Compensating for the Effects of CTI Using CIAO Software

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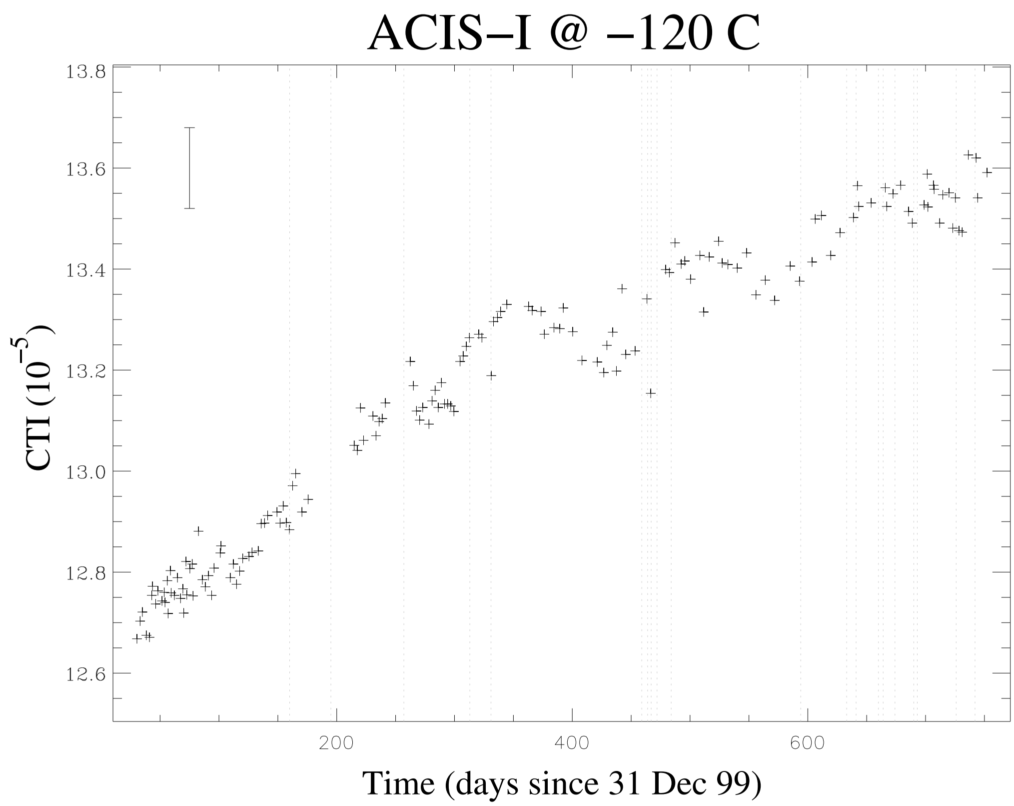
http://space.mit.edu/~gea/tmp/head_020420_cti_talk_1.0.ps

CTI

As a result of charged-particle radiation, the charge-transfer inefficiency (CTI, i.e. fractional charge loss per pixel) of the frontside-illuminated CCDs is becoming worse.

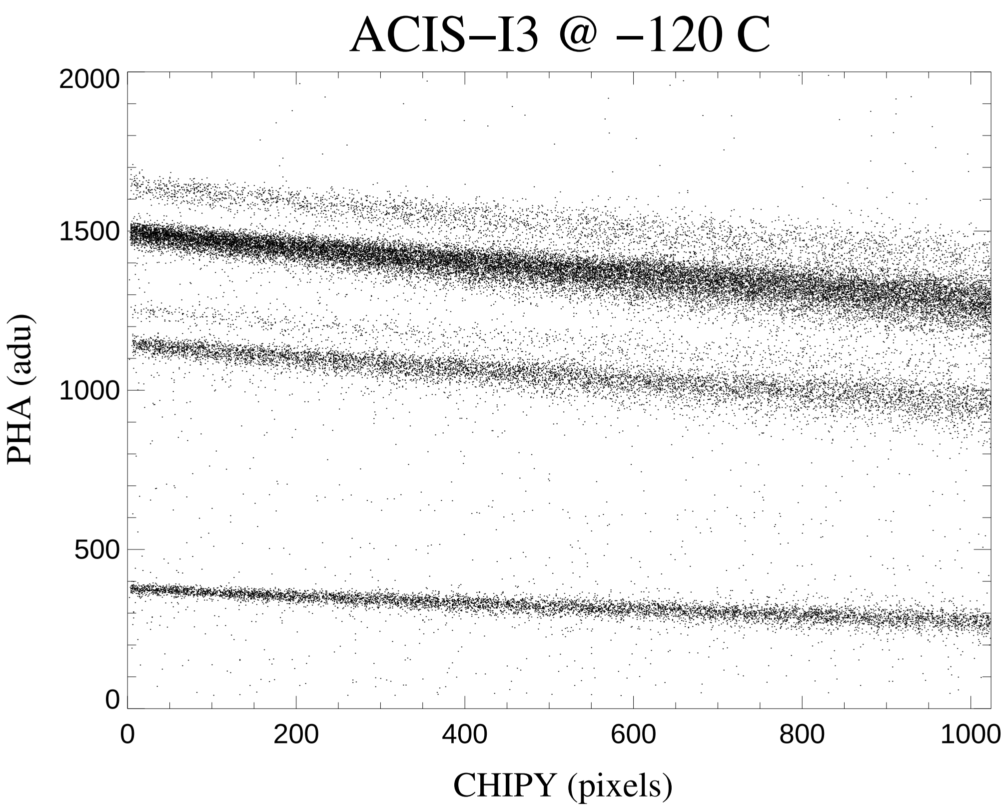
Courtesy Catherine Grant



Affects of CTI

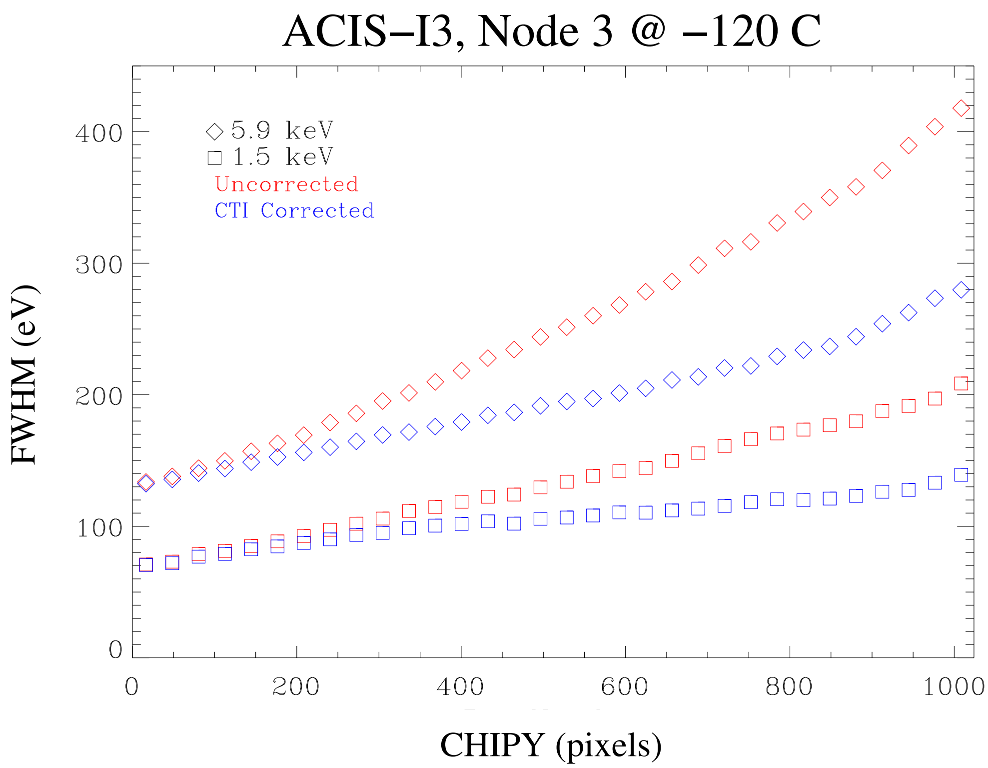
When the charge associated with an event is read out, some of the charge is trapped and released later. Therefore, the total amount of charge read out is less than the amount of charge deposited, which results in an apparent "gain shift" and a degraded energy resolution. The distribution of charge in a 3 pixel $\times$ 3 pixel event island is "smeared out" in the read-out direction. This affect can cause GRADE "migration."

1 Apparent Gain Shift

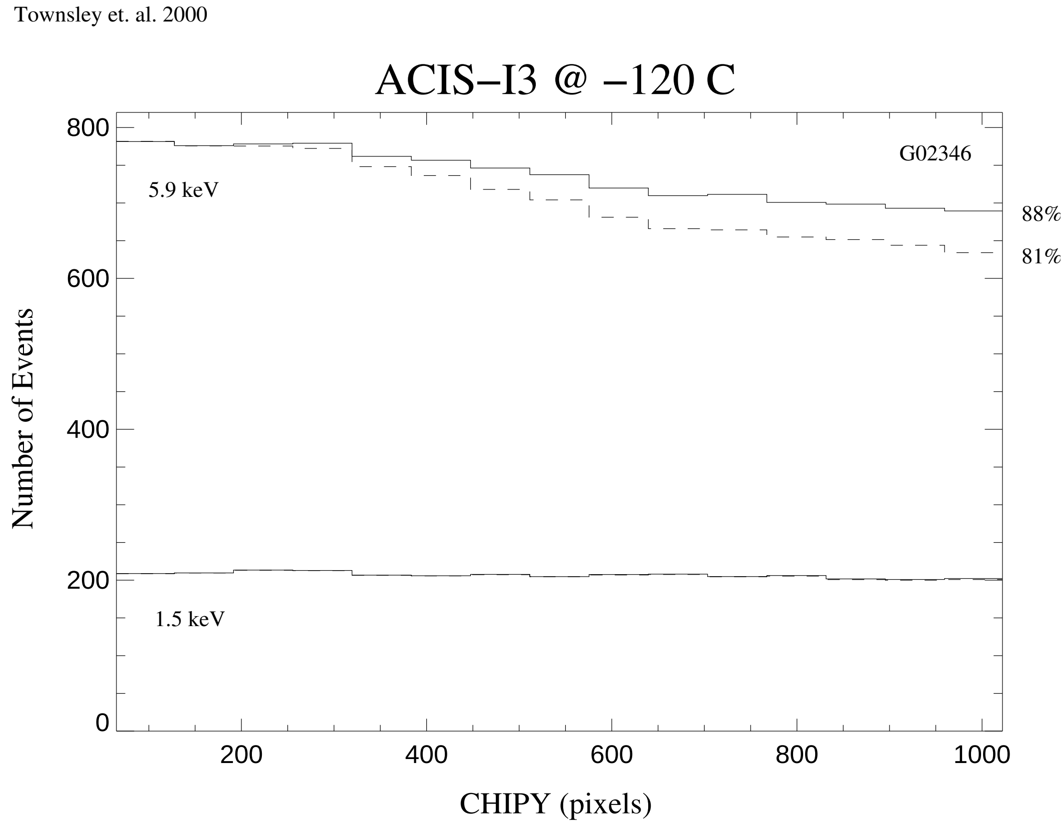


2 Degraded Energy Resolution

Courtesy Catherine Grant



3 GRADE Migration



Algorithm

The algorithm iteratively adds charge to an event island and redistributes the charge in the island based on the following features of CTI.

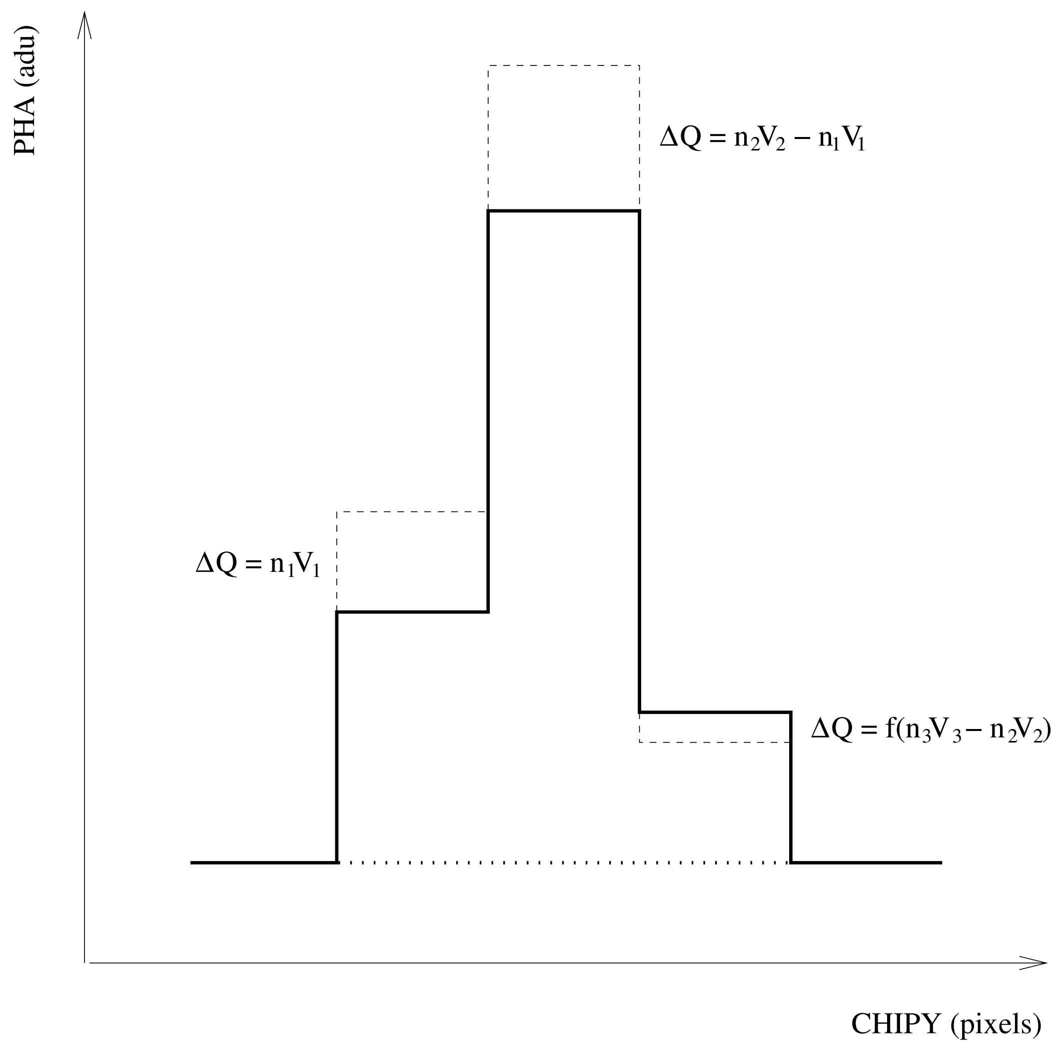
- The amount of charge lost from a pixel may be expressed in terms of the density of charge traps n and the volume V occupied by a charge packet:
$$\Delta Q[i,j] = n_{i,j} V_{i,j}. \tag{1}$$
This situation is assumed to apply to a pixel if the amount of charge in the preceding pixel is less than the split threshold or unknown.

- The charge in one pixel can be "shielded" by the charge in a preceding pixel:
$$\Delta Q[i,j] = n_{i,j} V_{i,j} - n_{i,j-1} V_{i,j-1}. \tag{2}$$
This situation is assumed to apply to the cases where the amount of charge in a pixel is greater than or equal to the amount of charge in the preceding pixel.

- The charge in a pixel can be "trailed" into a following pixel:
$$\Delta Q[i,j] = f(n_{i,j} V_{i,j} - n_{i,j-1} V_{i,j-1}). \tag{3}$$
This condition is assumed to apply to all cases where the amount of charge in a pixel is less than the amount of charge in the preceding pixel.

A Schematic

This schematic illustrates the amount of charge associated with three adjacent pixels in a 3 pixel $\times$ 3 pixel event island. The solid lines are the charge distribution as read out. The dashed lines are the charge distribution after adjusting for the effects of CTI.



An Example

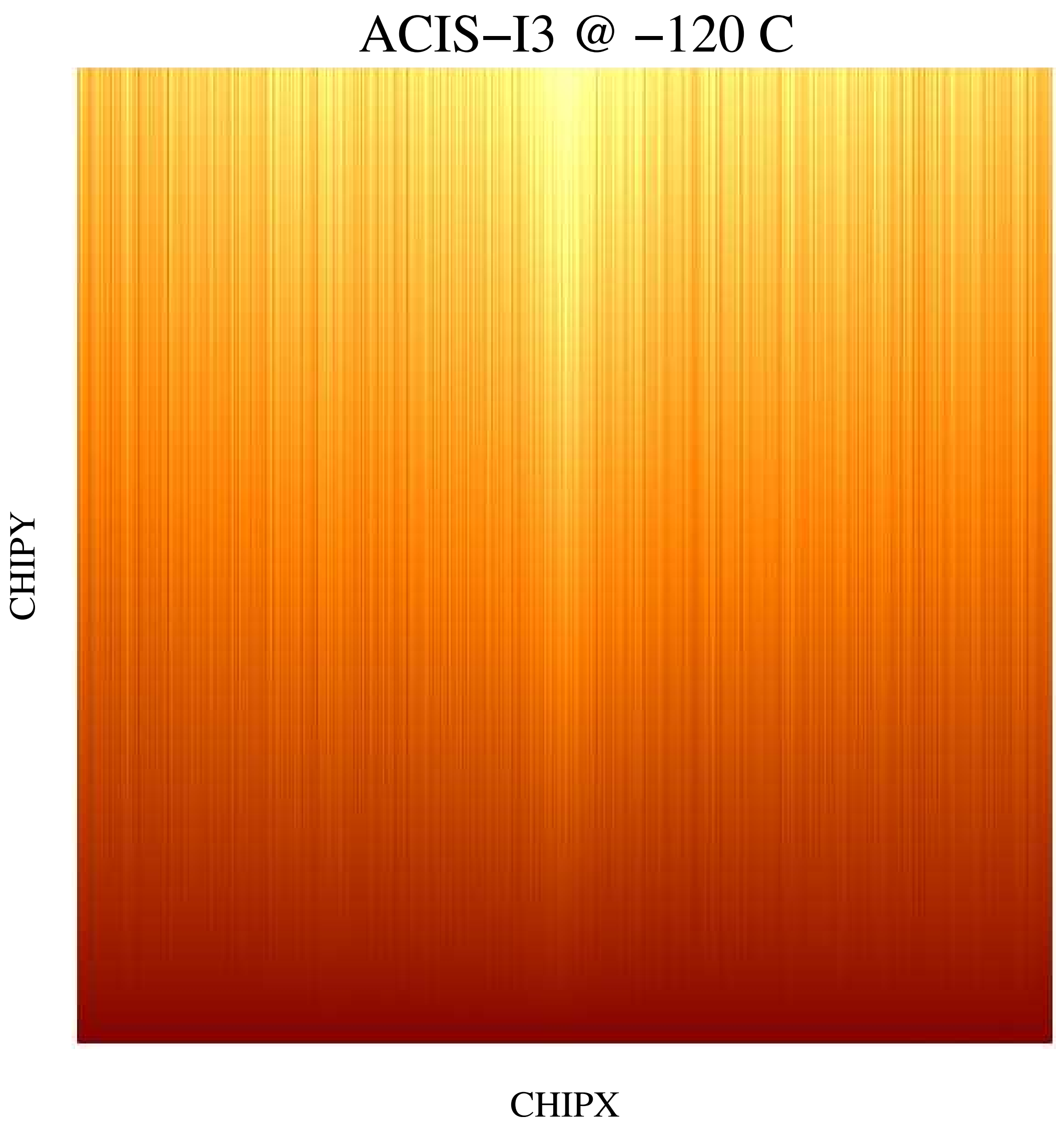
Consider the amount of charge in the CTI-adjusted event island (PHAS_ADJ) after iteration i of the 168th event of obsid 737.

i	$PHAS\_ADJ_i$			$PHAS\_ADJ_i - PHAS\_ADJ_{i-1}$		
	15.00	26.00	30.00	NA	NA	NA
0	24.00	40.00	38.00	NA	NA	NA
	9.00	24.00	36.00	NA	NA	NA
	14.93	25.91	29.95	−0.07	−0.09	−0.05
1	31.52	42.52	38.30	7.52	2.52	0.30
	9.00	32.09	45.42	0.00	8.09	9.42
	⋮			⋮		
	14.87	25.90	29.95	0.00	0.00	0.00
4	32.86	41.11	37.95	0.02	−0.08	0.00
	9.00	33.66	46.82	0.00	0.03	0.02

Computing $n_{i,j}$ and $V_{i,j}$

A new CTI CALDB ARD file has been created. It includes serial CTI trap-density maps for ACIS-I0, -I1, -I2, -I3, and -S2. The value of the trap-density for an event ($n_{i,j}$) is read from the appropriate pixel (i, j) of the trap-density map for the CCD on which the event occurred.

1 One Trap-Density Map

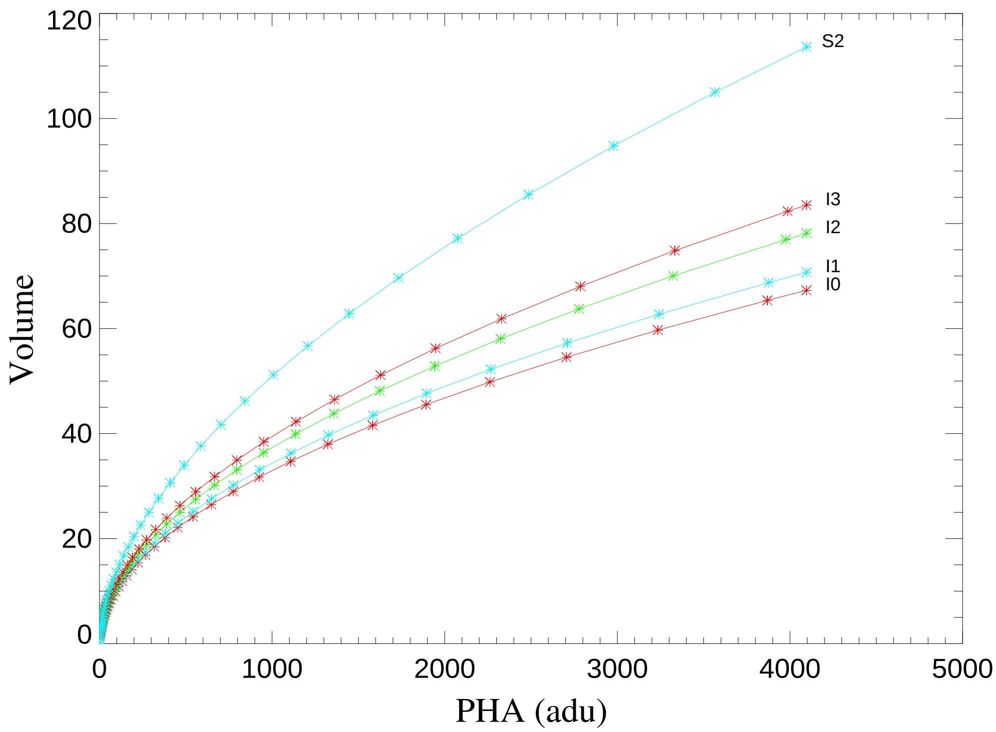


2 Volume

The volume occupied by the charge in a pixel is modeled as a function of the amount of charge in the pixel:

$$V_{i,j} = \text{PHAS\_ADJ}[i,j]^{\alpha}, \tag{4}$$

where $\alpha \approx 0.5$ (0.51–0.57).



Usage

Once the code (acis_process_events) with the CTI-adjustment is available, the adjustment can be performed by typing

```
acis_process_events
    infile=acisf00737_000N002_evt1.fits
    outfile=acisf00737_cti_adjusted_evt1.fits
    acaofffile=none
    apply_cti=yes
    [ctifile=acisD2000-01-29ctiN0671.fits]
    [eventdef=...,f:phas_adj,...]
    [max_cti_iter=15]
    [cti_converge=0.1]
    stop=none
```

Changes to ACIS Event Data

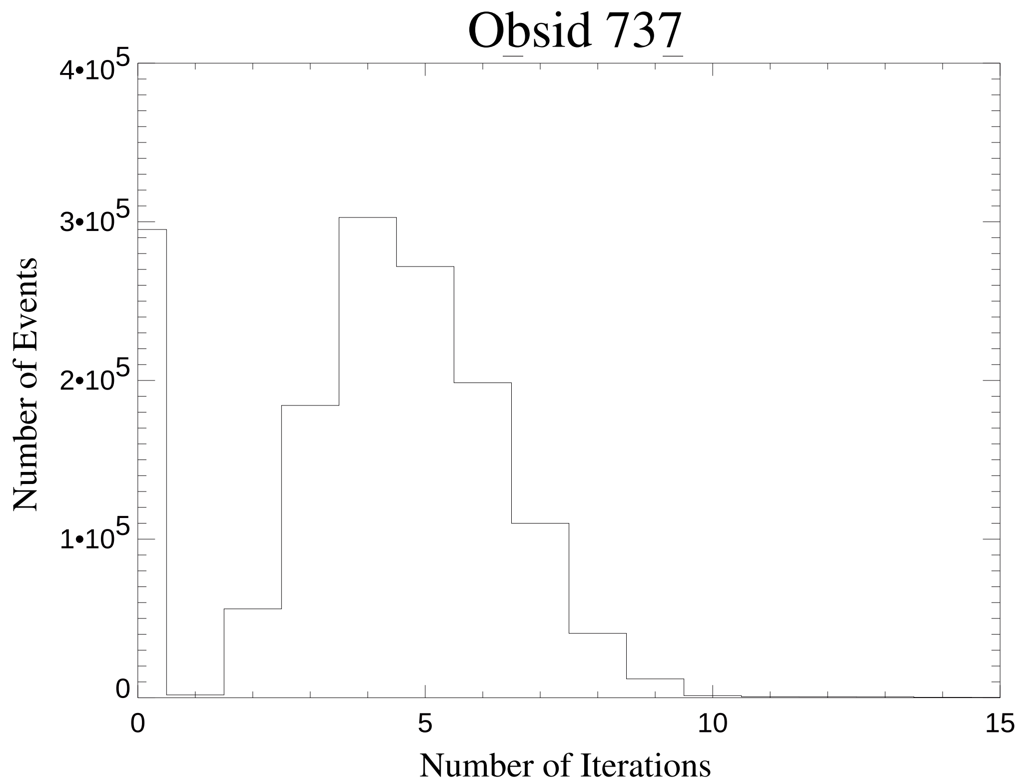
The differences between a CTI-adjusted ACIS event data file and an unadjusted file are highlighted in the following table in blue.

No CTI Adjustment	CTI Adjusted
TIME	TIME
EXPNO	EXPNO
CCD_ID	CCD_ID
NODE_ID	NODE_ID
CHIPX	CHIPX
CHIPY	CHIPY
TDETX	TDETX
TDETY	TDETY
DETX	DETX
DETY	DETY
X	X
Y	Y
PHAS	PHAS
...	PHAS_ADJ
PHA	PHA
ENERGY	ENERGY
PI	PI
FLTGRADE	FLTGRADE
GRADE	GRADE
STATUS	STATUS (bit 20)

- The column named PHAS_ADJ is created when the adjustment is applied.
- CTI-adjusted data include both of the columns PHAS (unadjusted event island) and PHAS_ADJ (CTI-adjusted event island). Since the unadjusted column is retained, the tool acis_process_events can be used to reprocess the data and either turn off the CTI adjustment or update the adjustment using a new calibration file (if desired).
- The values of PHA, ENERGY, PI, FLTGRADE, and GRADE are computed using the column PHAS_ADJ instead of the column PHAS if the adjustment is applied.
- Bit 20 (of 0–31) in the STATUS column is set to one (i.e. the event is labeled as "bad") if the computation of PHAS_ADJ does not converge after the maximum number of iterations (15 by default) is performed.

Number of Iterations

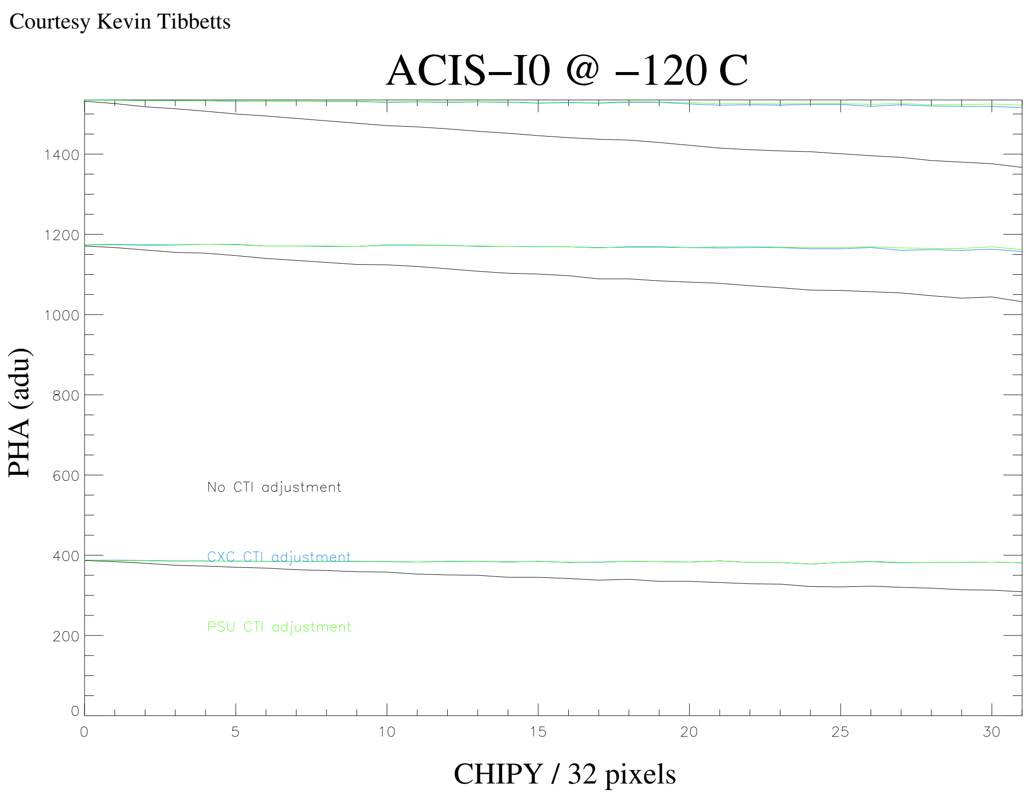
The CTI adjustments typically converge in less than 15 iterations.



Does It Help?

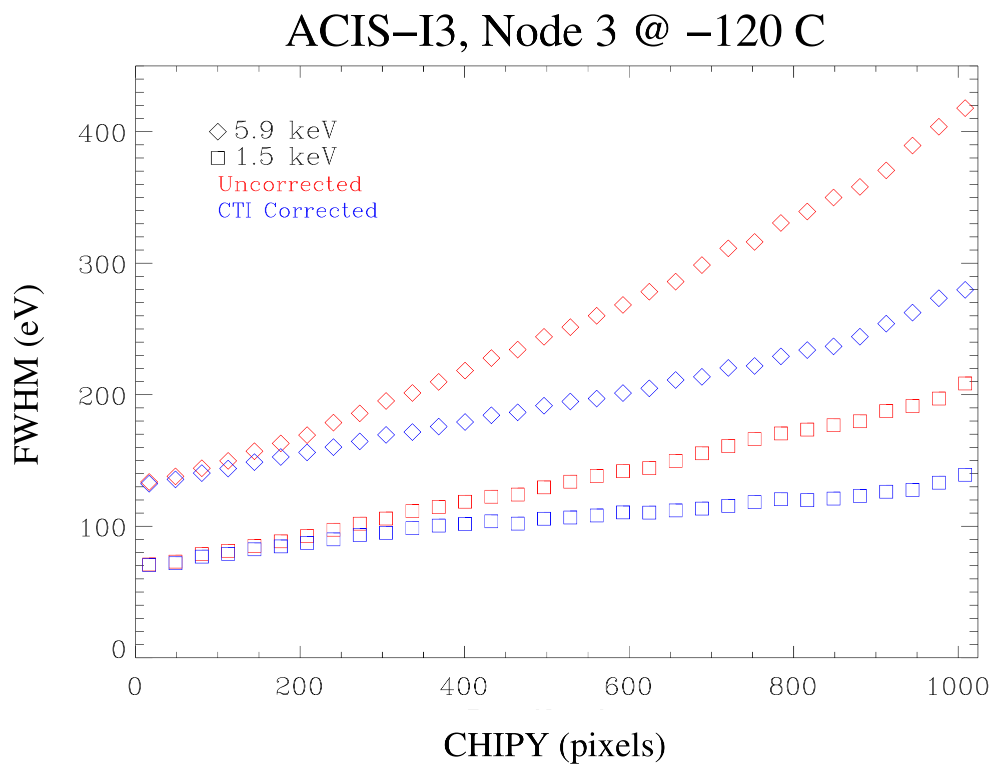
Does the use of a CTI adjustment mitigate the affects of CTI (i.e. the apparent gain shift, the degradation in the energy resolution, and GRADE migration)?

1 Apparent Gain Shift



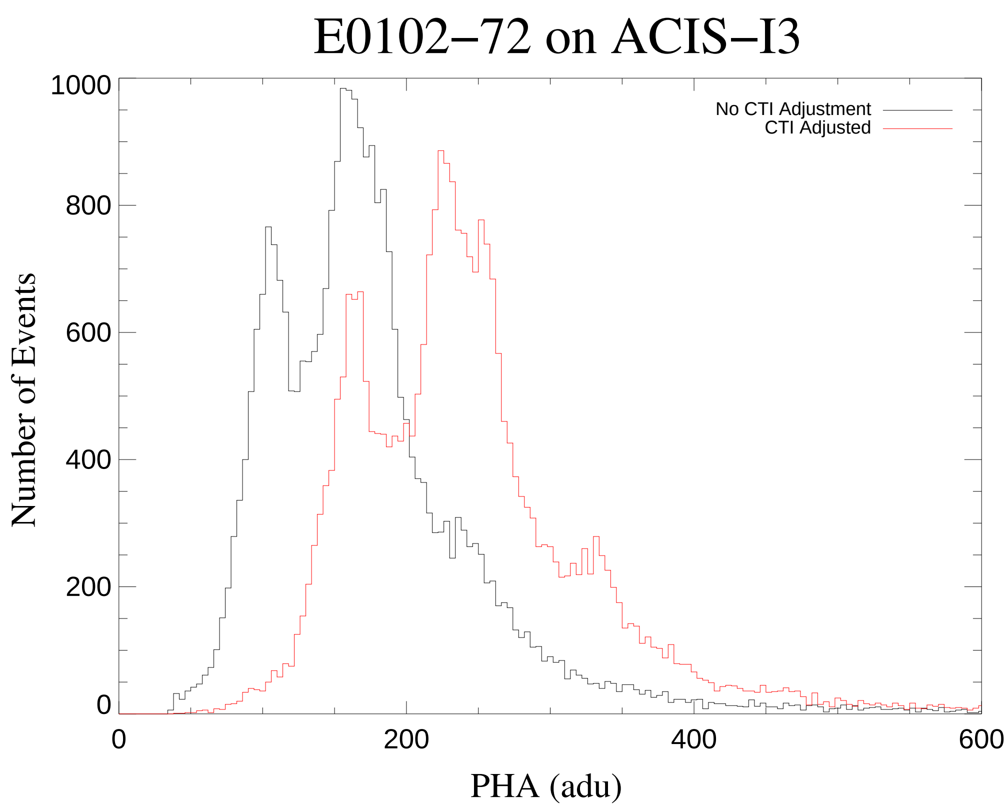
2 Degraded Energy Resolution

Courtesy Catherine Grant



3 A Sample Spectrum

The following figure is a sample of how the CTI adjustment affects the spectral data for a source (the supernova remnant 1E0102.2–7219) at the aim point on the ACIS-I3 CCD. The affects of the apparent gain shift and the degradation in the energy resolution are evident.



Plucinsky et al. (2001) have investigated whether the CTI adjustment improves the results of spectral fits for this source. For more information, see http://xxx.lanl.gov/pdf/astro-ph/0111363.

Summary

- ☺ The CIAO tool acis_process_events includes an optional CTI-adjustment algorithm.
- ☺ The algorithm compensates for some of the affects of CTI.
- ☹ The version of the tool which includes the algorithm is not publically available yet because we are still working to calibrate CTI adjusted data (i.e. new FEF, GAIN, OSIP, and QEU CALDB files).
- ☺ Once calibrated, the algorithm can be used in the pipeline for all new TIMED FAINT and VFAINT mode observations and existing data can be reprocessed.

Selected References

PSU CTI Corrector code: http://www.astro.psu.edu/users/townsley /cti/install.html

Townsley, L. K. et al. 2000, ApJ, 534, L139

MIT ACIS Team, 22 March 2001 memo, "ACIS CTI Correction," http://space.mit.edu/ACIS/cticor.pdf

Plucinsky, P. P. 2001, http://xxx.lanl.gov/pdf/astro-ph/0111363

The CIAO code spec: http://space.mit.edu/ gea/docs/ memo_cti_correction_4.7.ps