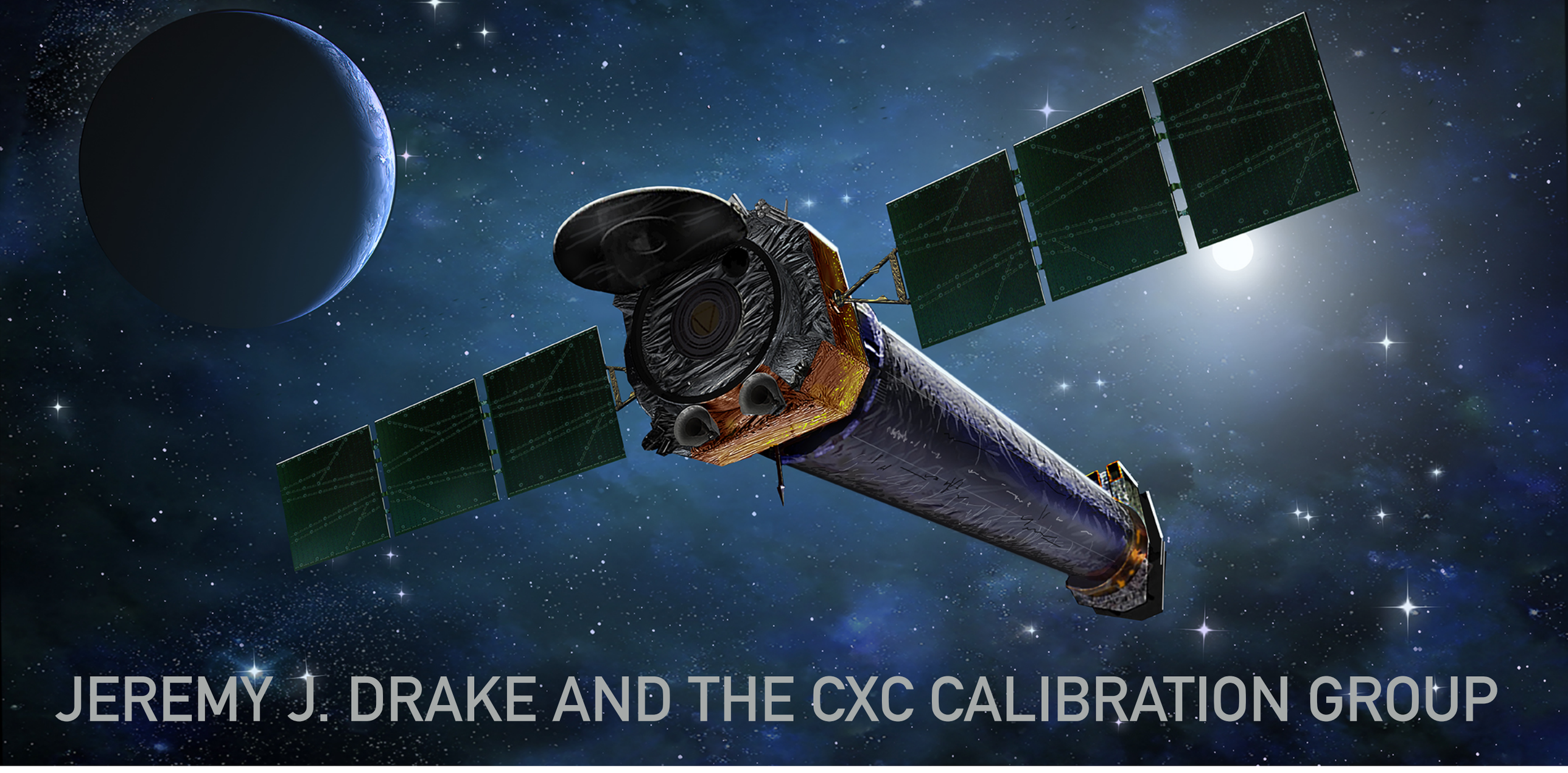
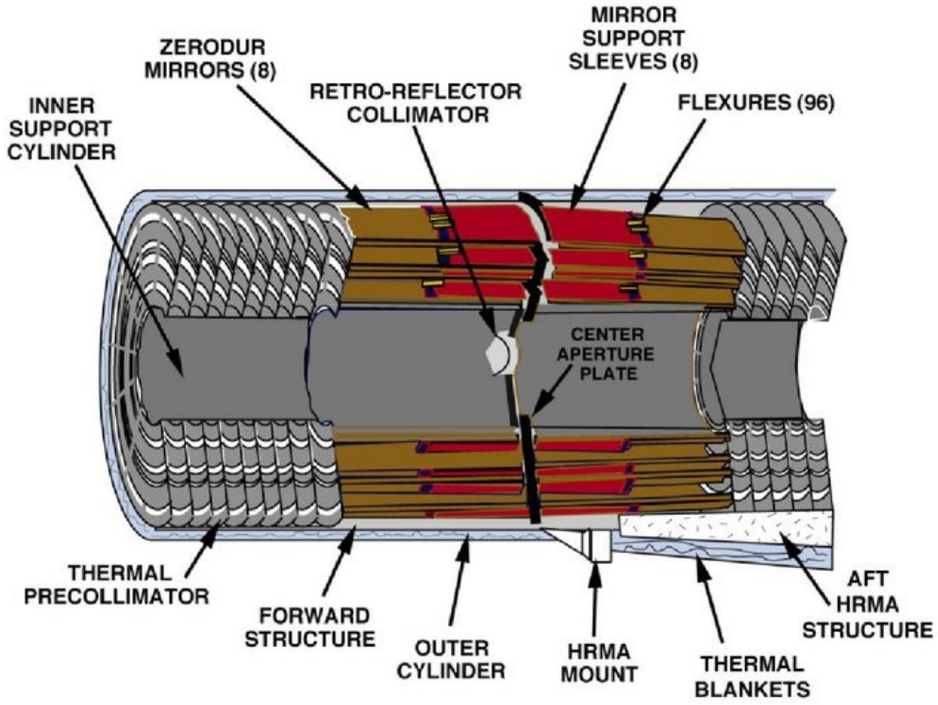
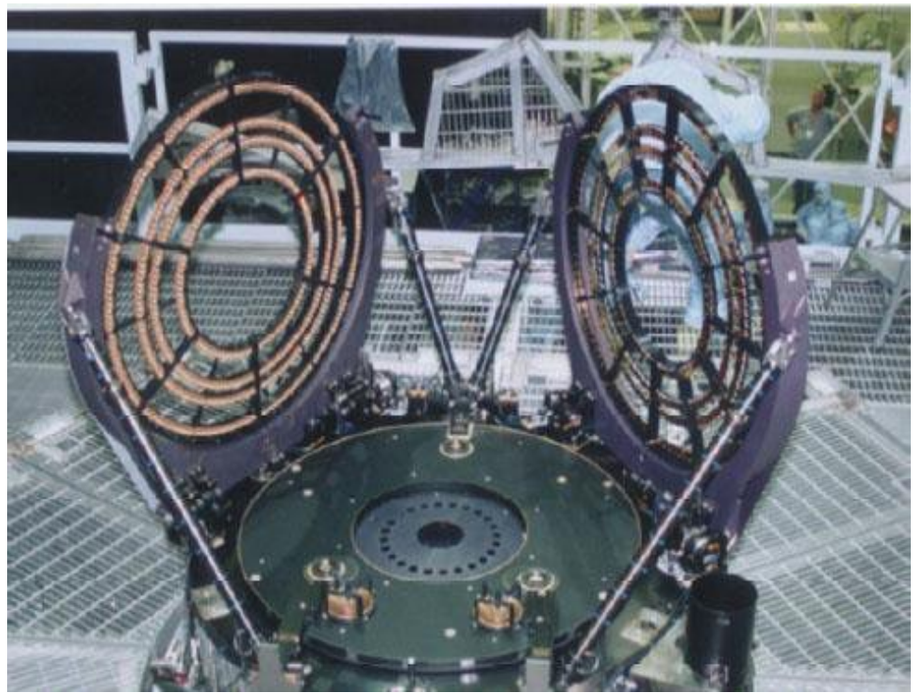


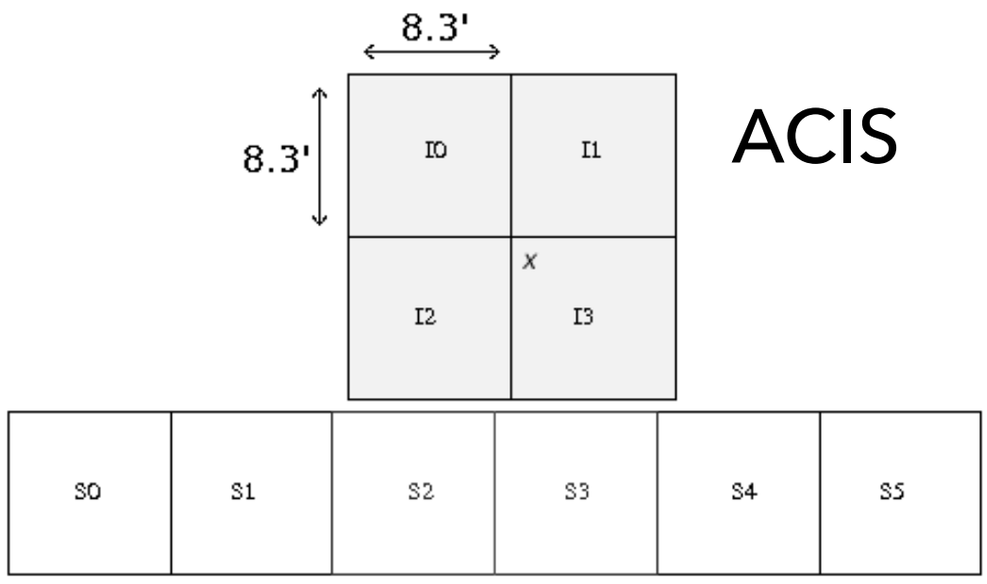
JEREMY J. DRAKE AND THE CXC CALIBRATION GROUP

CHANDRA CALIBRATION: PROBLEMS AND (SOME) SOLUTIONS

CHANDRA HARDWARE COMPONENTS

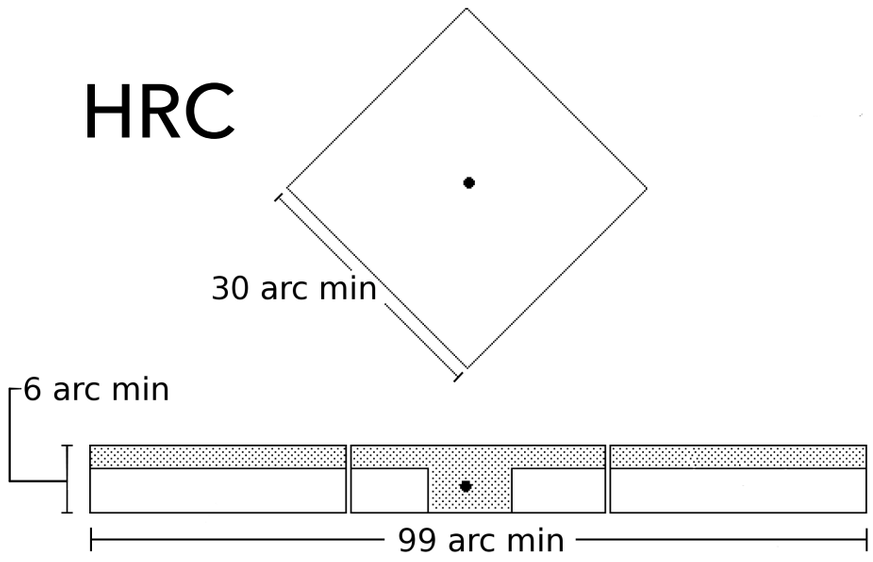




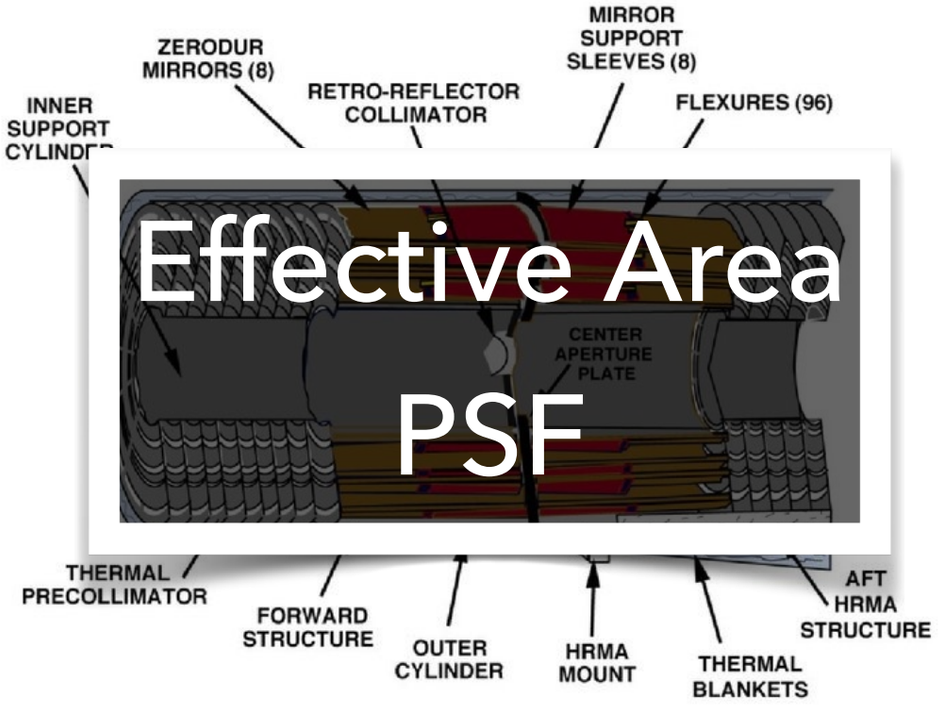


ACIS

HRC

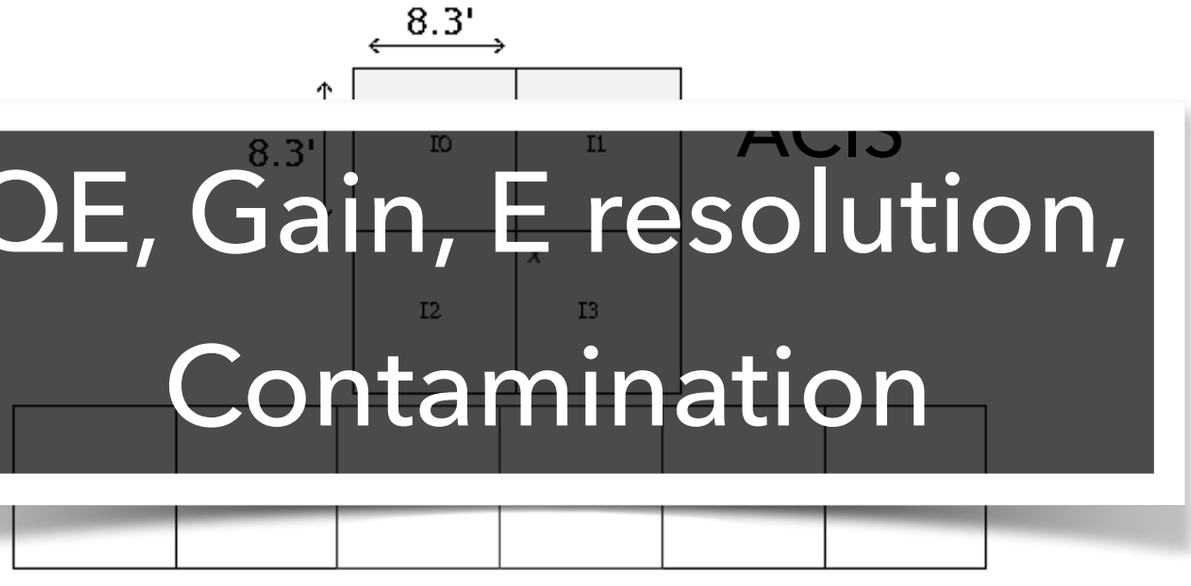


CHANDRA HARDWARE COMPONENTS

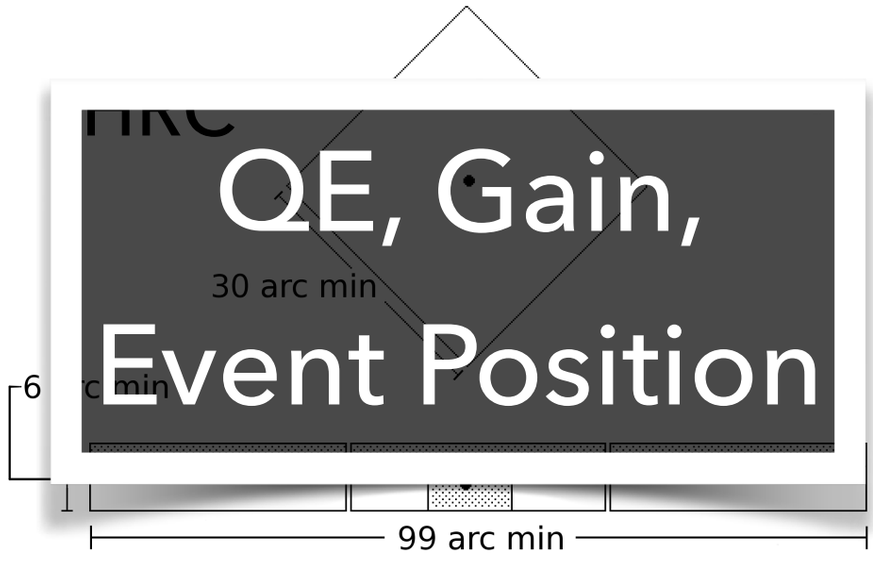


Effective Area
PSF

Diffraction Efficiency
LRF, Dispersion



QE, Gain, E resolution,
Contamination



QE, Gain,
Event Position

OUTLINE

- ACIS
  - External Calibration Source decay
  - Temperature-dependent gain
  - Contamination
- HRC
  - A-side electronics failure
  - QE decline; gain decline
- Point Spread Function
  - Secular trend or worsening PSF in HRC-S

OUTLINE

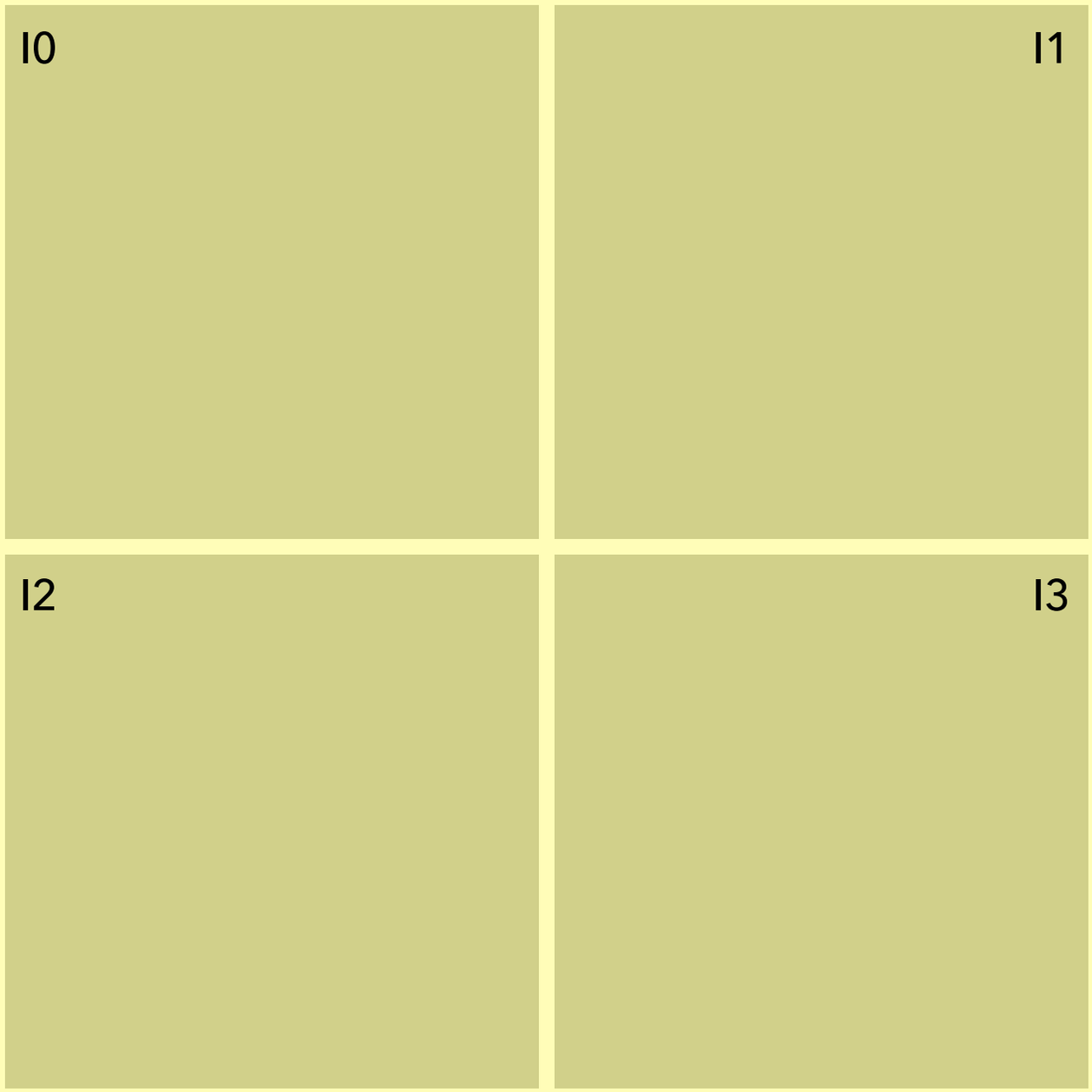
- ACIS
  - External Calibration Source decay
  - Temperature-dependent gain
  - Contamination
- HRC
  - A-side electronics failure
  - QE decline; gain decline
- Point Spread Function
  - Secular trend or worsening PSF in HRC-S

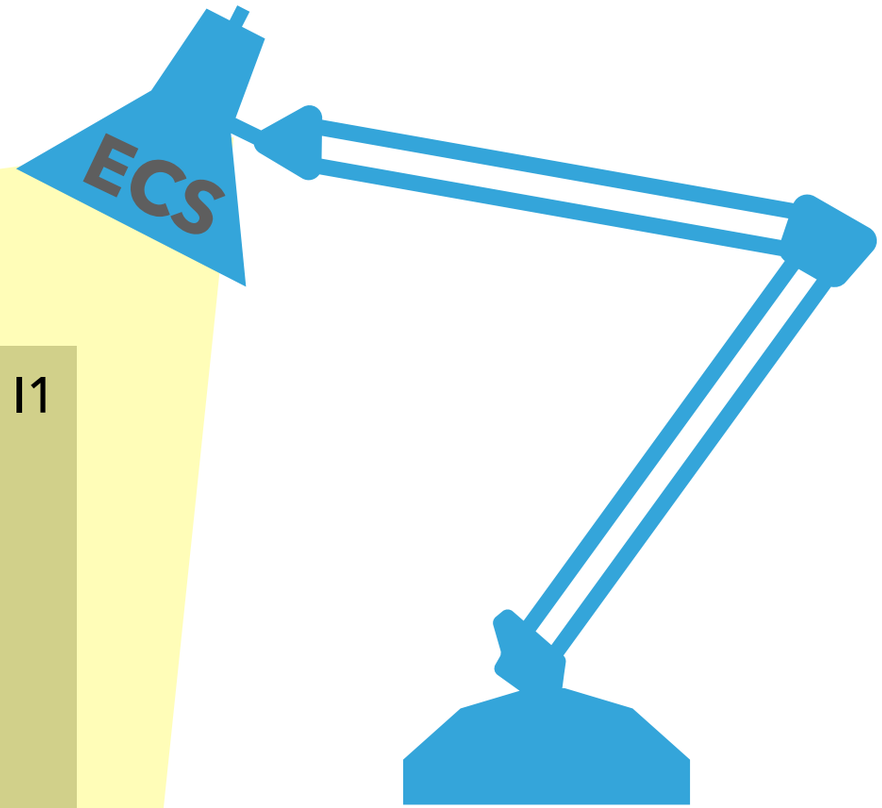
Take home:

Always use latest CALDB!

ADVANCED CCD IMAGING SPECTROMETER (ACIS)

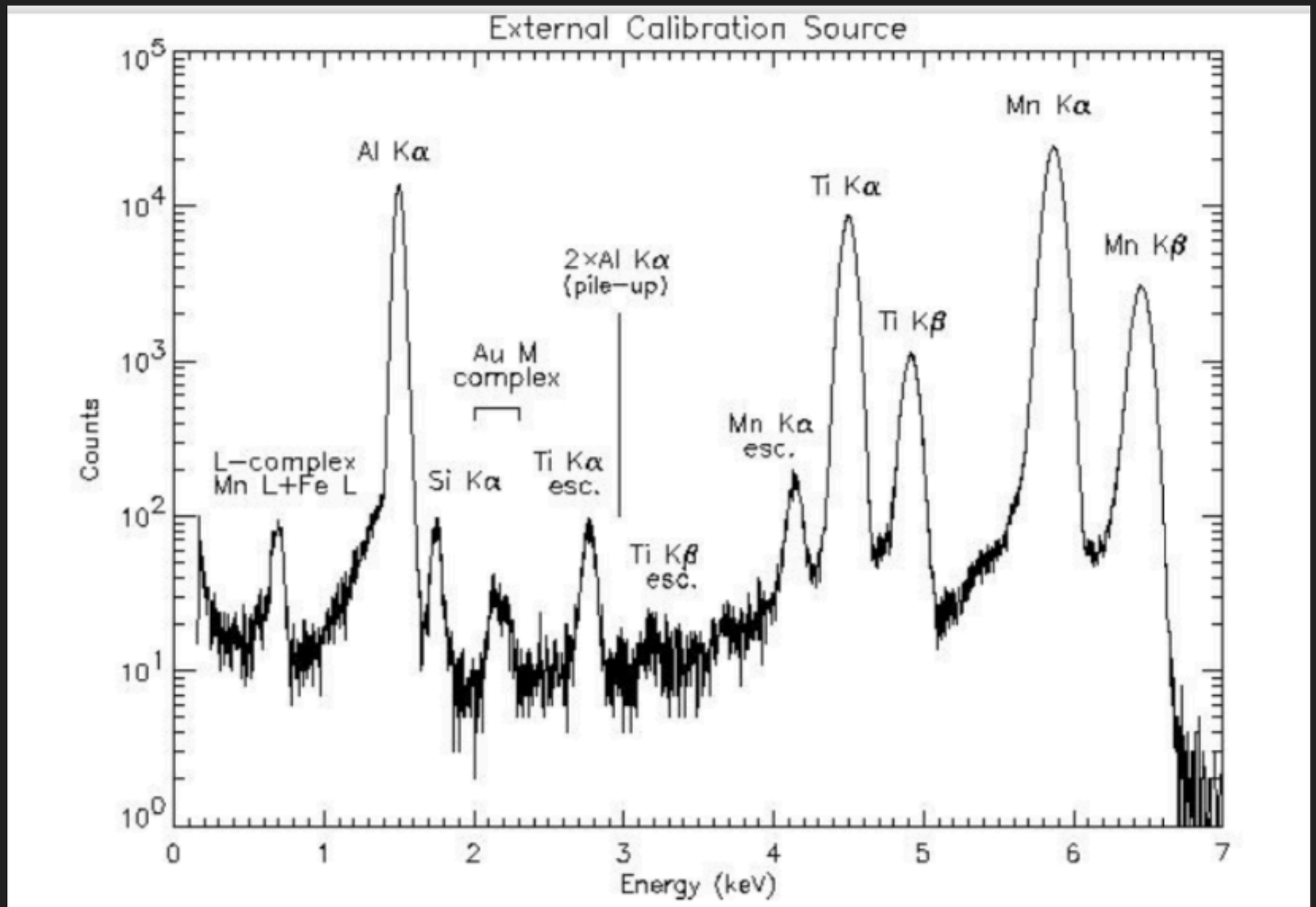
GAIN ISSUES: DECAY OF ECS SIGNAL





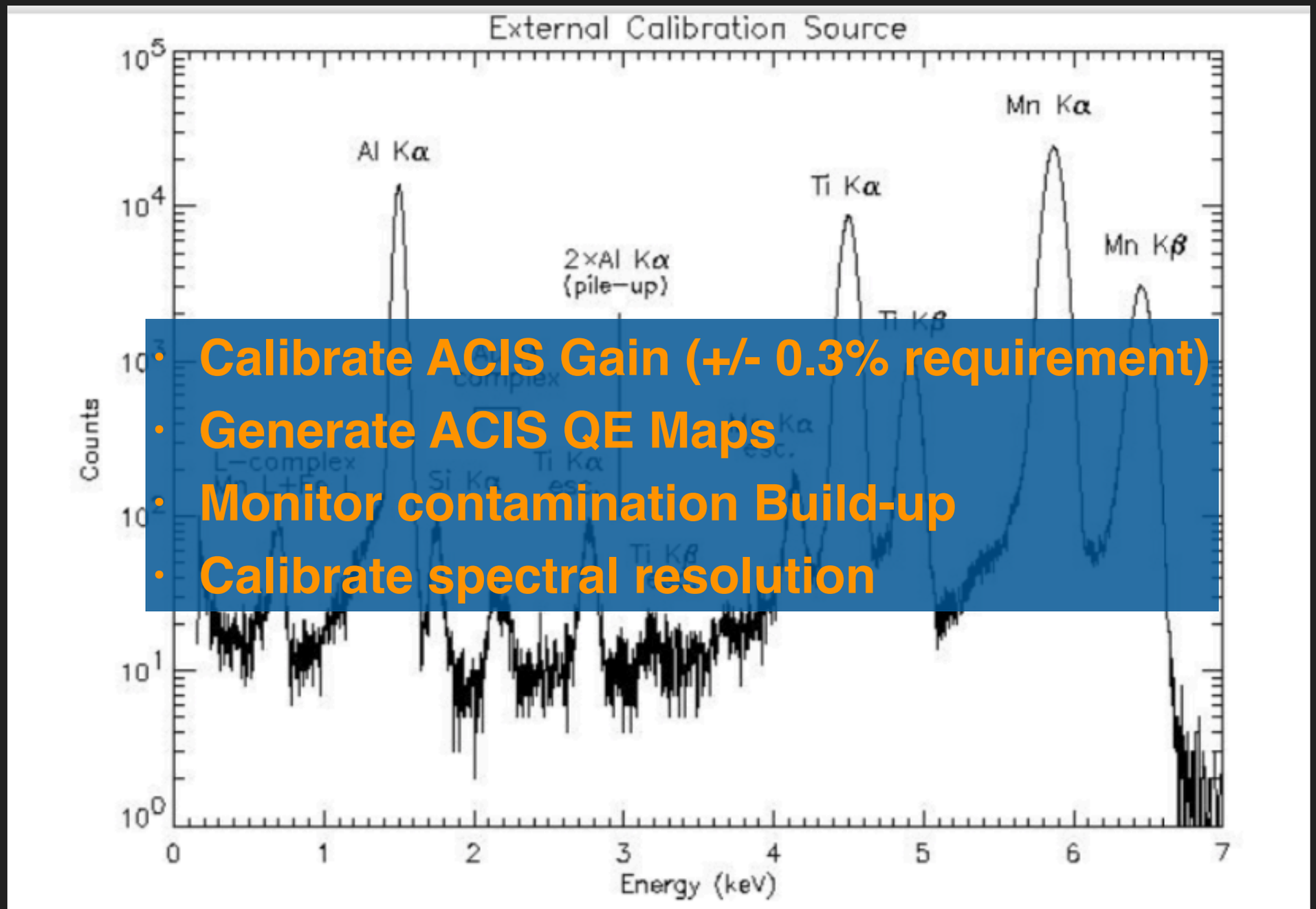
- Fe55 source with Al+Ti target
- Al Kα at 1.49 keV
- Ti Kα and Kβ at 4.51 & 4.93 keV
- Mn Kα and Kβ at 5.90 & 6.49 keV

GAIN ISSUES: DECAY OF ECS SIGNAL



Half-life
τ = 2.71 yr

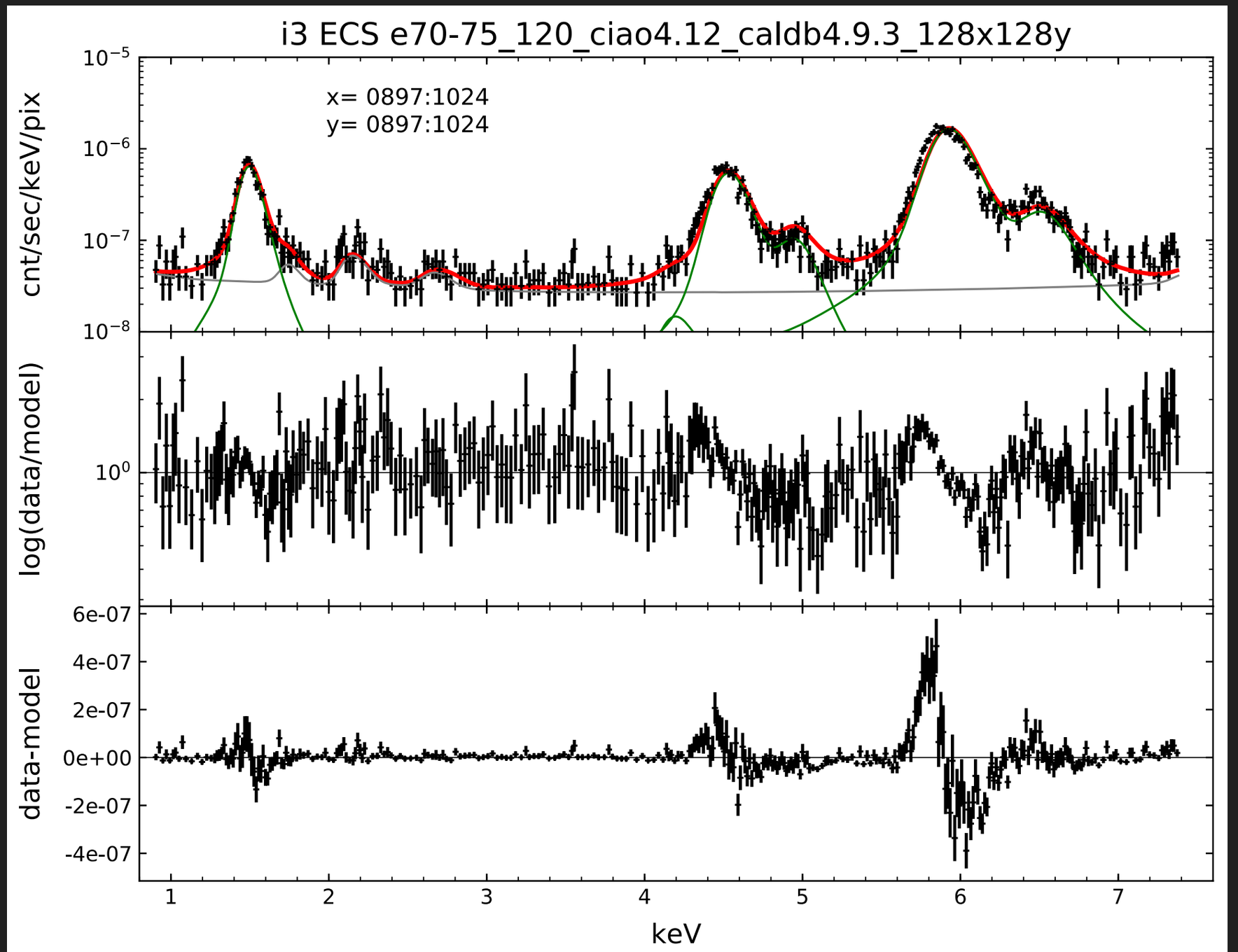
GAIN ISSUES: DECAY OF ECS SIGNAL



- Calibrate ACIS Gain (+/- 0.3% requirement)
- Generate ACIS QE Maps
- Monitor contamination Build-up
- Calibrate spectral resolution

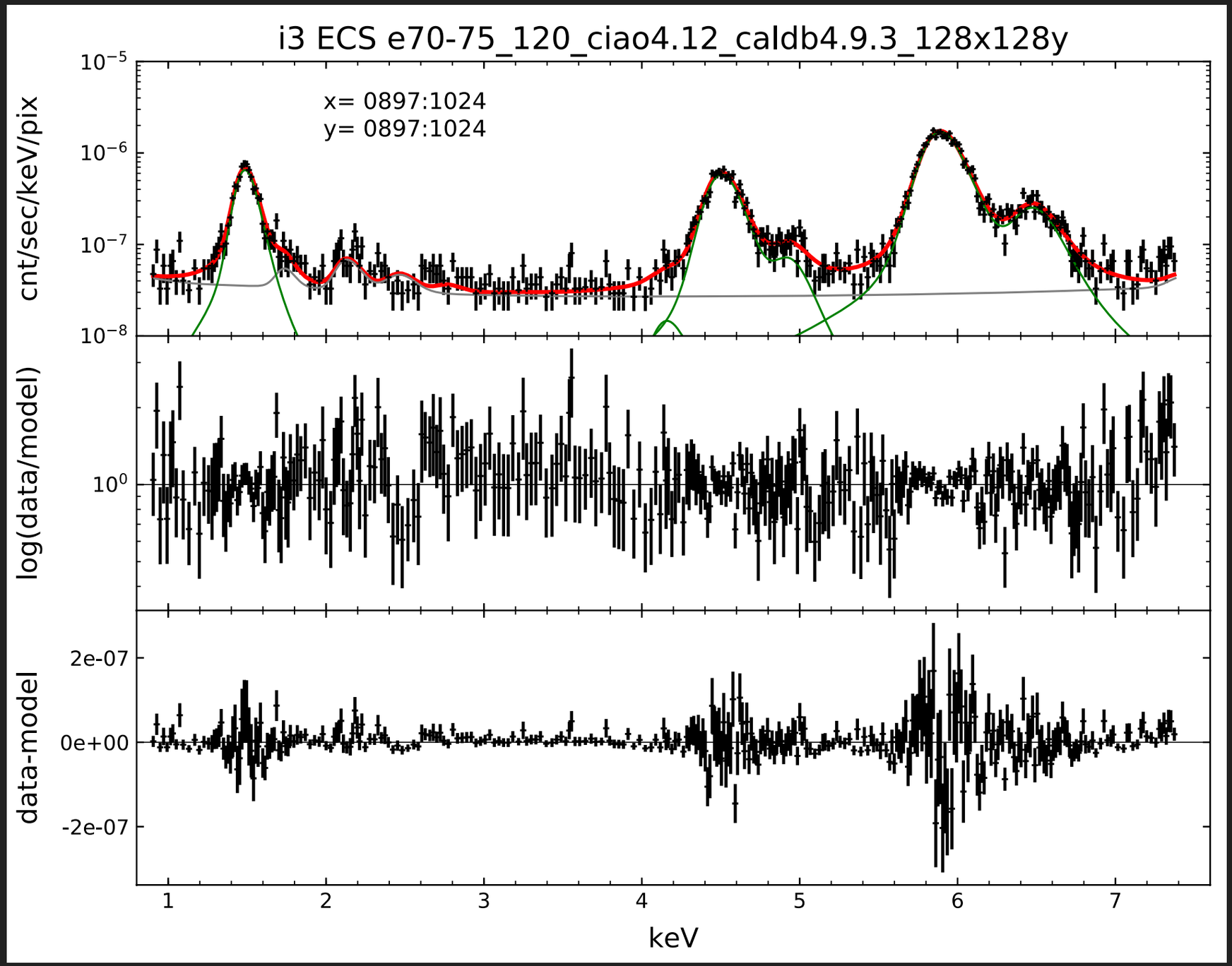
Half-life
τ = 2.71 yr

GAIN ISSUES: DECAY OF ECS SIGNAL



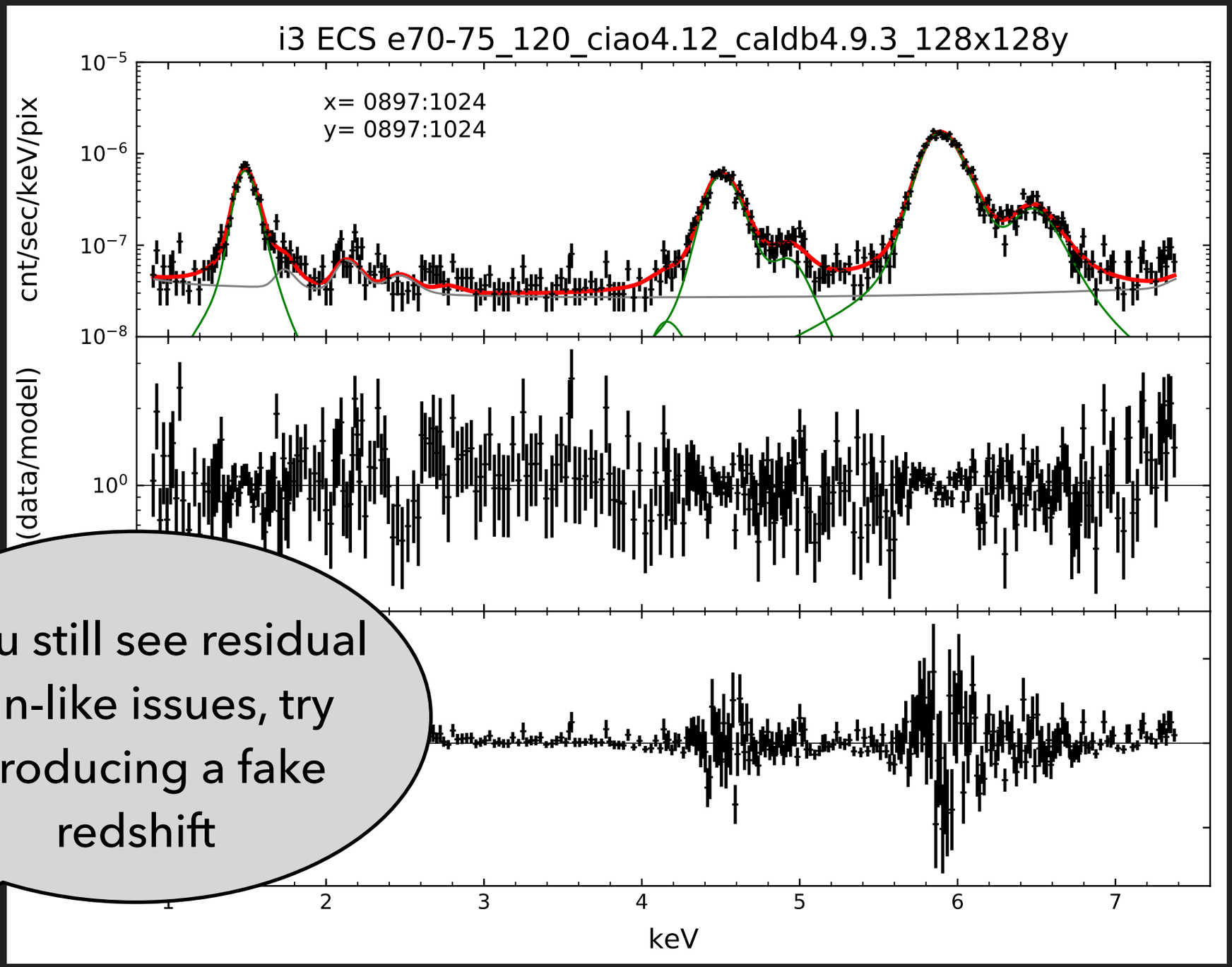
0.6% gain offset applied

GAIN ISSUES: DECAY OF ECS SIGNAL



0% gain offset applied

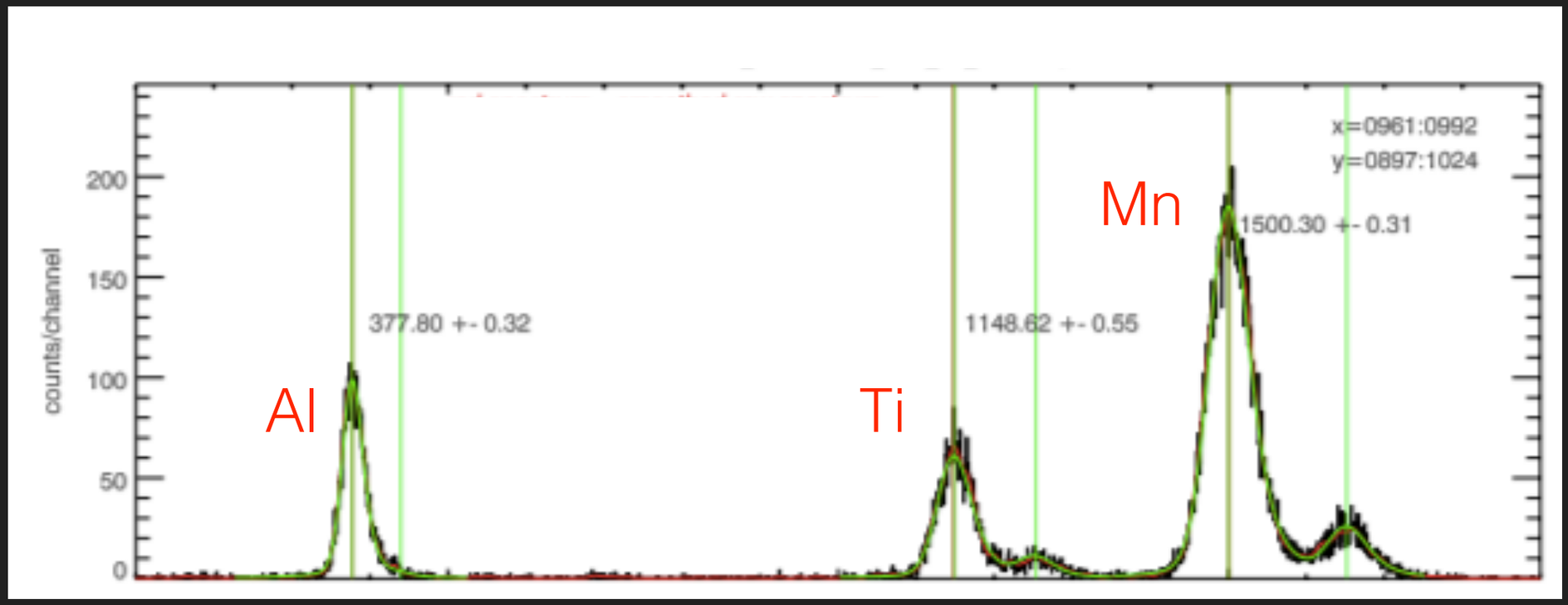
GAIN ISSUES: DECAY OF ECS SIGNAL



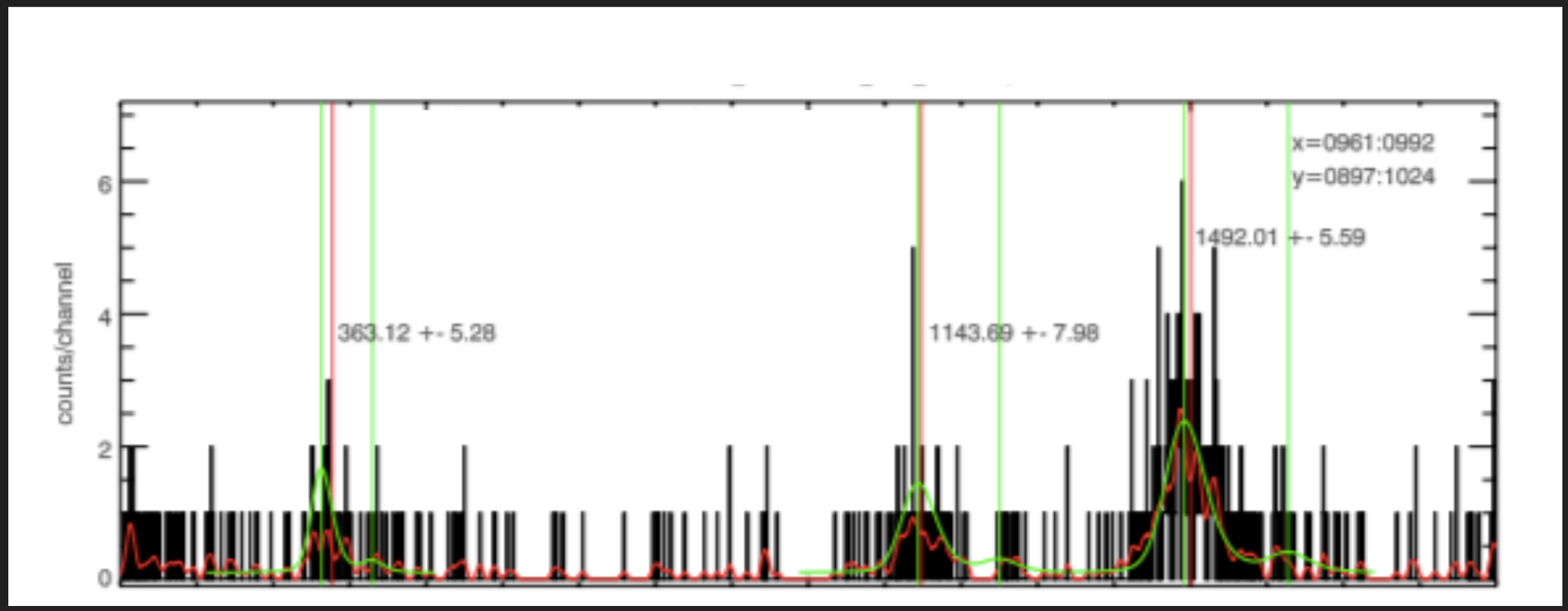
If you still see residual gain-like issues, try introducing a fake redshift

0% gain offset applied

Epoch 1 (32 x 32 pixels - three months)



Epochs 79+80 (32 x 128 pixels - six months)

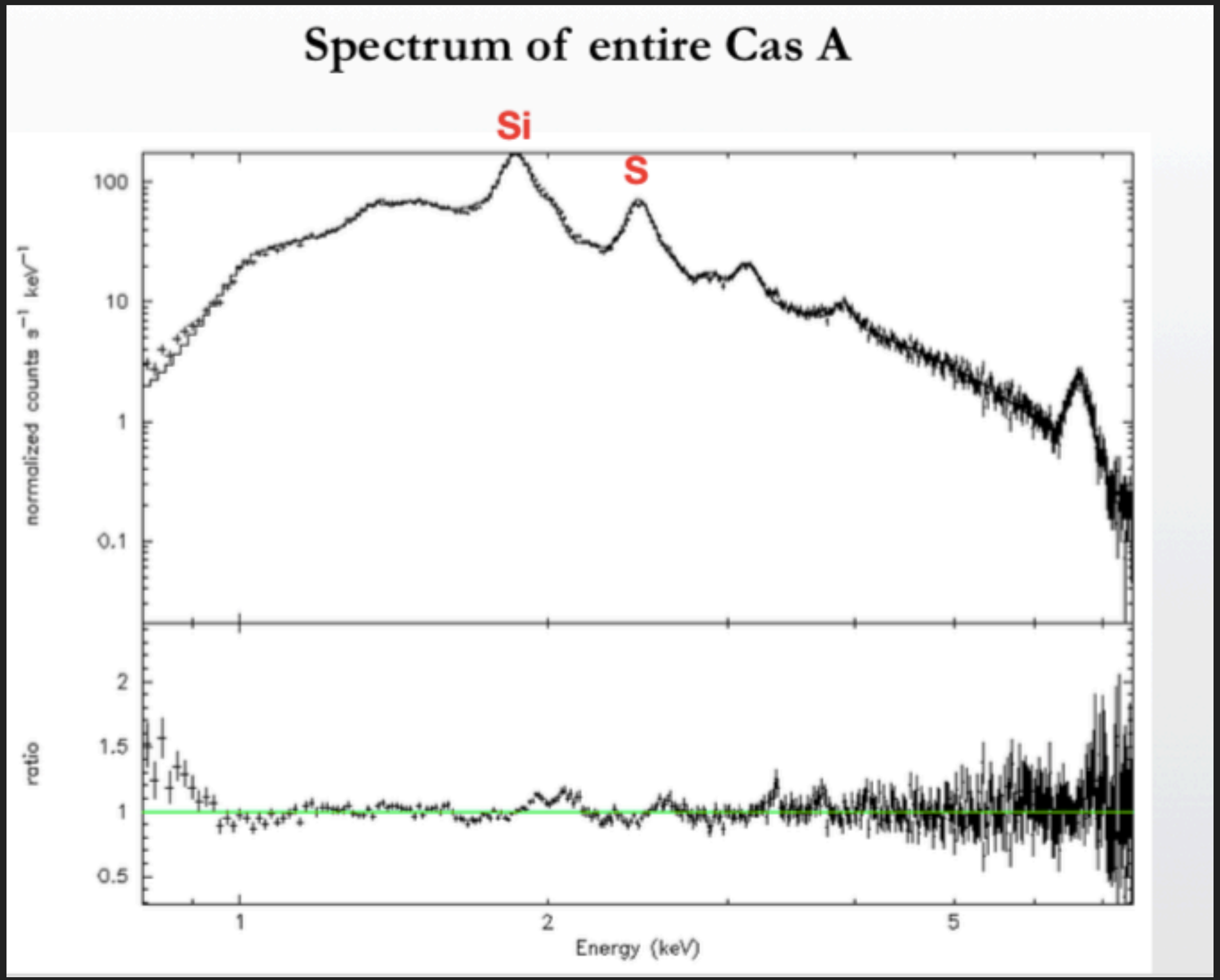


ADJUSTMENTS TO HOW THE ACIS GAIN IS CALIBRATED

- **Initially calibrated on 32 x 32 pixel regions every three months**
- **Calibrated on 64 by 64 regions every three months**
- **Calibrated on 64 x 64 pixel regions every six months**
- **Calibrated on 32 x 128 (chipx by chipy) regions every six months**

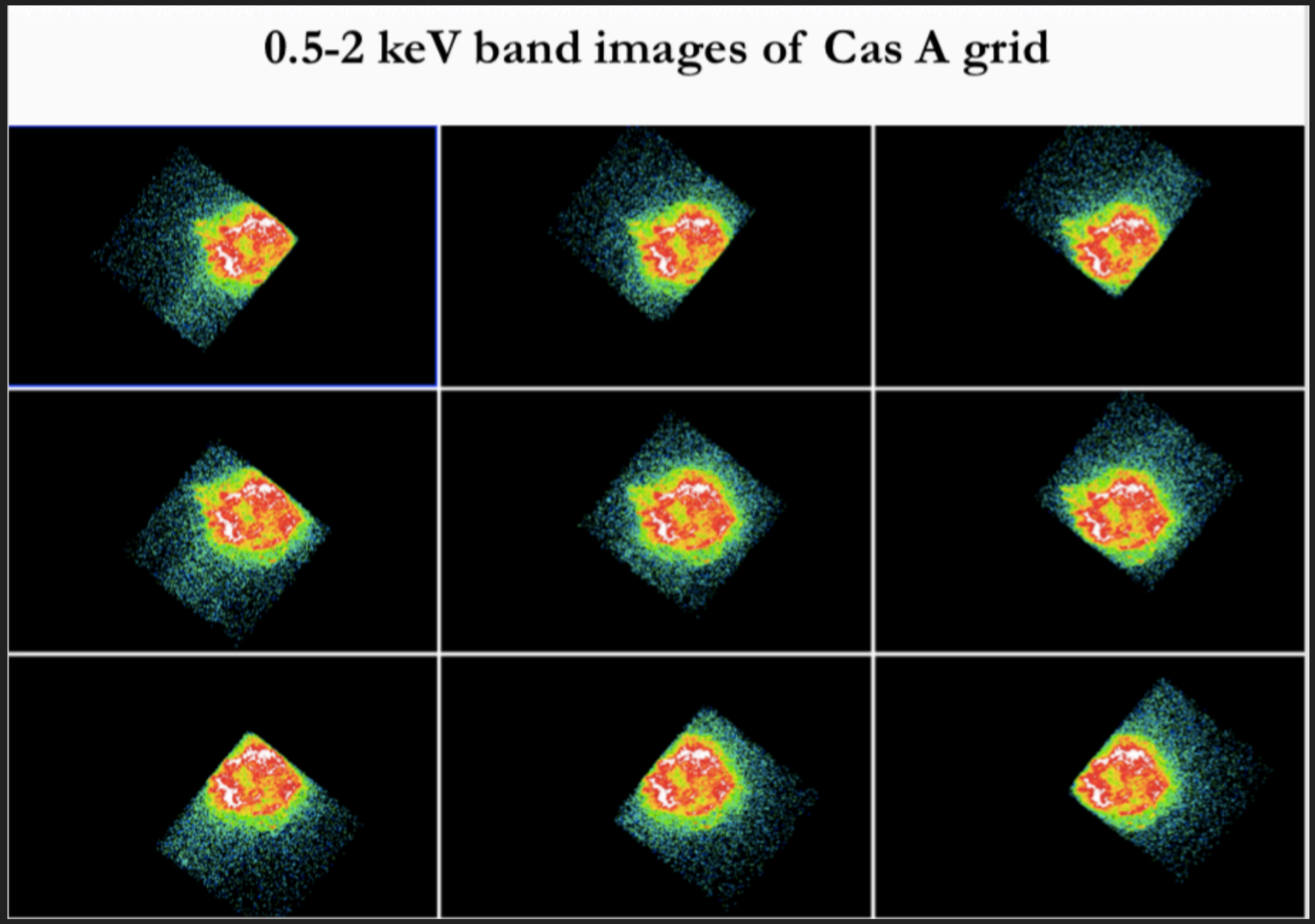
The Future - Cas A(?)

Cas A as a Possible Target for Calibrating the ACIS Gain

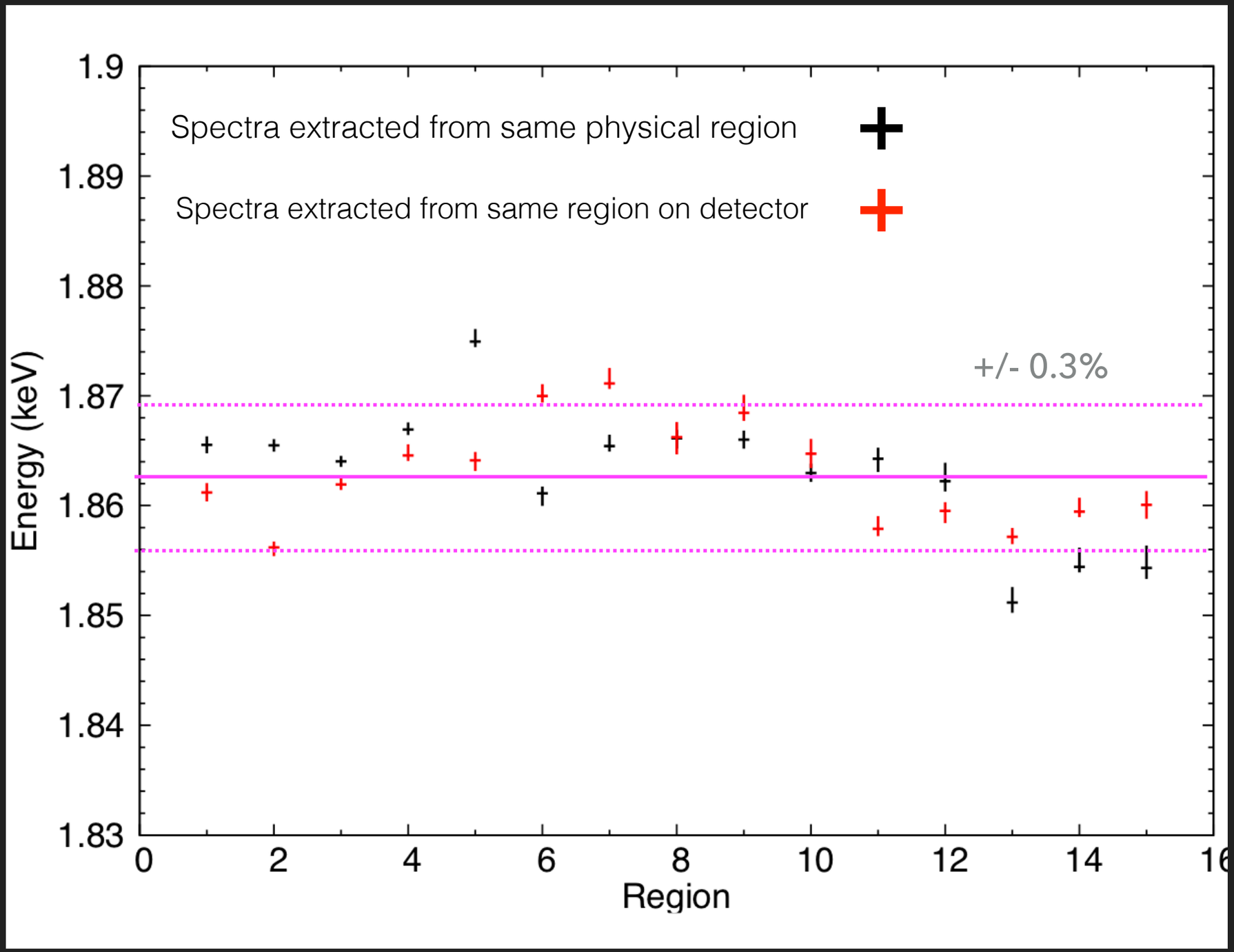


A raster scan (3 x 3) of Cas A was competed on I3 in July

Each exposure was 2 ksec.

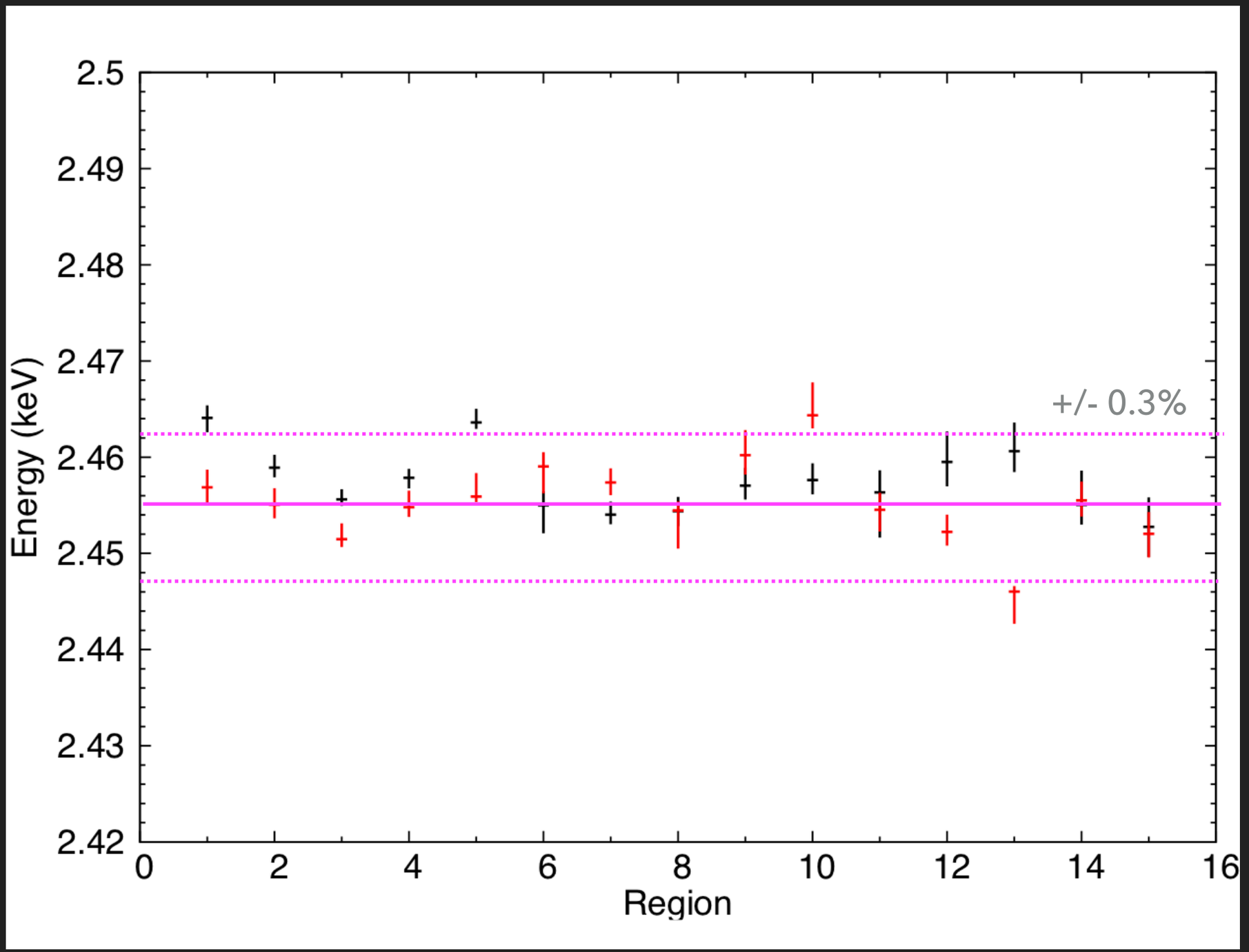


CAS A AS A GAIN CALIBRATION SOURCE



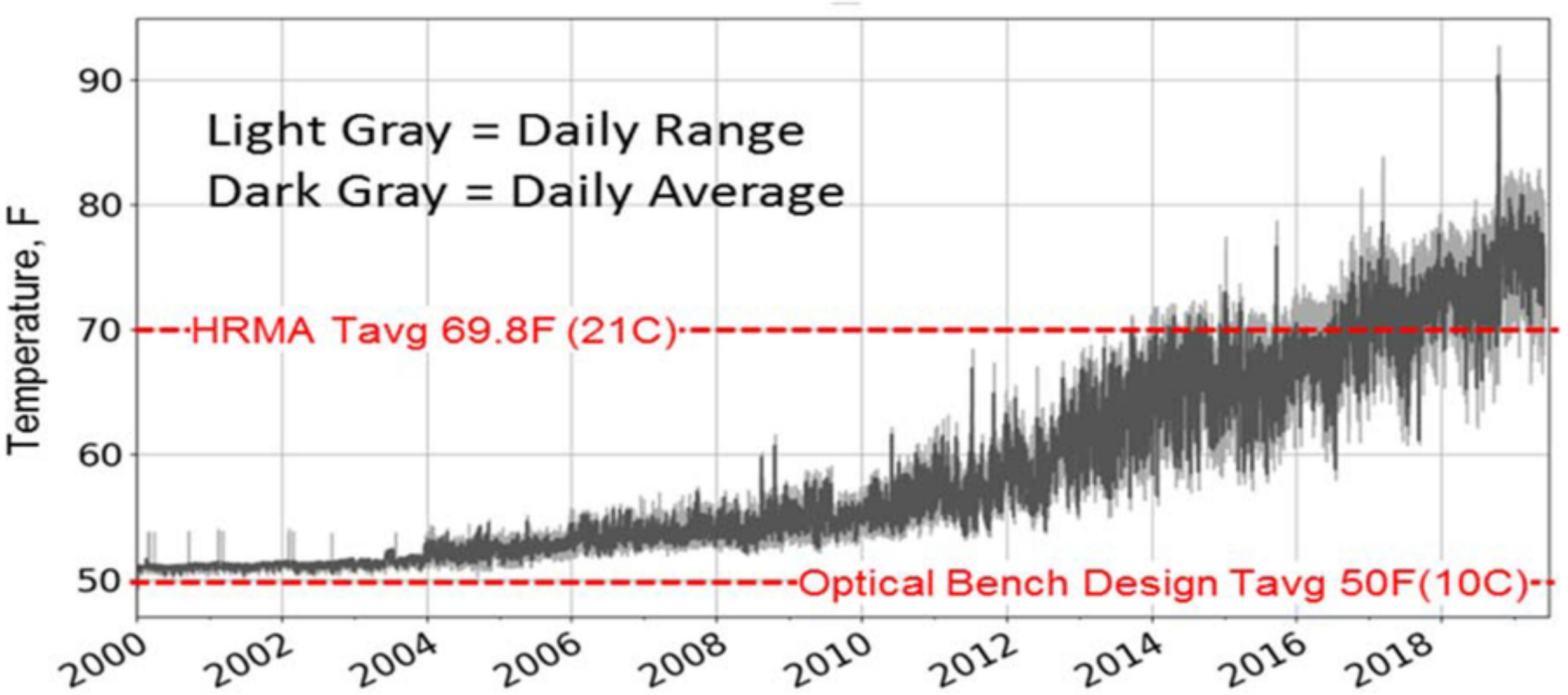
Cas A - Si XIII

CAS A AS A GAIN CALIBRATION SOURCE



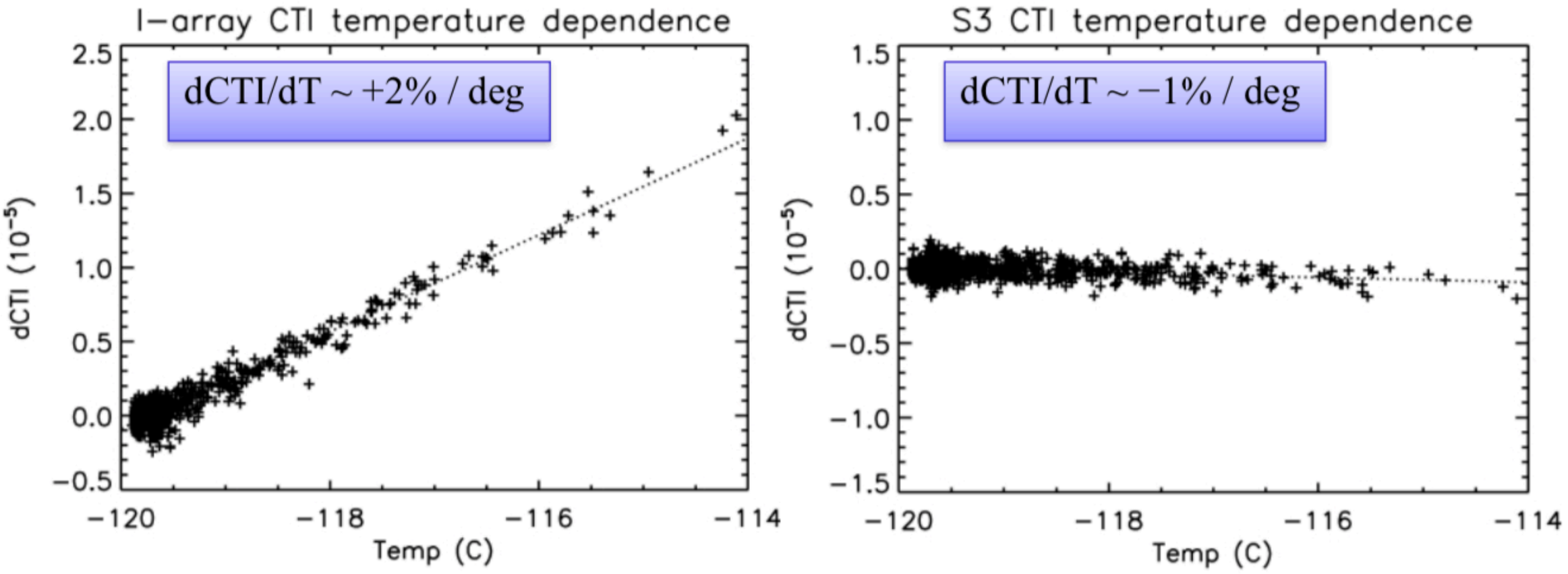
Cas A - S XV

ACIS TEMPERATURE-DEPENDENT CALIBRATION



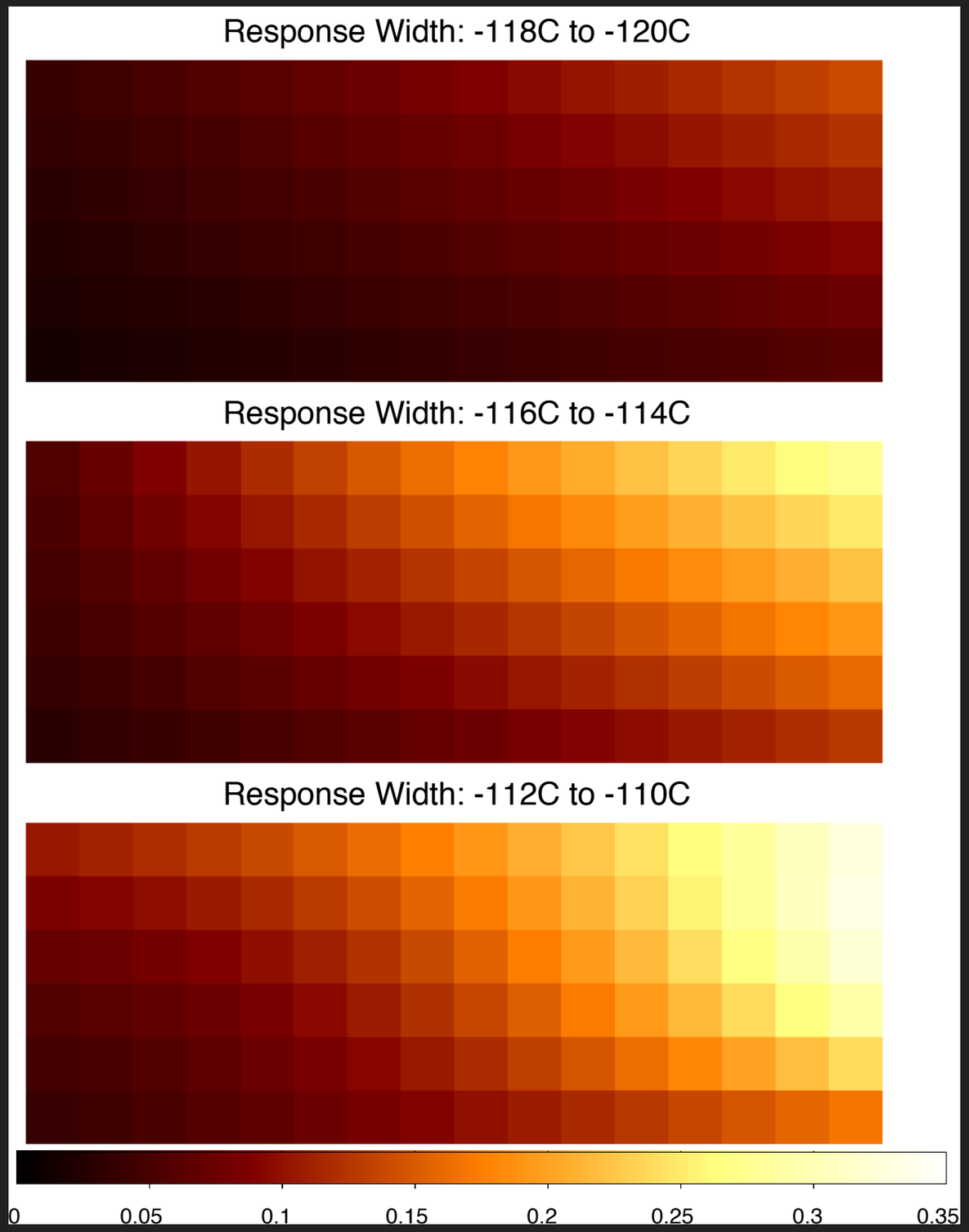
Havey et al (2019)

ACIS TEMPERATURE-DEPENDENT CALIBRATION



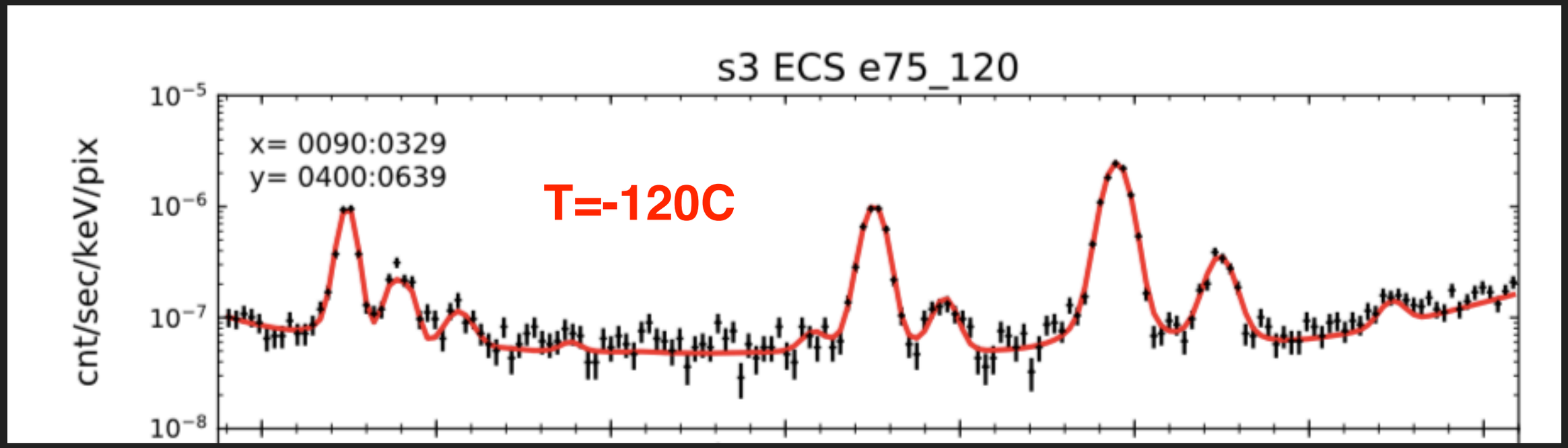
- Charge Transfer Inefficiency affects QE (grade migration), energy resolution, gain
- Important for ACIS-I, less so for ACIS-S

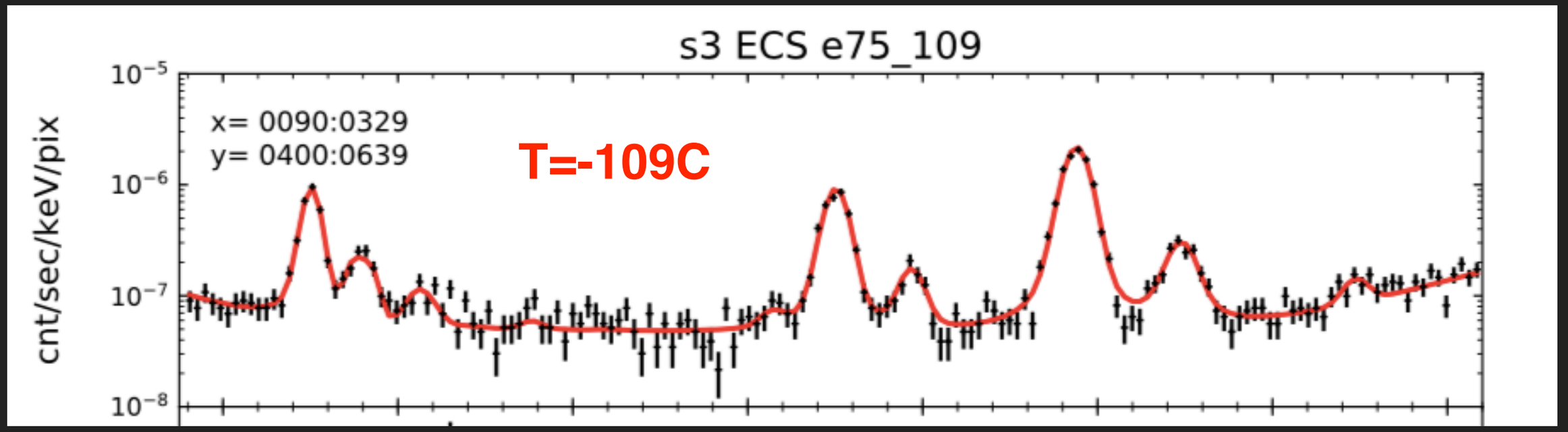
Fitted Line widths vs Temperature on I3



Color scale corresponds to line width

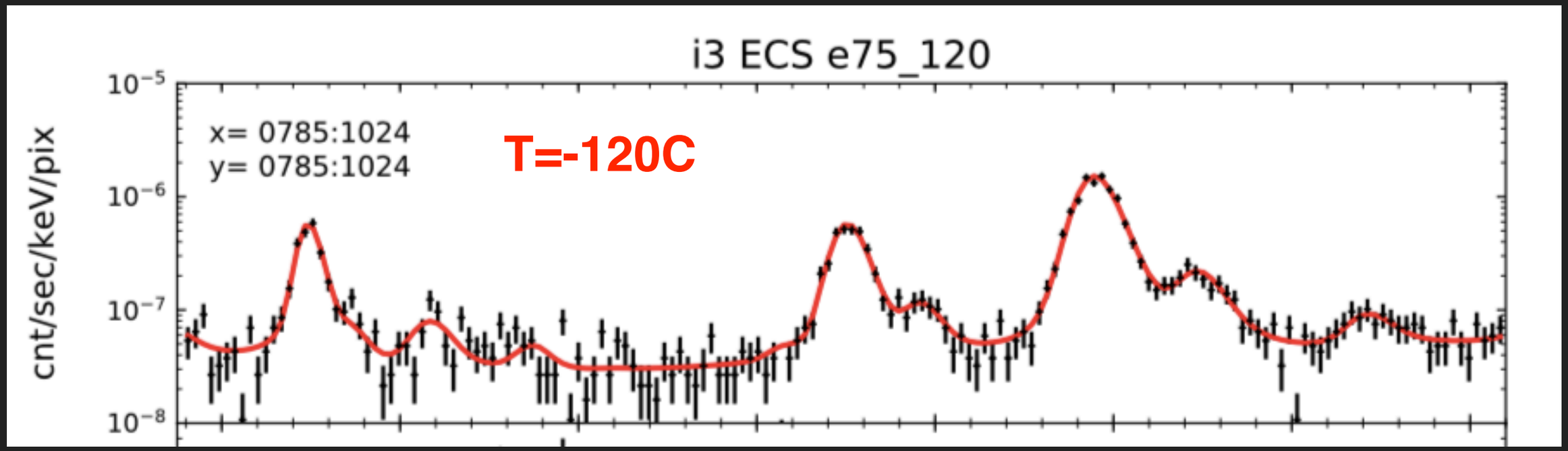
S3-aimpoint Spectral Resolution vs. Temperature

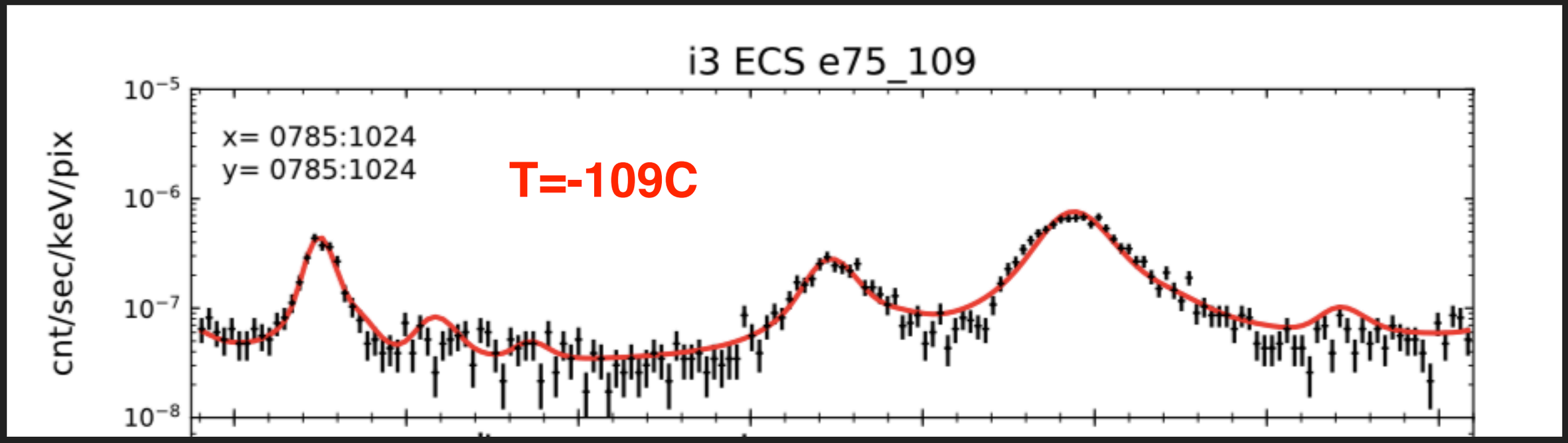




The Calibration team has given approval for S3 only observations up to -109C

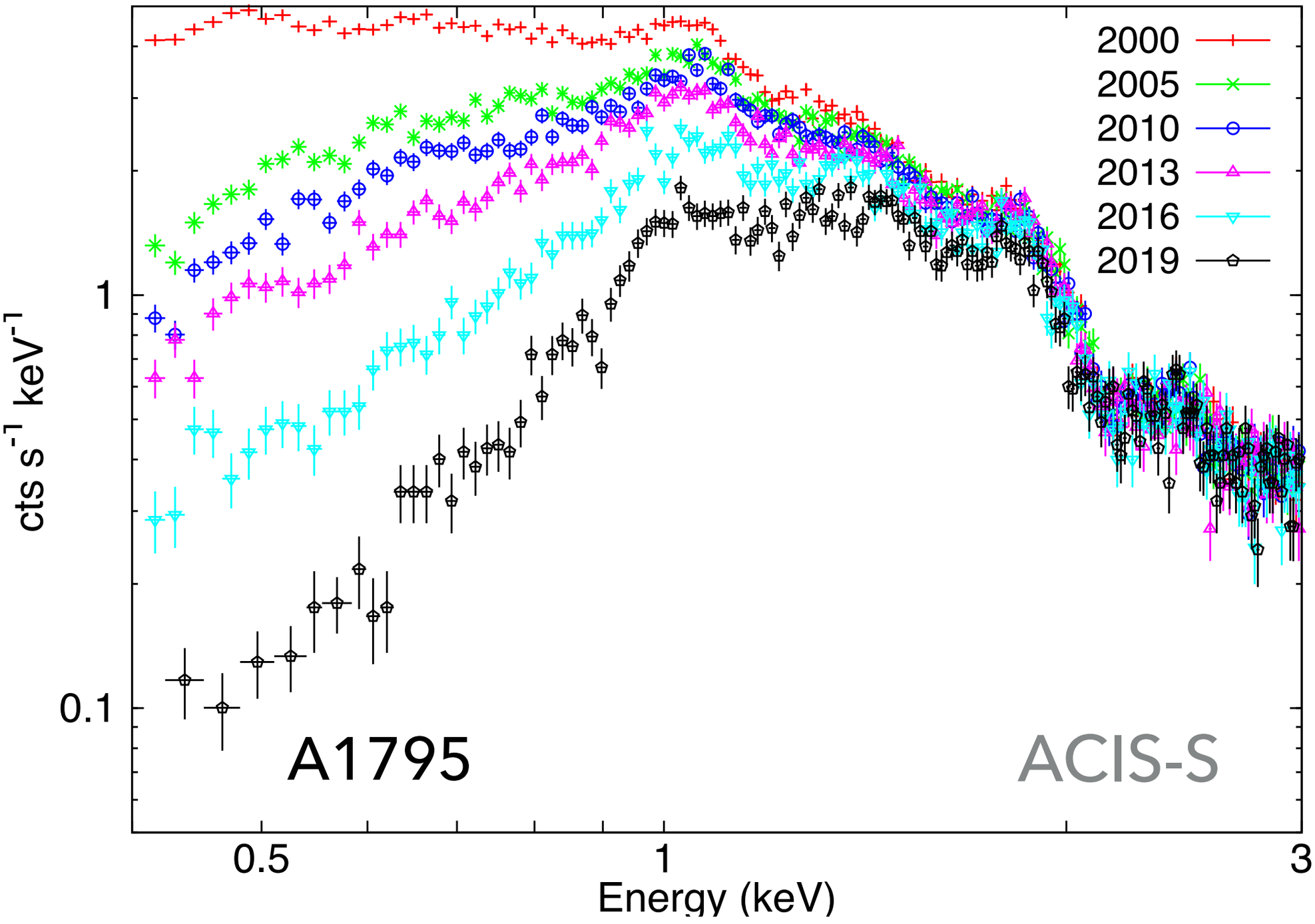
I3-aimpoint Spectral Resolution vs. Temperature



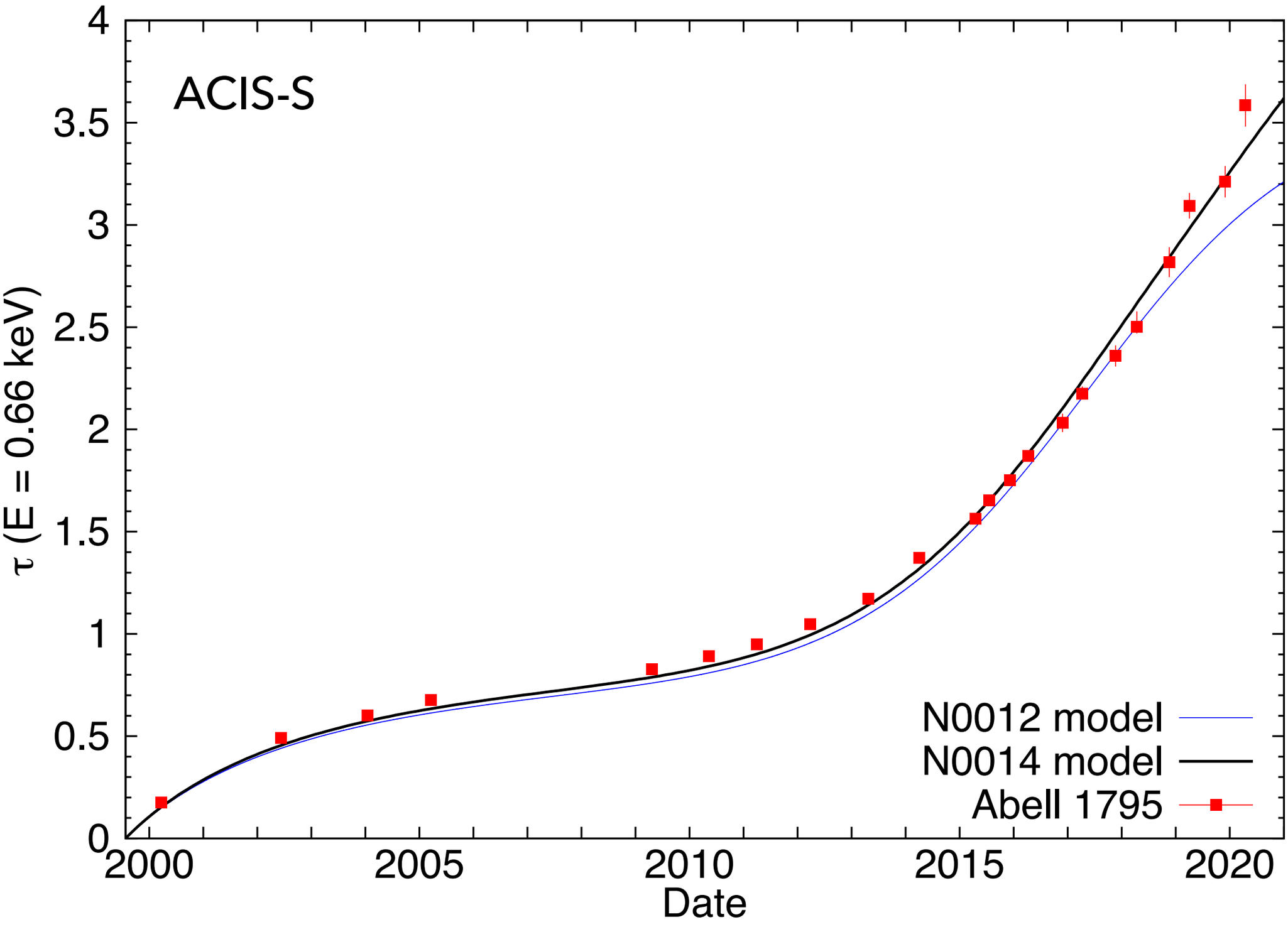


The thermal limit for FI observations remains at -112C

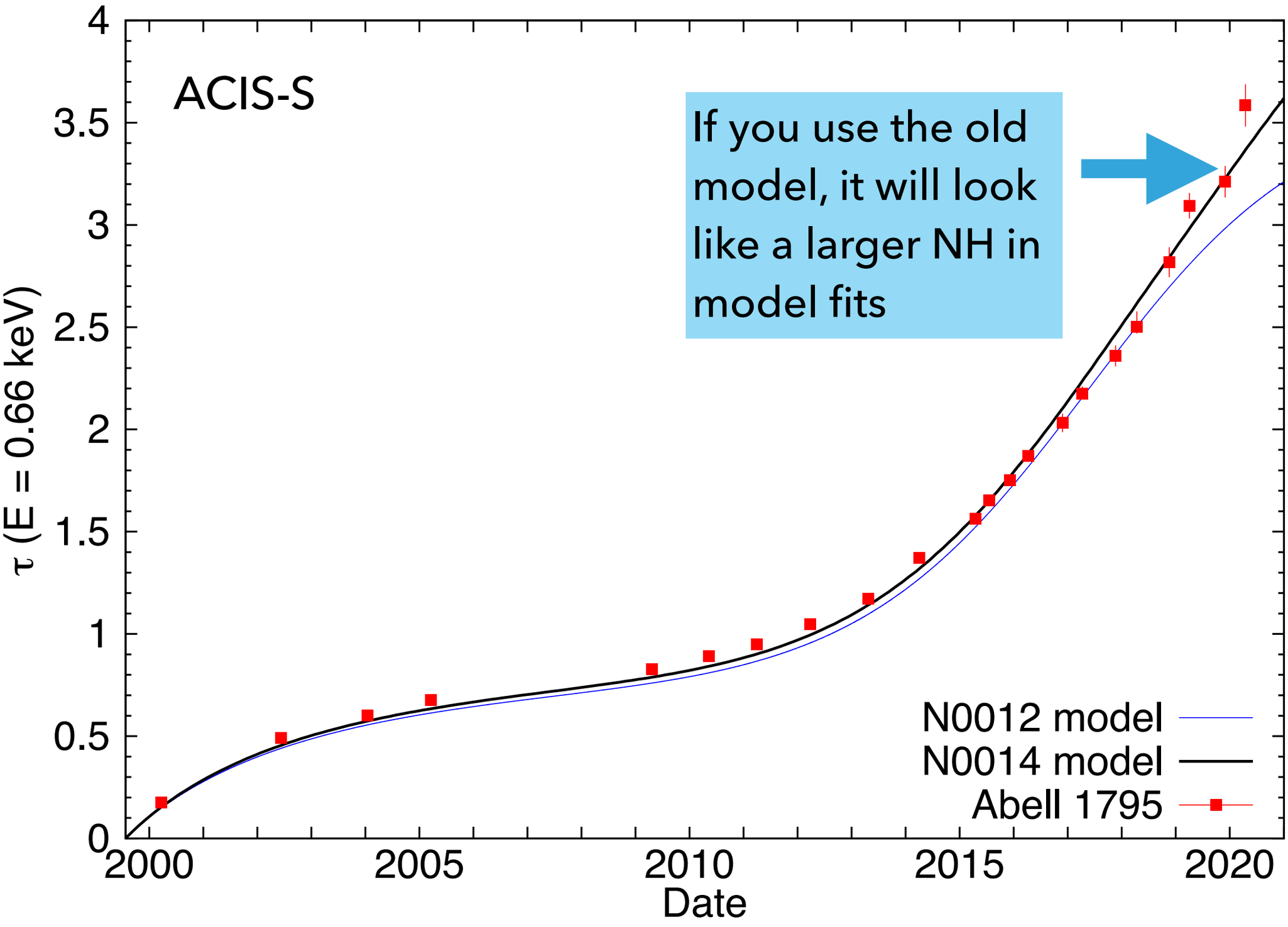
FILTER CONTAMINATION LAYER



FILTER CONTAMINATION LAYER

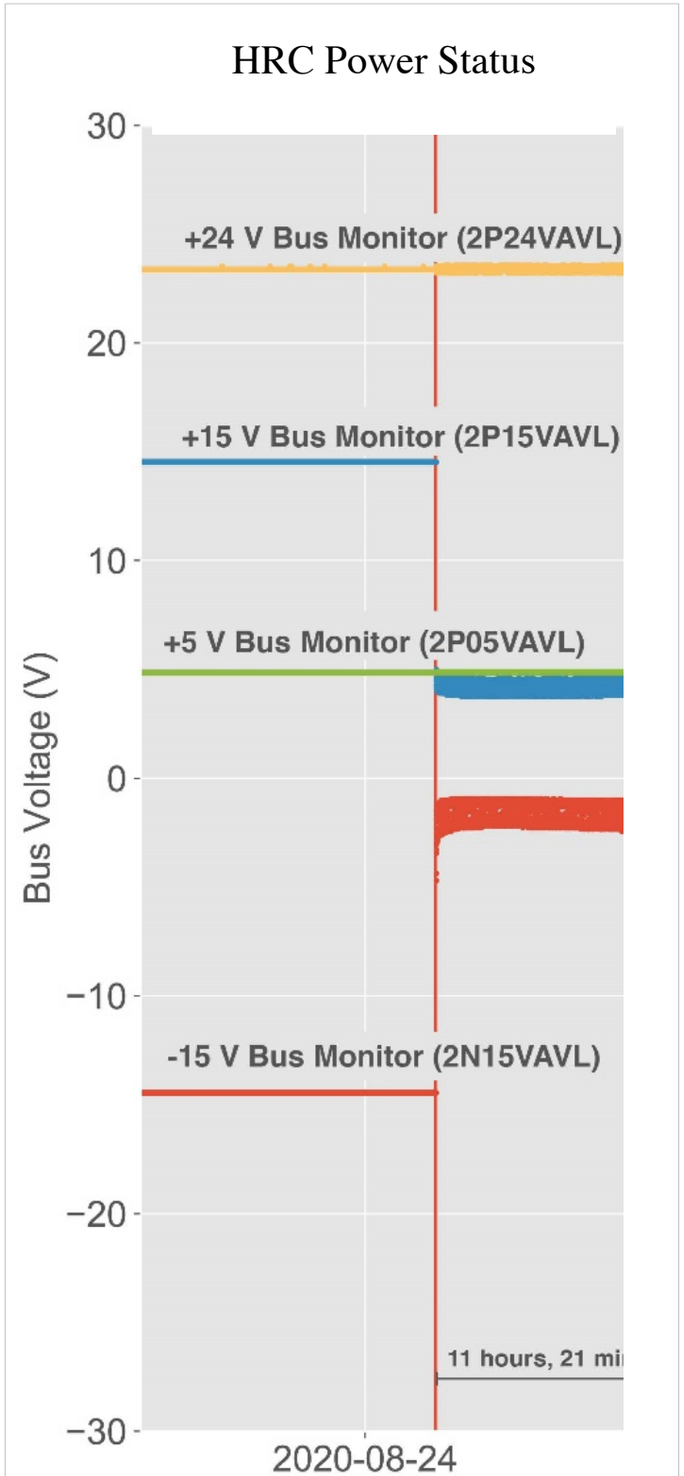


FILTER CONTAMINATION LAYER



HIGH RESOLUTION CAMERA

ANOMALY OVERVIEW



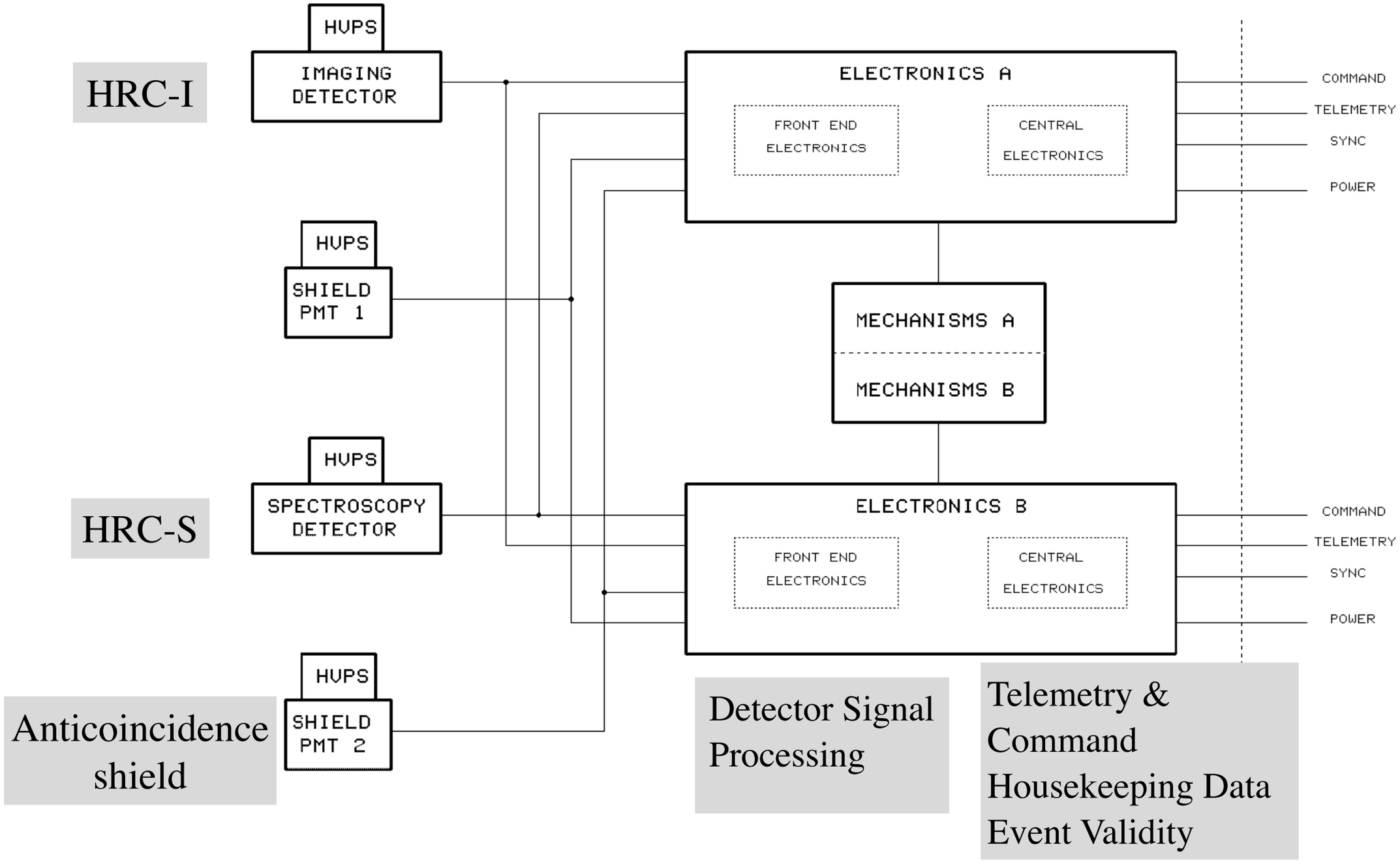
August 24, 2020 anomalous power configuration from HRC

- +15 V and -15 V power showed anomalous values
- Increased noise on +24 V power
- Increased Central Electronics A box temperature
- Unreliable secondary science data
- Instrument otherwise as expected

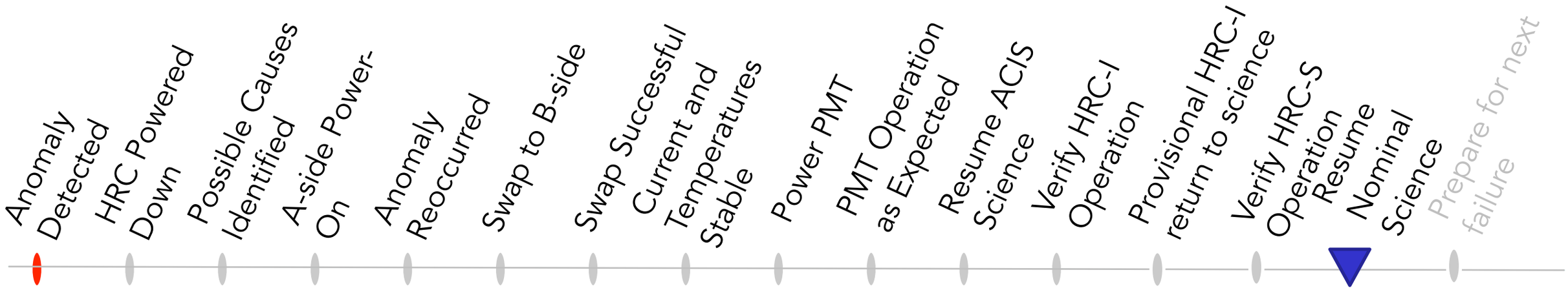
Response

- Spacecraft and ACIS teams reported no anomalies
- Instrument team determined problem within HRC electronics and recommended immediate power-off of HRC
- HRC radiation monitoring capability protects both SIs ➔ Both Science Instruments (SIs) safed and HRC powered down

HARDWARE OVERVIEW



TIMELINE AND DECISION POINTS



8/24 8/26 8/31 9/07 9/12 10/26

Anomaly	Recovery	ACIS-only Science	ACIS/HRC-I Science	Nominal Operations

- Root cause isolated to hardware within the HRC CEA-A
- Recovery has been incremental, with soak periods between steps, to ensure each function is stable before proceeding
- Two successful check-out observations - a slow manual power ramp-up and a nominal ramp-up – for each detector
- Return to nominal HRC science planned for November 23 weekly schedule

CURRENT HRC POWER CONFIGURATION

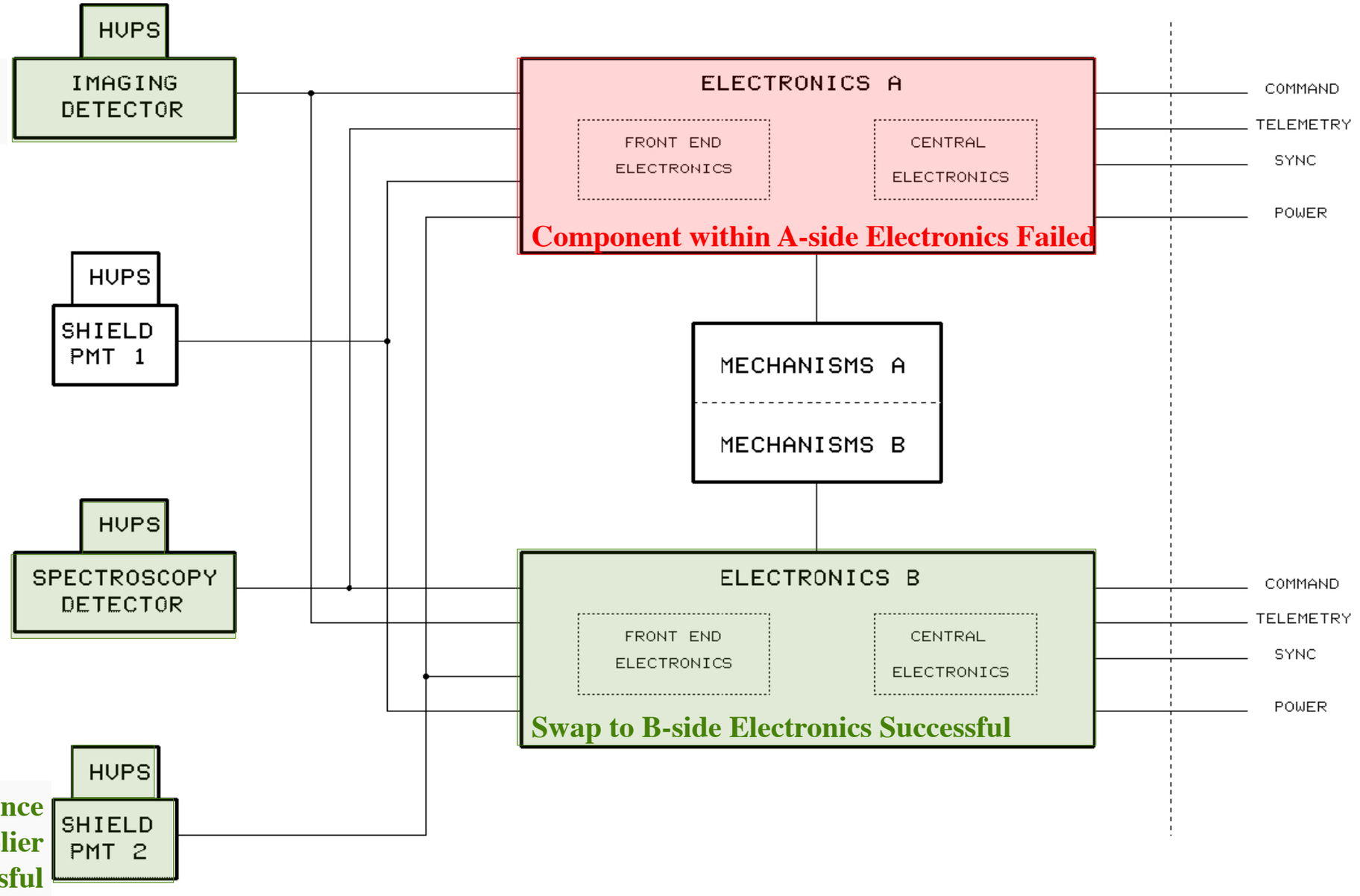
HRC-I performance confirmed nominal

Electronics Provide Conditioned Power and Command Processing

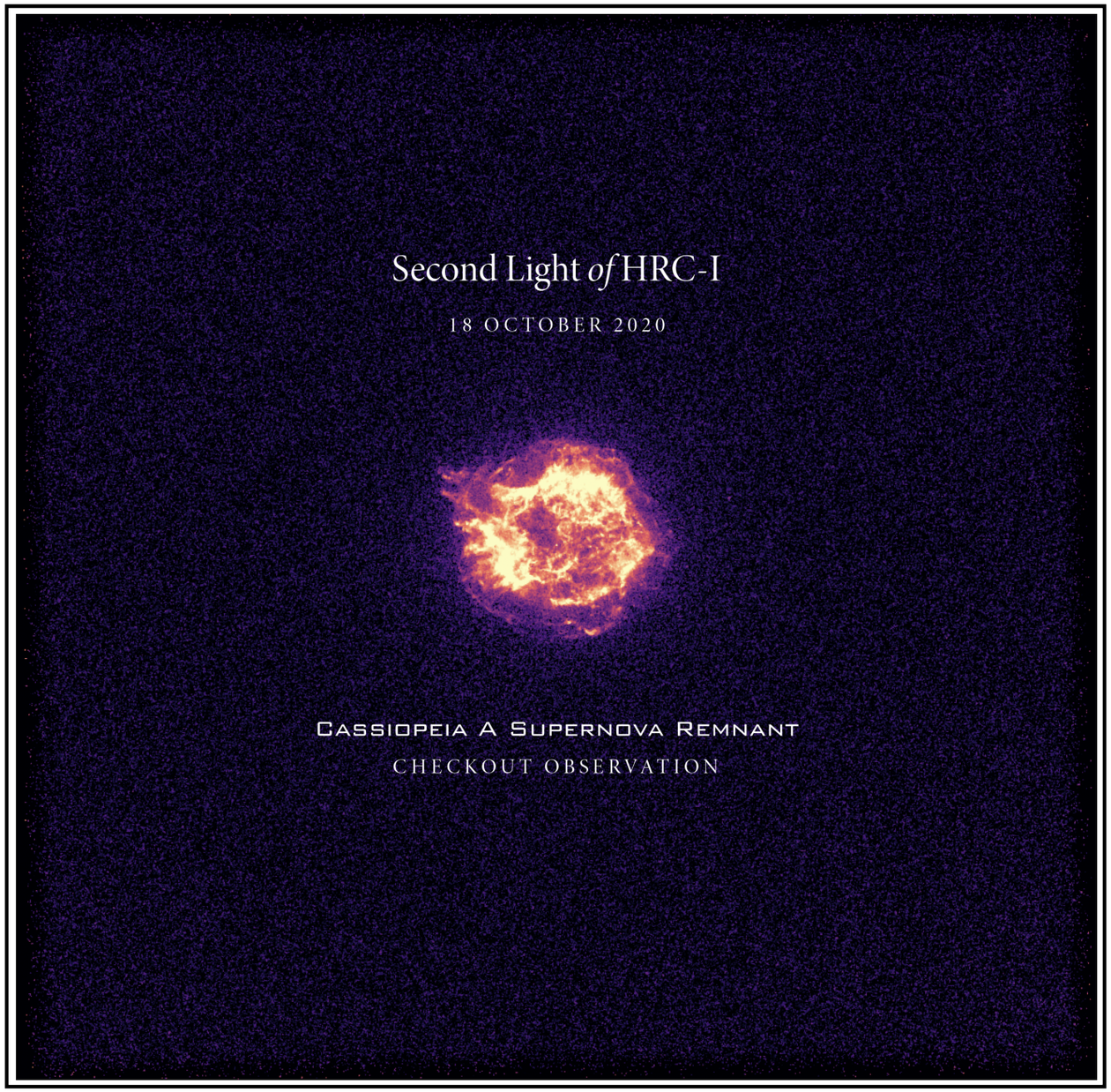
High Voltage Power Supplies are the same hardware as pre-anomaly

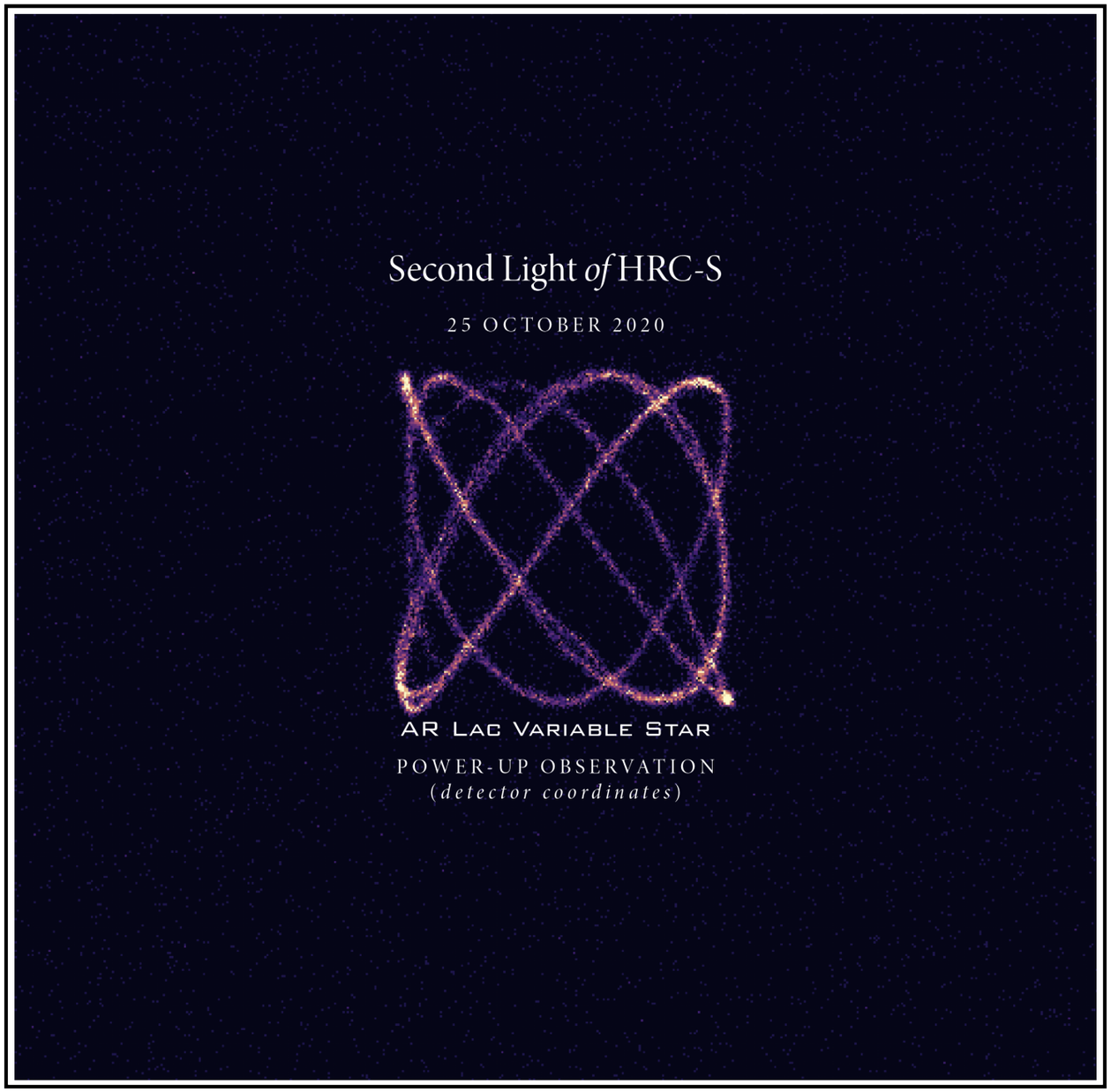
HRC-S check-out underway. Check-out #1 successful in R/T.

Power-up of Anticoincidence Shield with Photomultiplier (PMT) Successful



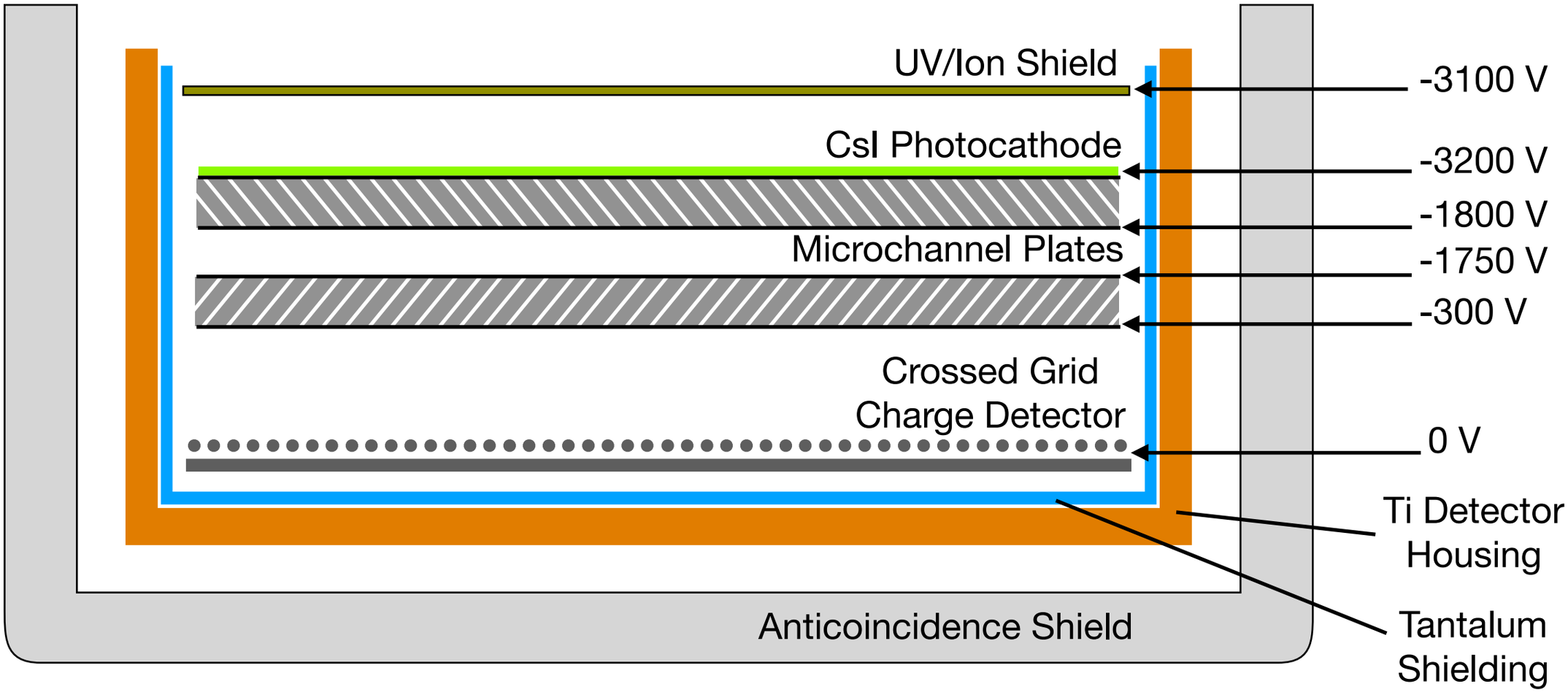
CHANDRA X-RAY OBSERVATORY



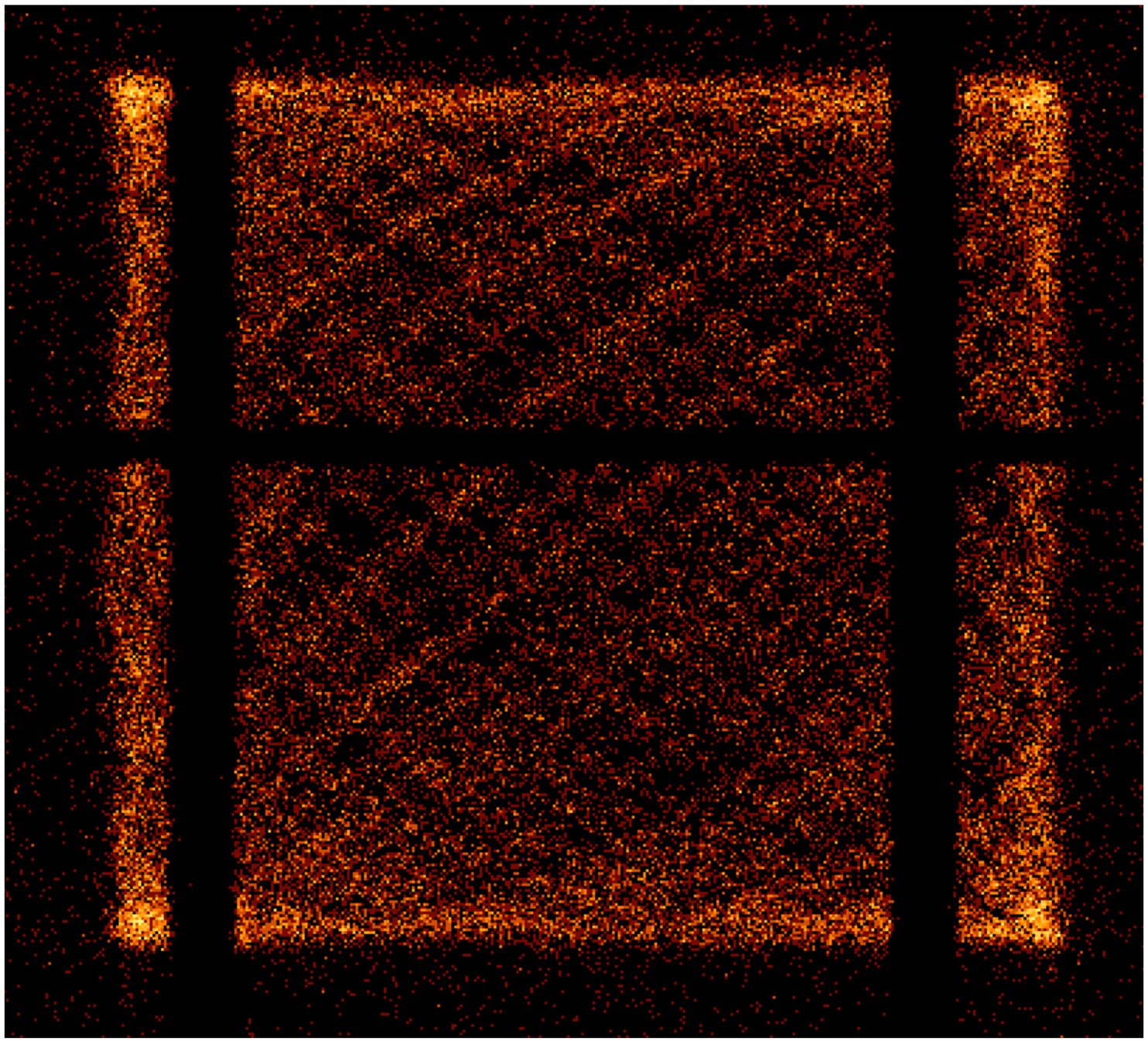


Both detectors are now back on-line and performing nominally (phew!)

Thanks to D. Patnaud

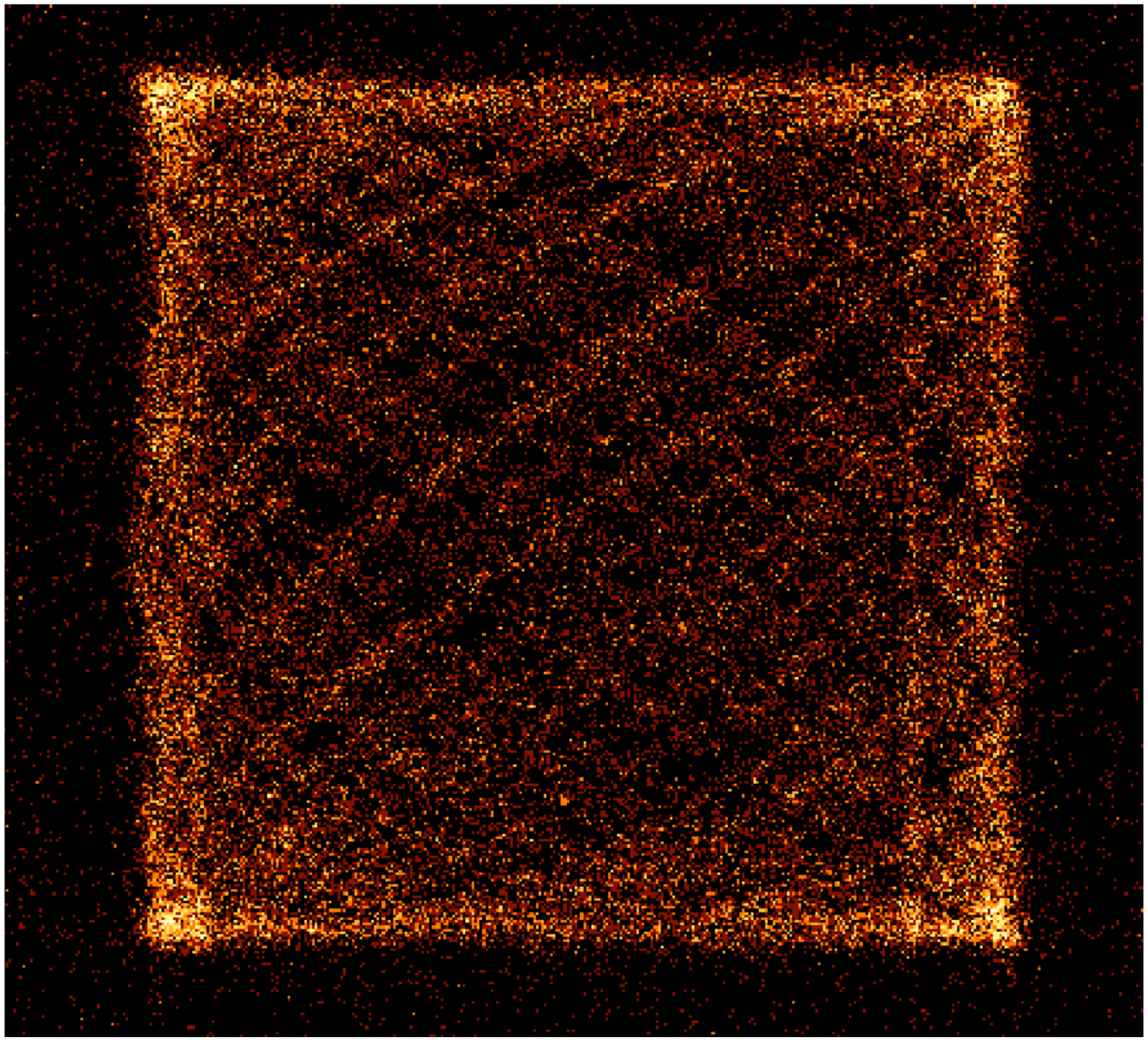

UV/Ion Shield
CsI Photocathode
Microchannel Plates
Crossed Grid
Charge Detector
Anticoincidence Shield
-3100 V
-3200 V
-1800 V
-1750 V
-300 V
0 V
Ti Detector
Housing
Tantalum
Shielding

TEST OF A ➡ B SWITCHOVER: 0TH ORDER DITHER



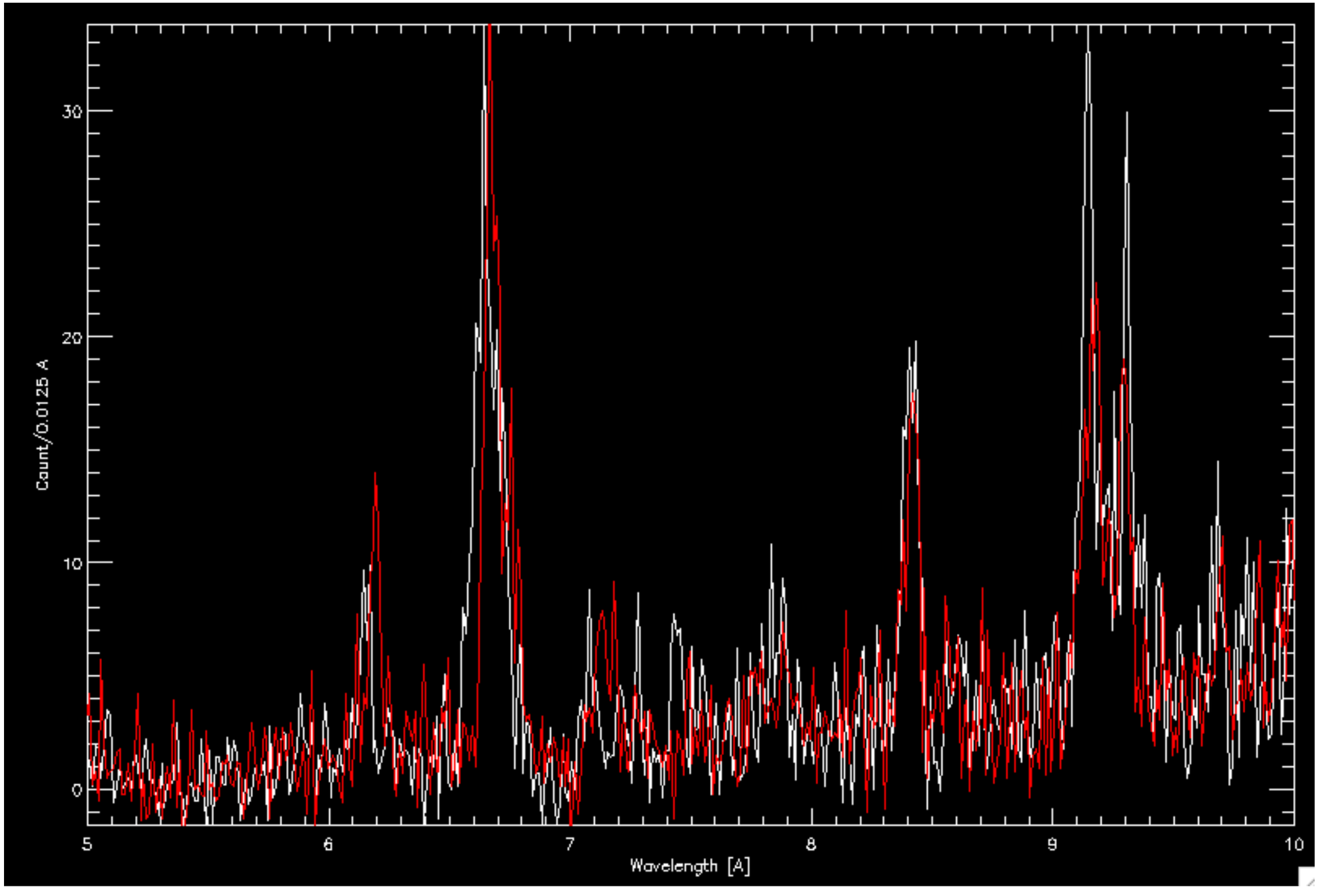
Capella LETG+HRC-S on 2020-11-10

TEST OF A ➡ B SWITCHOVER: 0TH ORDER DITHER



Capella LETG+HRC-S on 2020-11-10

POSSIBLE ISSUES FROM A ➡ B SWITCHOVER: DISPERSION, QE



Capella LETG+HRC-S on 2020-11-10

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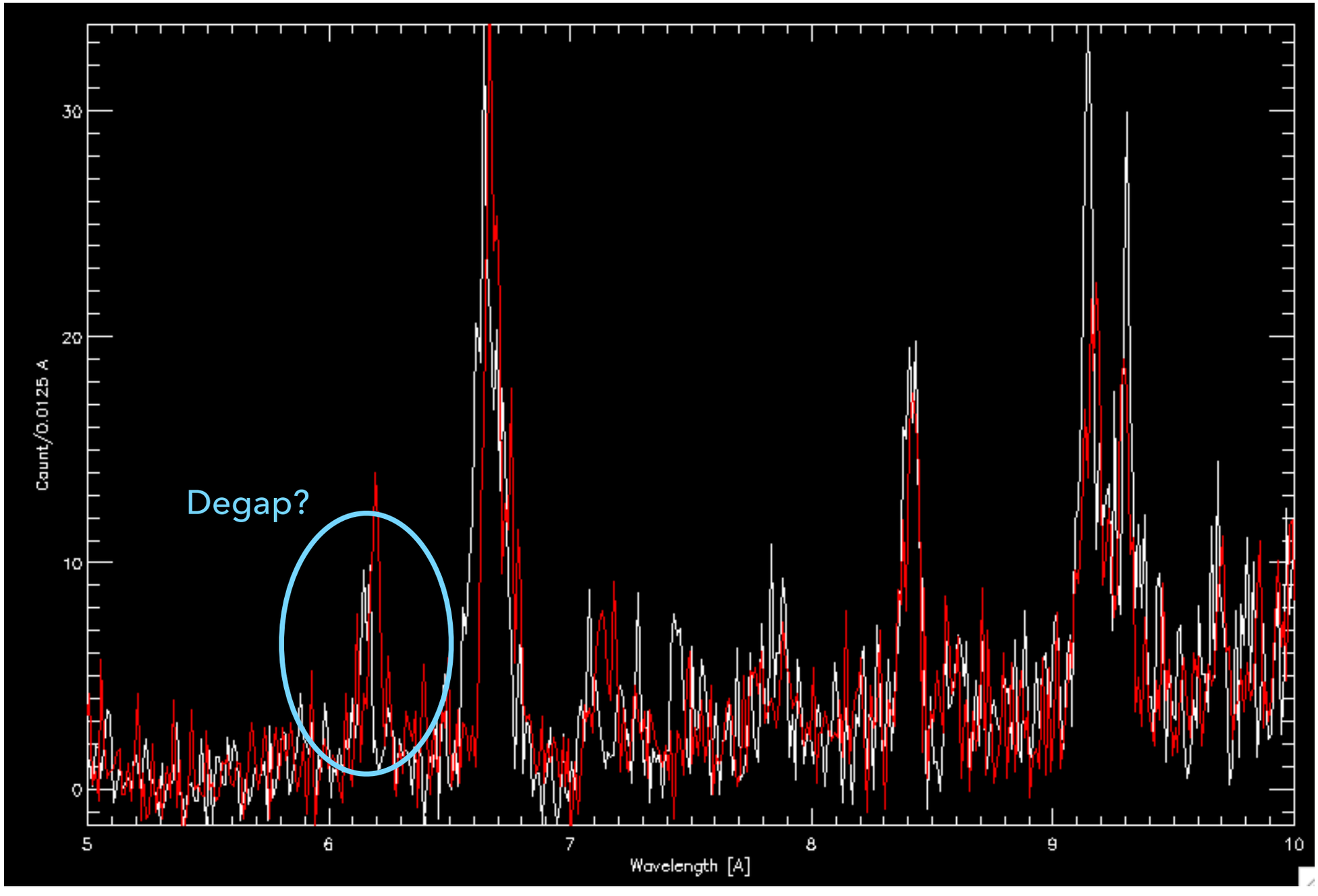
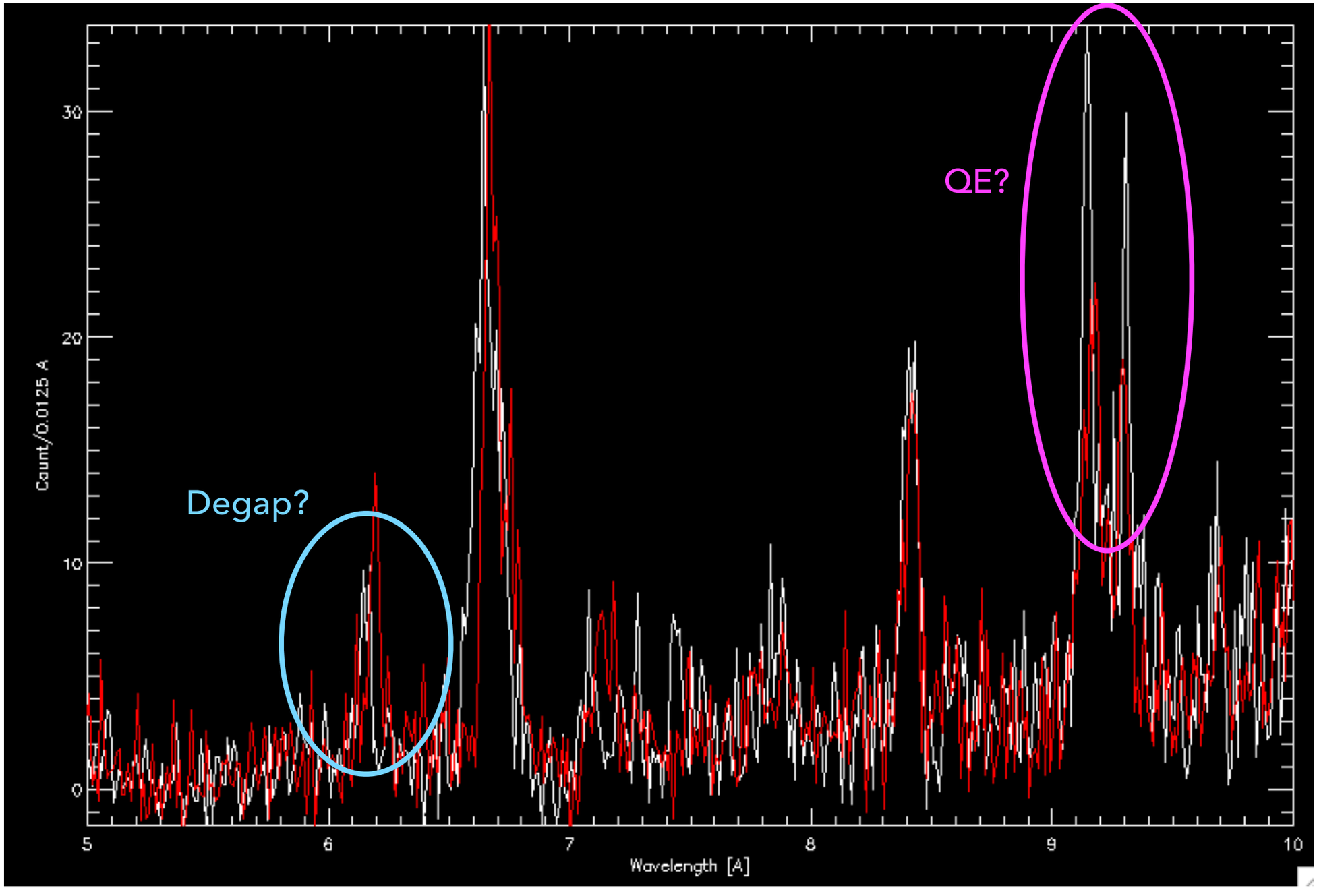


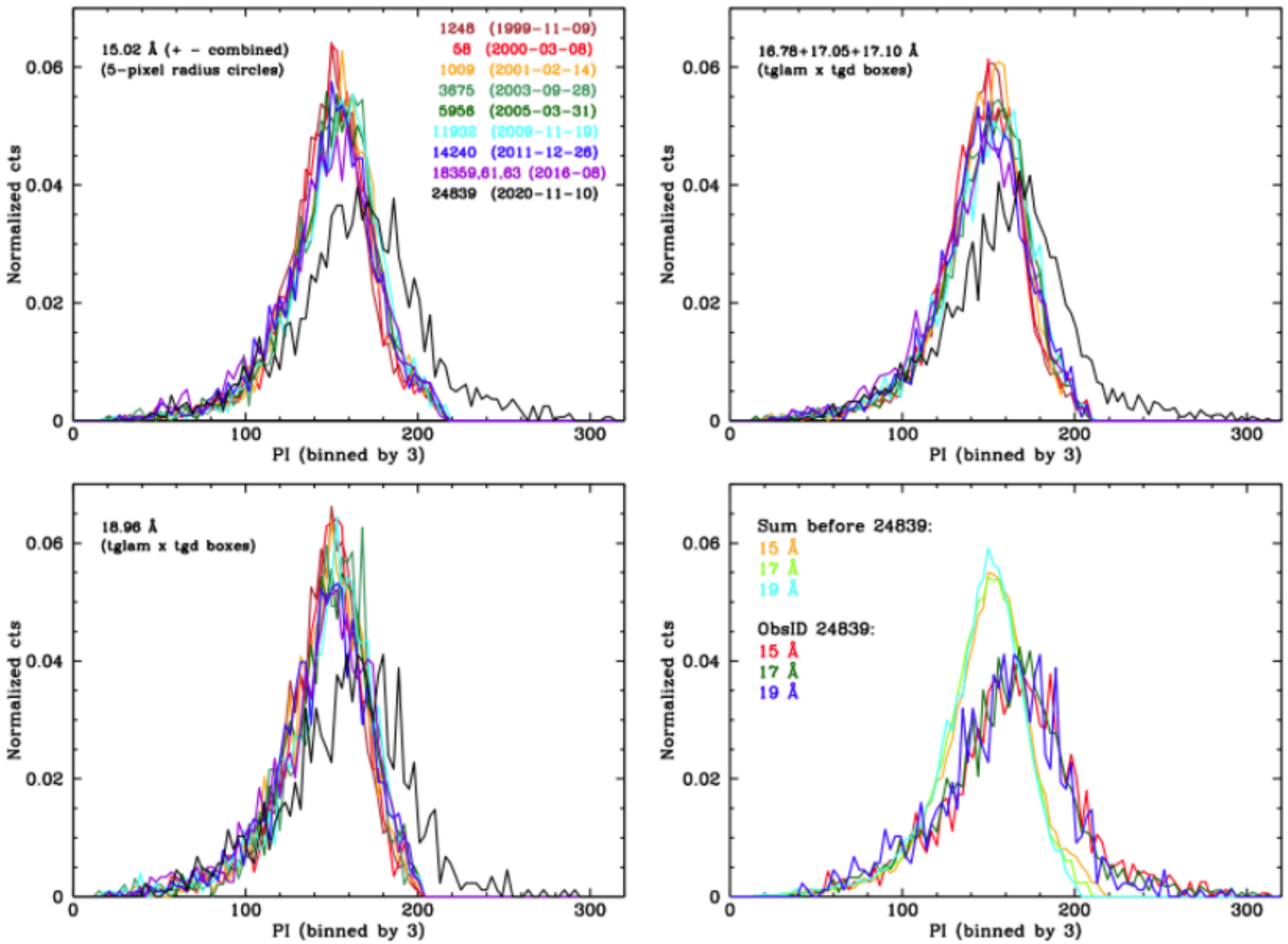
Capella LETG+HRC-S on 2020-11-10

POSSIBLE ISSUES FROM A ➡ B SWITCHOVER: DISPERSION, QE



Capella LETG+HRC-S on 2020-11-10

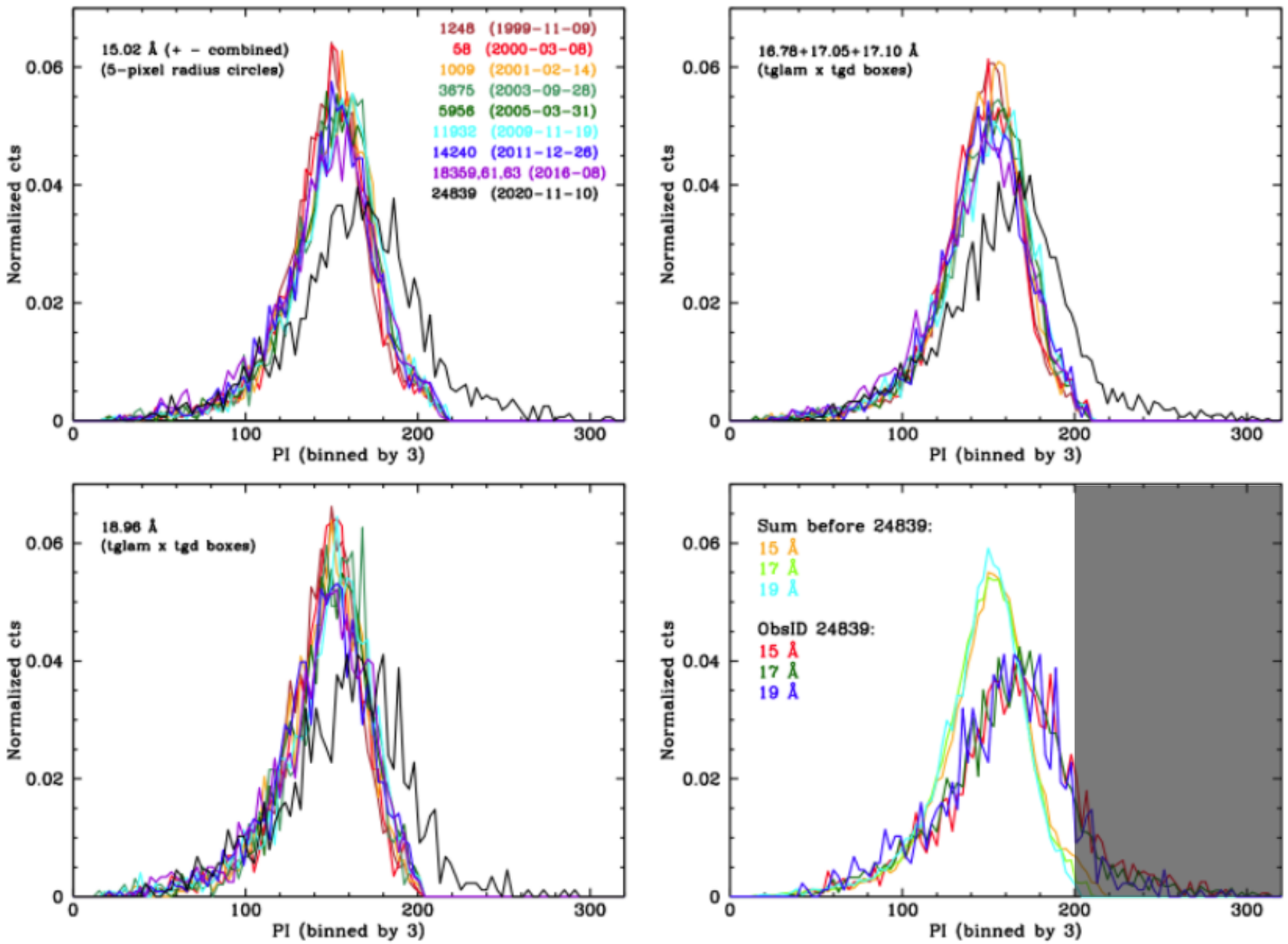
POSSIBLE ISSUES FROM A ➡ B SWITCHOVER: GAIN



- Median gain 9% higher than Side A
- Broader distribution
- Background filter will remove > 1% of events at some wavelengths

Capella LETG+HRC-S on 2020-11-10

POSSIBLE ISSUES FROM A ➡ B SWITCHOVER: GAIN



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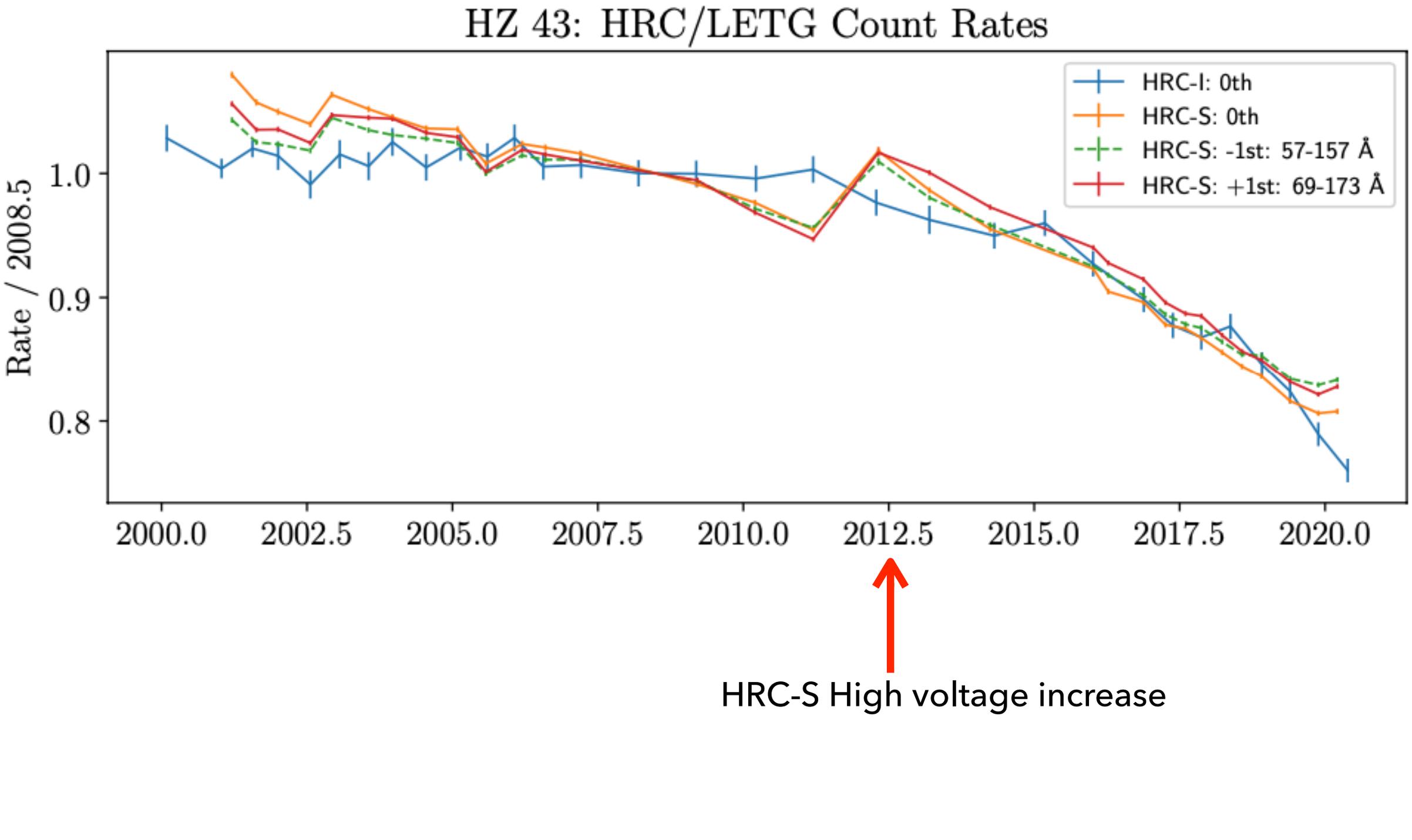
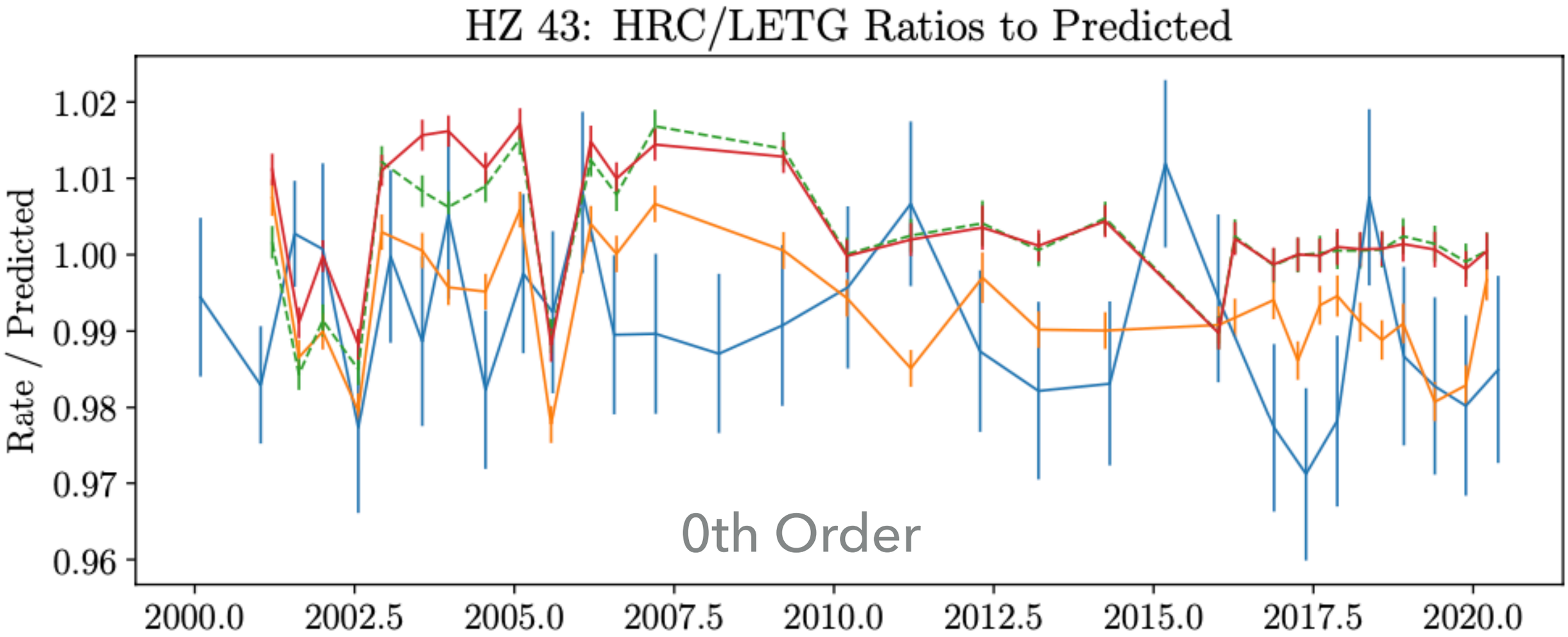
Capella LETG+HRC-S on 2020-11-10

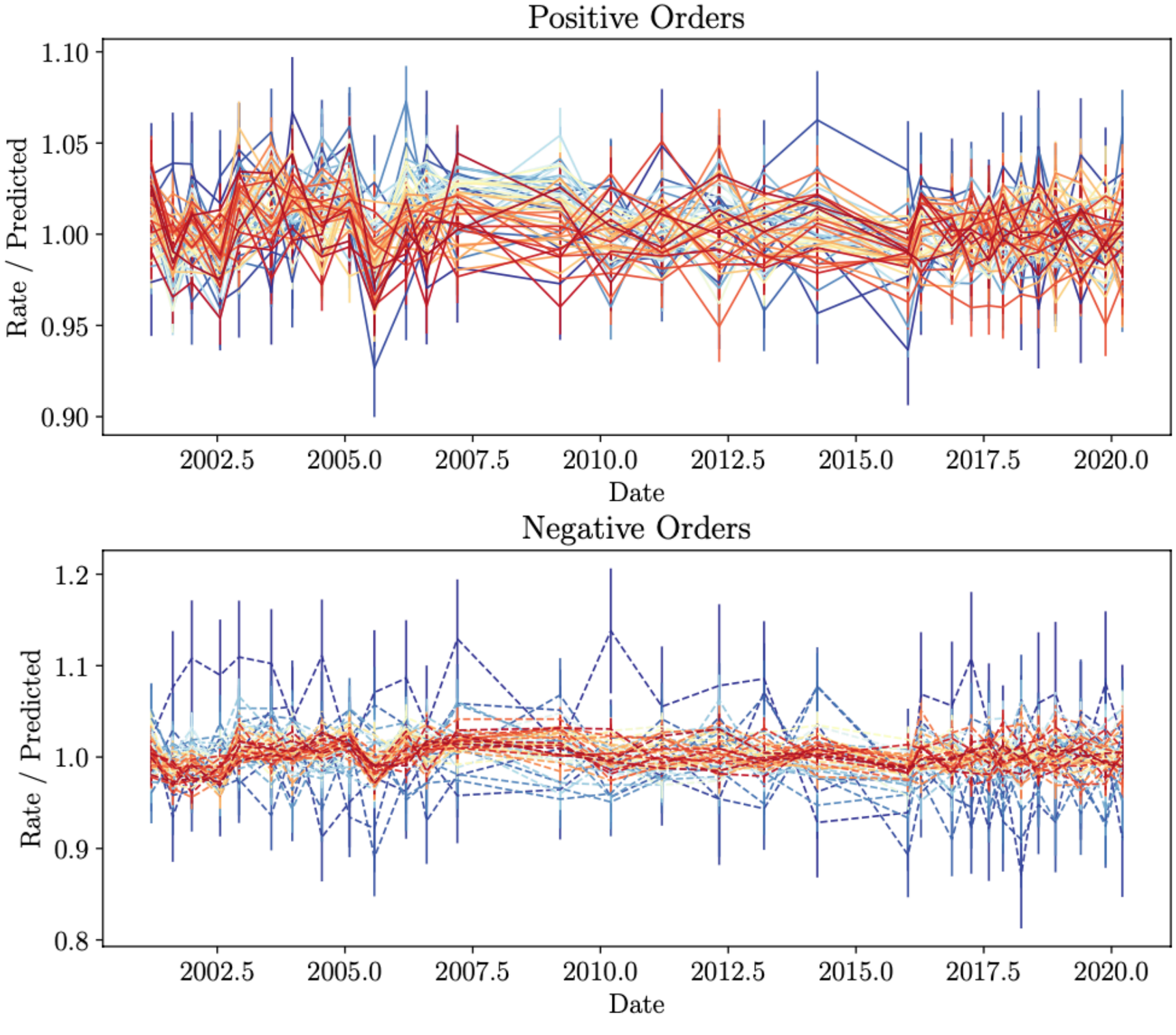
QUANTUM EFFICIENCY DECLINE



QUANTUM EFFICIENCY DECLINE

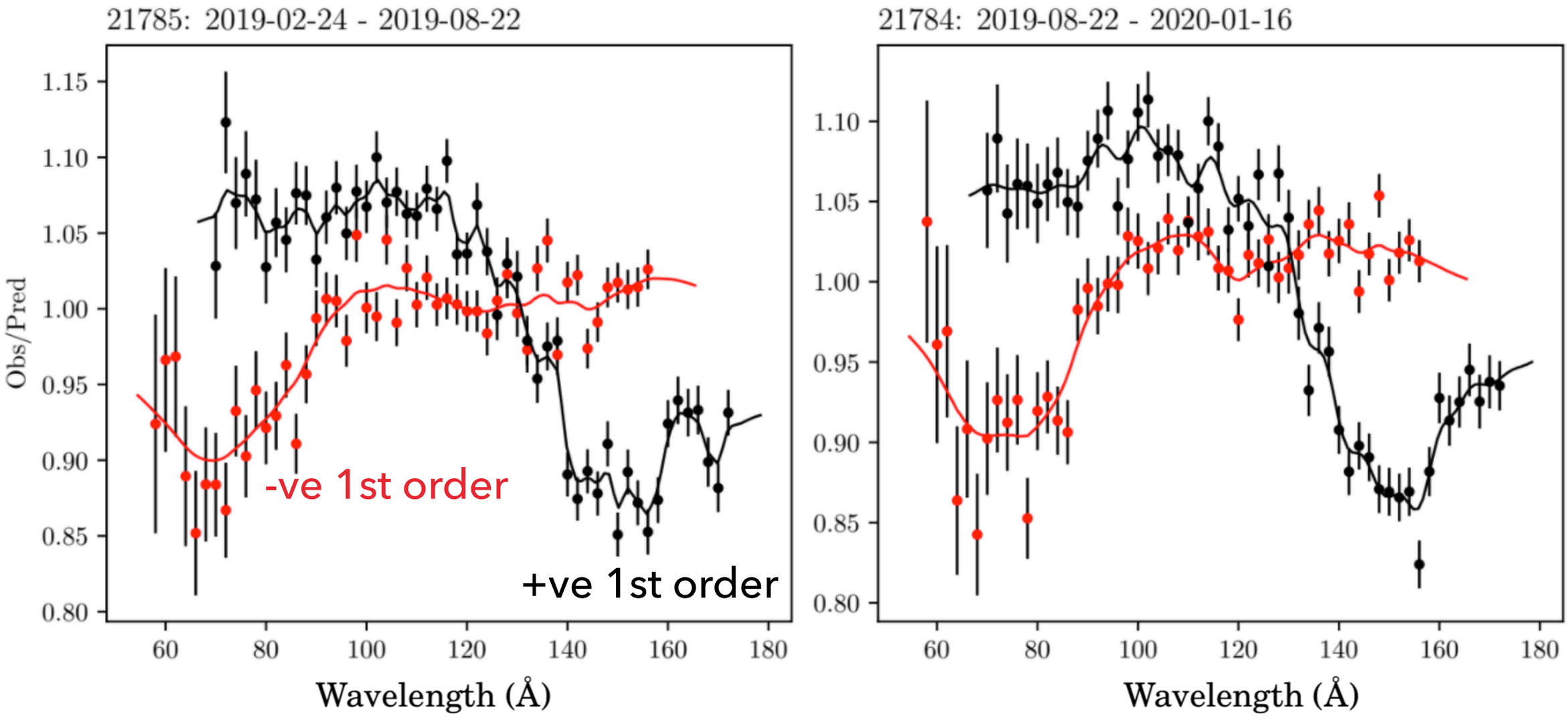


QUANTUM EFFICIENCY DECLINE



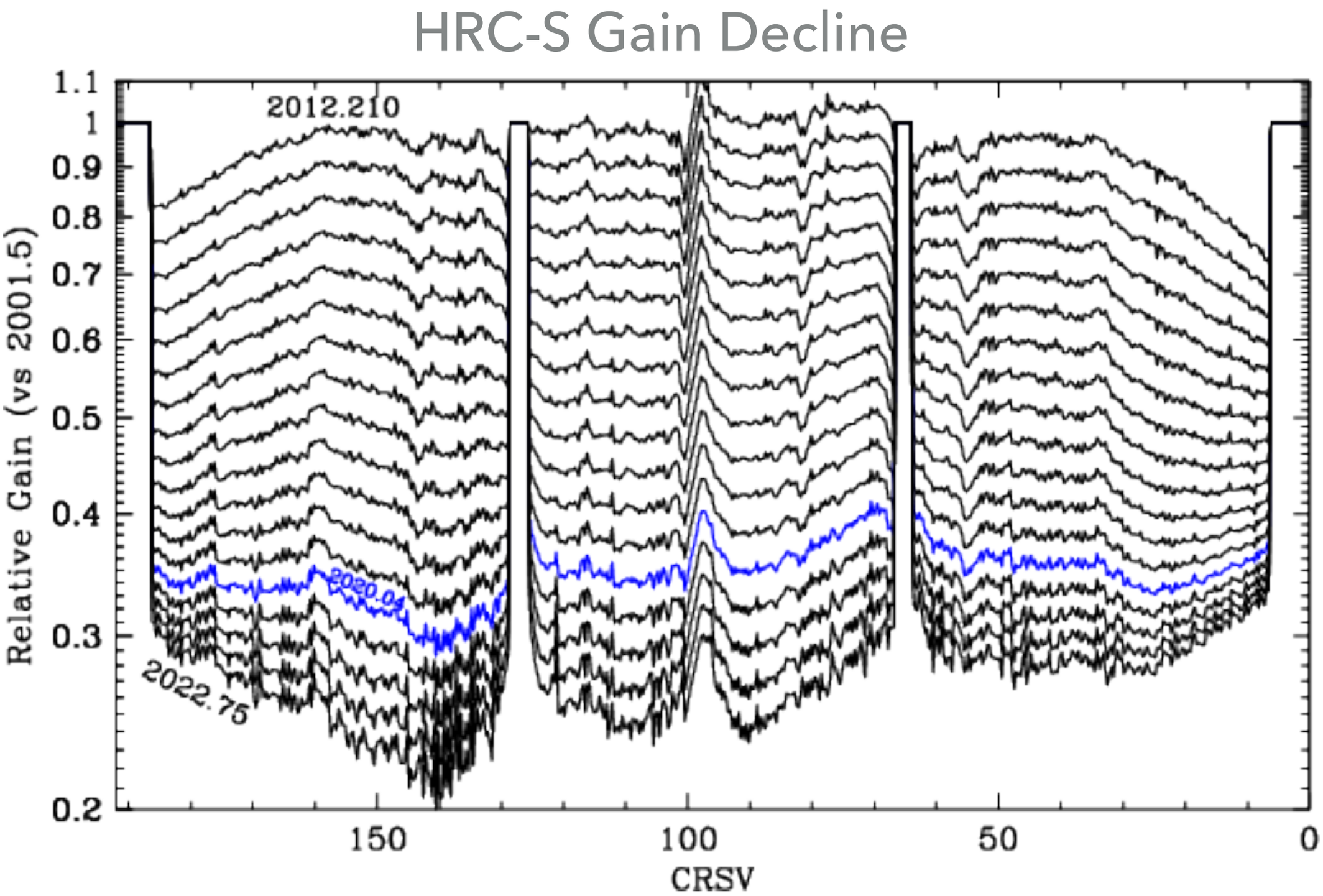
QUANTUM EFFICIENCY DECLINE

HZ43 LETG+HRC-S Empirical QEU Corrections



Corrections expressed relative to 2.35%/yr grey decline

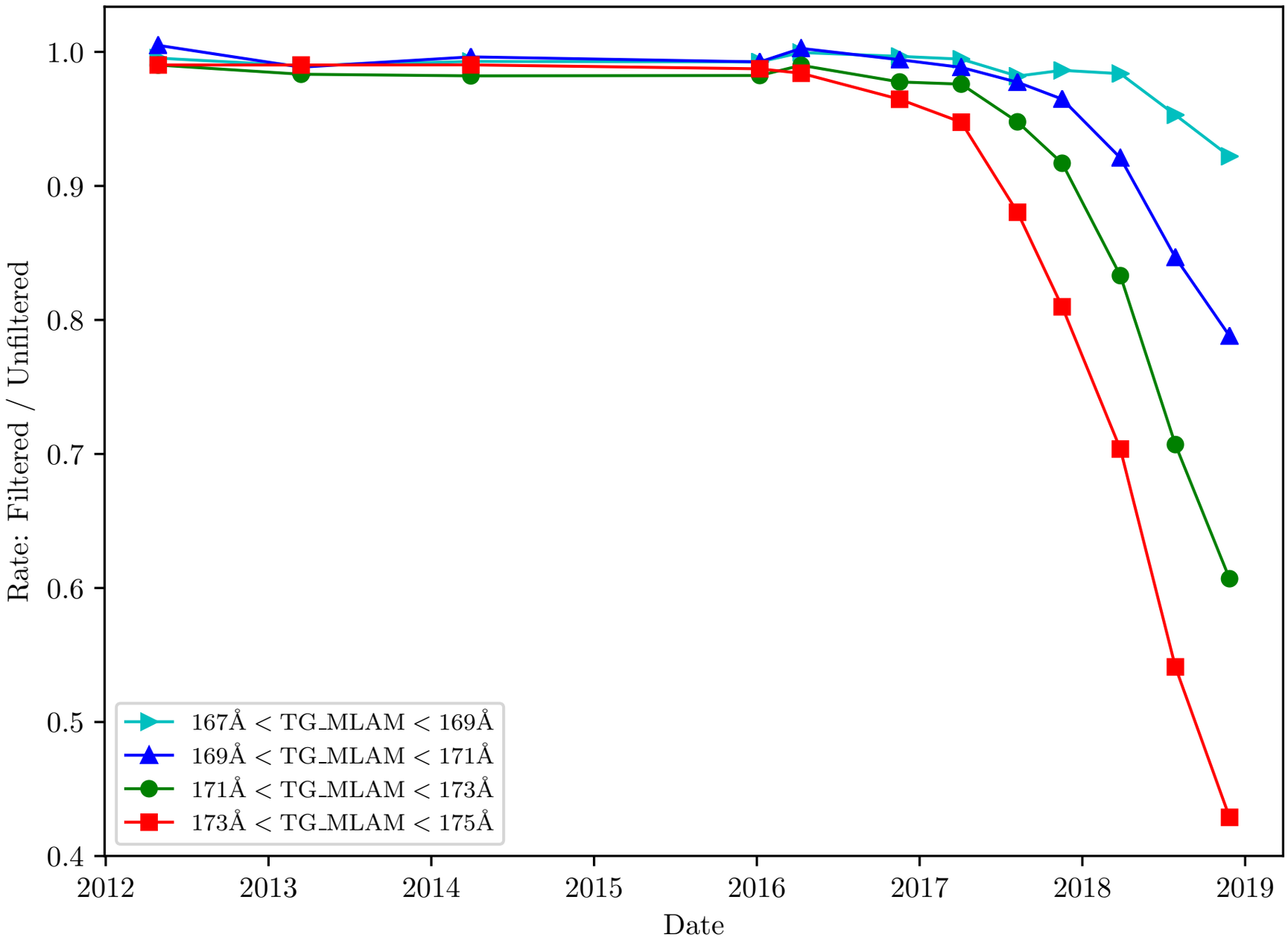
QUANTUM EFFICIENCY DECLINE



QUANTUM EFFICIENCY DECLINE

Gain-related problems for PI-base background filtering

- +ve order long wavelength source signal now same PI as lowest PI background events
- PI-base bg filtering removes significant signal



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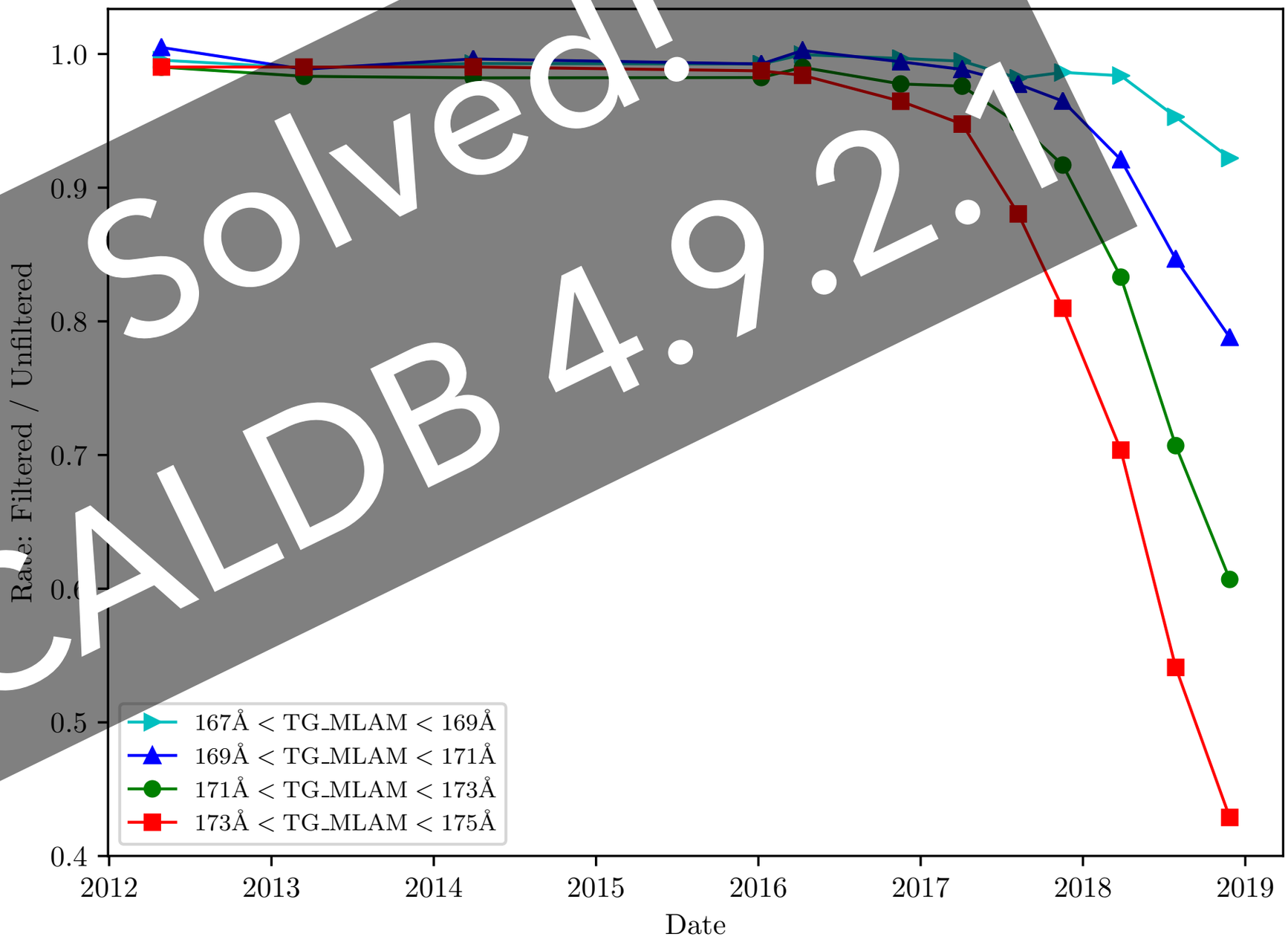
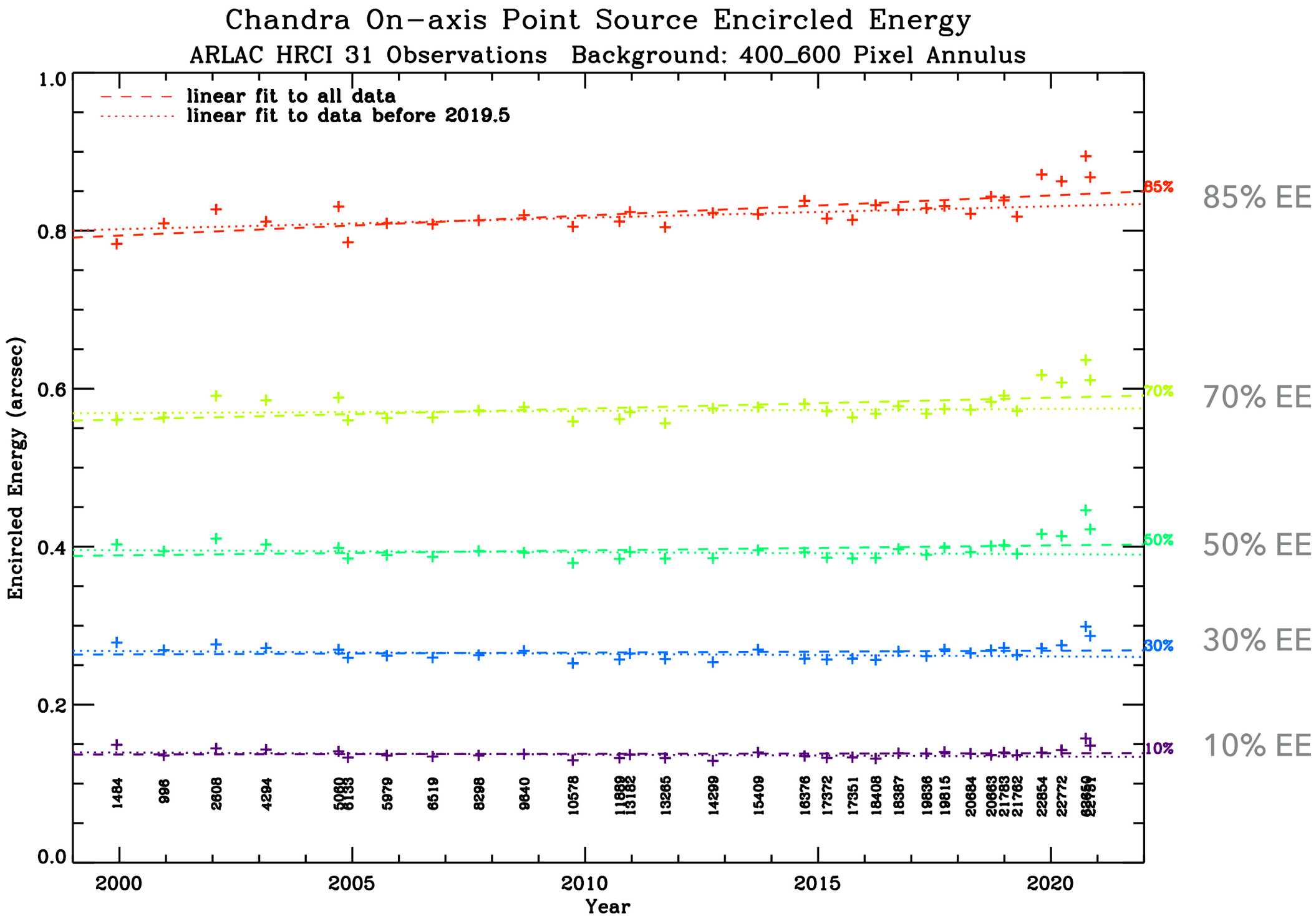
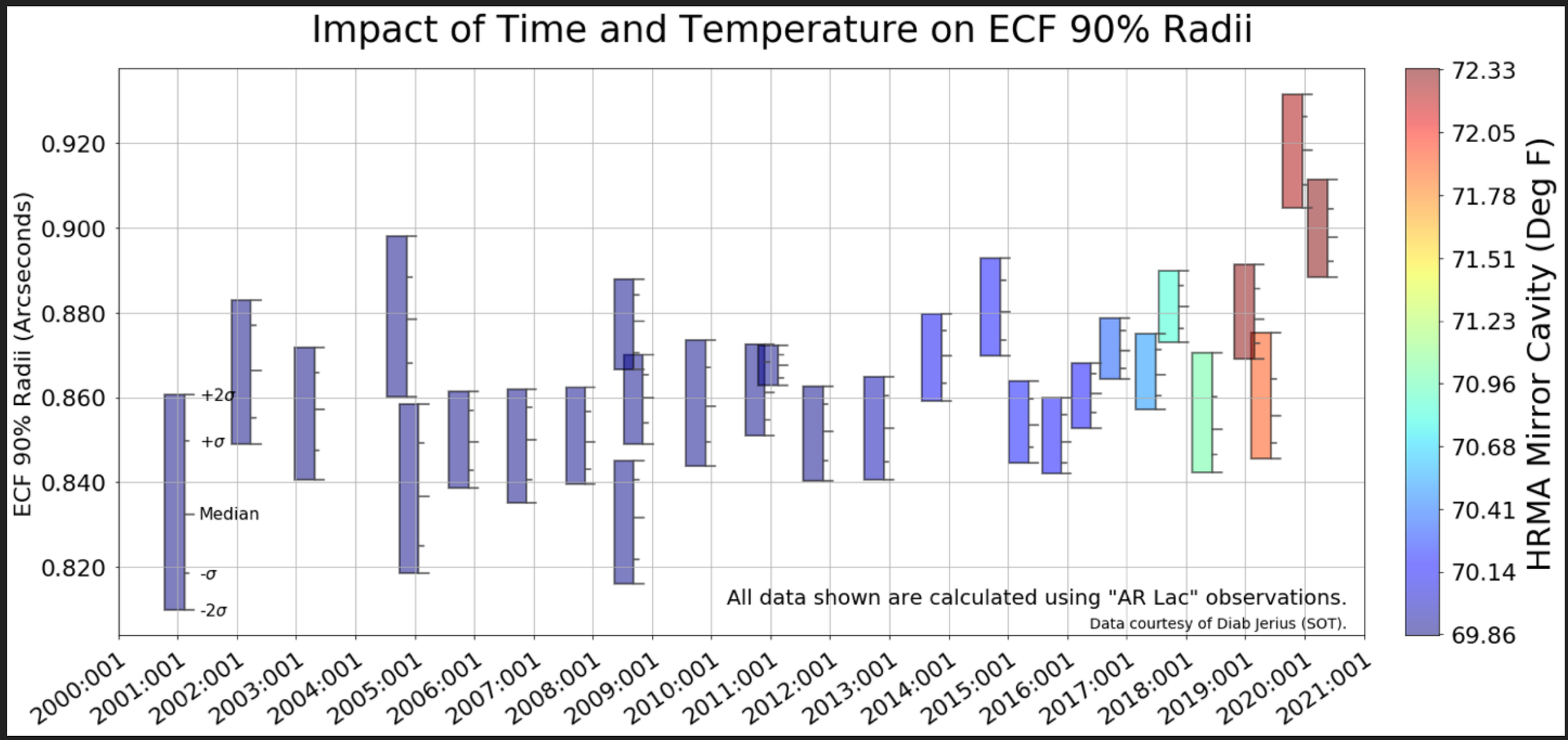


POINT SPREAD FUNCTION

PSF MONITORING: STEADY SMALL INCREASE OF PSF ON HRC-I,S



PSF MONITORING: STEADY SMALL INCREASE OF PSF ON HRC-I,S



HRC PSF

- The HRC-I and HRC-S PSFs are steadily increasing in width; for HRC-S ~10% larger now than at the start of the mission
- Cause: uncertain, but possibly: HRMA temperature; gain decline
- Degradation is possibly related to decline in gain
  - Intrinsic detector psf?
  - Degap drift?
  - No evidence of a change in ACIS (but MUCH more difficult to see/measure)

SUMMARY

- Chandra calibration challenges are as a result of aging and decline of satellite thermal control and instrument performance and accumulation of contamination on ACIS
- The ACIS ECS is fading to beyond practical use for regular gain calibration. Cas A appears to provide a useful substitute
- As Chandra warms, ACIS performance is adversely affected and
- ACIS contamination model is being regularly updated; the contamination build-up rate is not slowing
- HRC-S PSF is slowly broadening; this behavior is not currently understood but might be HRMA temperature and/or detector gain
- Continuing HRC-S QE secular changes are being calibrated (HV increase on HRC-S likey in 2021).