CTI evolution and its impact on spectral resolution in different orbital environments

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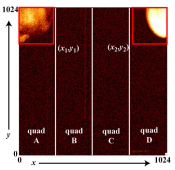
Abstract

Suzaku and the Chandra X-ray Observatory both use CCD cameras for imaging spectroscopy of the X-ray sky. The CCDs themselves are similar in design, being fabricated at MIT's Lincoln Laboratory, but are operated under different conditions and in different orbital environments. We discuss the evolution of charge transfer inefficiency (CTI), a measure of radiation damage, and its impact on spectral resolution with particular emphasis on the effect of operational differences, such as focal plane temperature, and particle environments in low- and high-Earth orbit. We also discuss the efficacy of the charge injection capability of the Suzaku XIS detector in reducing both the absolute CTI and the rate of CTI increase.

Instruments and Data

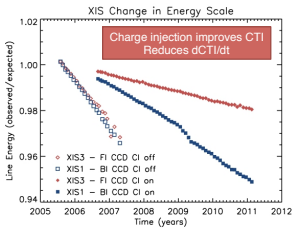
- Front- (FI) and back-illuminated (BI) CCDs
- Similar format, architecture, pixel size
- Different orbits, background levels, operating temperatures
- Advanced CCD Imaging Spectrometer (ACIS)
  - Elliptical 64-hour orbit transits radiation belts
  - Operating temperature -120C
- X-ray Imaging Spectrometer (XIS)
  - Low-Earth orbit, lower particle background
  - Operating temperature -90C
  - Capable of charge injection
- Calibration sources
  - Radioactive Fe-55
  - strongest line is Mn-Kα (5.9 keV)
  - ACIS observed twice each orbit; uniform illumination
  - XIS always viewing; illuminates upper corners
- Data Analysis
  - Unprocessed eventlists; no CTI or gain correction; G02346
  - XIS source illumination doesn't allow for true CTI measurement; comparing line centroid and width in upper corners

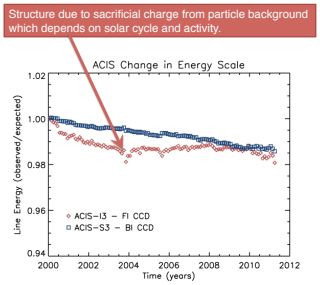
XIS2 Fe-55 illumination



Evolution of Energy Scale

- Radiation damage modified by sacrificial charge

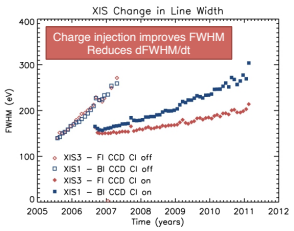


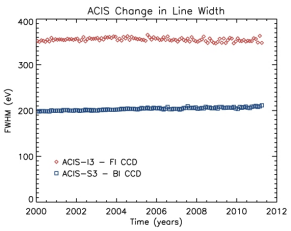


Increasing CTI leads to decreasing energy scale. Structure in ACIS FI CCD due to sacrificial charge (seen also in measured CTI). ACIS BI CCD and XIS are less sensitive to sacrificial charge. XIS particle background stable on month timescales.

Evolution of Line Width

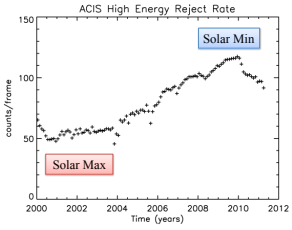
- Complicated interplay between increasing CTI, trailing charge and event/split thresholds



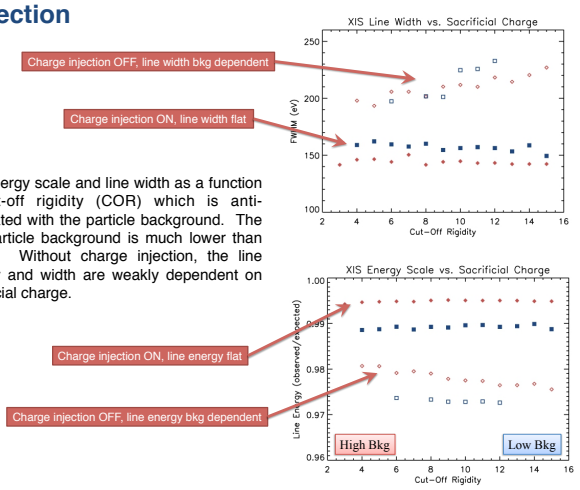


The evolution of spectral resolution for ACIS and XIS is quite different. Line width increase is much larger on XIS then ACIS, even when scaled to the corresponding line energy change.

Sacrificial Charge and Charge Injection



Particle background at the ACIS detector is highly variable. Well correlated with cosmic-ray protons measured by ACE SIS (E > 10 MeV). Anti-correlated with the solar cycle. Similar structures are seen in the energy scale due to sacrificial charge.



XIS energy scale and line width as a function of cut-off rigidity (COR) which is anti-correlated with the particle background. The XIS particle background is much lower than ACIS. Without charge injection, the line energy and width are weakly dependent on sacrificial charge.

Summary

- Evolution of the energy scale and spectral resolution for ACIS and XIS CCDs are quite different
- XIS rate of CTI increase much larger than ACIS
  - 5x for FI CCD, 9x for BI CCD (with CI on)
- ACIS FI CTI much more sensitive to particle background sacrificial charge than ACIS BI (or XIS)
- Line width increase is much larger on XIS than for ACIS, even when scaled to the corresponding CTI change
- XIS charge injection removes any dependence on external sacrificial charge

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