MIT
Center for Space Research **Chandra X-Ray Center**

MEMORANDUM
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To: Martin Elvis, SDS Group Leader
From: Glenn E. Allen, SDS
Subject: Applying a Time-Dependent Gain Adjustment
Revision: 1.3
URL: http://space.mit.edu/CXC/docs/docs.html#tgain_spec
File: /nfs/cxc/h2/gea/sds/docs/memos/memo_apply_tgain_1.3.tex

1 acis_process_events

1.1 Description

The continuous exposure of the ACIS CCDs to particle radiation causes a steady increase in the charge-transfer inefficiency (CTI) of the detectors. As a result, the typical pulse height recorded for an X-ray of a given energy is declining with time. This kind of change in the "gain" of the detectors and a change in the electronic gain of the ACIS-I1 CCD is calibrated (for CTI-adjusted data) and recorded in a set of "t_gain" ARD files. This document describes how the information in these files is used by acis_process_events to apply a time-dependent gain adjustment to ACIS event data. The time-dependent gain adjustment is applied after the CTI adjustment because the gain adjustment is calibrated using CTI-adjusted data.

1.2 Input

1. A Level 0, 1, 1.5, or 2 event data file (acis*evt0.fits, acis*evt1.fits, acis*evt1a.fits, or acis*evt2.fits)
2. A "t_gain" ARD file (e.g. acisD2001-05-01t_gainN0001.fits)

1.3 Output

1. An event data file

1.4 Parameters

1. tgainfile,s,h,"CALDB",,,"Name of input gain adjustment file (⟨filename⟩ — CALDB — none — NONE)"
2. apply_tgain,b,h,yes,,,"Apply time-dependent gain adjustment?"

1.5 Processing

1. Verify that the specified input files exist. If the parameter clobber = "no," then verify that the output file does not exist. If apply_tgain = "yes" and tgainfile = "none" or "NONE" (or does not exist), then write a warning message that the time-dependent gain adjustment is not being applied because a valid calibration file is not specified.

2. For each event i in the input event data file, find the row r in the t_gain ARD file that satisfies all three of the conditions

$$\mathrm{CCD\_ID}_r = \mathrm{ccd\_id}_i \tag{1}$$

$$\mathrm{CHIPX\_LO}_r \le \mathrm{chipx}_i \le \mathrm{CHIPX\_HI}_r, \text{ and} \tag{2}$$

$$\mathrm{CHIPY\_LO}_r \le \mathrm{chipy}_i \le \mathrm{CHIPY\_HI}_r, \tag{3}$$

   where ccd_id, chipx and chipy are the names of columns in the event data file and CCD_ID, CHIPX_LO, CHIPX_HI, CHIPY_LO and CHIPY_HI are the names of columns in the ARD file. $\mathrm{ccd\_id}_i$, chipx_i and chipy_i are the values of ccd_id, chipx and chipy for event i. $\mathrm{CCD\_ID}_r$, $\mathrm{CHIPX\_LO}_r$, $\mathrm{CHIPX\_HI}_r$, $\mathrm{CHIPY\_LO}_r$ and $\mathrm{CHIPY\_HI}_r$ are the values of CCD_ID, CHIPX_LO, CHIPX_HI, CHIPY_LO and CHIPY_HI for row r of the t_gain ARD file.

3. The values in the columns PHA, DELTPHA1 and DELTPHA2 for row r of the ARD file are used to compute the adjustment to the value of pha for event i. These three columns are vector columns. The number of valid elements in each column for row r is specified by $\mathrm{NPOINTS}_r$, where NPOINTS is the name of a column in the ARD file. If the number of elements in the vectors PHA_r, $\mathrm{DELTPHA1}_r$ and $\mathrm{DELTPHA2}_r$ is greater than $\mathrm{NPOINTS}_r$, then the ends of the vectors are padded with zeroes.

   The appropriate element n of the vector PHA_r is determined by using the condition

$$\mathrm{PHA}_r[n] \le \mathrm{pha}_i < \mathrm{PHA}_r[n+1]. \tag{4}$$

   Here, the first and last elements of the vector PHA_r are denoted $\mathrm{PHA}_r[1]$ and $\mathrm{PHA}_r[\mathrm{NPOINTS}_r]$, respectively. If $\mathrm{pha}_i < \mathrm{PHA}_r[1]$, then $n = 1$. If $\mathrm{pha}_i \ge \mathrm{PHA}_r[\mathrm{NPOINTS}_r]$, then $n = \mathrm{NPOINTS}_r - 1$ (not $\mathrm{NPOINTS}_r$).

   The value of pha_i is the pulse height of event i in the event data file. If the CTI adjustment is performed, then pha_i is the CTI-adjusted pulse height. (The CTI adjustment is performed before the time-dependent gain adjustment.) For GRADED mode observations, pha_i can be either pha_i or $\mathrm{pha\_ro}_i$ (see Tables 1 and 2).

4. The adjustment to the value of pha_i at $t = \mathrm{EPOCH1}$ is computed by performing a linear interpolation (or extrapolation) of the values in the vector $\mathrm{DELTPHA1}_r$:

$$\Delta\mathrm{pha1} = \frac{\mathrm{pha}_i - \mathrm{PHA}_r[n]}{\mathrm{PHA}_r[n+1] - \mathrm{PHA}_r[n]} \left(\mathrm{DELTPHA1}_r[n+1] - \mathrm{DELTPHA1}_r[n]\right) + \mathrm{DELTPHA1}_r[n]. \tag{5}$$

   For GRADED mode observations, pha_i can be either pha_i or $\mathrm{pha\_ro}_i$ (see Tables 1 and 2). EPOCH1 (and EPOCH2) are the names of keywords in the header of the t_gain file.

5. If EPOCH2 > EPOCH1 and $\mathrm{DELTPHA2}_r[\mathrm{NPOINTS}_r] \ne 0$, then the estimate of the adjustment to the value of pha_i at $t = \mathrm{EPOCH2}$ is

$$\Delta\mathrm{pha2} = \frac{\mathrm{pha}_i - \mathrm{PHA}_r[n]}{\mathrm{PHA}_r[n+1] - \mathrm{PHA}_r[n]} \left(\mathrm{DELTPHA2}_r[n+1] - \mathrm{DELTPHA2}_r[n]\right) + \mathrm{DELTPHA2}_r[n]. \tag{6}$$

   For GRADED mode observations, pha_i can be either pha_i or $\mathrm{pha\_ro}_i$ (see Tables 1 and 2).

   If EPOCH2 ≤ EPOCH1 or $\mathrm{DELTPHA2}_r[\mathrm{NPOINTS}_r] = 0$, then

$$\Delta\mathrm{pha2} = \Delta\mathrm{pha1} \text{ and} \tag{7}$$

$$\mathrm{EPOCH2} = \mathrm{EPOCH1} + 10^7 \text{ s}. \tag{8}$$

6. The pulse height adjustment at $t = \text{time}_i$ is

$$\Delta\text{pha} = \frac{\text{time}_i - \text{EPOCH1}}{\text{EPOCH2} - \text{EPOCH1}} (\Delta\text{pha2} - \Delta\text{pha1}) + \Delta\text{pha1}, \tag{9}$$

   where time_i is the time associated with event i.

7. The adjusted value of the pulse height for event i is[1]

$$\text{pha}'_i = \text{pha}_i + \Delta\text{pha} + a, \tag{10}$$

   where a is a uniform random deviate in the range $[-0.5, +0.5)$ adu. If $\text{pha}'_i > 32760$, then $\text{pha}'_i = 32760$.

8. Steps 2 to 7 are performed for every event in the input file.

9. The values of pha'_i (instead of pha_i) are written to the output file[1].

10. The name of the t_gain ARD file used is written to the keyword TGAINFIL and the value of the keyword TGAINCOR is set to "T" (True)[1].

[1]The content of the output file is contingent on several input conditions. See Tables 1 and 2 for the details.

Table 1. Input Conditions

Case	Parameter apply_tgain	Parameter doevtgrade	Keyword TGAINCOR	Keyword DATAMODE[a]	Column PHA_RO
1	yes	yes	F/missing	not GRADED	doesn't exist
2	yes	yes	F/missing	not GRADED	exists
3	yes	yes	F/missing	GRADED	doesn't exist
4	yes	yes	F/missing	GRADED	exists
5	yes	yes	T	not GRADED	doesn't exist
6	yes	yes	T	not GRADED	exists
7	yes	yes	T	GRADED	doesn't exist
8	yes	yes	T	GRADED	exists
9	yes	no	F/missing	not GRADED	doesn't exist
10	yes	no	F/missing	not GRADED	exists
11	yes	no	F/missing	GRADED	doesn't exist
12	yes	no	F/missing	GRADED	exists
13	yes	no	T	not GRADED	doesn't exist
14	yes	no	T	not GRADED	exists
15	yes	no	T	GRADED	doesn't exist
16	yes	no	T	GRADED	exists
17	no	yes	F/missing	not GRADED	doesn't exist
18	no	yes	F/missing	not GRADED	exists
19	no	yes	F/missing	GRADED	doesn't exist
20	no	yes	F/missing	GRADED	exists
21	no	yes	T	not GRADED	doesn't exist
22	no	yes	T	not GRADED	exists
23	no	yes	T	GRADED	doesn't exist
24	no	yes	T	GRADED	exists
25	no	no	F/missing	not GRADED	doesn't exist
26	no	no	F/missing	not GRADED	exists
27	no	no	F/missing	GRADED	doesn't exist
28	no	no	F/missing	GRADED	exists
29	no	no	T	not GRADED	doesn't exist
30	no	no	T	not GRADED	exists
31	no	no	T	GRADED	doesn't exist
32	no	no	T	GRADED	exists

[a] The DATAMODEs "GRADED," "GRADED_HISTO," "CC_GRADED," and "CC33_GRADED" are collectively refered to as GRADED.

Table 2. Output

Case	Column PHA	Column PHA_RO	Keyword TGAINCOR	Keyword TGAINFIL	Notes
1	Adjust PHA[a]	Unadjusted PHA[b]	T	⟨t_gain⟩	SDP
2	Adjust PHA[a]	Unadjusted PHA[b]	T	⟨t_gain⟩	Recompute PHA and tgain
3	Adjust PHA	Unadjusted PHA	T	⟨t_gain⟩	SDP
4	Adjust PHA_RO[c]	Input PHA_RO	T	⟨t_gain⟩	Compute tgain only
5	Adjust PHA[a]	Unadjusted PHA[b]	T	⟨t_gain⟩	Recompute PHA and tgain
6	Adjust PHA[a]	Unadjusted PHA[b]	T	⟨t_gain⟩	Recompute PHA and tgain
7	Don't adjust[d]	Zero	T	Copy[f]	Error
8	Adjust PHA_RO[c]	Input PHA_RO	T	⟨t_gain⟩	Compute tgain only
9	Adjust PHA[e]	Input PHA	T	⟨t_gain⟩	Compute tgain only
10	Adjust PHA_RO[c]	Input PHA_RO	T	⟨t_gain⟩	Compute tgain only
11	Adjust PHA[e]	Zero	T	⟨t_gain⟩	Compute tgain only
12	Adjust PHA_RO[c]	Input PHA_RO	T	⟨t_gain⟩	Compute tgain only
13	Don't adjust[d]	Input PHA_RO	T	Copy	Don't apply twice
14	Adjust PHA_RO[c]	Input PHA_RO	T	⟨t_gain⟩	Compute tgain only
15	Don't adjust	Zero	T	Copy[f]	Error
16	Adjust PHA_RO[c]	Input PHA_RO	T	⟨t_gain⟩	Compute tgain only
17	Don't adjust	PHA	F	NONE	Compute PHA only
18	Don't adjust	Input PHA_RO	F	Copy[f]	Compute PHA only
19	Don't adjust	PHA	F	NONE	Calculation disabled
20	Don't adjust	Input PHA_RO	F	Copy[f]	Calculation disabled
21	Don't adjust	PHA	F	NONE	Compute PHA only
22	Don't adjust	Input PHA_RO	T	Copy[f]	Compute PHA only
23	Don't adjust	Zero	T	Copy[f]	Calculation disabled
24	Don't adjust	Input PHA_RO	T	Copy[f]	Calculation disabled
25	Don't adjust	PHA	F	NONE	Calculation disabled
26	Don't adjust	Input PHA_RO	F	Copy[f]	Calculation disabled
27	Don't adjust	PHA	F	NONE	Calculation disabled
28	Don't adjust	Input PHA_RO	F	Copy[f]	Calculation disabled
29	Don't adjust	PHA	F	NONE	Calculation disabled
30	Don't adjust	Input PHA_RO	T	Copy[f]	Calculation disabled
31	Don't adjust	Zero	T	Copy[f]	Calculation disabled
32	Don't adjust	Input PHA_RO	T	Copy[f]	Calculation disabled

[a] Compute PHA from PHAS.
[b] No gain adjustment applied. CTI adjustment may be applied.
[c] Input value of PHA_RO.
[d] Write a warning message.
[e] Input value of PHA.
[f] The keyword is copied only if it exists.