Low energy response calibration and long term gain monitoring of the NuSTAR detectors

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Low energy response calibration

- Bright source low energy discrepancies between FPMA & FPMB, between other observatory
- Expand the lower energy limits

Crab Stray-light (IACHEC 2016 Pune)

OLD values:
CZT = 0.187
Pt = 0.138
i.e. not ARF related
Low energy response calibration

- Threshold refinement

**FPMA**

**FPMB**

Grefenstette, SPIE 2018
Low energy response calibration

- How the threshold adjustment affect to the RMF
  → multi-pixel events

Grefenstette, SPIE 2018
Low energy response calibration

- New RMF
  - Geant4 + charge transport (WP)

![Diagram showing NuSTAR Response (RMF) using Shield and Depth Cut with Aperture flux, Hit Shield, and Hit Detector labeled.]
Low energy response calibration

- Validation
  - nuabs parameter has been adjusted
Low energy response calibration

- **Validation**
  - nuabs parameter has been adjusted

![Graph showing number of pixels vs. 2.5-4 keV average diff from mean.](image)

![Graph showing ratio vs. Energy (keV), indicating a linear relationship.](image)
Long-Term Gain monitoring

- **Transfer function**
  - $PI = PI_0 \times \text{Slope}(\text{Temp}, \text{time}) + \text{Offset}(\text{Temp})$

In-flight calibration source $^{155}\text{Eu}$
- Deploy on 2012 (IOC)
  - confirmed ground calibration
- Deployed on 2015
  - gain dropped
  - CALDB incorporates linear 0.2%/year gain drop
Long-Term Gain monitoring

- Background lines
  - Use year-long integrations of background lines at 105, 122 and 144 keV
Long-Term Gain monitoring

- Background lines
  - Linear 0.2% per year gain drop

Start to deviate from 0.2% per year linear correction
Long-Term Gain monitoring

- Background lines
  - Turn off time-dependence and reprocess the archive.

* Indicating a non-linear function
Long-Term Gain monitoring

- Offset
  - Most Fe-K sources time variable
  - Cas A extended and dynamically broadened

→ Use Kepler
Long-Term Gain monitoring

- Offset - Kepler
  
  Use baseline model (continuum + lines)
  
  Use XSPEC “gain” fit formalism with SLOPE=1

Results: Offset between 2014

2017/04: $12 \pm 10$ eV
2017/10: $-25 \pm 11$ eV
2018/06: $6 \pm 10$ eV
2019/03: $-26 \pm 7$ eV

* No offset shift measured
Summary

- Low energy discrepancy is still under investigation
  - New RMF is generated based on threshold measurements. It is now under validation.
  - Need more study

- Long term gain monitoring
  
  \[ PI = P_{I0} \times \text{Slope}(\text{Temp}, \text{time}) + \text{Offset}(\text{Temp}) \]

  - Slope (gain) indicate a deviation from the current 0.2% per year linear correction. → Require CALDB update
  - Offset still show no time dependence

→ We will Continue monitor