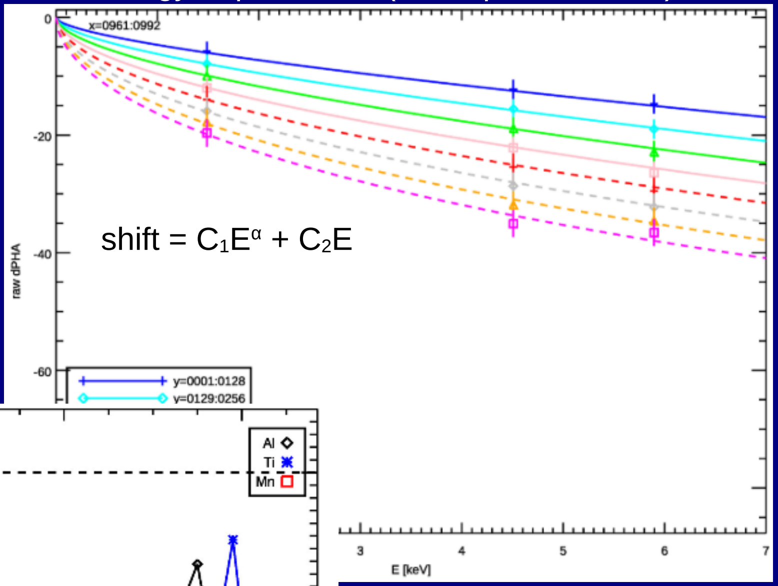
ACIS Gain Corrections with Cas A + Perseus

- Time-Dependent Gain Changes
- Motivation to use AP Sources
  - Perseus 6.7 keV Fe
  - Cas A 1.8 keV Si
- “Fully Illuminating” CCD with Maths
- Accuracy Expectation / Future

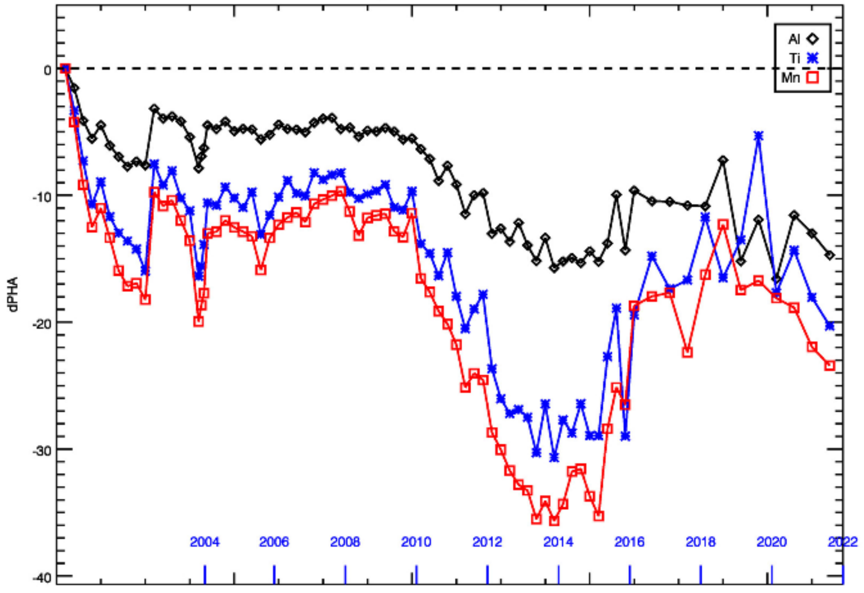
ACIS Time-Dependent Gain – CTI Effects

- **TGain CALDB files account for:**
  - CTI time-dependence (solar cycle / cosmic rays, electronic drift)
  - CTI energy dependence → CTI increases non-linearly with energy
  - CTI spatial dependence → CTI increases with row number due to # of charge traps that event charge travels through to readout
- **CTI CALDB files + CTI corrector algorithm in acis_process_events tool account for:**
  - CTI temperature dependence → CTI increases with FP_TEMP

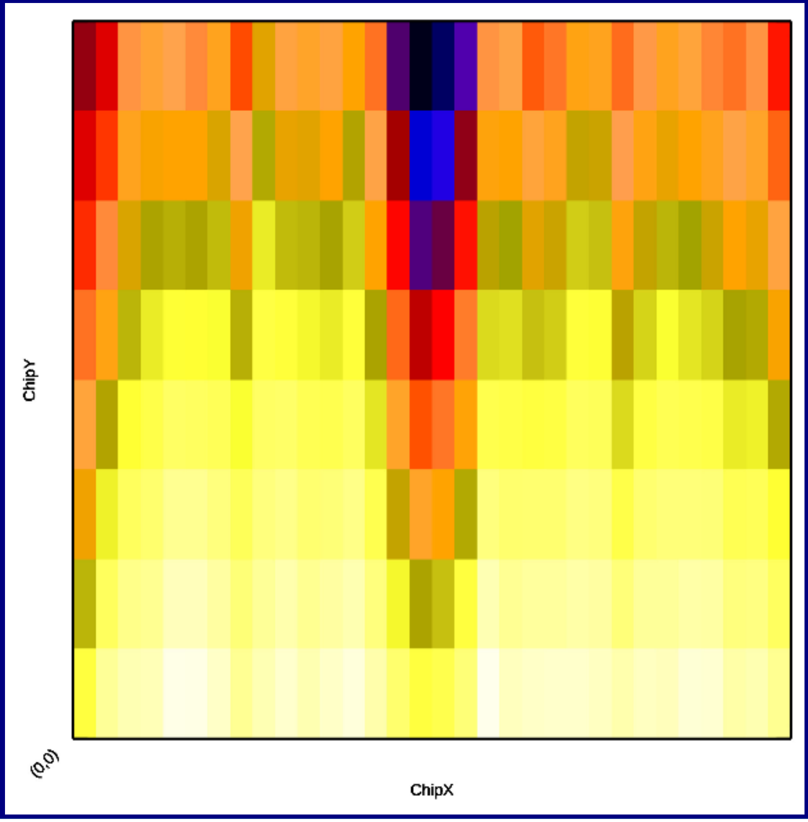
energy dependence (I3 aimpoint column)



time dependence (I3)



spatial-dependence (I3)



< 2024 ACIS TGain Correction

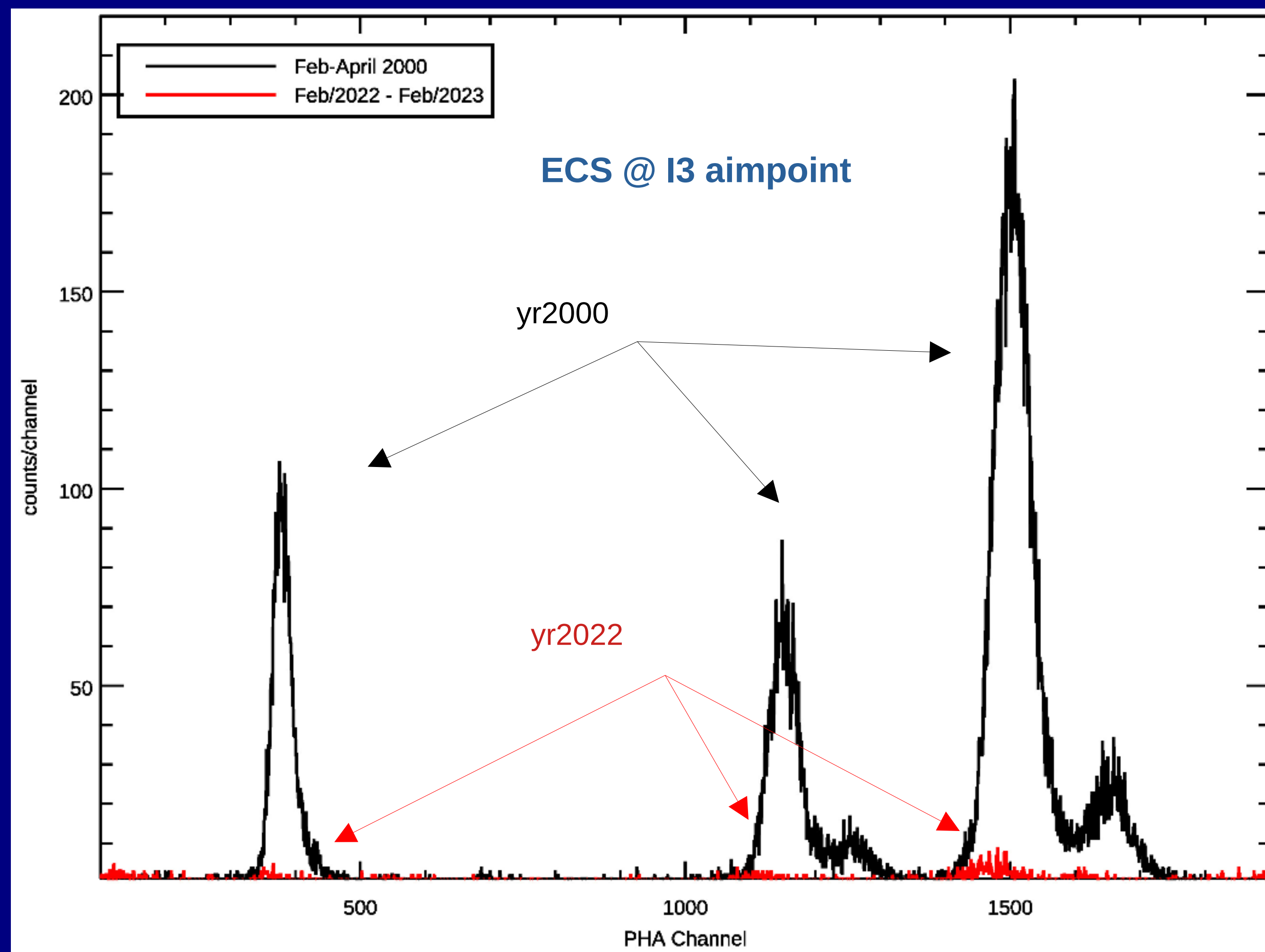
< 2024 Method

- ^{55}Fe produces bright Al, Ti, Mn lines (ECS), **fully illuminating** ACIS-I and ACIS-S
- Measure pulse height amplitude (PHA, an ADU unit) line center for bright Al-Kα, Ti-Kα, and Mn-Kα line positions
- dPHA = PHA shift from year 2000 line centers
- Repeat for each 32x column, use dPHA @ Al/Ti/Mn to fit for energy dependence

Result
dPHA(chip X,Y, E)
per 32x128y pixel tile

Decaying ECS

- ^{55}Fe decay with 2.7 year ½ life
- Chandra has been flying for 25 years!
- Decay Mitigation:
  - Time binning 3→6→12-month intervals
  - Spatial binning 32x128 → 32x256
  - Relaxing focal plane temperature constraints



Perseus Isolated 6.7keV Fe-Heα

- 10 ksec Obs x6 chips (primary imaging CCDs: ACIS-I, S2/3)
- 1x per year
- Extended emission, simple spectrum with bright & isolated Fe @ 6.7 keV

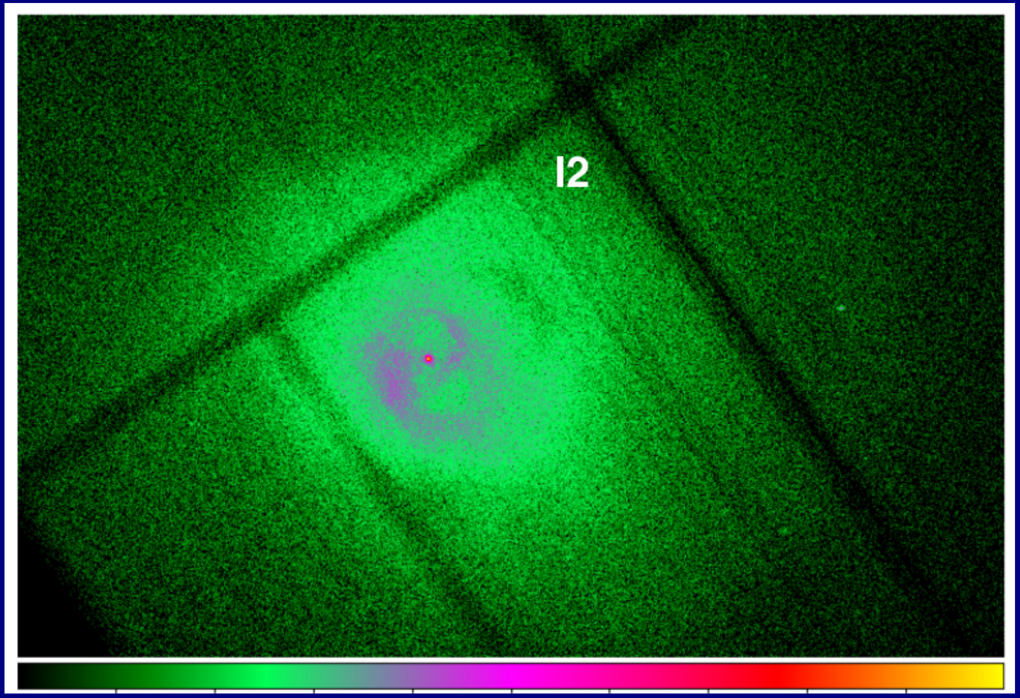
Procedure

- Fit Fe LineE in 32x128y chip(x,y) tiles
- dE = measured LineE – Fe_baseline
- Convert dE → dPHA (shift in PHA) units using CALDB DETGAIN (eV vs PHA)

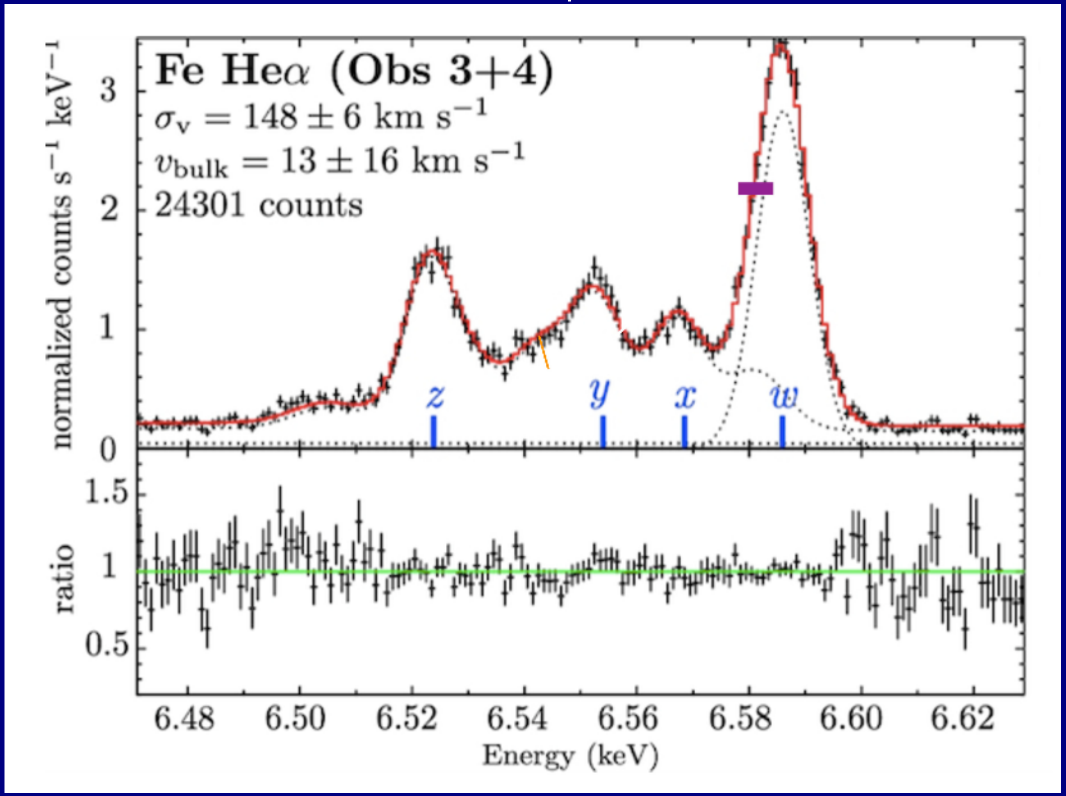
Result

- dPHA(chip X,Y) @ 6.7 keV

ACIS I2 Illumination

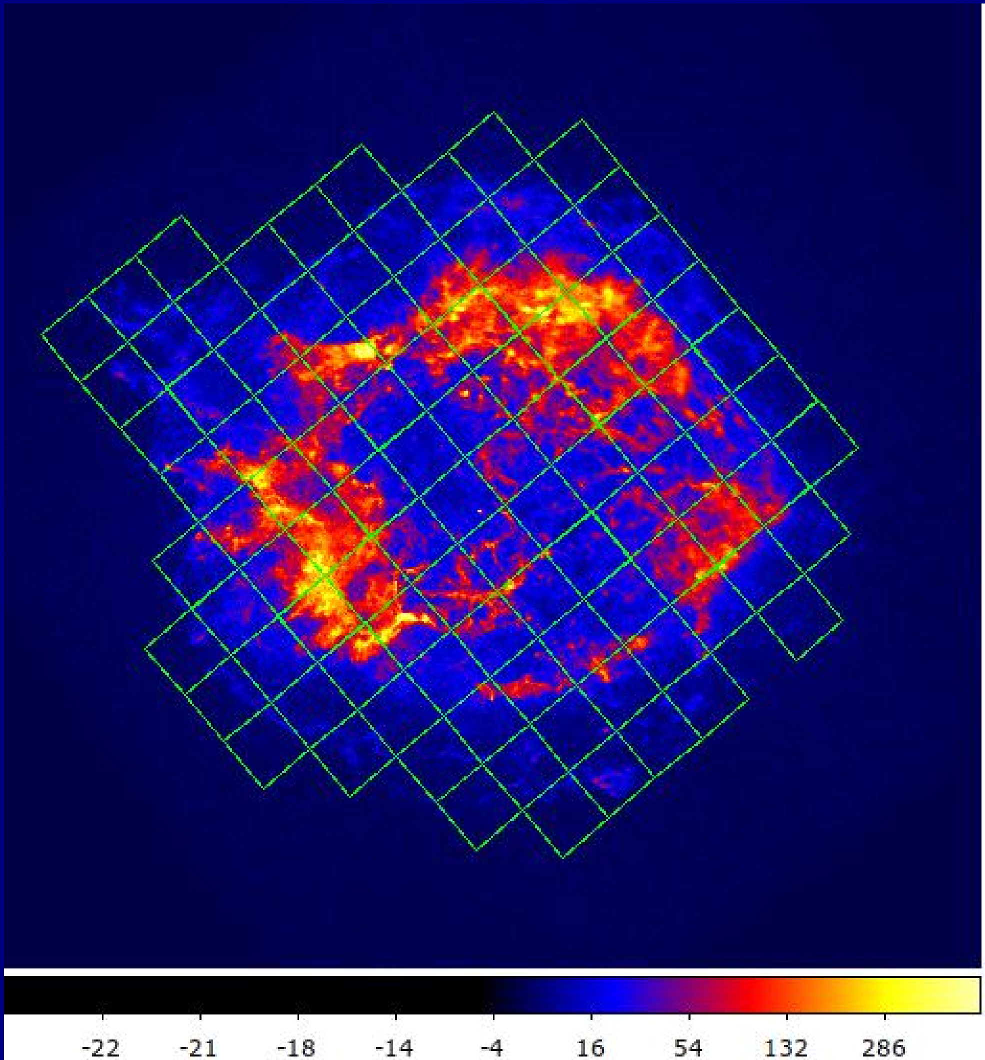


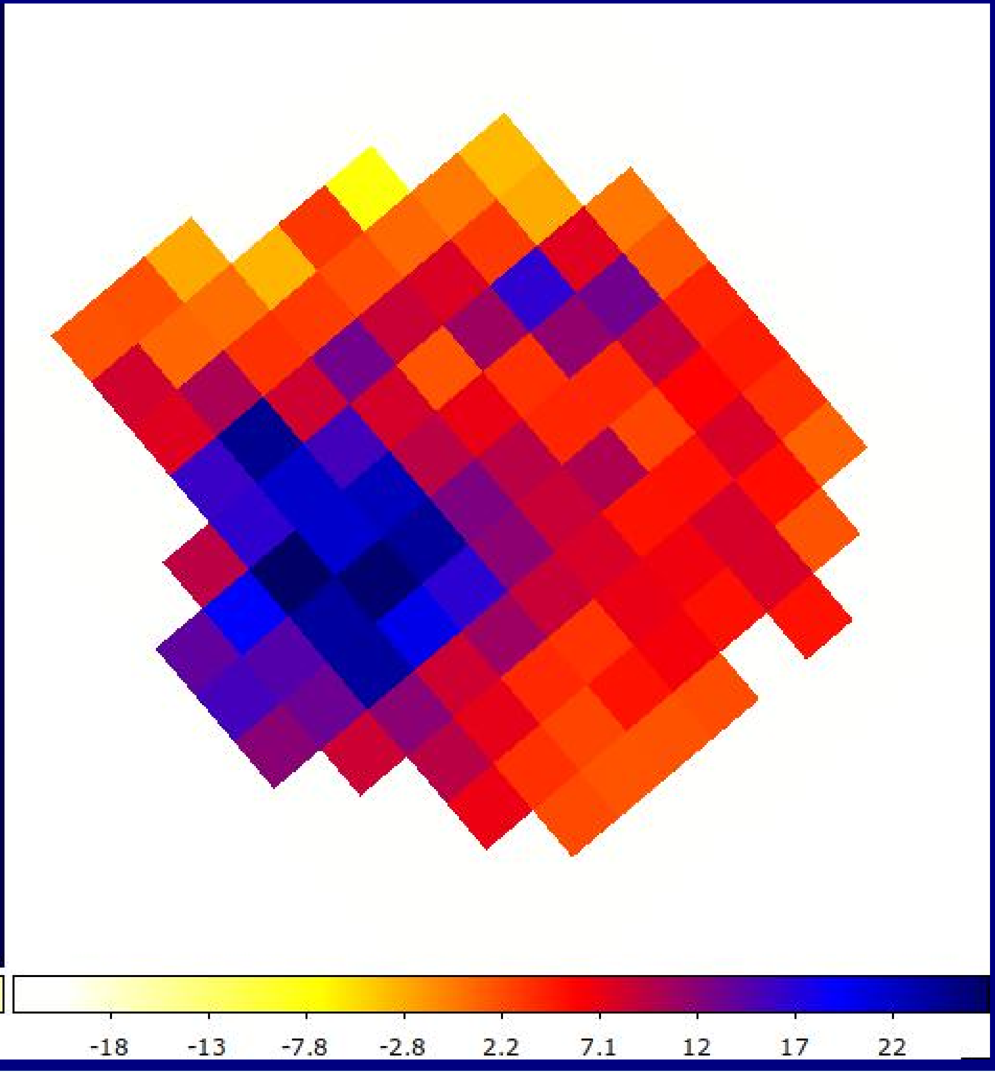
HITOMI Spectrum



Cas A 1.856keV Si-Heα

- 1 ksec Obs x6 chips (I0/1/2, S1/2/4), 2 ksec Obs I3 and S3
- Extended emission
  - ~50 32x128 tiles with counts >100 in Si line
- … Bulk motion complications ~ -20 to +30 eV (-3,000 to +5,000 km/sec)
  - Early epoch fits for "baseline" Si LineE per tile
  - dE = measured LineE – Si_baseline



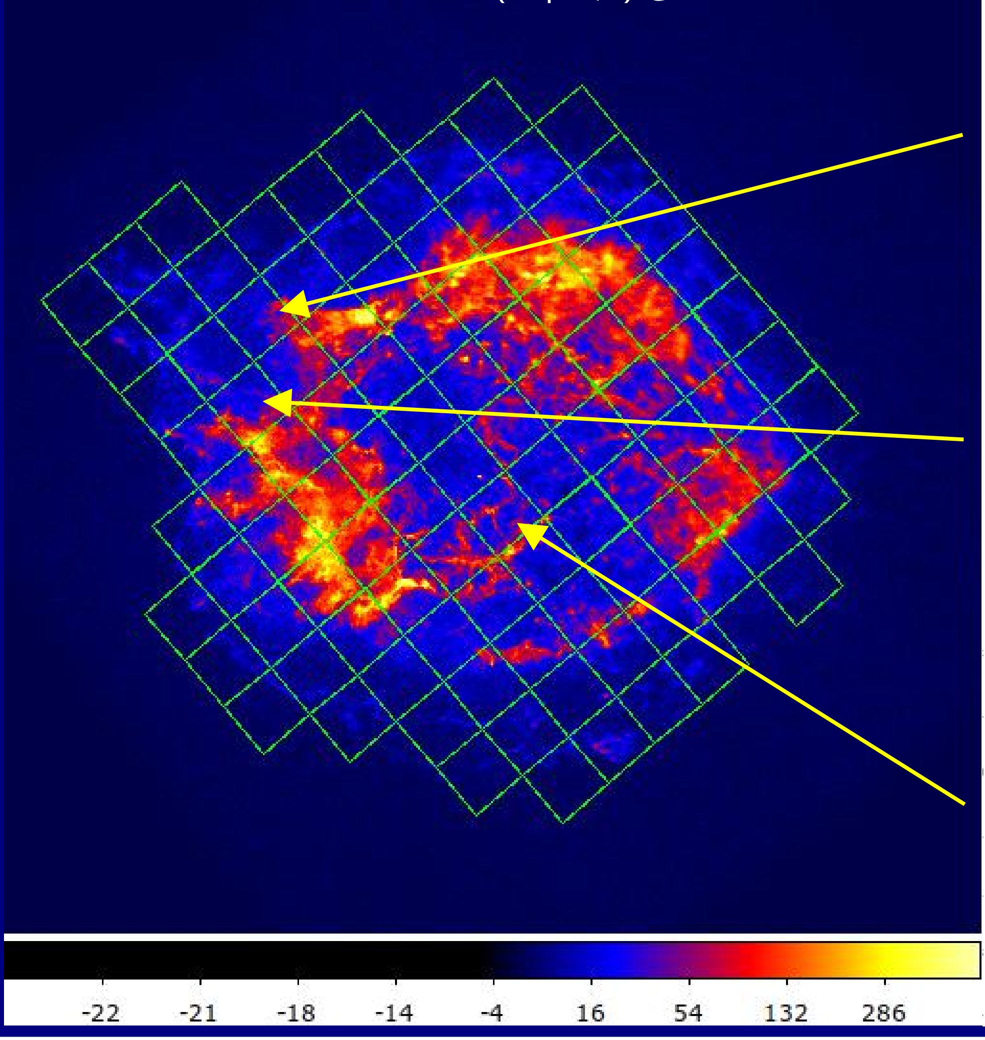


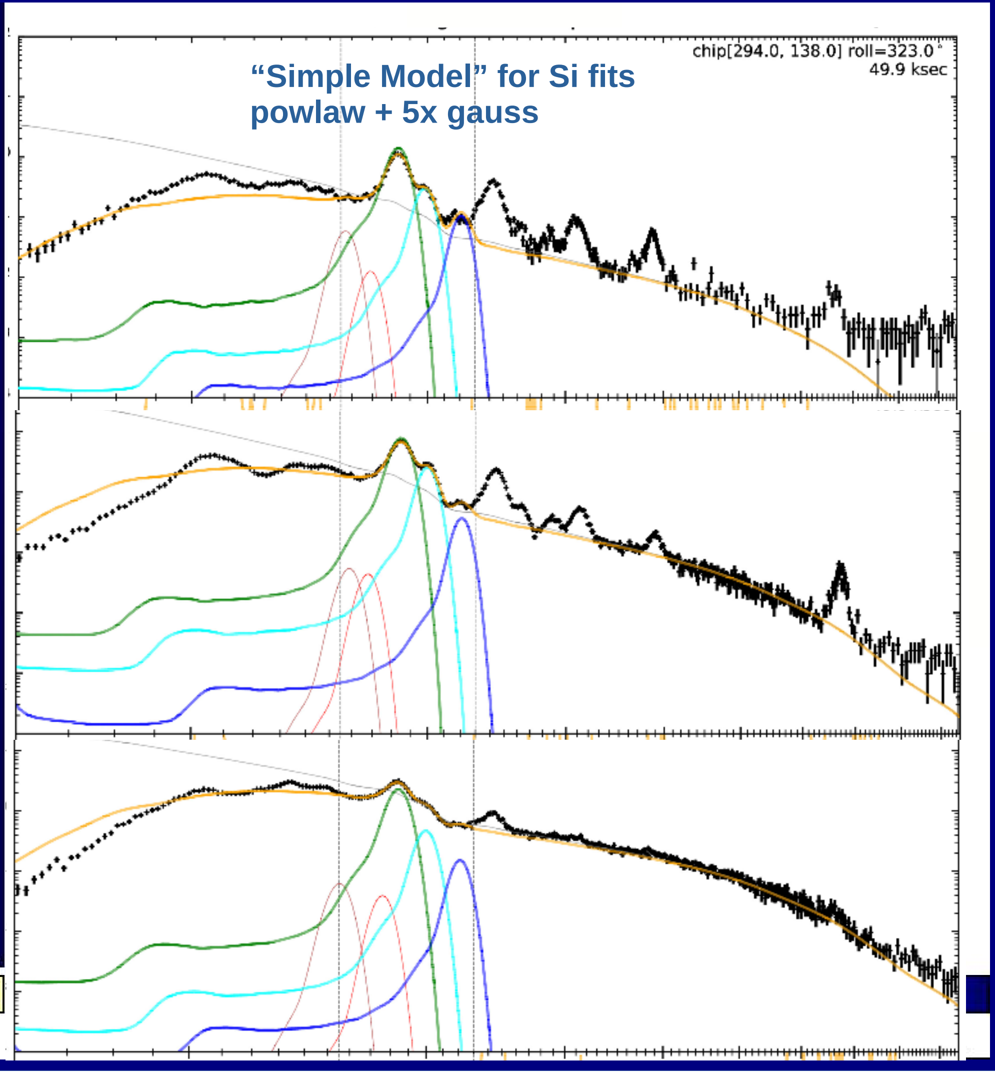
Cas A 1.856keV Si-Heα

- 1 ksec Obs x6 chips (I0/1/2, S1/2/4), 2 ksec Obs I3 and S3
- Extended emission
  - ~50 32x128 tiles with counts >100 in Si line

- … Bulk motion complications
- … Spectrum spatial variation complications → fit in sky coords, then convert back to chip coords

- … Complicated analysis before obtaining
  - dPHA(chip X,Y) @ 1.856 keV



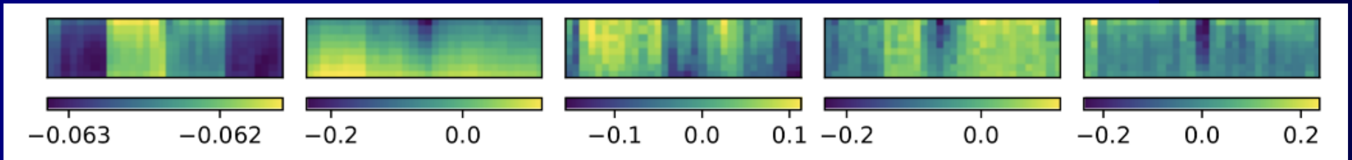


Deep S3 GRADED Mode for Baseline Si LineE / tile

Filling in the Illumination Gaps – Applying PCA

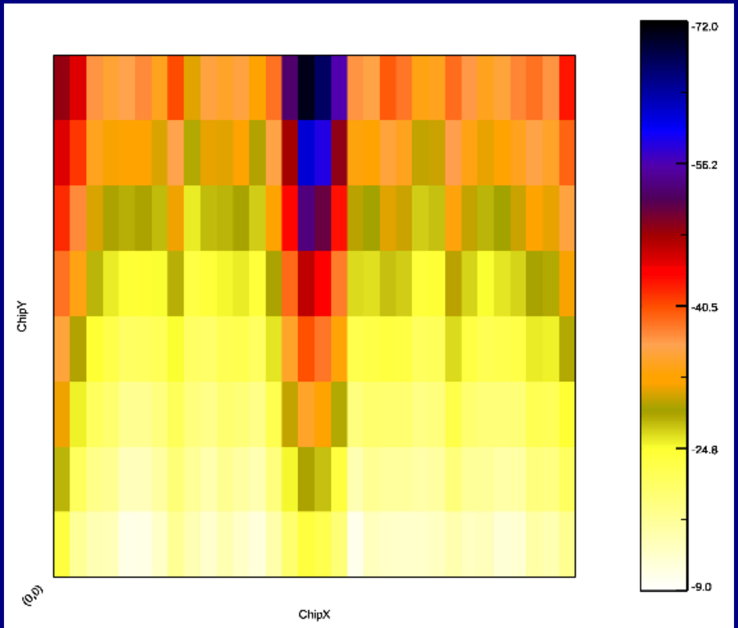
- Use Principle Component Analysis [PCA] to scale TGain spatial structure using Si positions where Si is bright enough to measure
- Prep:
  - Convert TGain pattern from each epoch to 256x1 array (dPHA array of 32x128 regions)
  - PCA accurately describes spatial pattern with 5 components (base vectors)
  - 1st components describes largest variations – ex. node boundaries
  - Remaining components describe decreasingly important modifications to recreate the structure
- Spatial structure for any given TGain epoch can be recreated with only a few uniquely scaled PCA components

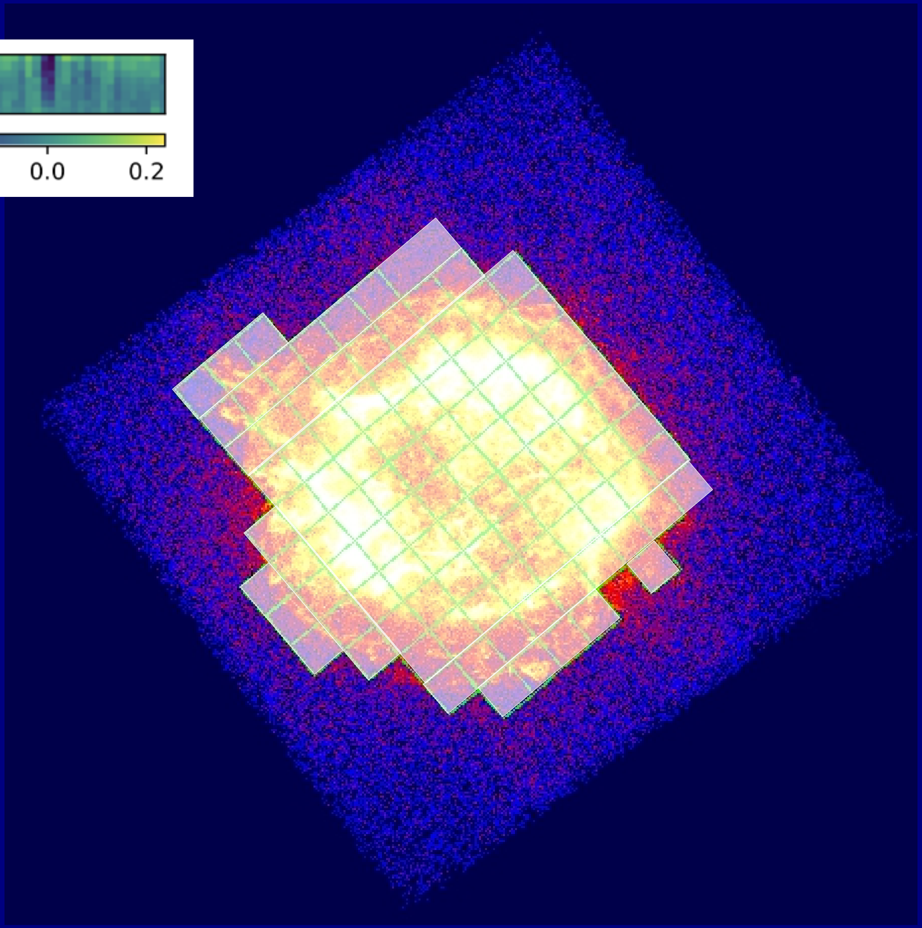
5x Most Significant PCA Components



x epoch2022 scaling factors

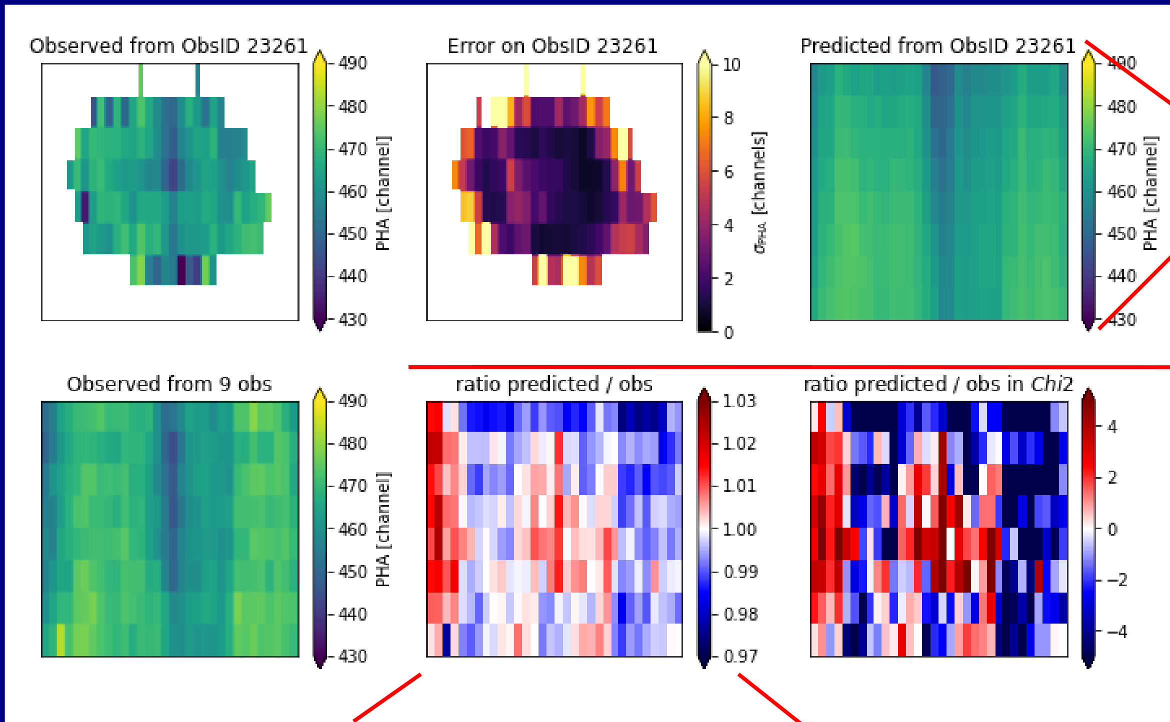
= recreation of epoch2022 spatial gain structure





Filling in the Illumination Gaps – Applying PCA

- Scaling factors calculated from tiles where Si is bright enough to measure dPHA (LineE shift)
  - ☝ number of tiles measurements return ☝ accuracy filling the missing unmeasured chip tiles

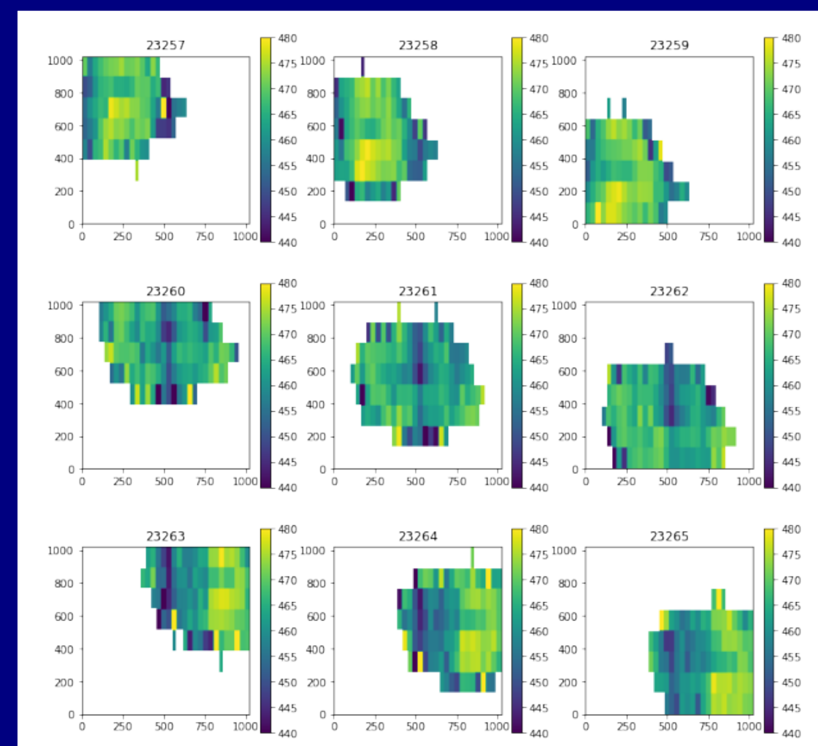


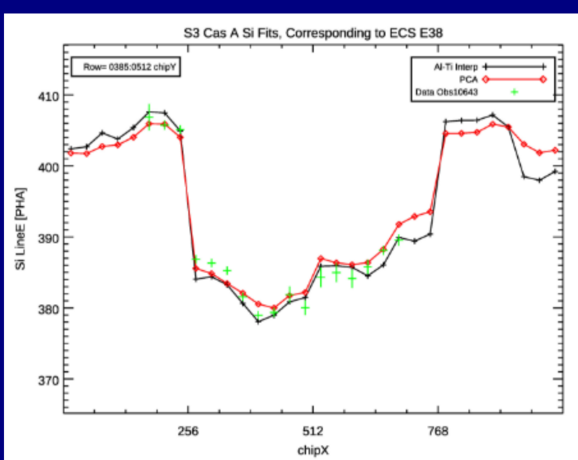
Spatial map of Si created with 1x pointing of Cas A to scale PCA components

Preliminary Results – Before Bulk Motion Accounting

Residuals in spatial structure using only 1x 2ksec Cas A pointing

Measured Si positions for 9x offset pointings of Cas A



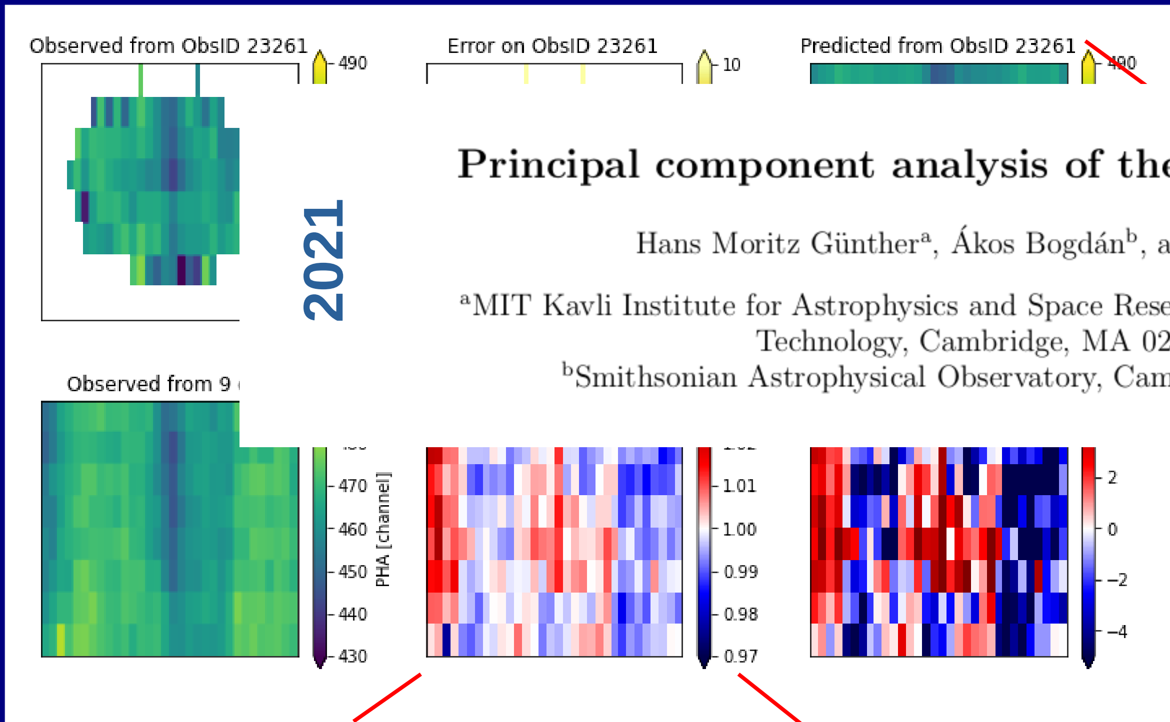


Si position interpolated from ECS Al & Ti positions compared to PCA prediction

Chip location:
Y= 385:512
X= 1:1024

Filling in the Illumination Gaps

- Scaling factors calculated from tiles with available measurements
  - ☝ number of tiles measurements return ☝ accuracy filling the missing unmeasured chip tiles



Principal component analysis of the Chandra ACIS gain

2021

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of Cas A to

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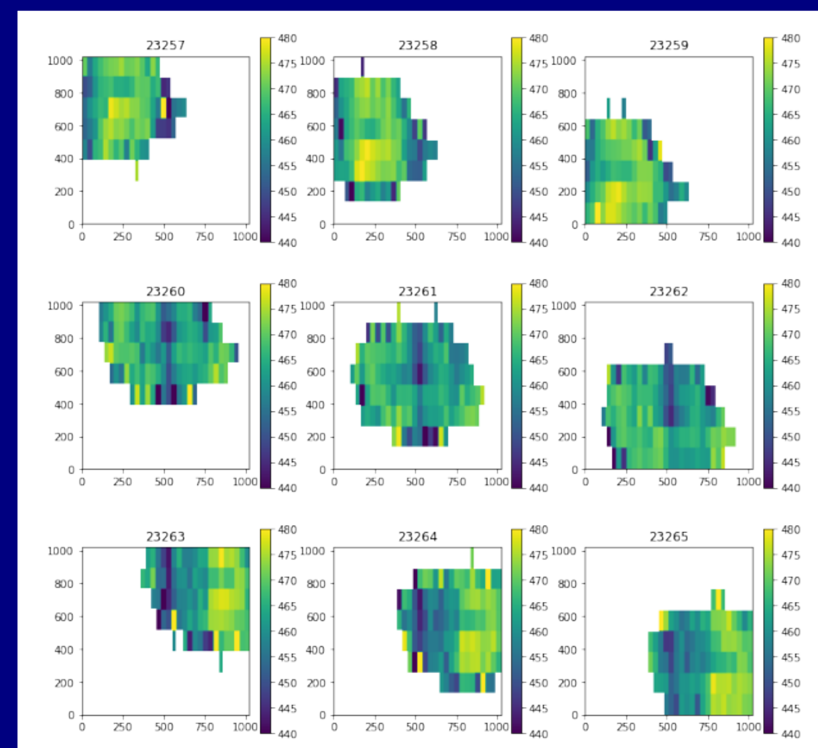
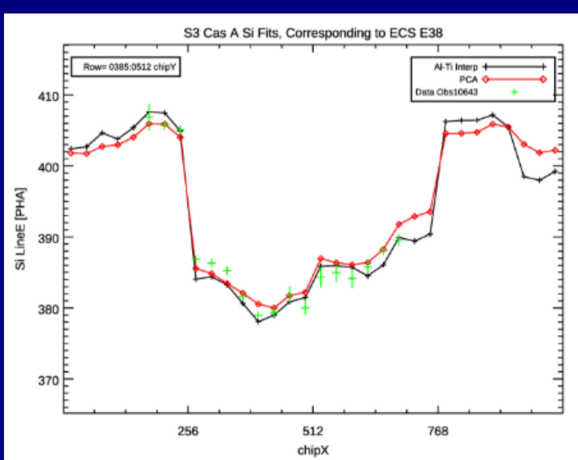
Measured Si positions for 9x offset pointings of Cas A





Si position interpolated from ECS Al & Ti positions compared to PCA prediction

Chip location:
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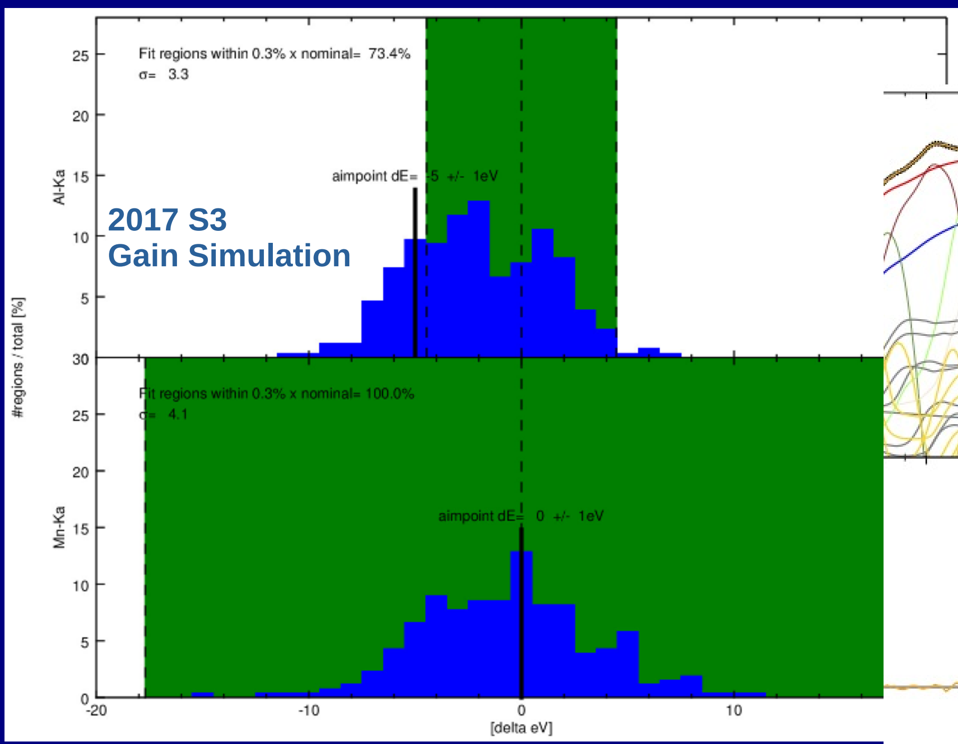
ACIS Gain Accuracy

Cas A + Perseus = TGain Calibration Method for the next ____ years of Chandra

ACIS S0/S5 (primarily gratings use): TGain scaled to by S2
ACIS S1/S4 (secondary imaging): Energy dependence fixed to historic values (reduced higher-energy accuracy)

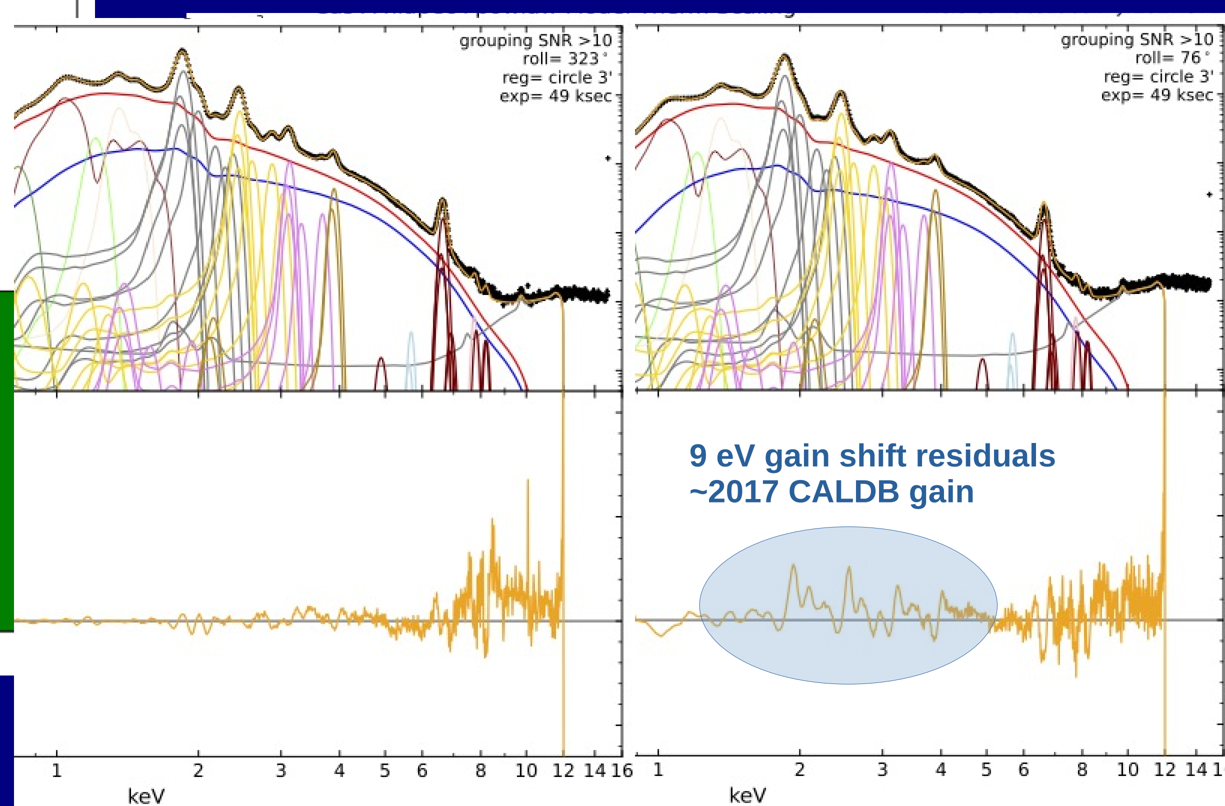
ACIS-I, S2/3/4 (primary imaging)
- Expectation 68% of 32x128y tiles within: ~0.6%
- Previously with strong ECS measurements: >0.3%

% tiles within 0.3% nominal LineE



Cas A Model + S3 Obs

2002 **2017**



*** More ACIS + Cas A Wednesday @ Thermal SN