Using ACIS on the Chandra X-ray Observatory as a particle radiation monitor

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Chandra Radiation Protection
- Highly elliptical orbit, transits wide range of particle environments
- Radiation belts, Magnetosphere/pause, Solar wind
- CCDs highly sensitive to radiation damage, particularly soft protons in radiation belts and from solar storms
- Radiation protection plan developed early in mission
- Protection procedure = ACIS translated out of the focal plane to protect against soft protons, powered off
- Three-pronged plan:
  - Planned protection during radiation belt transits
  - Weekly command level sets ACIS to environment to estimate region type
  - Autonomous protection triggered by on-board radiation monitor (EPHIN)
- On-board (remote) (RBC) monitors EPHIN channels, commands a shutdown when mean reach a trigger level
- Manual intervention upon assessment of damaging space-weather conditions

Testing the ACIS Algorithm
- Applied ACIS radiation monitor algorithm to entire thirteen-year history of threshold crossing rates
  - Heterogeneous data set
  - X-ray source types
  - Representative of future heterogeneity
- Are the ACIS triggers real radiation events? Yes!
  - Sunspot activity, all high radiation environments
  - Twelve while ACIS in the focal plane
  - Two didn’t quite reach EPHIN trigger levels
- How effective is ACIS radiation protection?
  - Pre-2009 comparisons for consistent EPHIN usage
  - Ten ACS triggers corresponding to radiation shutdowns
  - Twelve on-board radiation shutdowns while ACIS was taking data with no EPHIN trigger
  - ACIS-radiation monitor thresholds about half of the on-board shutdowns
  - Lower limit on effectiveness in the absence of EPHIN, since ACIS data are truncated by EPHIN shutdown

Summary
- ACIS can act as its own radiation monitor which provides some protection against solar storms
- Limitations on coverage and effectiveness:
  - ACIS must be taking event data (not during biases or HRC observations)
  - ACIS must be in the focal plane (not during out-of-focus plane calibration observations)
  - Most effective for radiation events with sharp initial rise, less effective for complicated time profiles ( ineffective if rates are high but declining)
- Radiation monitor software patch active on-board Chandra, awaiting first ACIS-based radiation shutdown
- Trigger levels will be re-evaluated a few times a year to better match the changing quiescent background due to the solar cycle

EPHIN - Chandra’s particle detector
- Monitors local radiation environment, provides autonomous radiation protection
- As Chandra ages, thermal control of EPHIN is difficult
- Elevated EPHIN temperatures produce anomalous noise, can dominate particle signal
- EPHIN performance for autonomous radiation protection is a concern

ACIS rates versus EPHIN

History of ACIS Threshold Crossing Rates

ACIS Monitor Software Patch
- Developed flight software patch installed Nov 2011
  - Operating as expected, no anomalies
  - No impact on science data
  - No false triggers from bright X-ray sources
- Two real triggers from high radiation environment
- Patch parameters adjustable, updated in Apr 2012 to optimal values
- Chandra OBC patched on May 2012 to respond to ACIS radiation alerts

ACIS as its own radiation monitor
- First explored in Grant+ 2010, Proc. SPIE 7732
  - Yes, ACIS can be used to detect radiation events
- Developed flight software patch, examines ACIS data in real-time, sends alert to Chandra OBC when it detects high radiation levels
- ACIS flight software patch installed Nov 2011
  - Operating as expected, no anomalies
- EPHIN effectiveness for autonomous radiation protection is a concern
  - Threshold crossing rate includes contributions both from X-ray sources in the field and from the particle background.