NUSTAR CZT GAIN MONITORING

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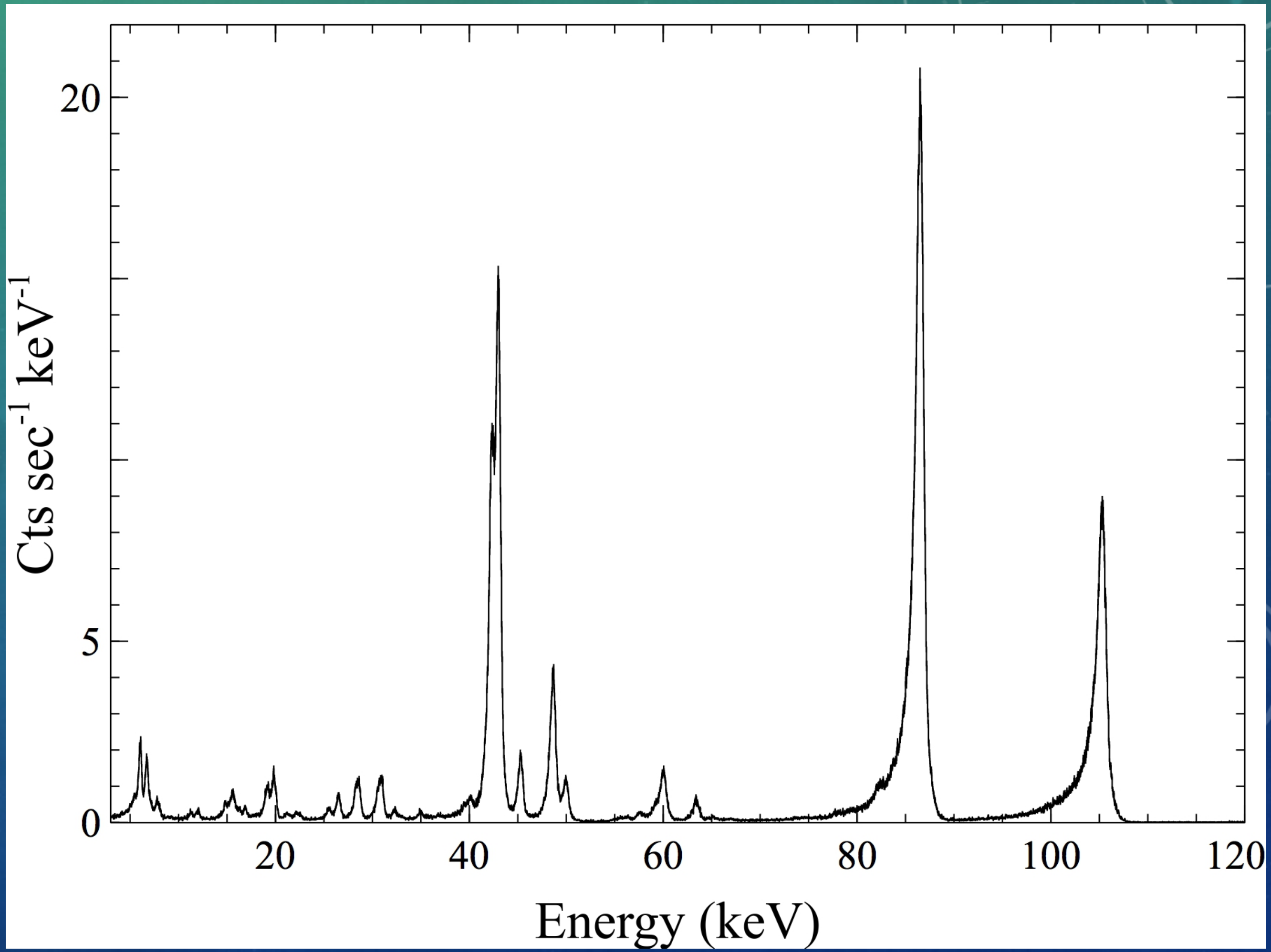
LONG-TERM GAIN MONITORING

- Basic transfer function: $PI = PI_0 * SLOPE(Temp, time) + OFFSET(Temp)$
- Initial SLOPE and OFFSET values determined during ground calibration.
  - ^{241}Am, ^{155}Eu, ^{57}Co for gain.
  - Controlled temperature slews for Temp dependence.
    - But detectors controlled on-orbit to ~0.1 degC
  - Ground calibration confirmed in 2012 with on-board ^{155}Eu source.

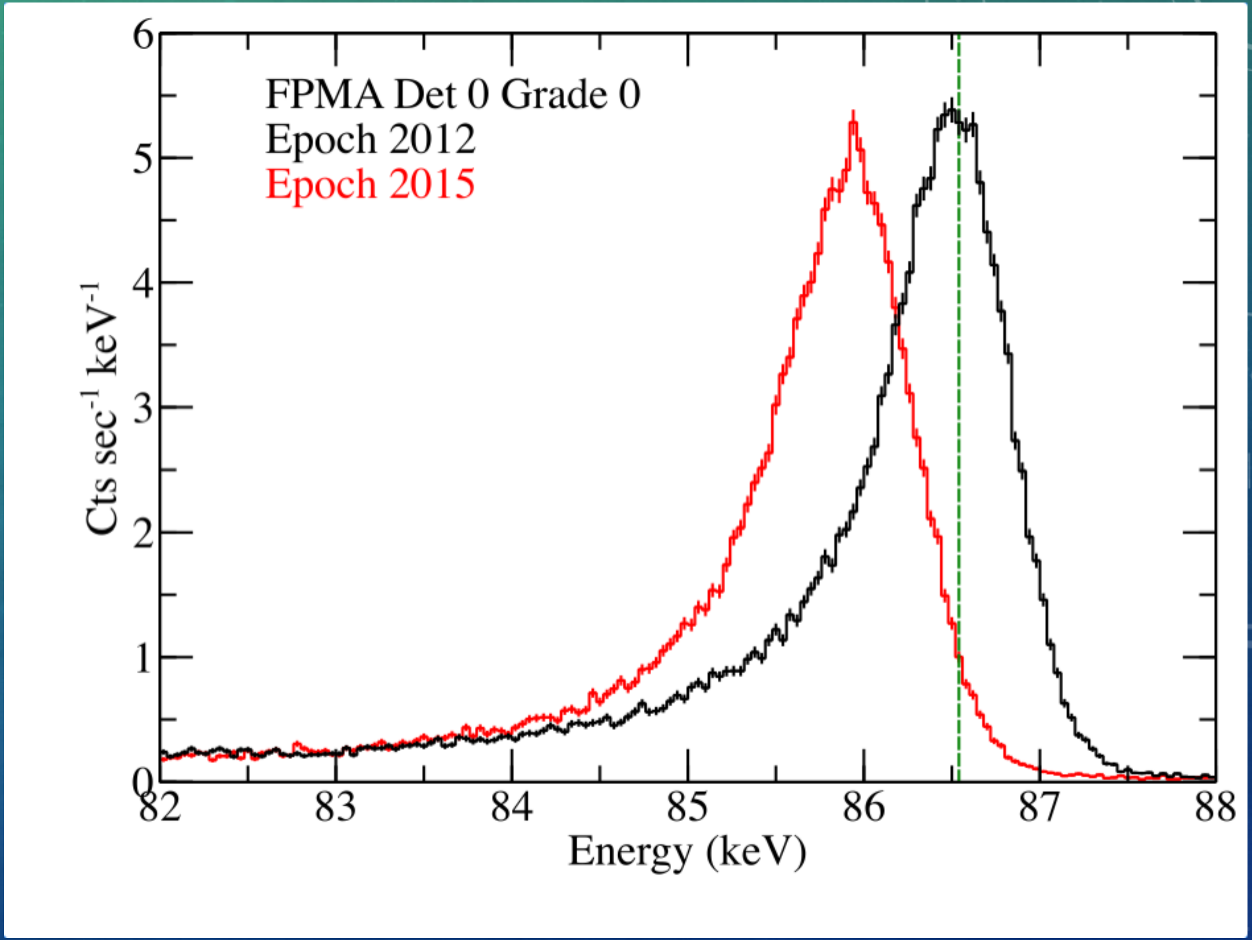
IN-FLIGHT CALIBRATION

- ^{155}Eu source on a deployable arm.
- Provides sharp lines at 86 and 105 keV, forest of blended X-ray lines at lower energies.
- Deployed in 2012 (IOC) and 2015.



IN-FLIGHT CALIBRATION

- Source deployed once in 2012 (post-launch) and once in 2015.
- Current CALDB incorporates a linear 0.2% / year gain drop between 2012 and 2015.
- Can we monitor calibration lines without deployment?



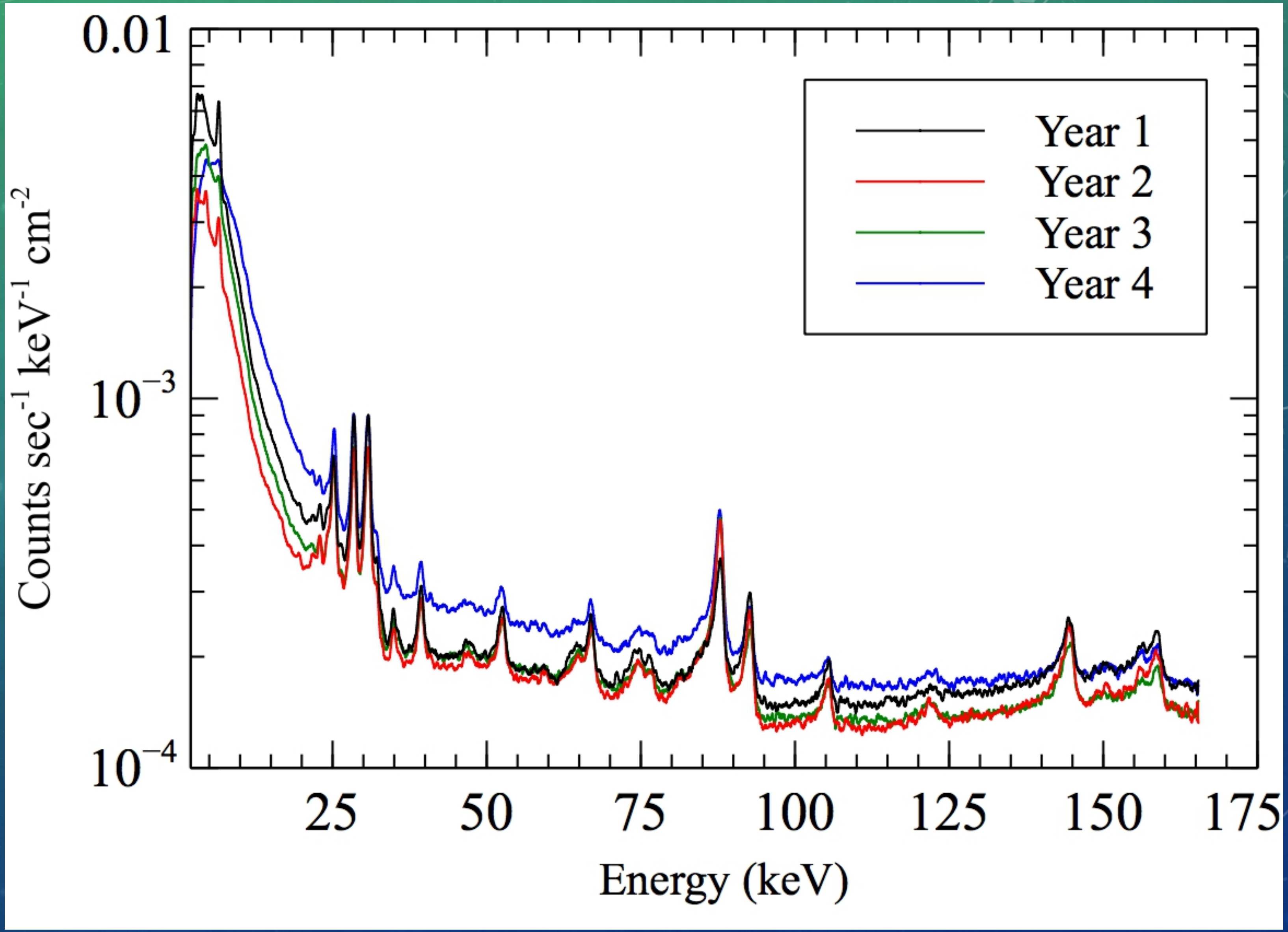
LONG-TERM GAIN MONITORING

- Basic transfer function: $PI = PI_0 * SLOPE(Temp, time) + OFFSET(Temp)$
- Goal: Determine any time-dependence in the SLOPE and OFFSET parameters.
- Because of the large dynamic range (2-200 keV) need two methods to determine any time-dependent variations in the SLOPE and OFFSET parameters.
  - Method 1: Use background lines at 105, 121, and 144 keV to monitor the SLOPE variations with time.
  - Method 2: Use routine observations of Kepler to monitor any OFFSET variations with time.

BROADBAND BACKGROUND

Year-over-year background spectrum have viable lines.

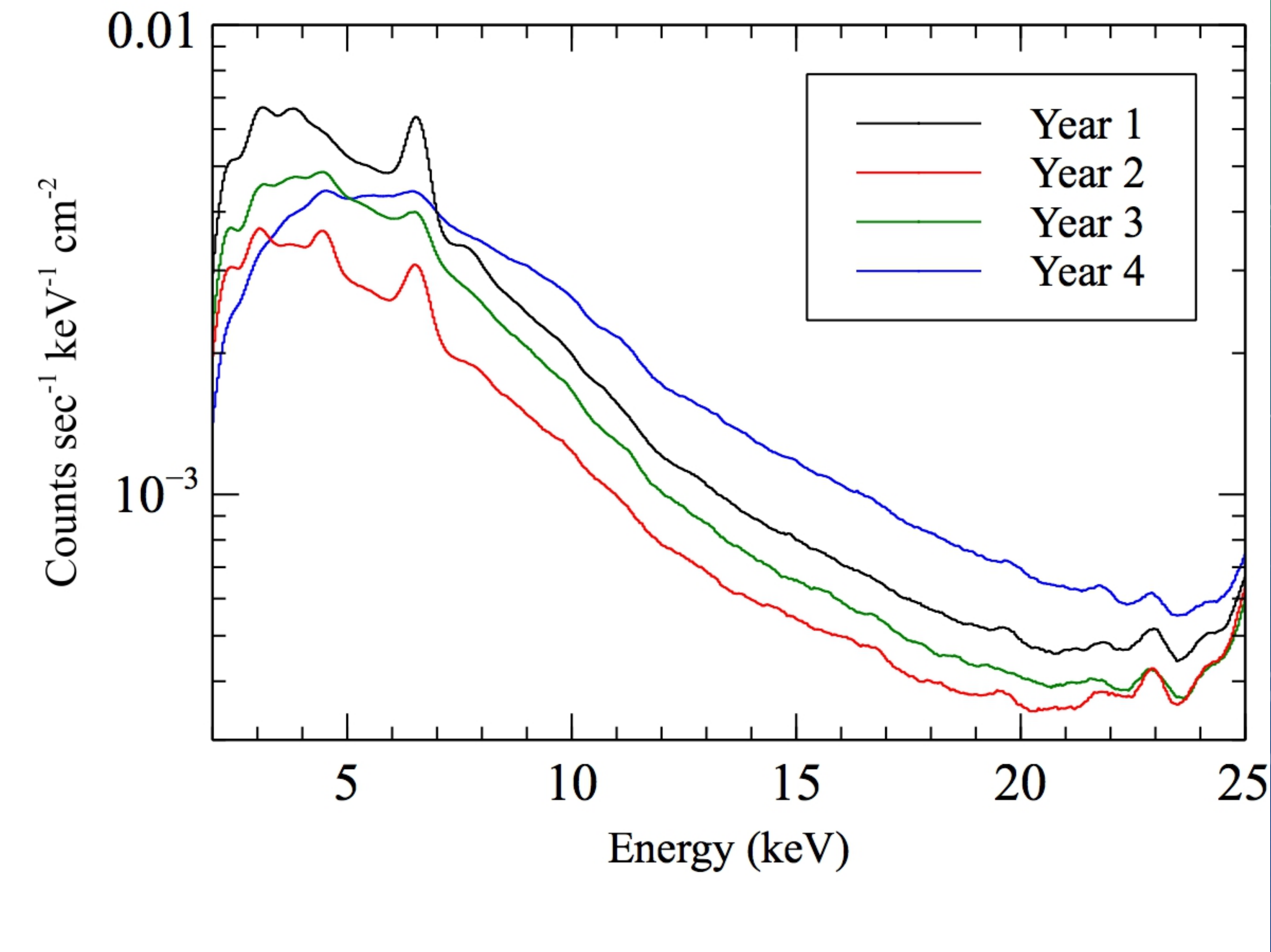
Low-energy lines (<20 keV) dominated by CXB and solar background.



SOLAR ACTIVITY

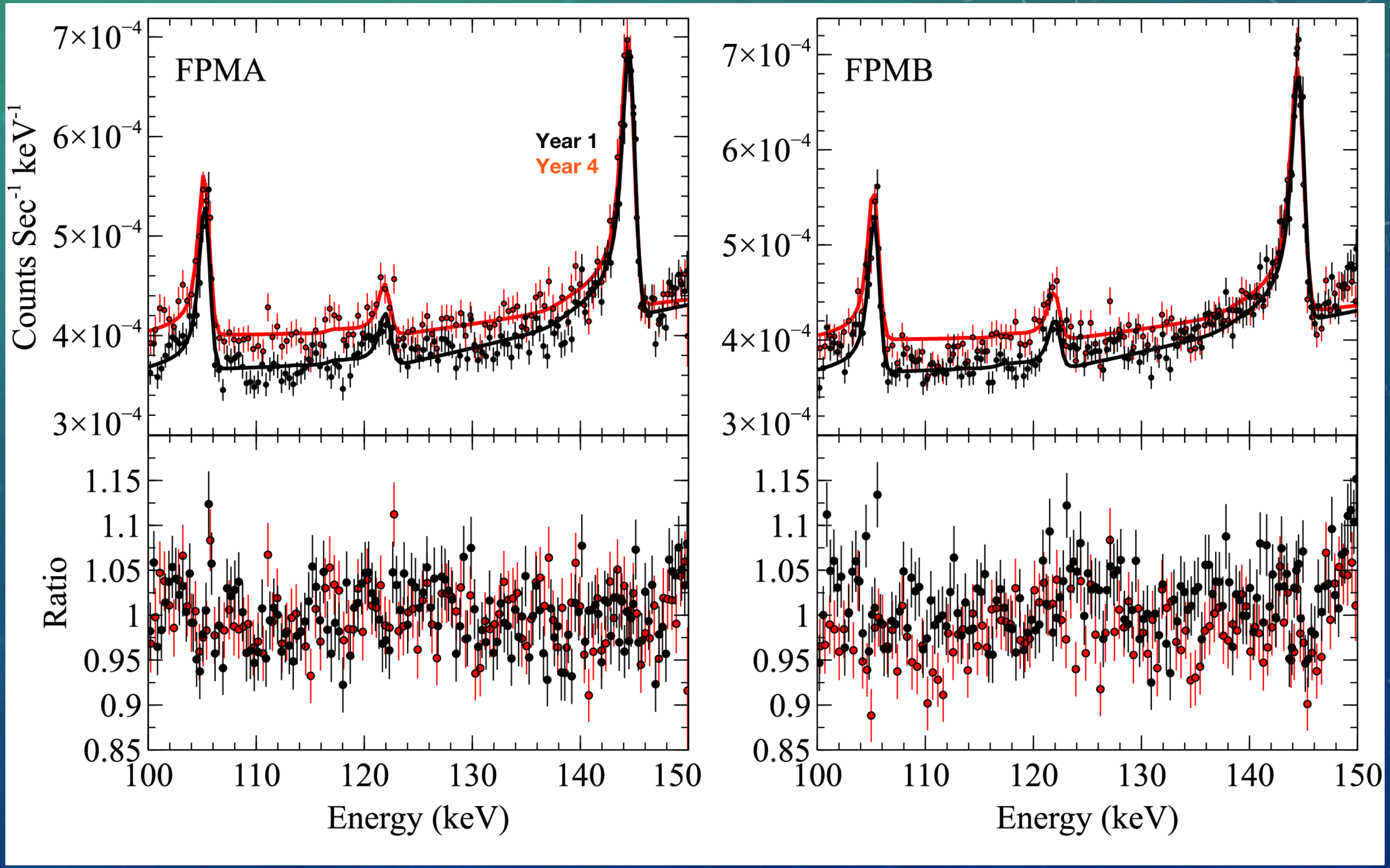
Changes in line emission (should?) track the solar cycle.

>15 keV emission tracks the particle continuum.



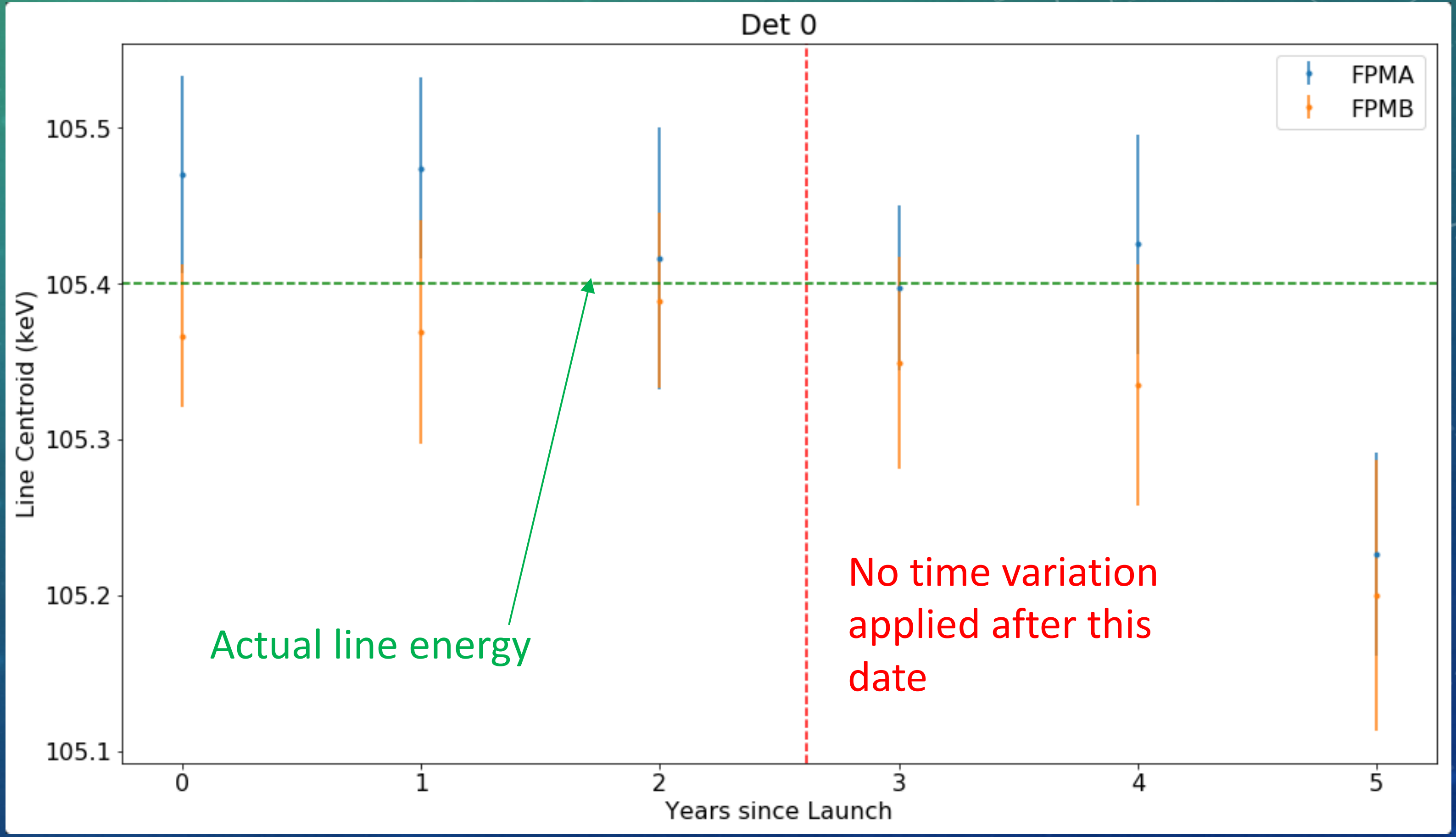
LONG-TERM GAIN MONITORING: BACKGROUND LINES

- Use year-long integrations of background lines at 105, 122, and 144 keV.
- 105 keV line is a calibration source “leaking” into the FoV.
- 122 and 144 lines are internal activation lines in CZT.
- Also have to model variations in the internal continuum (down-scattered gamma-rays and particles).



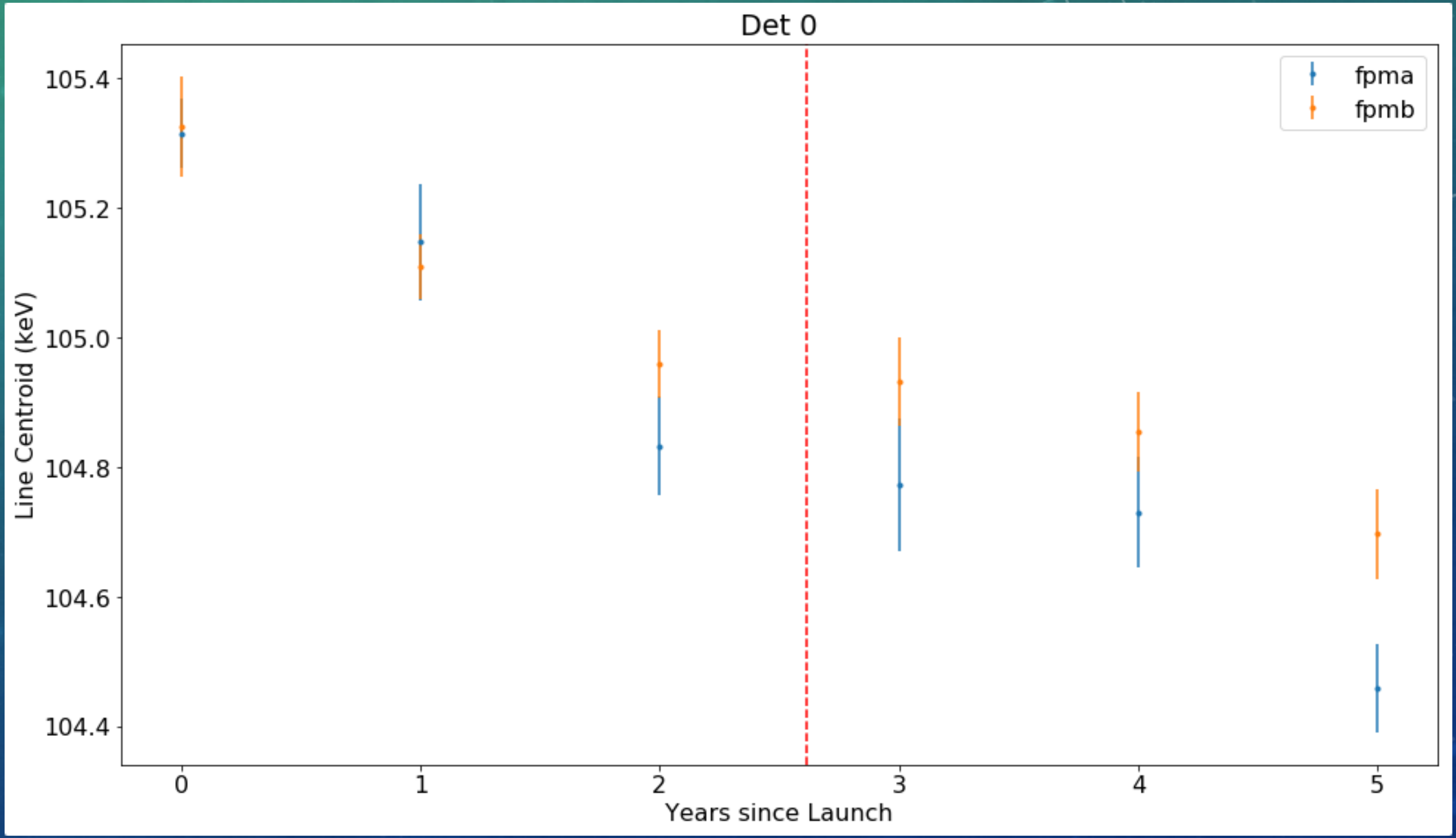
LONG-TERM GAIN MONITORING: BACKGROUND LINES

- Based on 2012-2015 data, saw a "linear" 0.2% per year drop. Accounted for in current CALDB.
- Current CALDB does not apply any additional gain drift after 2015.
- But, lines appear to have plateau'd since then.
- Investigating actual shape of gain change.



LONG-TERM GAIN MONITORING: BACKGROUND LINES

- Turn off time-dependence and reprocess the entire archive.
- See the 0.2% / year drop in the first three years (2012 – 2015).
- Plateau and (maybe) additional drop in Year 5.
- Unclear what's going on here…Swift?



LONG-TERM GAIN MONITORING: OFFSETS

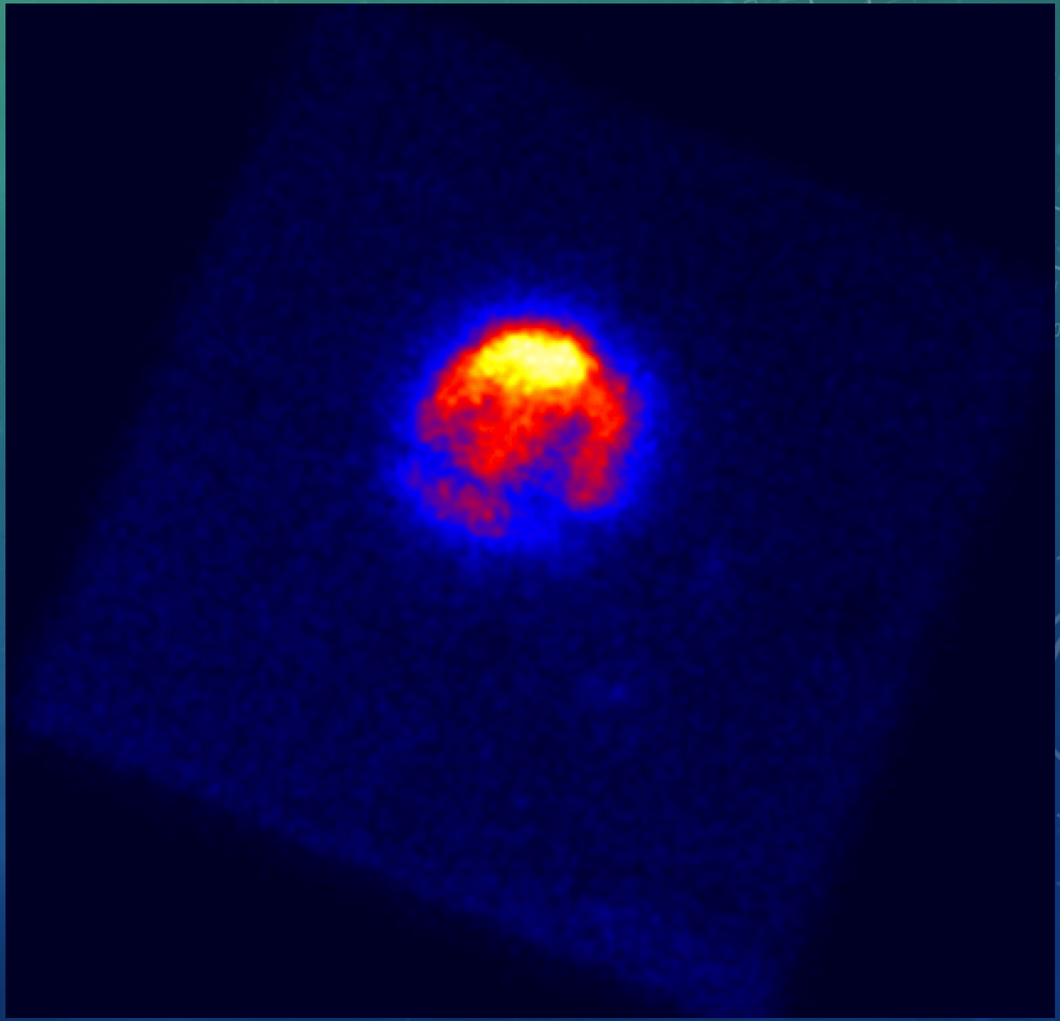
- OFFSETs baseline on 2012 cal source deployment and edges from absorption features.

- Assume OFFSET has no time dependence (based on low-energy edges in the response).

- Try to use an astrophysical source to track OFFSETs.
  - The trick: No great source around with >2 keV lines.
  - Cas A extended and dynamically broadened.
  - Most Fe-K sources (AGN, LMXBs, etc) time-variable.

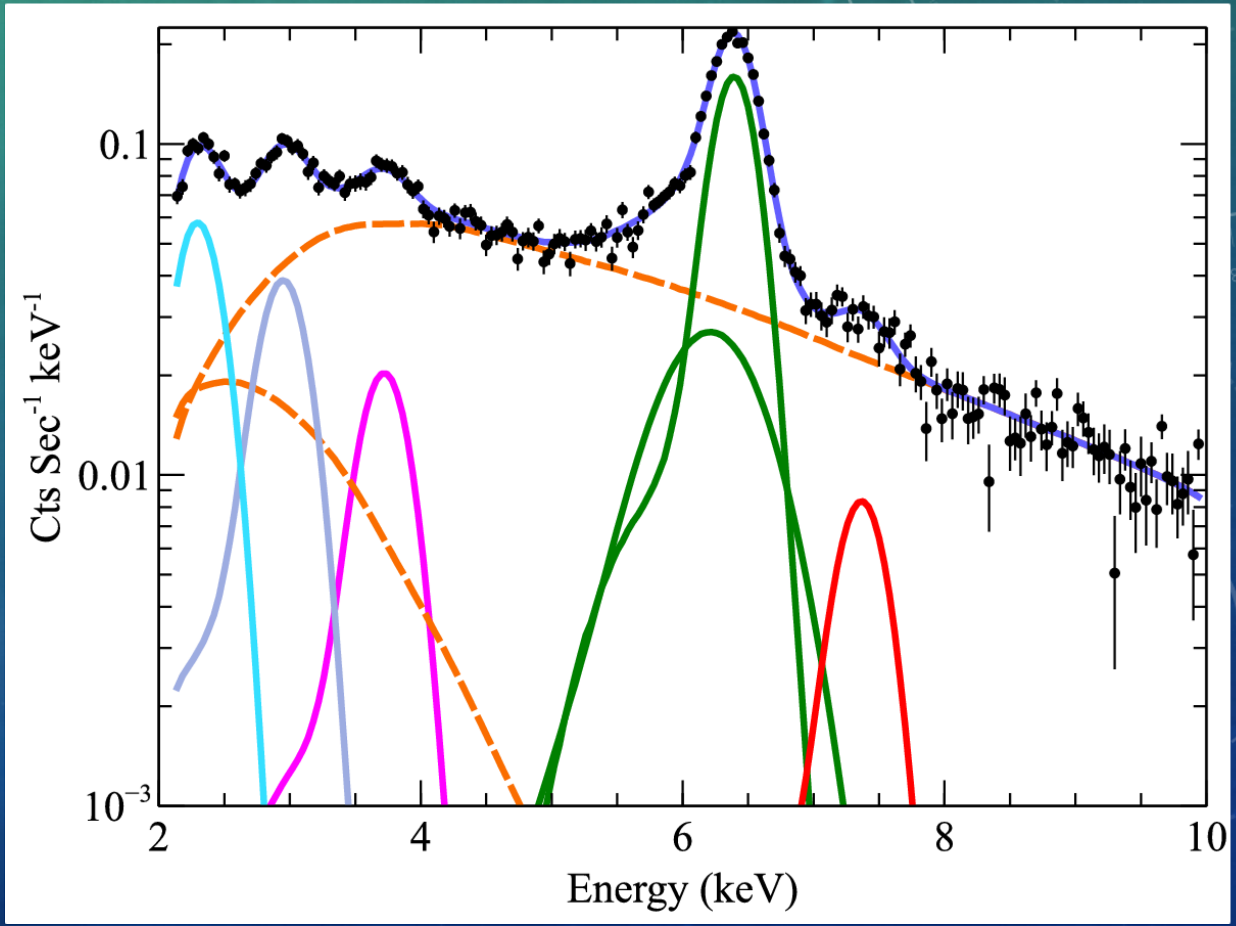
LONG-TERM GAIN MONITORING: OFFSETS

- Use Kepler.
- Relatively small for NuSTAR (uniform instrument response).
- N/S asymmetry in line energies, but integrated spectrum is narrow.



LONG-TERM GAIN MONITORING: OFFSETS

- Use baseline model (continuum + lines).
- Use XSPEC "gain" fit formalism with SLOPE==1.
- Measured change in OFFSET between 2014 and 2017 are:
    - 12+/-10 (2017/April)
    - -25 +/- (2017/Oct)
- So no measured change for now.
    - Recall: 1 NuSTAR channel == 40 eV.
- Will continue monitoring at 6-month intervals.



CONCLUSIONS

- Current CALDB reproduces high-energy background line energies to 0.1% over all dates
  - Except maybe current year.
  - Will continue to monitor background over time to see if there is need for an additional term in the CALDB.
  - Exploring detector-to-detector variations and origin of long-term variation fro first-principles.

- OFFSET still appears to have no time dependence.
  - Will continue monitoring over time as part of standard calibration budget.