The Effects of Orbital Environment on X-ray CCD Performance
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Summary
• Comparison of performance evolution of Chandra ACIS and Suzaku XIS
  – Similar CCDs, different orbits and radiation environments
• The evolution of line energy and spectral resolution for ACIS and XIS
  CCDs is very different
• XIS charge injection provides substantial performance improvement and
  reduces rate of performance degradation from radiation damage

• After compensating for differences in temperature and sacrificial
  charge from the particle background and charge injection:
  – Rate of charge transfer inefficiency increase (line energy decrease)
    due to radiation damage is ~4 times larger for XIS than ACIS
• Suzaku is in low-Earth orbit: lower, stable particle background, but
  higher accumulated radiation damage
• Chandra is in high-Earth orbit: higher, more variable particle
  background, but lower accumulated radiation damage

Instruments and Data
• Both front- (FI) and back-illuminated (BI) CCDs
• Similar format, architecture, pixel size
• Different orbits, operating temperatures
• Chandra’s Advanced CCD Imaging Spectrometer (ACIS)
  – Elliptical 64-hour orbit, transits radiation belts
  – Operating temperature ~120°C
• Suzaku’s X-ray Imaging Spectrometer (XIS)
  – Low-Earth orbit, transits South Atlantic Anomaly
  – Operating temperature ~90°C
  – Capable of charge injection
• Calibration source
  – Radioactive Fe-55; Strongest line is Mn-Kα (5.9 keV)

• Data analysis
  – Unprocessed event lists; no gain or CTI corrections
  – Results do not reflect what typical user would find
    with standard data products
  – Line centroid and width in the upper corners used as a
    proxy for Charge Transfer Inefficiency (CTI)

Evolution of Energy Scale
• Measured energy scale evolution is due to radiation damage modified
  by sacrificial charge

Evolution of Line Width
• Complicated interplay between increasing CTI, trailing charge and event/split thresholds

Particle Environment in Low- and High-Earth Orbit
• Both Chandra and Suzaku stop observing during
  transits of the radiation belts and the South Atlantic Anomaly. The trapped protons do not contribute to
  the observed particle background.
• During observations, the background is primarily due
  to Galactic cosmic rays (GCR), which are partially
  shielded by the Earth’s magnetic field. Suzaku in
  low-Earth orbit benefits from more shielding than
  Chandra.
• The trapped proton spectrum in the South Atlantic
  Anomaly transited by Suzaku is much harder than the
  outer radiation belts transited by Chandra.
• While the integral flux of trapped protons seen by
  Chandra is higher, they have low energies which
  cannot reach the stowed ACIS CCDs. The harder
  protons seen by Suzaku can pass through the
  spacecraft and damage the CCDs.

Sacrificial Charge and Particle Background
Particle background on the ACIS detector (black crosses) is highly variable and is well
correlated with cosmic-ray protons (E $>$ 10 MeV) and anti-correlated with the solar cycle.
Similar structures are seen in the line energy
due to sacrificial charge (red diamonds).

Observed particle background spectra for ACIS
and XIS. The XIS particle background is much
lower than ACIS. These data have been filtered
by event grade (G92546) which is less effective
at background reduction for BI CCDs than the
FI CCDs.

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