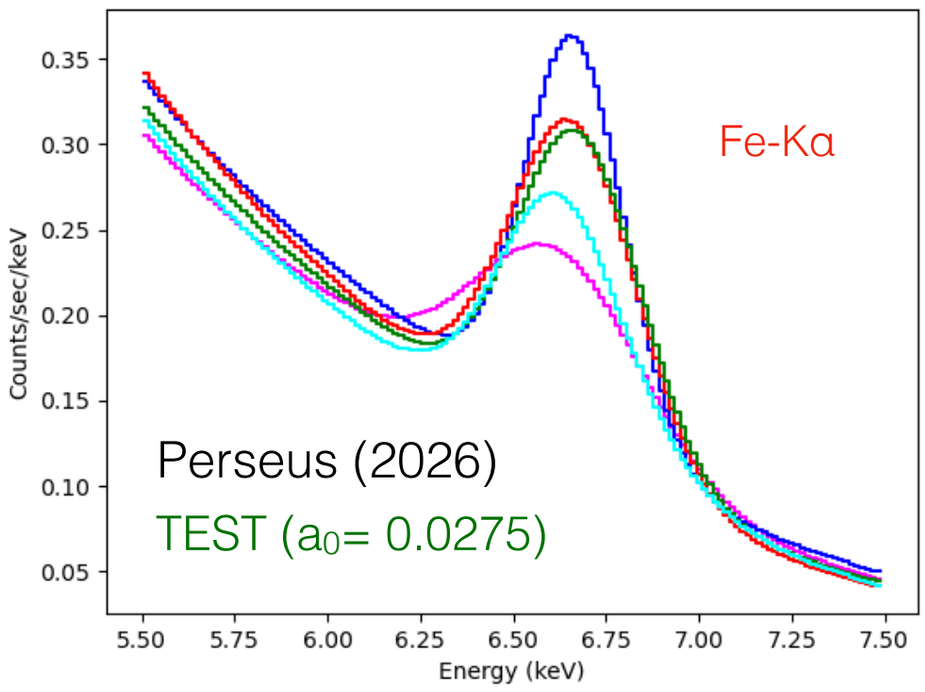


# Perseus and A2029 data - Fe-Kα line centroid vs. focal plane temperature

Adjust the temperature-dependent gain correction
by changing the coefficient of the linear term ($a_0$)



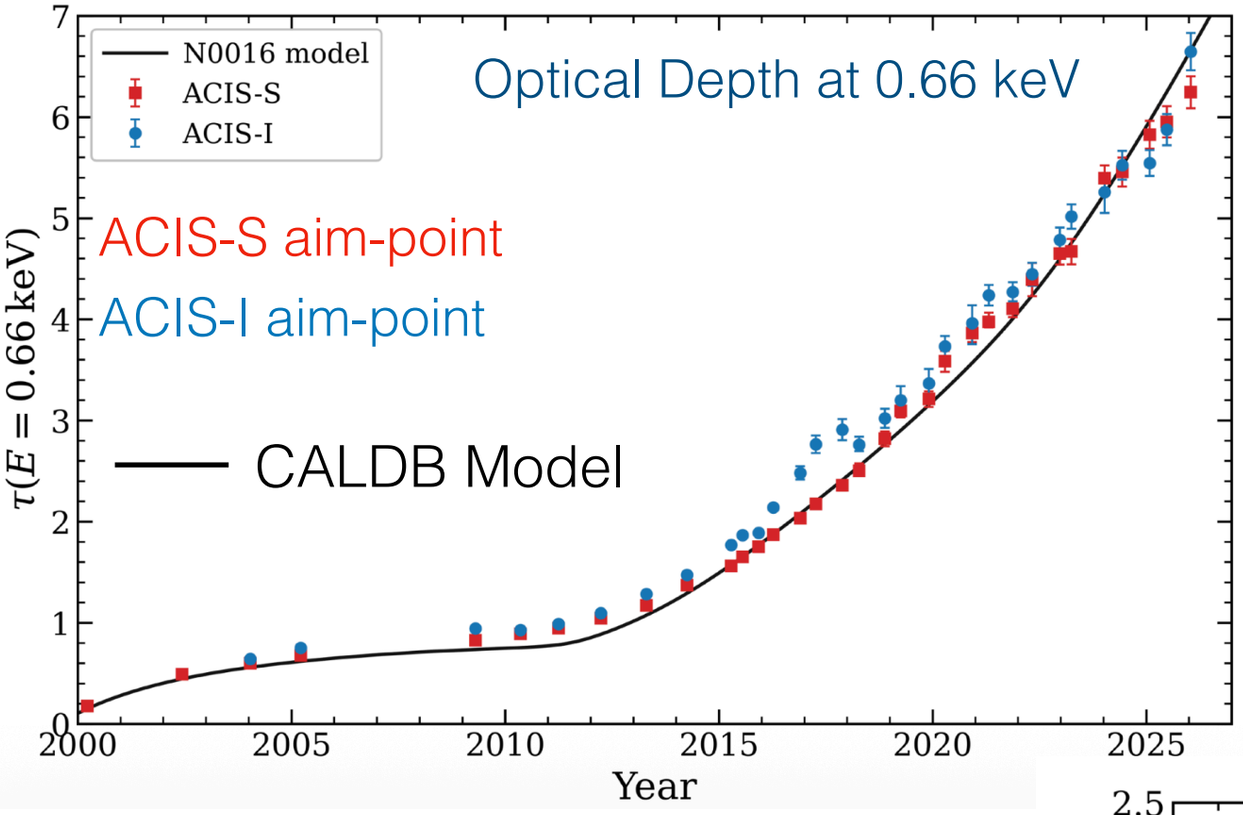




Needed corrections:

- Adjust the recent time-dependent gain correction
- Adjust $a_0$ for ACIS-I0, I1, I2, I3, S3

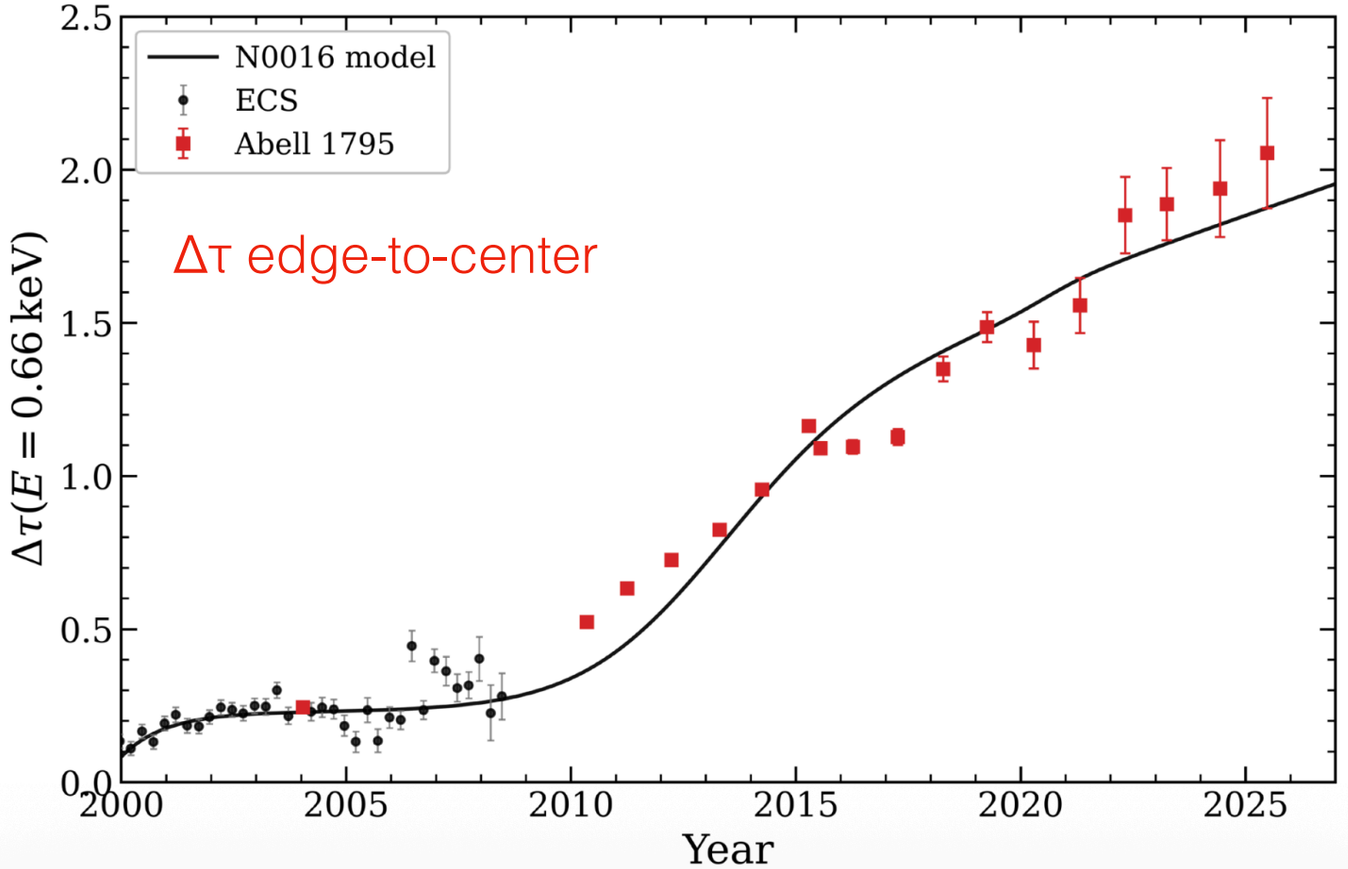
# Monitoring the contaminant on the ACIS filters




Primary calibration targets:

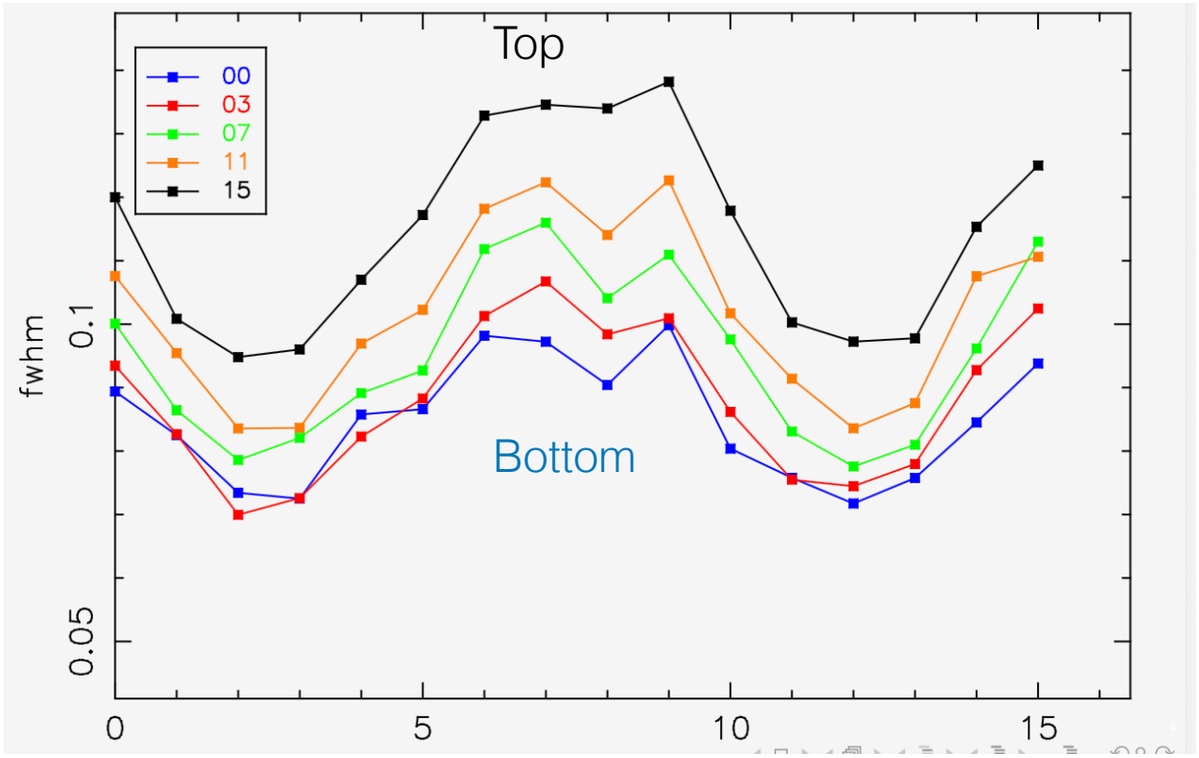
- Abell 1795
- Big Dither LETG/ACIS-S observations of Mkn 421
- E0102-72

**Conclusion:** No reason to update the ACIS contamination model at this time



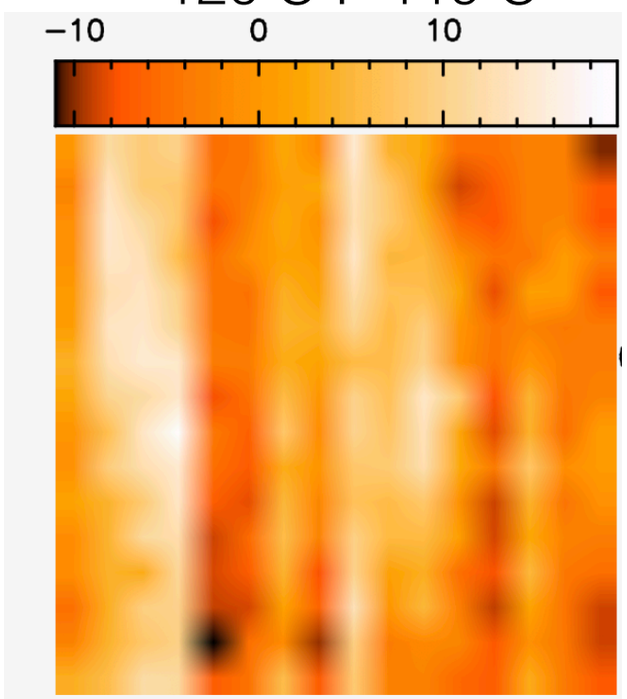
# Update to the ACIS-S3 response

- Divide ECS data into 7 FP temperature intervals between -120 and -107 C
- Fit widths of Al, Ti, and Mn lines in 32x32 pixel regions and each temperature bin




Linewidth is greater at large chipy and near the n1/n2 node boundary

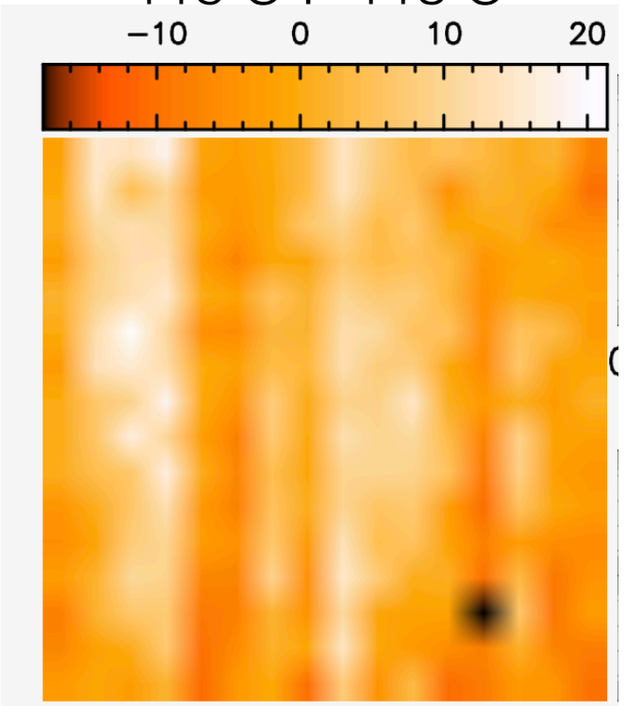
-120 C : -119 C




Residuals from fitting a gaussian to Mn-Kα line with a test version of the S3 rmf

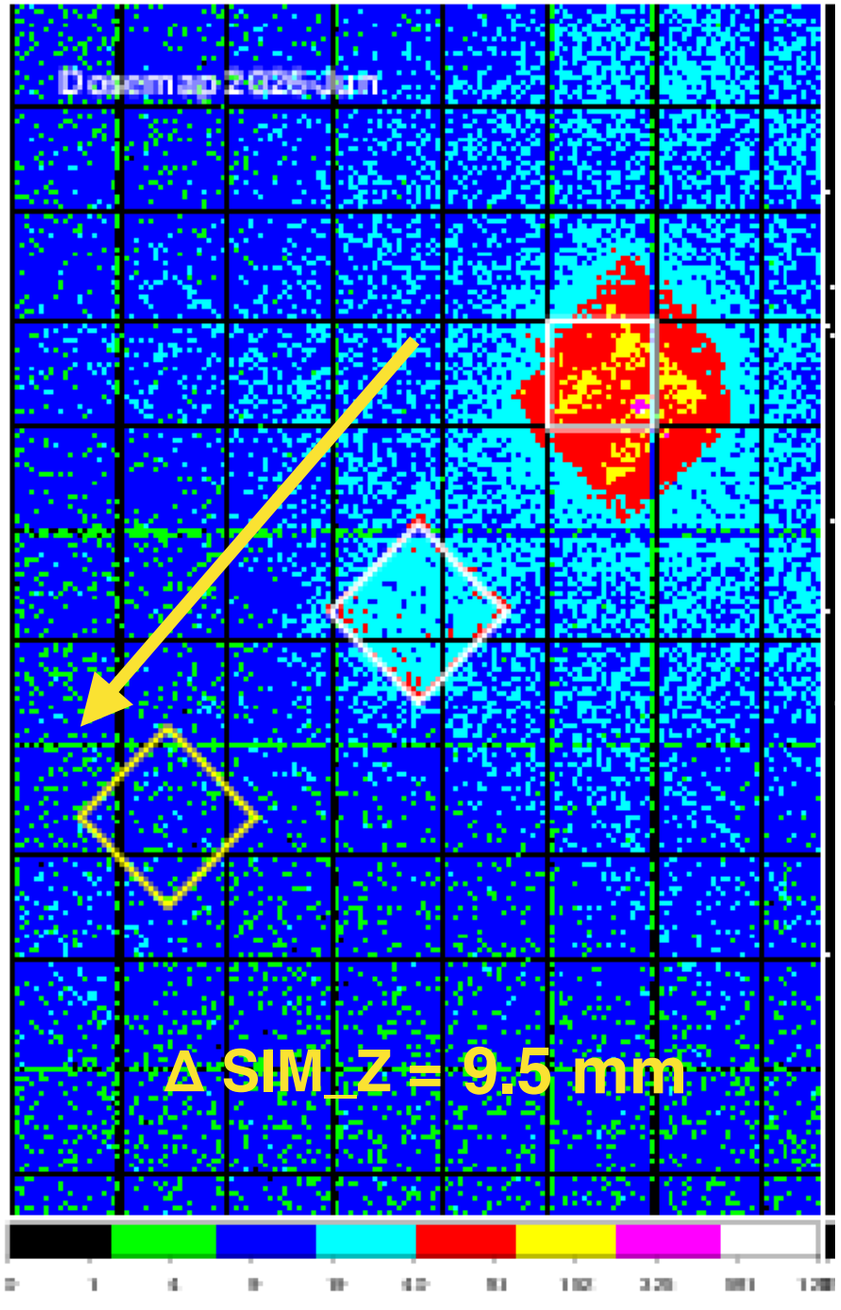
**1σ in the residuals ~ 10 eV**

-115 C : -113 C

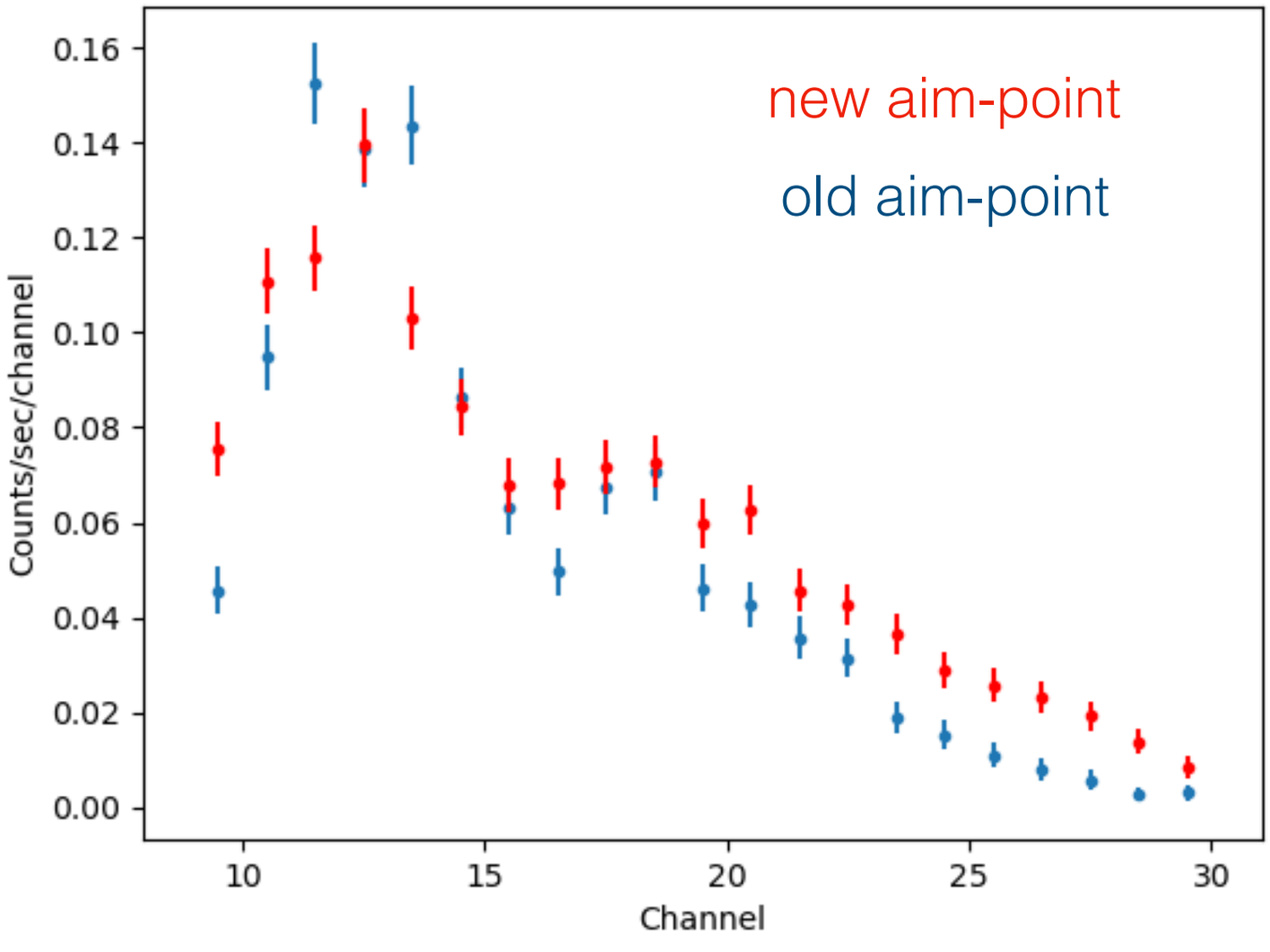


# Adjustment to the HRC-I aim-point

HRC-I total dosage map
In detector coordinates



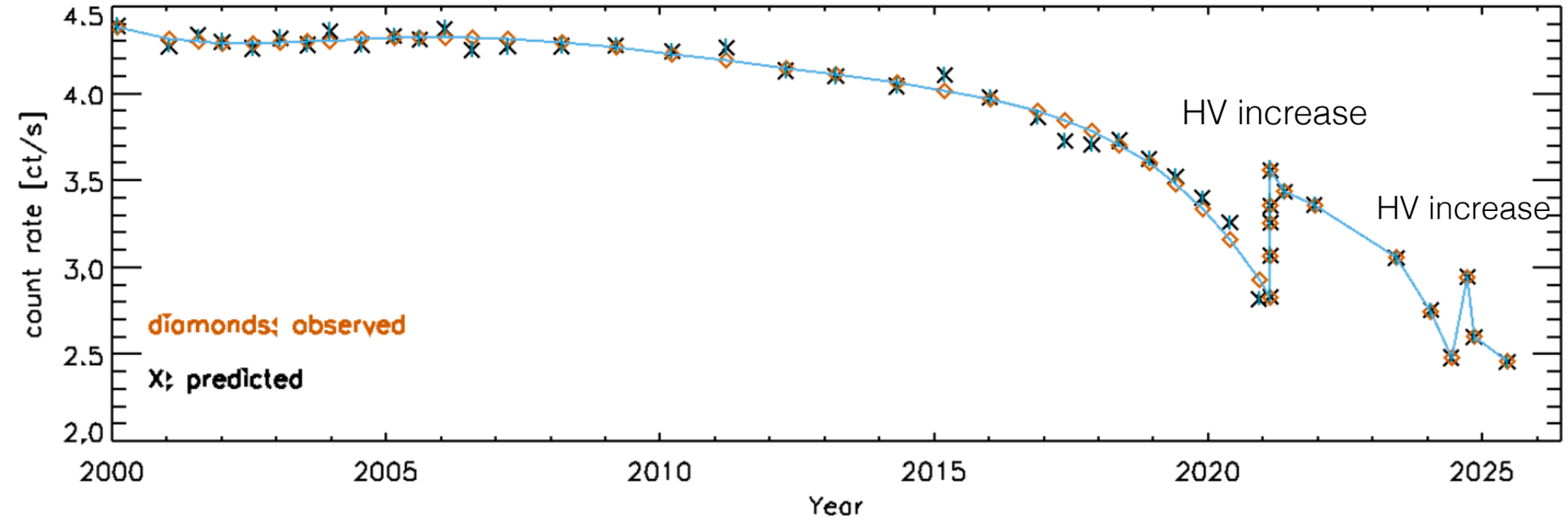

HZ43 spectra - gain shift between old and new
HRC-I aim-points



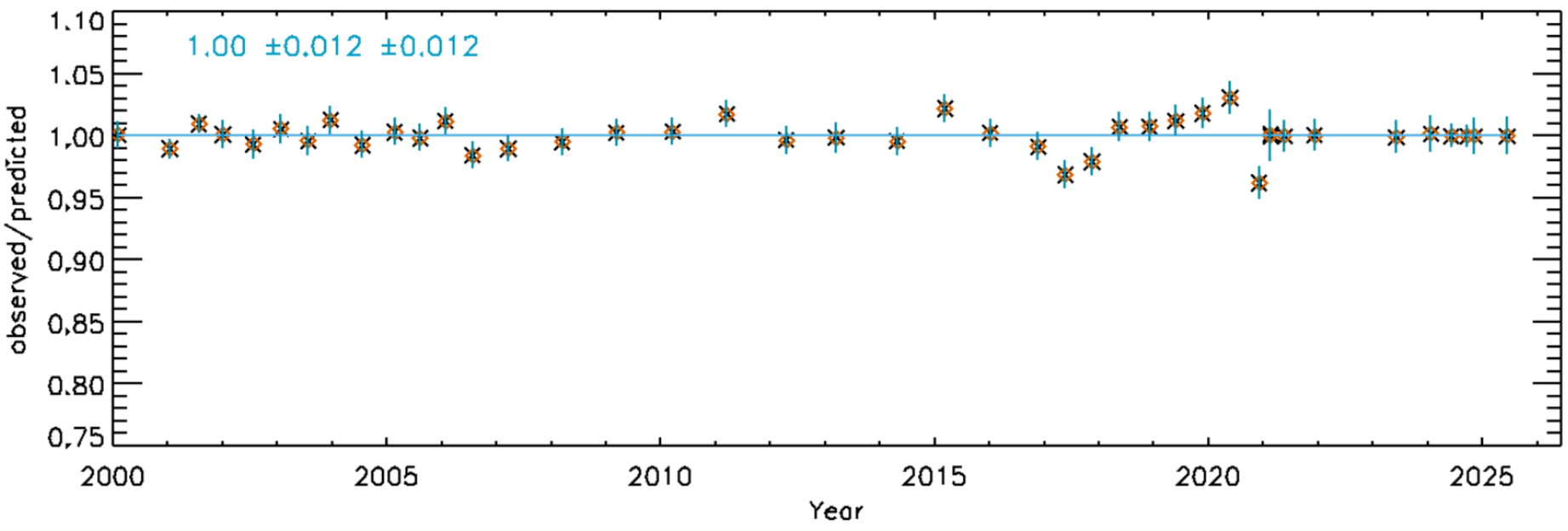
# Update to the set of time-tagged HRC-I QE

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

Observed HRC-I/LETG 0th order HZ 43 count rate

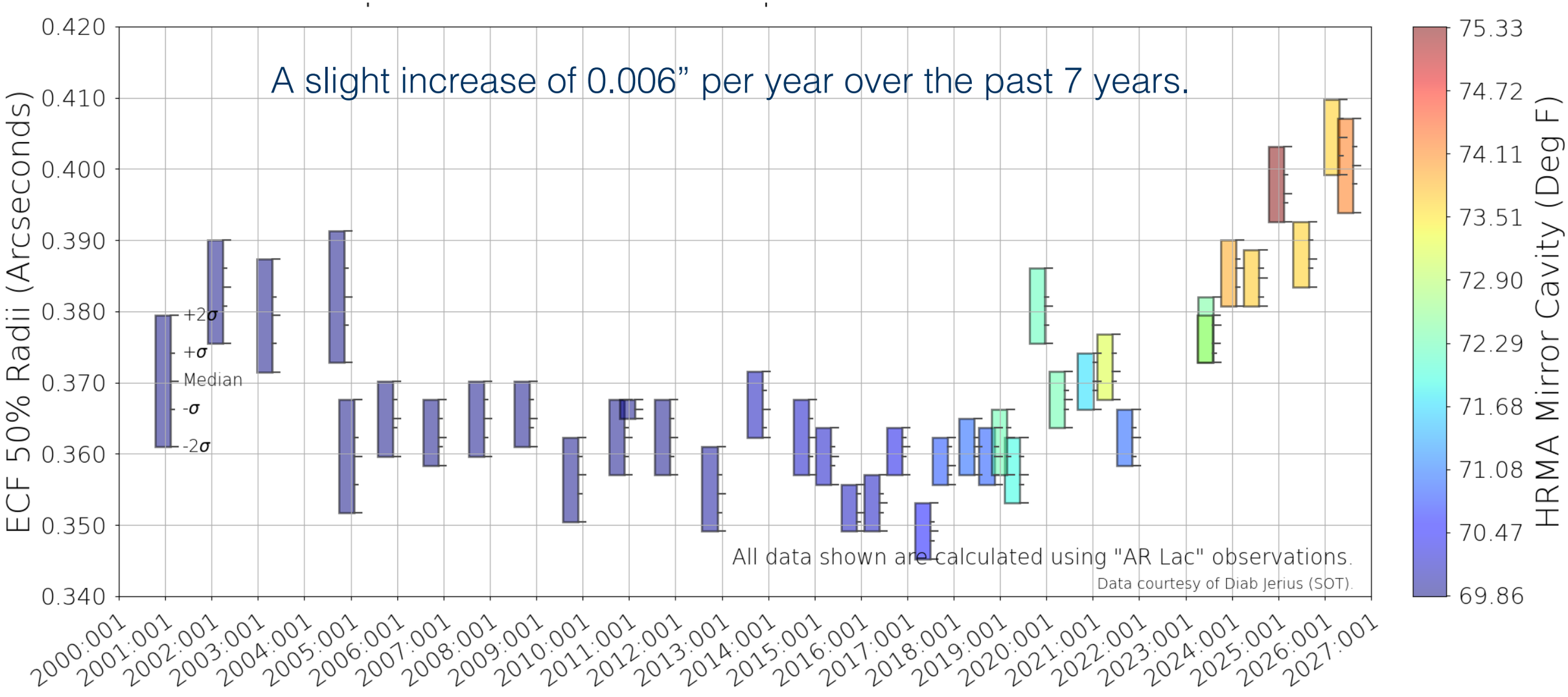



HZ43 flux normalized to early observation



# PSF Monitoring

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




Possible Causes:

1) Temperature gradients on the HRMA (None detected)
2) Detector effects (accounts for some of the change)
3) Thermal expansion of the optical bench (under investigation)

# Near-Term Calibration Plans

## ACIS

- Release an updated time-dependent gain correction file for data taken in the 2025-present timeframe
- Release an updated temperature-dependent gain correction file
- Release an updated energy-dependent gain correction file
- Release an updated ACIS-S3 response file to account for line broadening at warm focal plane temperatures
- Generate a stet of ACIS blank sky observations by co-adding data accumulated over the past four years
- Continue to monitor the contaminant on the ACIS filters

## HRC

- Release updated QE and QEU products for both the HRC-I and HRC-S

## Optics

- Continue to monitor the PSF
- Analyze the upcoming plate focus test (Dec. 2026)