Chandra ACIS-I3 Response Width

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Introduction

- degradation of thermal blankets $\Rightarrow$ more and more difficult to maintain cold focal plane
- last few years, more observations with some or all of the exposure at elevated temperatures
- study how ACIS response depends on focal plane temperature using ECS data
  - combine ECS data for Epochs 60, 61, 62, 63, 64
  - slice into temperature intervals (currently, 1° C wide);
  - initial study:
    -120.19 to -119.19
    -118.19 to -117.19
    -116.19 to -115.19
  - where sufficient data is available, fit the ECS lines (width parameters scaled and tied so that of Al-Kα width)
  - fit Al-Kα width vs. `chipy` (per node)

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Chandra Approach to Modeling ACIS Response

ACIS response factored into:

- `p2_resp`
  - ideal (undamaged) CCD response matrix (basic CCD physics: escape peak, shoulders, etc.)
  - "scatter matrix" (response broadening due to CTI)
- `det_gain`
  - `pha` of response peak ⇒ `Energy`
  - `pha` ⇒ `Energy` ⇒ `pi`
- `p2_resp` and `det_gain` tightly coupled:
  - `p2_resp` + `det_gain` ⇒ `rmf`
  - `rmf` peak vs `chipx`, `chipy`, `energy` ⇒ `det_gain`
- `p2_resp` and `det_gain` calibrated using (Epoch 1) External Calibration Source (ECS) spectra

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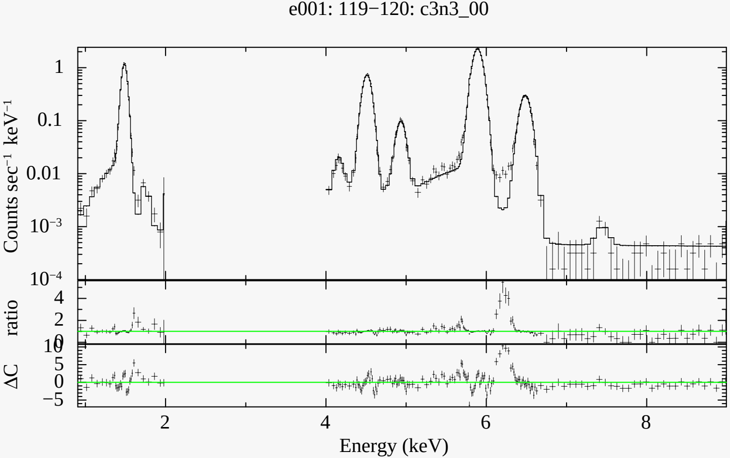
Introduction

FI CCD CTI Scatter matrix:

- 256×32 tiles (chip coords):
- `PHACHAN`(`pha` channel [ADU])
  - 40, 60, 80, 100, 128, 180, 230, 300, 380, 460, 512, 670, 1025, 1535, 2050, 3100
- `L1_WIDTH` [ADU] for each (`PHACHAN`)

- Kα, Kβ lines for Al, Ti, and Mn, covering $\sim 1.5 - 6\,$keV.



Introduction

- FI chip scatter matrix: broadening by an asymmetric Lorentz function

$$R_{scat}(E) = 1/\left[1 + [(E - E_0)/\Delta(E_0)]^2\right]^{\alpha}$$

where

$$\alpha = \begin{cases} 3.70 & \text{for } E < E_0 \\ 1.90 & \text{for } E > E_0 \end{cases}$$

ECS spectra using

- asymmetric Lorentz function broadening profile (Xspec local model)
- RMF without CTI broadening

Fitting ECS data

Fit main ECS lines (plus $\Gamma = 0.2$ powerlaw for background):

$\mathrm{AlK}_{\alpha,\beta}$, $\mathrm{TiK}_{\alpha,\beta}$, $\mathrm{MnK}_{\alpha,\beta}$ (+ NiK_{α})

Width function:

$$\Delta \propto \left(E_0^{0.12} + 0.3\, E_0 \right) \tag{1}$$

Allow $\Delta_{\mathrm{Al-K}\alpha}$ to vary; tie the rest to $\Delta_{\mathrm{Al-K}\alpha}$ using Eq. (1):

$$\begin{array}{ccccccccc} \Delta_{\mathrm{Al-K}\alpha} & : & \Delta_{\mathrm{Ti-K}\alpha} & : & \Delta_{\mathrm{Ti-K}\beta} & : & \Delta_{\mathrm{Mn-K}\alpha} & : & \Delta_{\mathrm{Mn-K}\beta} \\ 1 & : & 1.7066 & : & 1.7995 & : & 2.0312 & : & 2.1397 \end{array}$$

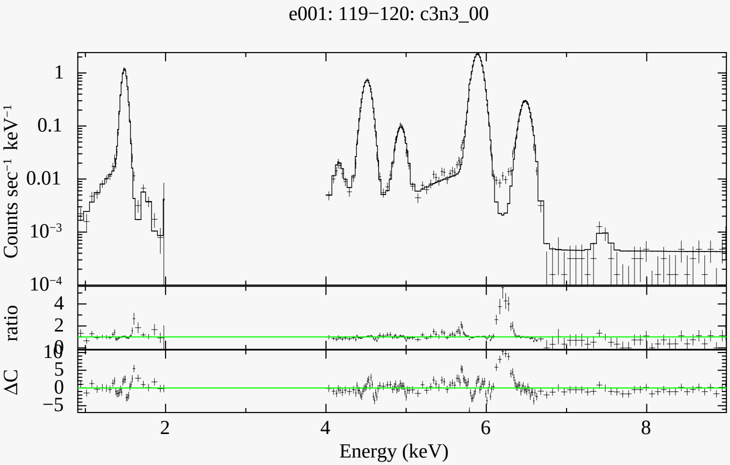
Kβ line energies tied to Kα line energies (multiplicative factor); can probably be relaxed for high quality data.

Line norm: Al-Kβ = 0.01 Al-Kα

Some Representative Fits

Epoch 1, -120.19 to -119.19

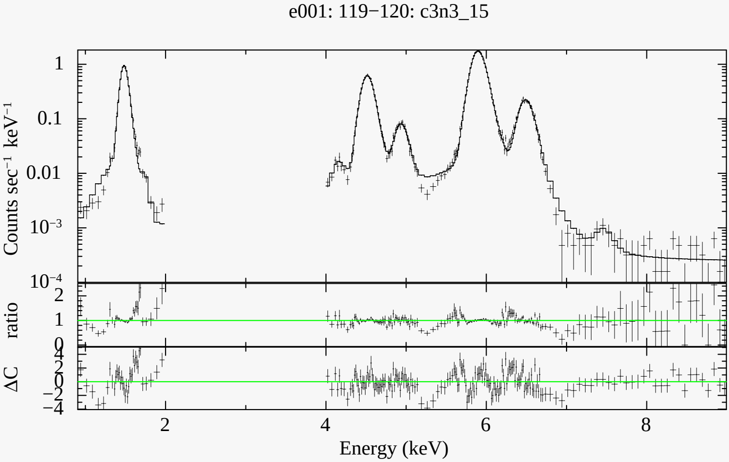
I3, node 3, 32 rows adjacent to framestore



Some Representative Fits

Epoch 1, -120.19 to -119.19

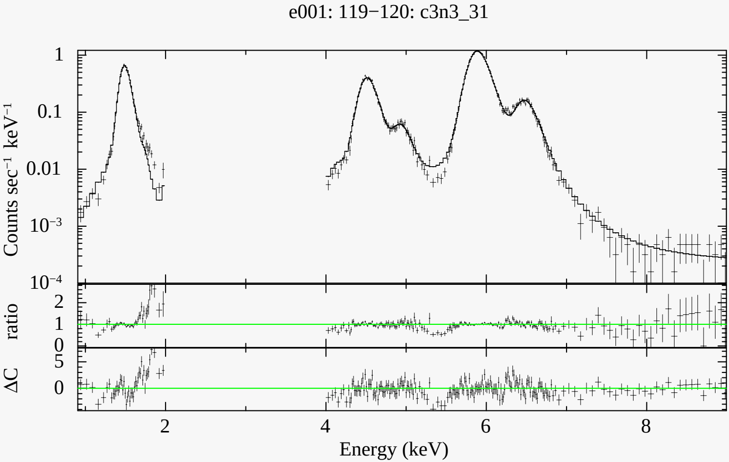
I3, node 3, 32 rows, middle of the chip



Some Representative Fits

Epoch 1, -120.19 to -119.19

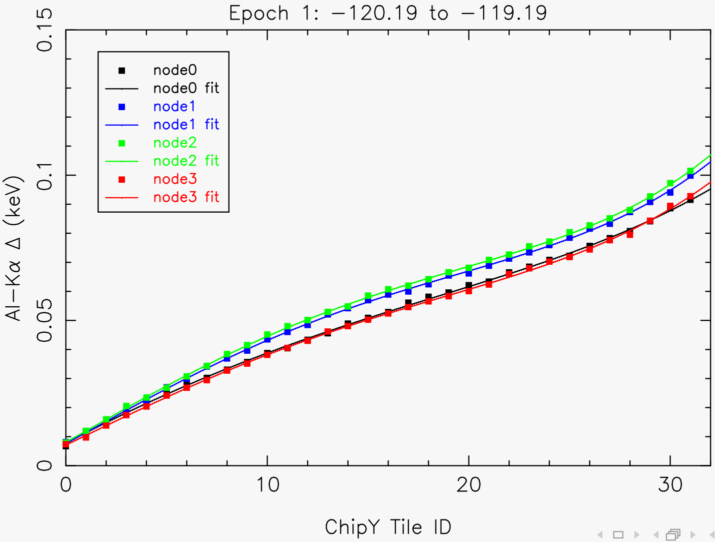
I3, node 3, 32 rows far edge of the chip



Fit Width vs. `chipy` (4th degree Chebyshev)

Epoch 1, I3: -119.19C to -120.19C

Al-Kα width vs. `chipy`



Variation With Focal Plane Temperature

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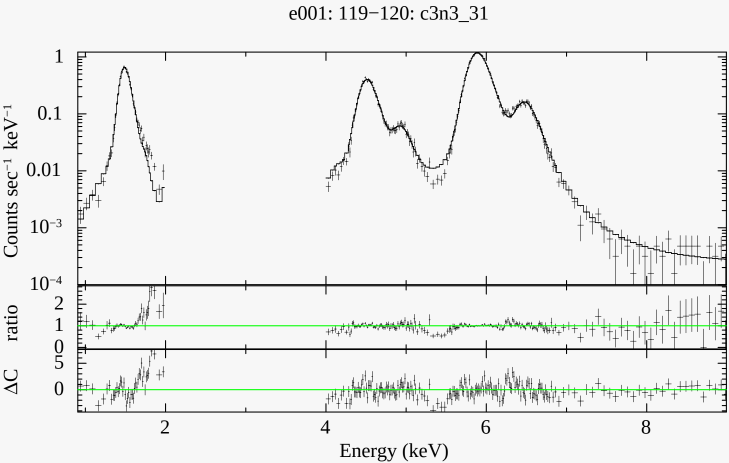
Variation With Focal Plane Temperature

I3 node 3: 32 rows adjacent to edge opposite to framestore
Epoch 1, -120.19 to -119.19



Variation With Focal Plane Temperature

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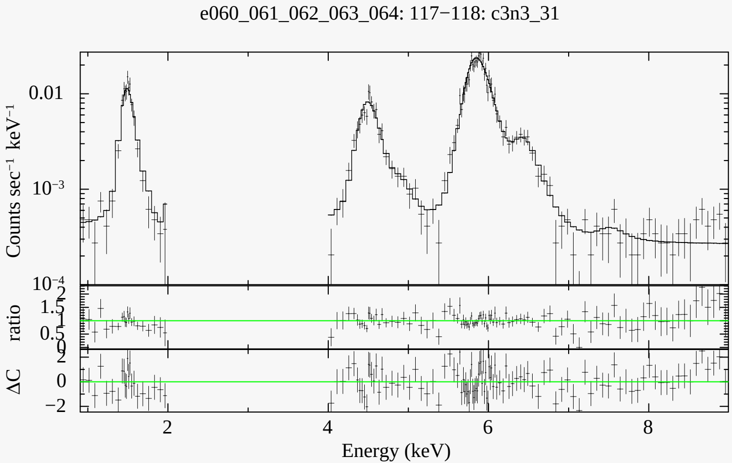

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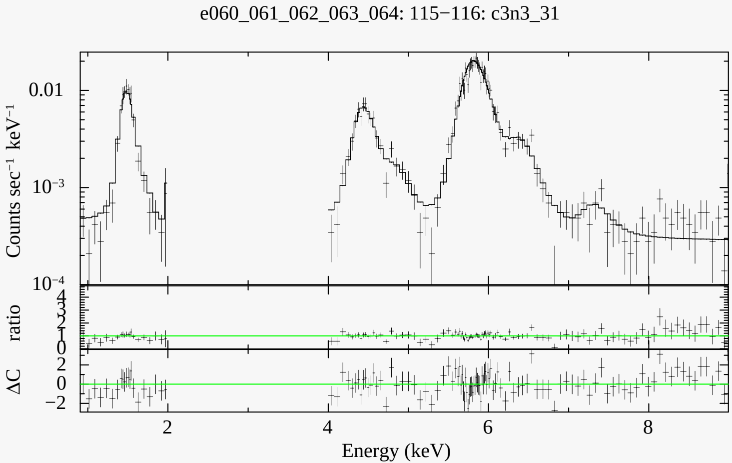
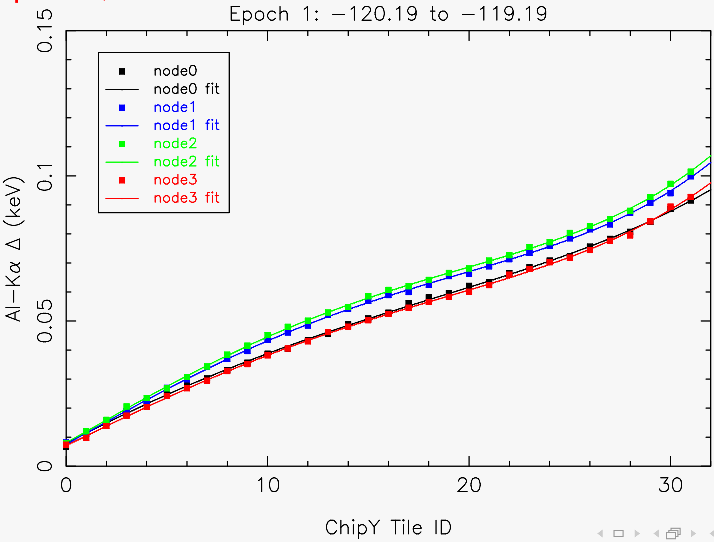


Al-Kα Response Width

Variation vs. Focal Plane Temperature

Epoch 1, I3: -119.19C to -120.19C



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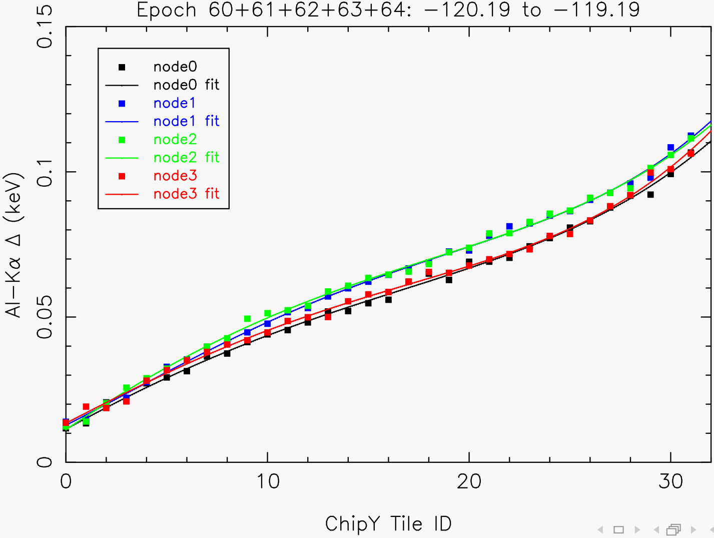

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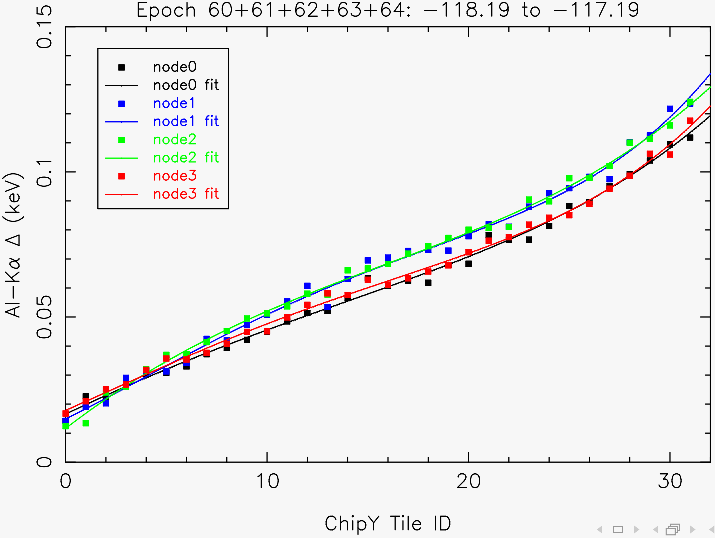

Al-Kα Response Width

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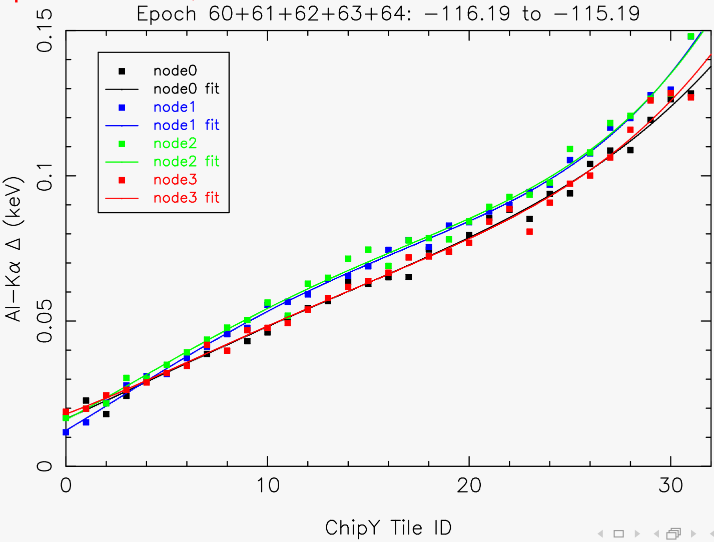

Steps to CALDB `p2_resp` (FI)

- Scatter matrix tabulates width Δ in ADU vs. `PHA`
- ECS fits give $\Delta(E)$ at energy of Al-Kα

So,

For each node and tile:

- $\Delta(\text{Al-K}\alpha) \Rightarrow \Delta(E)$ using width function, $\Delta \propto \left(E_0^{0.12} + 0.3\, E_0\right)$
- $E_{\text{chan}} \Rightarrow$ `phachan` using `det_gain`
- map $\Delta(E_{\text{chan}}) \Rightarrow \Delta(\text{ADU})$ using `det_gain`

Inject new `L1_WIDTH` into appropriate `p2_resp` rows.

Summary

- Investigated response width vs:
  - node
  - `chipy`
  - `focal plane temperature`
- Preliminary results
  - Modest dependence on time?
  - Stronger dependence on focal plane temperature
- To be done:
  - examine intermediate times (say, every 5 years
  - examine other temperatures
  - look at finer `chipx` gridding for `p2_resp` (with finer gridding in the matching `det_gain`)
  - construct modified `p2_resp` (and `det_gain`?)