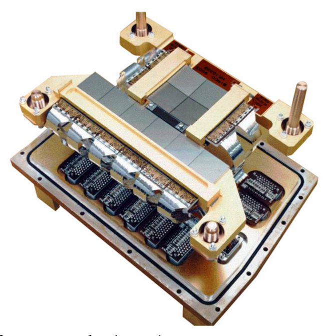
The ACIS Instrument on the Chandra X-ray Observatory: Instrument Status and Performance Evolution

Catherine Grant (MIT Kavli Institute) **and the ACIS instrument team**

Abstract

The Advanced CCD Imaging Spectrometer (ACIS) is one of two focal-plane instruments on the Chandra X-ray Observatory. After more than twelve years in orbit, ACIS continues to perform well. The response of ACIS has evolved over the lifetime of the observatory due to increasing radiation damage, molecular contamination and aging in general. Here we present highlights from the instrument team's monitoring program and our expectations for the future.

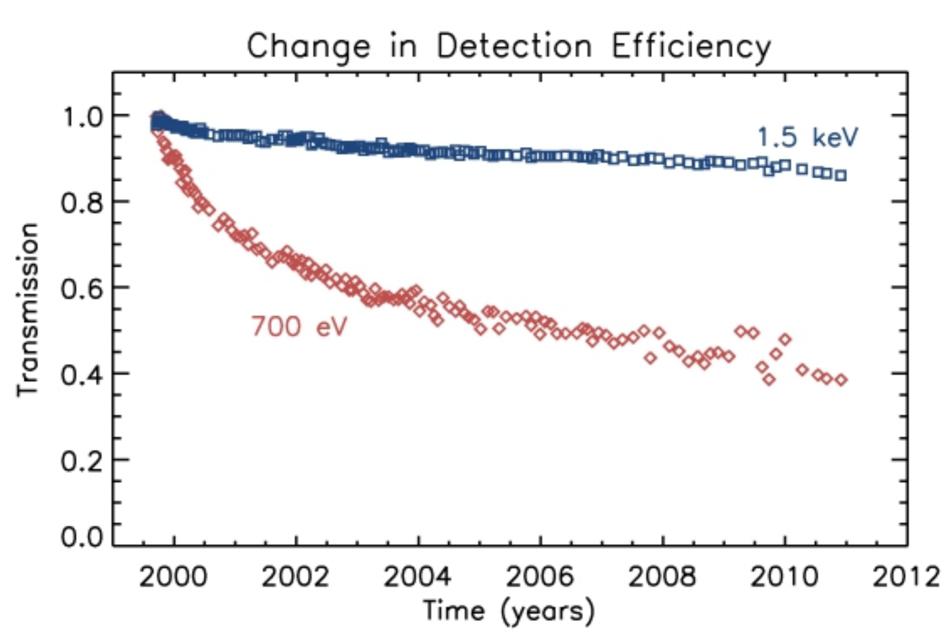
Instrument and Data



- Advanced CCD Imaging Spectrometer (ACIS)
  - 10 CCDs; 8 front-illuminated (FI), 2 back-illuminated (BI)
  - Simultaneous high-resolution imaging and moderate-resolution spectroscopy
  - Used alone or as a readout for the transmission grating
  - Highly-elliptical 64-hour orbit transits radiation belts at perigee
- ACIS External Calibration Source (ECS)
  - Radioactive Fe-55 with Al and Ti fluorescence targets
  - Strongest line is Mn-Kα (5.9 keV)
  - Observed twice each orbit; before and after radiation belt passages
  - Eventlists not processed with the standard pipeline which provides some mitigation

Molecular Contamination

- Hydrocarbon contaminant is accumulating on the ACIS filter
- Strong absorption at low energies, less important above 1 keV



Drop in low-energy detection efficiency due to increasing absorption from the contaminant measured at 700 eV and 1.5 keV. The contaminant continues to accumulate at a slow rate.

Summary

- Slow changes in performance consistent with expectations for increasing radiation damage and contamination deposition
- Performance changes do not substantially degrade instrument capabilities
- Quiescent (i.e. non-flaring) particle background should continue to drop as we approach solar maximum
- ACIS hardware and software continue to perform nominally
- No known limitations on ACIS lifetime

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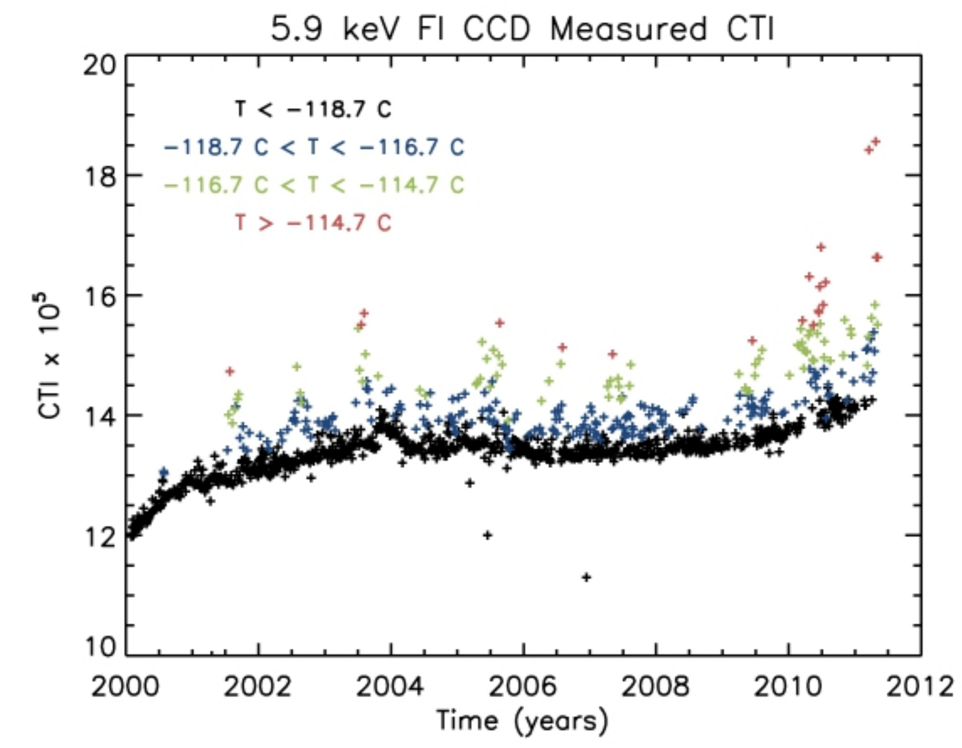
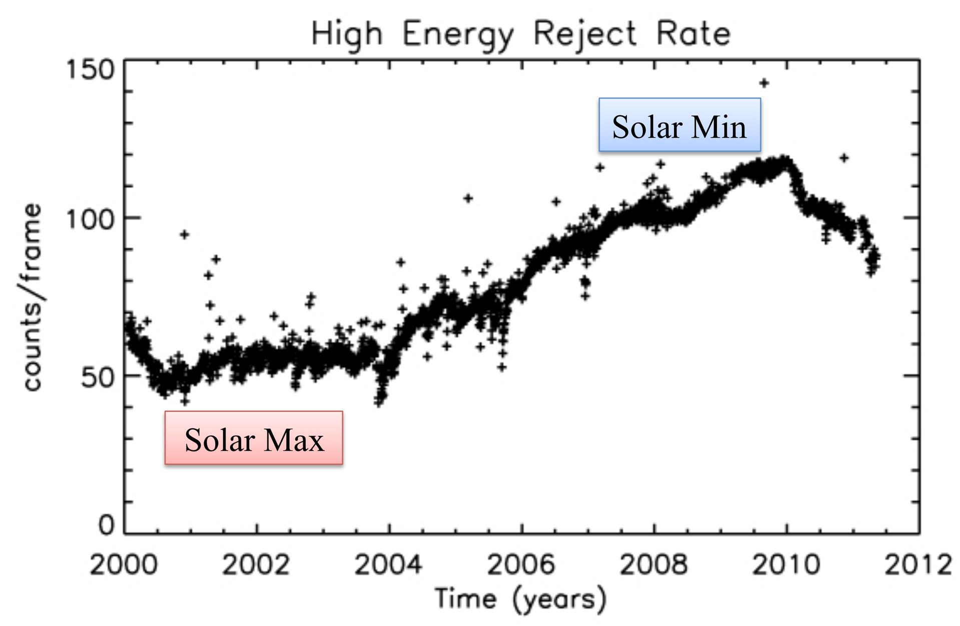
Charge Transfer Inefficiency

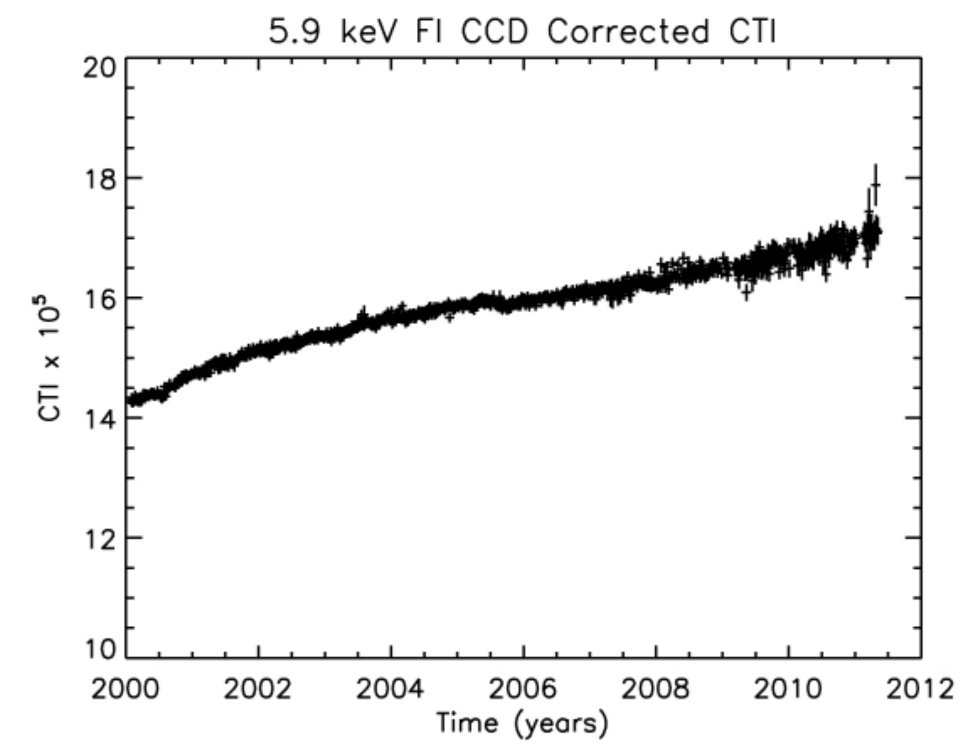
- Charge transfer inefficiency (CTI)
  - Caused by manufacturing defects and radiation damage
  - Degrades spectral resolution and detection efficiency
  - Sensitive to temperature and sacrificial charge from the particle background
  - FI and BI CCDs behave differently
  - BI CCDs are much less sensitive to temperature and sacrificial charge
- Pre-launch: CTI (FI) < 10^{-6}, CTI (BI) ~ 10^{-5}
- After initial radiation belt passages (Aug-Sep 1999): CTI (FI) ~ 10^{-4}, CTI (BI) ~ 10^{-5}
- After correcting for sacrificial charge and temperature:
  - dCTI/dt ~ 2×10^{-6} / yr (FI CCDs)
  - dCTI/dt ~ 1×10^{-6} / yr (BI CCDs)



Evolution of measured CTI for the FI CCDs. Each point is a single ECS observation. The colors indicate times of warmer focal plane temperature which increases CTI. The remaining structure is a combination of real radiation damage and changing particle background.



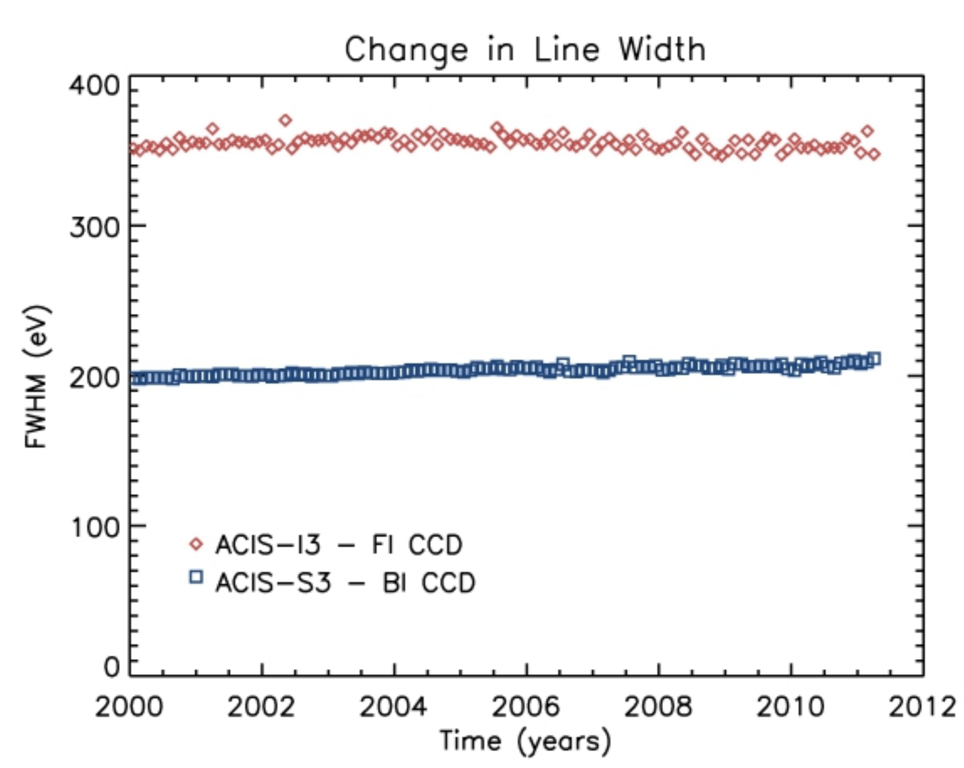
Particle background at the ACIS detector. Well correlated with cosmic-ray protons measured by ACE SIS (E > 10 MeV). Anti-correlated with the solar cycle. Note that many of the structures seen here are also seen in reverse in the measured CTI.



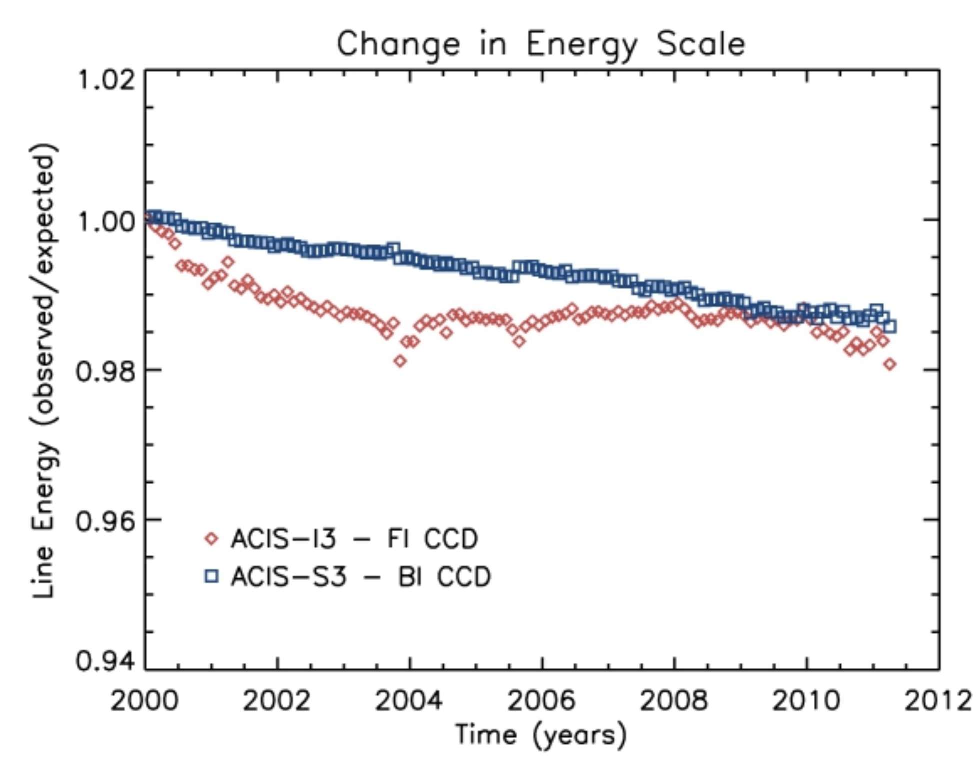
Evolution of CTI for the FI CCDs after correcting for temperature and sacrificial charge.

Energy Scale and Line Width

- Measured far from the readout where effects of CTI are maximized and performance is most degraded
- Slow decay in energy scale with time
  - Directly related to increasing CTI
  - Structure in FI CCD due to sacrificial charge (seen also in measured CTI)
  - BI CCDs less sensitive to sacrificial charge and radiation damage
- Line width nearly constant
  - Complicated interplay between increasing CTI and trailing charge and event thresholds



The line width for both FI and BI CCDs is nearly flat. Standard processing includes a CTI correction which improves the line width to ~230 eV (FI) and ~170 eV (BI).



Increasing CTI leads to decreasing energy scale. Structure in FI CCD due to sacrificial charge (seen also in measured CTI). BI CCD is less sensitive to sacrificial charge. Energy scale changes are corrected in standard processing.