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ACIS CTI Correction

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For instructions on how to apply the CTI correction to your data, see the Apply the ACIS CTI Correction thread.

New time−dependent CTI corrections for the back−illuminated ACIS chips (ACIS−S1 and S3) were released in CALDB 3.3.0 (18 December 2006). This is the first release where the serial and parallel CTI correction is available for the BI chips. Only calibration for the BI chips has changed in these files; calibration for the FI chips is identical to the v5 files. The How CIAO 3.4 and CALDB 3.3.0 Affect Your Analysis section of the CIAO release notes explains how the files will affect your analysis.

A new QEU file for −120 C observations was also released in CALDB 3.3.0. Refer to the ***Grade Migration and Detection Efficiency*** section of this document for more information.

Abstract

The tool acis_process_events now includes a charge transfer inefficiency (CTI) adjustment procedure that can be used to compensate for most of the effects of CTI. This adjustment can significantly improve the spectral resolution of the data.

Introduction

When X−rays (and cosmic rays) deposit charge in an ACIS CCD, the charge is read out using one of four sets of read−out electronics. Each read out is used for a specific 256 pixel x 1024 pixel subset (node) of the CCD. Since charge is read out at only one location on a node, the charge at all other locations must be moved to the read out. Charge is moved both vertically (i.e. in the negative CHIPY or "parallel" direction) and horizontally (i.e. in the positive or negative CHIPX or "serial" direction). The total number of pixels through which charge must be moved depends on the location at which charge is deposited on the CCD. As charge is moved, some may be lost to charge traps that are distributed across the detector. The mean fractional amount of charge lost per pixel transferred is called the charge transfer inefficiency (CTI). At launch, the values of CTI were $< 1 \times 10^{-6}$ and $< 3 \times 10^{-6}$ for parallel and serial motion, respectively, on a front−illuminated CCD and $= 1-3 \times 10^{-5}$ and $= 8-16 \times 10^{-5}$ for parallel and serial motion, respectively, on a back−illuminated CCD (at 5.9 keV and −120 C). Due to the accumulated effects of cosmic radiation damage, the number of charge traps (and, hence, the CTI) on the CCDs is increasing with time. As of September 1, 2002, the values of CTI are about $1-2 \times 10^{-4}$ and $< 4 \times 10^{-6}$ for parallel and serial motion, respectively, on a front−illuminated CCD and about $2-3 \times 10^{-5}$ and $6-14 \times 10^{-5}$ for parallel and serial motion, respectively, on a back−illuminated CCD (at 5.9 keV and −120 C).

As of CALDB v3.1.0 (23 June 2005), parallel CTI calibration products are available for the ACIS−I0, I1, I2, I3, S0, S2, S4, and S5 CCDs. Parallel and serial calibration for the back−illuminated chips (ACIS−S1, S3) were released in CALDB v3.3.0 (18 December 2006).

Gain Shift and Spectral Resolution

CTI affects the measured spectral distribution of astrophysical sources in two ways:

1. Since some of the charge is trapped, the amount of charge read out is less than the amount of charge deposited. This effect causes the measured pulse−height distribution for a source to be shifted to lower pulse heights (i.e. results in an apparent gain shift).
2. For a variety of reasons, CTI causes a degradation in the energy resolution of a CCD. The measured pulse−height distribution of a monoenergetic source (or a line feature) is broadened.

These effects are functions of the location where an X−ray interacts in a CCD because they depend on the number of traps through which charge is moved. Therefore, it is necessary to calibrate the gain and spectral response of several separate regions on each CCD.

An algorithm has been developed to estimate the amount of charge deposited on a CCD for an event from the amount of charge read out and the location of the event on the detector. This algorithm is implemented in the tool `acis_process_events`. Use of the CTI adjustment eliminates nearly all of the apparent gain shift and can significantly improve the energy resolution of a detector. (The energy resolution is not fully restored because charge trapping is a stochastic process and we do not know the different charge trapping histories of each event.)

Grade Migration and Detection Efficiency

Charge captured by a trap is typically released on a short time scale. A significant amount of the trapped charge is released into the pixel immediately following the pixel from which it was trapped. As a result, the distribution of charge in a 3 pixel x 3 pixel event island is "smeared out" in the read−out direction. The GRADE (and FLTGRADE) of an event is a numerical representation of the distribution of charge in the event island. If enough charge is added to a pixel to yield a pulse height that is greater than or equal to the split threshold (e.g. 13 adu), then the GRADE associated with the measured distribution of charge at the read out may be different than the GRADE associated with the distribution of charge produced at the location where the event interacted with the detector. This effect, called "grade migration," depends on the amount of charge deposited (i.e. the energy of an X−ray) and the location of the event on the CCD. Since events whose GRADEs are changed from a "good" value (0, 2, 3, 4, or 6) to a "bad" value (1, 5, or 7) are excluded from Level 2 event files, grade migration results in an apparent reduction in the detection efficiency of a CCD. The apparent reduction in the detection efficiency was calibrated for data obtained at −120 C. This information is contained in the QEU file.

When the CTI correction is applied to the BI ACIS chips, a number of low−energy events are recovered, because their grades had migrated to BAD grades as a result of loss of charge at the readout. This presents a change in the QE uniformity (QEU) with the CTI correction as compared with the QEU without CTI correction. (For the FI chips, this effect is negligible due to their much−reduced low−energy QE.) For the BI chips, however, it was necessary to create a new QEU file (version N0006) for −120 C observations.

References

- MIT ACIS Team, 22 March 2001 memo, ACIS CTI Correction (PDF, 52 pp)
- Plucinsky, P. P. 2001, The Low−Energy Spectral Response of the ACIS CCDs (PDF, 8pp)
- Townsley, L. K. et al. 2000, ApJ, 534, L139, PSU CTI Corrector code (HTML)

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