MIT Kavli Institute **Chandra X-Ray Center**

MEMORANDUM
July 2, 2015

To:	Jonathan McDowell, SDS Group Leader
From:	Glenn E. Allen, SDS
Subject:	`acis_process_events` spec
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1 acis_process_events

This spec, which is incomplete, describes some of processing steps for continuous-clocking mode data.

1.1 Description

1.2 Input

1.3 Output

1.4 Parameters

1.5 Processing

1.5.1 Error checking

The following steps are performed once prior to the processing of the data for each input ACIS event.

1. `obsfile`:

   (a) Validation:

      i. Existence:
      If

$$\texttt{obsfile} \neq \text{none and} \tag{1}$$
$$\texttt{obsfile} \neq \text{NONE} \tag{2}$$

      and the `obsfile` does not exist, then `obsfile` is changed to "none" and `acis_process_events` produces a warning message.

ii. Permission:
If

$$\begin{aligned} \texttt{obsfile} &\neq \text{none and} \quad (3) \\ \texttt{obsfile} &\neq \text{NONE} \quad (4) \end{aligned}$$

and the file permissions do not allow the `obsfile` to be read, then `obsfile` is changed to "none" and `acis_process_events` produces a warning message.

iii. `OBS_MODE`:
If

$$\begin{aligned} \texttt{obsfile} &\neq \text{none and} \quad (5) \\ \texttt{obsfile} &\neq \text{NONE,} \quad (6) \end{aligned}$$

then

A. If the `obsfile` does not include the keyword `obs_mode`, then `OBS_MODE` is set to "none".

B. If the `obsfile` includes the keyword `obs_mode` and

$$\begin{aligned} \texttt{obs\_mode} &= \text{pointing or} \quad (7) \\ \texttt{obs\_mode} &= \text{POINTING or} \quad (8) \\ \texttt{obs\_mode} &= \text{secondary or} \quad (9) \\ \texttt{obs\_mode} &= \text{SECONDARY,} \quad (10) \end{aligned}$$

then `OBS_MODE` is set to the value of `obs_mode`. Hereafter this keyword is referred to as `OBS_MODE`.

C. If the `obsfile` includes the keyword `obs_mode` and

$$\begin{aligned} \texttt{obs\_mode} &\neq \text{pointing and} \quad (11) \\ \texttt{obs\_mode} &\neq \text{POINTING and} \quad (12) \\ \texttt{obs\_mode} &\neq \text{secondary and} \quad (13) \\ \texttt{obs\_mode} &\neq \text{SECONDARY,} \quad (14) \end{aligned}$$

then `OBS_MODE` is set to "none".

2. `infile`:

(a) Existence:
If the `infile` does not exist, then `acis_process_events` exits with an error message.

(b) Permission:
If the `infile` exists and the file permissions do not allow it to be read, then `acis_process_events` exits with an error message.

(c) Validation:

i. `OBS_MODE`:
If `OBS_MODE` = none, then

A. The `OBS_MODE` is read from the HDU $h_{\rm in}$ keyword of the same name. Hereafter this keyword is referred to as `OBS_MODE`.

B. If the HDU $h_{\rm in}$ does not include the keyword `OBS_MODE`, then `OBS_MODE` is set to "none" and `acis_process_events` produces a warning message.

C. If the HDU h_{in} includes the keyword OBS_MODE and

$$\begin{aligned}\texttt{obs\_mode} &\neq \text{pointing and} &(15)\\ \texttt{obs\_mode} &\neq \text{POINTING and} &(16)\\ \texttt{obs\_mode} &\neq \text{secondary and} &(17)\\ \texttt{obs\_mode} &\neq \text{SECONDARY,} &(18)\end{aligned}$$

then OBS_MODE is set to "none" and acis_process_events produces a warning message.

ii. DATAMODE:
The DATAMODE is read from the HDU h_{in} keyword of the same name. If the HDU h_{in} does not include the keyword DATAMODE or if

$$\begin{aligned}\texttt{DATAMODE} &\neq \text{CC33\_FAINT and} &(19)\\ \texttt{DATAMODE} &\neq \text{CC33\_GRADED and} &(20)\\ \texttt{DATAMODE} &\neq \text{FAINT and} &(21)\\ \texttt{DATAMODE} &\neq \text{FAINT\_BIAS and} &(22)\\ \texttt{DATAMODE} &\neq \text{GRADED and} &(23)\\ \texttt{DATAMODE} &\neq \text{VFAINT,} &(24)\end{aligned}$$

then acis_process_events exits with an error message. Hereafter, the value of this keyword is referred to as $\texttt{DATAMODE}_{\text{in}}$.

iii. CONTENT:
If the infile does not have an HDU h_{in} with the keyword

$$\begin{aligned}\texttt{CONTENT} &= \text{EVT0 or} &(25)\\ \texttt{CONTENT} &= \text{EVT1 or} &(26)\\ \texttt{CONTENT} &= \text{TGEVT1 or} &(27)\\ \texttt{CONTENT} &= \text{EVT2,} &(28)\end{aligned}$$

then acis_process_events exits with an error message. Hereafter, the value of this keyword is referred to as $\texttt{CONTENT}_{\text{in}}$.

iv. TIME:
If HDU h_{in} of the infile does not include the column TIME, then acis_process_events exits with an error message. Hereafter, this column is referred to as $\texttt{TIME}_{\text{in}}$.

v. TIME_RO:
If

$$\begin{aligned}\texttt{DATAMODE}_{\text{in}} &= \text{CC33\_FAINT or} &(29)\\ \texttt{DATAMODE}_{\text{in}} &= \text{CC33\_GRADED} &(30)\end{aligned}$$

and

$$\begin{aligned}\texttt{CONTENT}_{\text{in}} &= \text{EVT1 or} &(31)\\ \texttt{CONTENT}_{\text{in}} &= \text{TGEVT1 or} &(32)\\ \texttt{CONTENT}_{\text{in}} &= \text{EVT2} &(33)\end{aligned}$$

and HDU h_{in} of the infile does not include the column TIME_RO, then acis_process_events exits with an error message. Hereafter, this column is referred to as $\texttt{TIME\_RO}_{\text{in}}$.

vi. EXPNO:
If HDU h_{in} the infile does not include the column EXPNO, then acis_process_events exits with an error message. Hereafter, this column is referred to as $\texttt{EXPNO}_{\text{in}}$.

vii. CCD_ID:

A. If

$$\texttt{CONTENT}_{\text{in}} = \text{EVT0} \tag{34}$$

and HDU h_{in} of the infile does not include the keyword CCD_ID, then acis_process_events exits with an error message. Hereafter, this keyword is referred to as $\texttt{CCD\_ID}_{\text{in}}$.

B. If

$$\texttt{CONTENT}_{\text{in}} = \text{EVT1 or} \tag{35}$$
$$\texttt{CONTENT}_{\text{in}} = \text{TGEVT1 or} \tag{36}$$
$$\texttt{CONTENT}_{\text{in}} = \text{EVT2} \tag{37}$$

and HDU h_{in} of the infile does not include the column CCD_ID, then acis_process_events exits with an error message. Hereafter, this column is referred to as $\texttt{CCD\_ID}_{\text{in}}$.

viii. CCDX:

A. If

$$\texttt{CONTENT}_{\text{in}} = \text{EVT0} \tag{38}$$

and HDU h_{in} of the infile does not include the column CCDX, then acis_process_events exits with an error message. Hereafter, this column is referred to as $\texttt{CCDX}_{\text{in}}$.

ix. CHIPX:

A. If

$$\texttt{CONTENT}_{\text{in}} = \text{EVT1 or} \tag{39}$$
$$\texttt{CONTENT}_{\text{in}} = \text{TGEVT1 or} \tag{40}$$
$$\texttt{CONTENT}_{\text{in}} = \text{EVT2} \tag{41}$$

and HDU h_{in} of the infile does not include the column CHIPX, then acis_process_events exits with an error message. Hereafter, this column is referred to as $\texttt{CHIPX}_{\text{in}}$.

x. CCDY:

A. If

$$\texttt{CONTENT}_{\text{in}} = \text{EVT0} \tag{42}$$

and

$$\texttt{DATAMODE}_{\text{in}} = \text{FAINT or} \tag{43}$$
$$\texttt{DATAMODE}_{\text{in}} = \text{FAINT\_BIAS or} \tag{44}$$
$$\texttt{DATAMODE}_{\text{in}} = \text{GRADED or} \tag{45}$$
$$\texttt{DATAMODE}_{\text{in}} = \text{VFAINT} \tag{46}$$

and HDU h_{in} of the infile does not include the column CCDY, then acis_process_events exits with an error message. Hereafter, this column is referred to as $\texttt{CCDY}_{\text{in}}$.

xi. TROW:

A. If

$$\texttt{CONTENT}_{\text{in}} = \text{EVT0} \tag{47}$$

and

$$\texttt{DATAMODE}_{\text{in}} = \text{CC33\_FAINT or} \tag{48}$$
$$\texttt{DATAMODE}_{\text{in}} = \text{CC33\_GRADED} \tag{49}$$

and HDU h_{in} of the infile does not include the column TROW, then acis_process_events exits with an error message. Hereafter, this column is referred to as $\texttt{TROW}_{\text{in}}$.

xii. CHIPY:

A. If

$$\texttt{CONTENT}_{\rm in} = \text{EVT1 or} \quad (50)$$
$$\texttt{CONTENT}_{\rm in} = \text{TGEVT1 or} \quad (51)$$
$$\texttt{CONTENT}_{\rm in} = \text{EVT2} \quad (52)$$

and HDU $h_{\rm in}$ of the infile does not include the column CHIPY, then acis_process_events exits with an error message. Hereafter, this column is referred to as $\texttt{CHIPY}_{\rm in}$.

xiii. TIMEDEL:

If

$$\texttt{DATAMODE}_{\rm in} = \text{CC33\_FAINT or} \quad (53)$$
$$\texttt{DATAMODE}_{\rm in} = \text{CC33\_GRADED} \quad (54)$$

and HDU $h_{\rm in}$ of the infile does not include the keyword TIMEDEL, then acis_process_events exits with an error message. Hereafter this keyword is referred to as $\texttt{TIMEDEL}_{\rm in}$.

xiv. RA_TARG, DEC_TARG, RA_NOM, DEC_NOM, RA_PNT, DEC_PNT, CHIPY_TG, CHIPY_ZO, and TG_M:

If

$$\texttt{OBS\_MODE} = \text{pointing or} \quad (55)$$
$$\texttt{OBS\_MODE} = \text{POINTING} \quad (56)$$

and

$$\texttt{DATAMODE}_{\rm in} = \text{CC33\_FAINT or} \quad (57)$$
$$\texttt{DATAMODE}_{\rm in} = \text{CC33\_GRADED,} \quad (58)$$

then

A. RA_TARG, DEC_TARG, RA_NOM, DEC_NOM, RA_PNT, DEC_PNT:

If HDU $h_{\rm in}$ of the infile does not include the keywords RA_TARG, DEC_TARG, RA_NOM, DEC_NOM, RA_PNT, and DEC_PNT, then acis_process_events exits with an error message. Hereafter these keywords are referred to as $\texttt{RA\_TARG}_{\rm in}$, $\texttt{DEC\_TARG}_{\rm in}$, $\texttt{RA\_NOM}_{\rm in}$, $\texttt{DEC\_NOM}_{\rm in}$, $\texttt{RA\_PNT}_{\rm in}$, and $\texttt{DEC\_PNT}_{\rm in}$, respectively.

B. CHIPY_TG, CHIPY_ZO, and TG_M:

If

$$\texttt{CONTENT}_{\rm in} = \text{TGEVT1} \quad (59)$$

and HDU $h_{\rm in}$ of the infile does not include the columns CHIPY_TG, CHIPY_ZO, and TG_M, then acis_process_events exits with an error message. Hereafter these columns are referred to as $\texttt{CHIPY\_TG}_{\rm in}$, $\texttt{CHIPY\_ZO}_{\rm in}$, and $\texttt{TG\_M}_{\rm in}$, respectively.

3. stop:

(a) Lowercase:

The parameter string is converted to contain only lower case letters.

(b) Validation:

i. Setting:

If

$$\texttt{stop} \neq \text{none and} \quad (60)$$

$$\begin{aligned} \texttt{stop} &\neq \text{chip and} && (61)\\ \texttt{stop} &\neq \text{tdet and} && (62)\\ \texttt{stop} &\neq \text{det and} && (63)\\ \texttt{stop} &\neq \text{tan and} && (64)\\ \texttt{stop} &\neq \text{sky,} && (65) \end{aligned}$$

then `stop` is changed to "none" and `acis_process_events` produces a warning message.

ii. `OBS_MODE`:
If

$$\begin{aligned} \texttt{OBS\_MODE} &\neq \text{pointing and} && (66)\\ \texttt{OBS\_MODE} &\neq \text{POINTING} && (67) \end{aligned}$$

and

$$\begin{aligned} \texttt{stop} &\neq \text{none and} && (68)\\ \texttt{stop} &\neq \text{chip and} && (69)\\ \texttt{stop} &\neq \text{tdet,} && (70) \end{aligned}$$

then `stop` is changed to "none" and `acis_process_events` produces a warning message.

4. `acaofffile`:

(a) Validation for CC mode:
If

$$\begin{aligned} \texttt{OBS\_MODE} &= \text{pointing or} && (71)\\ \texttt{OBS\_MODE} &= \text{POINTING} && (72) \end{aligned}$$

and

$$\begin{aligned} \texttt{DATAMODE}_{\text{in}} &= \text{CC33\_FAINT or} && (73)\\ \texttt{DATAMODE}_{\text{in}} &= \text{CC33\_GRADED,} && (74) \end{aligned}$$

then

i. Setting:
If

$$\begin{aligned} \texttt{acaofffile} &= \text{none or} && (75)\\ \texttt{acaofffile} &= \text{NONE,} && (76) \end{aligned}$$

then `acis_process_events` exits with an error message.

ii. Existence:
If the `acaofffile` does not exist, then `acis_process_events` exits with an error message.

iii. Permission:
If the `acaofffile` exists and the file permissions do not allow it to be read, then `acis_process_events` exits with an error message.

iv. `CONTENT`:
If the `acaofffile` does not have an HDU h_{acaoff} with the keyword

$$\texttt{CONTENT} = \text{ASPSOL,} \qquad (77)$$

then `acis_process_events` exits with an error message.

v. Keyword:
If HDU $h_{\rm acaoff}$ of the `acaofffile` does not include the keyword `TSTART`, then `acis_process_events` exits with an error message.

vi. Columns:
If HDU $h_{\rm acaoff}$ of the `acaofffile` does not include the columns `TIME`, `RA`, `DEC`, and `ROLL` then `acis_process_events` exits with an error message. Hereafter, these columns are referred to as $\texttt{TIME}_{\rm acaoff}$, $\texttt{RA}_{\rm acaoff}$, $\texttt{DEC}_{\rm acaoff}$, and $\texttt{ROLL}_{\rm acaoff}$.

vii. Sequential:
If more than one valid `acaofffile` is specified and the the values `TSTART` are not in increasing order, then `acis_process_events` exits with an error message.

5. `doevtgrade`:

(a) Lowercase:
The parameter string is converted to contain only lower case letters.

(b) Validation:
If

$$\texttt{doevtgrade} \neq \text{yes and} \tag{78}$$
$$\texttt{doevtgrade} \neq \text{no,} \tag{79}$$

then `acis_process_events` exits with an error message.

6. `apply_cti`:

(a) Lowercase:
The parameter string is converted to contain only lower case letters.

(b) Validation:

i. Setting:
If

$$\texttt{apply\_cti} \neq \text{yes and} \tag{80}$$
$$\texttt{apply\_cti} \neq \text{no,} \tag{81}$$

then `acis_process_events` exits with an error message.

ii. `PHAS`:
If

$$\texttt{apply\_cti} = \text{yes} \tag{82}$$

and the `infile` does not include the column `PHAS`, then `apply_cti` is changed to "no" and `acis_process_events` produces a warning message.

iii. `doevtgrade`:
If

$$\texttt{apply\_cti} = \text{yes and} \tag{83}$$
$$\texttt{doevtgrade} = \text{no,} \tag{84}$$

then `apply_cti` is changed to "no" and `acis_process_events` produces a warning message.

7. `alignmentfile`:

(a) Validation for CC mode:
If

$$\texttt{OBS\_MODE} = \text{pointing or} \quad (85)$$
$$\texttt{OBS\_MODE} = \text{POINTING} \quad (86)$$

and

$$\texttt{DATAMODE}_{\text{in}} = \text{CC33\_FAINT or} \quad (87)$$
$$\texttt{DATAMODE}_{\text{in}} = \text{CC33\_GRADED,} \quad (88)$$

then

i. Setting:
If

$$\texttt{alignmentfile} = \text{none or} \quad (89)$$
$$\texttt{alignmentfile} = \text{NONE,} \quad (90)$$

then `acis_process_events` exits with an error message.

ii. Existence:
If the `alignmentfile` does not exist, then `acis_process_events` exits with an error message.

iii. Permission:
If the `alignmentfile` exists and the file permissions do not allow it to be read, then `acis_process_events` exits with an error message.

iv. `CONTENT`:
If the `alignmentfile` does not have an HDU $h_{\text{alignment}}$ with the keyword

$$\texttt{CONTENT} = \text{ASPSOL,} \quad (91)$$

then `acis_process_events` exits with an error message.

v. Keyword:
If HDU $h_{\text{alignment}}$ of the `alignmentfile` does not include the keyword `TSTART`, then `acis_process_events` exits with an error message.

vi. Columns:
If HDU $h_{\text{alignment}}$ of the `alignmentfile` does not include the columns `DY`, `DZ`, and `DTHETA` then `acis_process_events` exits with an error message.

vii. Sequential:
If more than one valid `alignmentfile` is specified and the values `TSTART` are not in increasing order, then `acis_process_events` exits with an error message.

8. `badpixfile`:

(a) Validation:

i. Existence:
If

$$\texttt{badpixfile} \neq \text{none and} \quad (92)$$
$$\texttt{badpixfile} \neq \text{NONE} \quad (93)$$

and the `badpixfile` does not exist, then `badpixfile` is changed to “none” and `acis_process_events` produces a warning message.

ii. Permission:
If

$$\texttt{badpixfile} \neq \text{none and} \tag{94}$$
$$\texttt{badpixfile} \neq \text{NONE} \tag{95}$$

and the file permissions do not allow it to be read, then `badpixfile` is changed to "none" and `acis_process_events` produces a warning message.

iii. `CONTENT`:
If

$$\texttt{badpixfile} \neq \text{none and} \tag{96}$$
$$\texttt{badpixfile} \neq \text{NONE} \tag{97}$$

and the `badpixfile` does not have one or more HDUs h_{badpix} with the keyword

$$\texttt{CONTENT} = \text{BADPIX or} \tag{98}$$
$$\texttt{CONTENT} = \text{CDB\_ACIS\_BADPIX,} \tag{99}$$

then `badpixfile` is changed to "none" and `acis_process_events` produces a warning message.

iv. Keyword:
If

$$\texttt{badpixfile} \neq \text{none and} \tag{100}$$
$$\texttt{badpixfile} \neq \text{NONE} \tag{101}$$

and the HDU(s) h_{badpix} of the `badpixfile` do not include the keyword `CCD_ID`, then `badpixfile` is changed to "none" and `acis_process_events` produces a warning message. Hereafter this keyword is referred to as $\texttt{CCD\_ID}_{\text{badpix}}$.

v. Columns:
If

$$\texttt{badpixfile} \neq \text{none and} \tag{102}$$
$$\texttt{badpixfile} \neq \text{NONE} \tag{103}$$

and the HDU(s) h_{badpix} of the `badpixfile` do not include the columns `CHIPX`, `CHIPY`, `TIME`, `TIME_STOP`, and `STATUS`, then `badpixfile` is changed to "none" and `acis_process_events` produces a warning message. Hereafter these columns are referred to as $\texttt{CHIPX}_{\text{badpix}}$, $\texttt{CHIPY}_{\text{badpix}}$, $\texttt{TIME}_{\text{badpix}}$, $\texttt{TIME\_STOP}_{\text{badpix}}$, and $\texttt{STATUS}_{\text{badpix}}$, respectively.

9. `ctifile`:

(a) Validation:
If

$$\texttt{ctifile} \neq \text{caldb and} \tag{104}$$
$$\texttt{ctifile} \neq \text{CALDB,} \tag{105}$$

then

i. Existence:
If the `ctifile` does not exist, then `apply_cti` is changed to "no" and `acis_process_events` produces a warning message.

ii. Permission:
If the `ctifile` exists and the file permissions do not allow it to be read, then `apply_cti` is changed to "no" and `acis_process_events` produces a warning message.

iii. `CONTENT`:
If the `ctifile` does not have one or more HDUs $h_{\rm cti}$ with the keyword

$$\texttt{CONTENT} = \text{CDB\_ACIS\_CTI}, \tag{106}$$

then `apply_cti` is changed to "no" and `acis_process_events` produces a warning message.

iv. Columns:
If the first such HDU of the `ctifile` does not include the columns `CCD_ID`, `CHIPX_LO`, `CHIPX_HI`, `CHIPY_LO`, `CHIPY_HI`, `PHA`, `VOLUME_X`, `VOLUME_Y`, `FRCTRLX`, `FRCTRLY`, `TCTIX`, and `TCTIY`, then `apply_cti` is changed to "no" and `acis_process_events` produces a warning message.

10. `clobber`:

(a) Lowercase:
The parameter string is converted to contain only lower case letters.

(b) Validation:

i. Setting:
If

$$\texttt{clobber} \neq \text{yes and} \tag{107}$$
$$\texttt{clobber} \neq \text{no,} \tag{108}$$

then `clobber` is changed to "no" and `acis_process_events` produces a warning message.

ii. Permission:
If

$$\texttt{clobber} = \text{yes} \tag{109}$$

and the `outfile` exists and the file permissions of the `outfile` do not allow it to be overwritten, then `acis_process_events` exits with an error message.

iii. Don't overwrite:
If

$$\texttt{clobber} = \text{no} \tag{110}$$

and the `outfile` exists, then `acis_process_events` exits with an error message.

11. `pix_adj`:

(a) Lowercase:
The parameter string is converted to contain only lower case letters.

(b) Validation:

i. Setting:
If

$$\texttt{pix\_adj} \neq \text{centroid and} \tag{111}$$
$$\texttt{pix\_adj} \neq \text{edser and} \tag{112}$$
$$\texttt{pix\_adj} \neq \text{none and} \tag{113}$$
$$\texttt{pix\_adj} \neq \text{randomize,} \tag{114}$$

then `pix_adj` is changed to "none" and `acis_process_events` produces a warning message.

ii. `OBS_MODE`:
If

$$\texttt{OBS\_MODE} \neq \text{pointing and} \tag{115}$$
$$\texttt{OBS\_MODE} \neq \text{POINTING} \tag{116}$$

and

$$\texttt{pix\_adj} \neq \text{none,} \tag{117}$$

then `pix_adj` is changed to "none" and `acis_process_events` produces a warning message.

iii. `stop`:
If

$$\texttt{pix\_adj} = \text{centroid or} \tag{118}$$
$$\texttt{pix\_adj} = \text{edser or} \tag{119}$$
$$\texttt{pix\_adj} = \text{randomize} \tag{120}$$

and

$$\texttt{stop} \neq \text{sky,} \tag{121}$$

then `pix_adj` is changed to "none" and `acis_process_events` produces a warning message.

iv. `PHAS`:
If

$$\texttt{pix\_adj} = \text{centroid} \tag{122}$$

and the `infile` does not include the column `PHAS`, then `pix_adj` is changed to "none" and `acis_process_events` produces a warning message.

v. `FLTGRADE`:
If

$$\texttt{pix\_adj} = \text{edser} \tag{123}$$

and the `infile` does not include the column `FLTGRADE`, then `pix_adj` is changed to "none" and `acis_process_events` produces a warning message.

12. `subpixfile`:

(a) If

$$\texttt{pix\_adj} = \text{edser,} \tag{124}$$

then

i. Existence:
If the `subpixfile` does not exist, then `pix_adj` is changed to "none" and `acis_process_events` produces a warning message.

ii. Permission:
If the `subpixfile` exists and the file permissions do not allow it to be read, then `pix_adj` is changed to "none" and `acis_process_events` produces a warning message.

iii. Validation:

A. CONTENT:
If the subpixfile does not have one or more HDUs h_{subpix} with the keyword

$$\texttt{CONTENT} = \text{AXAF\_SUBPIX}, \tag{125}$$

then pix_adj is changed to "none" and acis_process_events produces a warning message.

B. Keyword:
If the HDUs h_{subpix} of the subpixfile do not include the keyword CCD_ID, then pix_adj is changed to "none" and acis_process_events produces a warning message.

C. Columns:
If the HDUs h_{subpix} of the subpixfile do not include binary tables with the columns FLTGRADE, NPOINTS, ENERGY, CHIPX_OFFSET, and CHIPY_OFFSET, then pix_adj is changed to "none" and acis_process_events produces a warning message. Hereafter these columns are referred to as $\texttt{FLTGRADE}_{\text{subpix}}$, $\texttt{NPOINTS}_{\text{subpix}}$, $\texttt{ENERGY}_{\text{subpix}}$, $\texttt{CHIPX\_OFFSET}_{\text{subpix}}$, and $\texttt{CHIPY\_OFFSET}_{\text{subpix}}$, respectively.

1.5.2 Initializations

1. Focal-point CCD:
   If

$$\texttt{OBS\_MODE} = \text{pointing or} \tag{126}$$
$$\texttt{OBS\_MODE} = \text{POINTING} \tag{127}$$

   and

$$\texttt{DATAMODE}_{\text{in}} = \text{CC33\_FAINT or} \tag{128}$$
$$\texttt{DATAMODE}_{\text{in}} = \text{CC33\_GRADED}, \tag{129}$$

   then the values of $\texttt{RA\_PNT}_{\text{in}}$ and $\texttt{DEC\_PNT}_{\text{in}}$ are used to determine the CCD_ID associated with the focal point. Hereafter this value is referred to as $\texttt{CCD\_ID}_{\text{focus}}$.*

2. Zeroth-order coordinates:
   If

$$\texttt{OBS\_MODE} = \text{pointing or} \tag{130}$$
$$\texttt{OBS\_MODE} = \text{POINTING} \tag{131}$$

   and

$$\texttt{DATAMODE}_{\text{in}} = \text{CC33\_FAINT or} \tag{132}$$
$$\texttt{DATAMODE}_{\text{in}} = \text{CC33\_GRADED} \tag{133}$$

   and

$$\texttt{CONTENT}_{\text{in}} = \text{TGEVT1}, \tag{134}$$

   then the $\texttt{CHIPY\_ZO}_{\text{in}}$ coordinates are processed to obtain the median value:

$$\texttt{CHIPY\_ZO}_{\text{med}} = \text{median}\left(\texttt{CHIPY\_ZO}_{\text{in}}\right). \tag{135}$$

*The focal point is the location associated with the optical axis in the absence of dither. This location should not be confused with the aim point, which is the location illuminated by an undithered point source provided that the source is not offset from the target location.

The calculation of this CHIPY_ZO statistic is performed using only the events for which

$$\texttt{CHIPY\_ZO} \neq \text{NULL} \tag{136}$$

and the TIME is in a good-time interval.†

3. acaofffile:

   (a) $\texttt{TIME}_{\text{min}}$ and $\texttt{TIME}_{\text{max}}$:
   If

$$\begin{aligned} \texttt{OBS\_MODE} &= \text{pointing or} && (137)\\ \texttt{OBS\_MODE} &= \text{POINTING,} && (138) \end{aligned}$$

   then the acaofffile data are processed to determine the earliest and latest times for which there is aspect information:

$$\begin{aligned} \texttt{TIME}_{\text{min}} &= \min\left(\texttt{TIME}_{\text{acaoff}}\right) \text{ and} && (139)\\ \texttt{TIME}_{\text{max}} &= \max\left(\texttt{TIME}_{\text{acaoff}}\right). && (140) \end{aligned}$$

   (b) If

$$\begin{aligned} \texttt{OBS\_MODE} &= \text{pointing or} && (141)\\ \texttt{OBS\_MODE} &= \text{POINTING} && (142) \end{aligned}$$

   and

$$\begin{aligned} \texttt{DATAMODE} &= \text{CC33\_FAINT or} && (143)\\ \texttt{DATAMODE} &= \text{CC33\_GRADED,} && (144) \end{aligned}$$

   then

   i. $\texttt{RA}_{\text{c}}$ and $\texttt{DEC}_{\text{c}}$:
   The acaofffile data are processed to determine the right ascension and declination coordinates near the center of the dither pattern:

$$\begin{aligned} \texttt{RA}_{\text{c}} &= \text{median}\left(\texttt{RA}_{\text{acaoff}}\right) \text{ and} && (145)\\ \texttt{DEC}_{\text{c}} &= \text{median}\left(\texttt{DEC}_{\text{acaoff}}\right). && (146) \end{aligned}$$

   ii. $\texttt{TIME}_{\text{c}}$:
   The acaofffile data are processed to determine the time $\texttt{TIME}_{\text{c}}$ at which the quantity

$$\cos\left(\texttt{DEC}_{\text{acaoff}}\right)\cos\left(\texttt{DEC}_{\text{c}}\right)\cos\left(\texttt{RA}_{\text{acaoff}} - \texttt{RA}_{\text{c}}\right) + \sin\left(\texttt{DEC}_{\text{acaoff}}\right)\sin\left(\texttt{DEC}_{\text{c}}\right) \tag{147}$$

   is maximized (i.e. the time at which the telescope is pointed the closest to $(\texttt{RA}_{\text{c}}, \texttt{DEC}_{\text{c}})$).

   iii. $\texttt{RA\_ADJ}_{\text{I}}$, $\texttt{DEC\_ADJ}_{\text{I}}$, $\texttt{RA\_ADJ}_{\text{S}}$, $\texttt{DEC\_ADJ}_{\text{S}}$:
   The effective values of RA and DEC are computed for the ACIS-I and ACIS-S arrays. These coordinates are used to determine the values of TIME and CHIPY_ADJ.

   A. ACIS-I aim point:
   For the ACIS-I array, the values of $\texttt{RA\_ADJ}_{\text{I}}$ and $\texttt{DEC\_ADJ}_{\text{I}}$ are initialized assuming that the source is at the ACIS-I aim point [i.e. that $(\texttt{TIME}, \texttt{CCD\_ID}, \texttt{CHIPX}, \texttt{CHIPY}) = (\texttt{TIME}_{\text{c}}, 3, 965, 963)$‡.

†While it would be better to use $\texttt{TIME\_RO} - (\texttt{CHIPY\_ZO} + 1028) \times \texttt{TIMEDEL}$ to compare to the gtis, the value of TIME_RO has not yet been read at this point in the code.

‡As described in the Proposers' Observatory Guide, the location of the aim point on the ACIS-I array has drifted with time. The location used here is within a few dozen pixels of the actual aim point, provided the default SIM_Y and SIM_Z offsets are used.

B. ACIS-S aim point:
For the ACIS-S array, the values of $\texttt{RA\_ADJ}_\mathrm{S}$ and $\texttt{DEC\_ADJ}_\mathrm{S}$ are initialized assuming that the source is at the ACIS-S aim point [i.e. that $(\texttt{TIME}, \texttt{CCD\_ID}, \texttt{CHIPX}, \texttt{CHIPY}) = (\texttt{TIME}_\mathrm{c}, 7, 227, 509)$[§].

C. Target location:
For the CCD at the focal point (i.e. $\texttt{CCD\_ID}_\mathrm{focus}$), the values of `CHIPY` are computed for each row of the `acaofffile`, assuming that the source is at the location specified by $\texttt{RA\_TARG}_\mathrm{in}$ and $\texttt{DEC\_TARG}_\mathrm{in}$. These values of `CHIPY` are referred to as `CHIPY_TARG`. If

$$\begin{aligned} \mathrm{median}\,(\texttt{CHIPY\_TARG}) &\geq 16.5 \text{ and} && (148)\\ \mathrm{median}\,(\texttt{CHIPY\_TARG}) &< 1008.5 \text{ and} && (149)\\ \texttt{CCD\_ID}_\mathrm{focus} &\geq 0 \text{ and} && (150)\\ \texttt{CCD\_ID}_\mathrm{focus} &\leq 3, && (151) \end{aligned}$$

then

$$\begin{aligned} \texttt{RA\_ADJ}_\mathrm{I} &= \texttt{RA\_TARG}_\mathrm{in} \text{ and} && (152)\\ \texttt{DEC\_ADJ}_\mathrm{I} &= \texttt{DEC\_TARG}_\mathrm{in}. && (153) \end{aligned}$$

If

$$\begin{aligned} \mathrm{median}\,(\texttt{CHIPY\_TARG}) &\geq 16.5 \text{ and} && (154)\\ \mathrm{median}\,(\texttt{CHIPY\_TARG}) &< 1008.5 \text{ and} && (155)\\ \texttt{CCD\_ID}_\mathrm{focus} &\geq 4 \text{ and} && (156)\\ \texttt{CCD\_ID}_\mathrm{focus} &\leq 9, && (157) \end{aligned}$$

then

$$\begin{aligned} \texttt{RA\_ADJ}_\mathrm{S} &= \texttt{RA\_TARG}_\mathrm{in} \text{ and} && (158)\\ \texttt{DEC\_ADJ}_\mathrm{S} &= \texttt{DEC\_TARG}_\mathrm{in}. && (159) \end{aligned}$$

1.5.3 Loop over events

The following steps are performed, in sequence, for each event.

1. `STATUS`:

   (a) Exists:
   If HDU h_in of the `infile` includes a 32-bit column named `STATUS`, then

      i. The values of the bits for an event are read from the `infile`.

      ii. The value of `STATUS`[k] is set to zero for bits k = 1–5, 14, 16–19, and 23 (of 0–31), bits that can be set by `acis_process_events`.

      iii. If

      $$\texttt{doevtgrade} = \text{yes}, \qquad (160)$$

      then the value of `STATUS`[20], the other bit that can be set by `acis_process_events`, is set to zero.

   (b) Does not exist:
   If HDU h_in does not include a 32-bit column named `STATUS`, then

[§] Again, the location used here is within a few dozen pixels of the actual aim point, provided the default `SIM_Y` and `SIM_Z` offsets are used.

i. A set of 32 bits are allocated for the event.
ii. The values of the 32 bits are initialized to zero.

2. `EXPNO`:
   (a) Read:
   The value of `EXPNO` for an event is given by $\texttt{EXPNO}_{\rm in}$.
   (b) Validation:
   If

$$\texttt{EXPNO} < 0 \text{ or} \quad (161)$$
$$\texttt{EXPNO} \geq 10^8, \quad (162)$$

   then `acis_process_events` produces a warning upon completion with a count of the total number of events for which one or the other of these conditions is true. These values should not occur.

3. `CCD_ID`:
   (a) Read:
   The value of `CCD_ID` for an event is given by $\texttt{CCD\_ID}_{\rm in}$.
   (b) Validation:
   If

$$\texttt{CCD\_ID} < 0 \text{ or} \quad (163)$$
$$\texttt{CCD\_ID} > 9, \quad (164)$$

   then `acis_process_events` exits with an error message because `CCD_ID`-dependent computations could fail if the value of `CCD_ID` is unphysical.

4. `CHIPX`:
   (a) Read:
   i. Level 0:
   If

$$\texttt{CONTENT}_{\rm in} = \text{EVT0}, \quad (165)$$

   then the value of `CHIPX` for an event is given by

$$\texttt{CHIPX} = \texttt{CCDX}_{\rm in} + 1. \quad (166)$$

   ii. Level 1, 1.5, or 2:
   If

$$\texttt{CONTENT}_{\rm in} = \text{EVT1 or} \quad (167)$$
$$\texttt{CONTENT}_{\rm in} = \text{TGEVT1 or} \quad (168)$$
$$\texttt{CONTENT}_{\rm in} = \text{EVT2}, \quad (169)$$

   then the value of `CHIPX` for an event is given by $\texttt{CHIPX}_{\rm in}$.
   (b) Validation:

i. Unphysical:
If

$$\begin{aligned} \texttt{CHIPX} &< 1 \text{ or} & (170)\\ \texttt{CHIPX} &> 1024, & (171)\end{aligned}$$

then `acis_process_events` exits with an error message because `CHIPX`-dependent computations could fail if the value of `CHIPX` is unphysical.

ii. Unexpected:
If

$$\begin{aligned} \texttt{CHIPX} &= 1 \text{ or} & (172)\\ \texttt{CHIPX} &= 1024, & (173)\end{aligned}$$

then `acis_process_events` produces a warning upon completion with a count of the total number of events for which one or the other of these conditions is true. Although these values are not unphysical, they should not occur.

5. `NODE_ID`:

(a) Calculate:
The `NODE_ID` of an event is given by

$$\texttt{NODE\_ID} = \text{int}\left(\frac{\texttt{CHIPX} - 1}{256}\right), \qquad (174)$$

where "int" means the integer portion of (i.e. truncate or round down) the quantity in parentheses.

6. `CHIPY`:

(a) Read:

i. Level 0:
If

$$\texttt{CONTENT}_{\text{in}} = \text{EVT0}, \qquad (175)$$

then

A. TE mode:
If

$$\begin{aligned} \texttt{DATAMODE}_{\text{in}} &= \text{FAINT or} & (176)\\ \texttt{DATAMODE}_{\text{in}} &= \text{FAINT\_BIAS or} & (177)\\ \texttt{DATAMODE}_{\text{in}} &= \text{GRADED or} & (178)\\ \texttt{DATAMODE}_{\text{in}} &= \text{VFAINT}, & (179)\end{aligned}$$

then the value of `CHIPY` for an event is given by

$$\texttt{CHIPY} = \texttt{CCDY}_{\text{in}} + 1. \qquad (180)$$

B. CC mode:
If

$$\begin{aligned} \texttt{DATAMODE}_{\text{in}} &= \text{CC33\_FAINT or} & (181)\\ \texttt{DATAMODE}_{\text{in}} &= \text{CC33\_GRADED}, & (182)\end{aligned}$$

then the value of `CHIPY` for an event is given by

$$\texttt{CHIPY} = \texttt{TROW}_{\text{in}} + 1. \qquad (183)$$

ii. Level 1, 1.5, or 2:
If

$$\texttt{CONTENT}_{\rm in} = \text{EVT1 or} \quad (184)$$
$$\texttt{CONTENT}_{\rm in} = \text{TGEVT1 or} \quad (185)$$
$$\texttt{CONTENT}_{\rm in} = \text{EVT2,} \quad (186)$$

then the value of `CHIPY` for an event is given by $\texttt{CHIPY}_{\rm in}$.

(b) Validation:

i. Unphysical:

A. TE mode:
If

$$\texttt{DATAMODE}_{\rm in} = \text{FAINT or} \quad (187)$$
$$\texttt{DATAMODE}_{\rm in} = \text{FAINT\_BIAS or} \quad (188)$$
$$\texttt{DATAMODE}_{\rm in} = \text{GRADED or} \quad (189)$$
$$\texttt{DATAMODE}_{\rm in} = \text{VFAINT} \quad (190)$$

and

$$\texttt{CHIPY} < 1 \text{ or} \quad (191)$$
$$\texttt{CHIPY} > 1024, \quad (192)$$

then `acis_process_events` exits with an error message because `CHIPY`-dependent computations could fail if the value of `CHIPY` is unphysical.

B. CC mode:
If

$$\texttt{DATAMODE}_{\rm in} = \text{CC33\_FAINT or} \quad (193)$$
$$\texttt{DATAMODE}_{\rm in} = \text{CC33\_GRADED} \quad (194)$$

and

$$\texttt{CHIPY} < 1 \text{ or} \quad (195)$$
$$\texttt{CHIPY} > 512, \quad (196)$$

then `acis_process_events` exits with an error message because the `CHIPY` value is out of range and `CHIPY`-dependent computations could fail if the value of `CHIPY` is unphysical (especially if it is less than 1).

ii. Unexpected:

A. FAINT, FAINT_BIAS, or GRADED:
If

$$\texttt{DATAMODE}_{\rm in} = \text{FAINT or} \quad (197)$$
$$\texttt{DATAMODE}_{\rm in} = \text{FAINT\_BIAS or} \quad (198)$$
$$\texttt{DATAMODE}_{\rm in} = \text{GRADED} \quad (199)$$

and

$$\texttt{CHIPY} = 1 \text{ or} \quad (200)$$
$$\texttt{CHIPY} = 1024, \quad (201)$$

then `acis_process_events` produces a warning upon completion with a count of the total number of events for which one or the other of these conditions is true. Although these values are not unphysical, they should not occur.

B. VFAINT:
If

$$\texttt{DATAMODE}_{\rm in} = \text{VFAINT} \tag{202}$$

and

$$\begin{aligned} \texttt{CHIPY} &= 1 \text{ or} && (203)\\ \texttt{CHIPY} &= 2 \text{ or} && (204)\\ \texttt{CHIPY} &= 1023 \text{ or} && (205)\\ \texttt{CHIPY} &= 1024, && (206) \end{aligned}$$

then `acis_process_events` produces a warning upon completion with a count of the total number of events for which one or another of these conditions is true. Although these values are not unphysical, they should not occur.

C. CC33_FAINT or CC33_GRADED:
If

$$\begin{aligned} \texttt{DATAMODE}_{\rm in} &= \text{CC33\_FAINT or} && (207)\\ \texttt{DATAMODE}_{\rm in} &= \text{CC33\_GRADED} && (208) \end{aligned}$$

and

$$\begin{aligned} \texttt{CHIPY} &= 1 \text{ or} && (209)\\ \texttt{CHIPY} &= 512, && (210) \end{aligned}$$

then `acis_process_events` produces a warning upon completion with a count of the total number of events for which one or the other of these conditions is true. Although these values are not unphysical, they should not occur.

7. `TG_M`:

(a) CC mode with gratings:
If

$$\begin{aligned} \texttt{OBS\_MODE} &= \text{pointing or} && (211)\\ \texttt{OBS\_MODE} &= \text{POINTING} && (212) \end{aligned}$$

and

$$\begin{aligned} \texttt{DATAMODE}_{\rm in} &= \text{CC33\_FAINT or} && (213)\\ \texttt{DATAMODE}_{\rm in} &= \text{CC33\_GRADED} && (214) \end{aligned}$$

and

$$\texttt{CONTENT}_{\rm in} = \text{TGEVT1}, \tag{215}$$

then

i. Read:
The value of `TG_M` for an event is given by $\texttt{TG\_M}_{\rm in}$.

ii. Validation:

A. If

$$\texttt{TG\_M} < -99, \tag{216}$$

then

$$\texttt{TG\_M} = -99 \tag{217}$$

and `acis_process_events` produces a warning upon completion with a count of the total number of events for which this condition is true. These values should not occur.

B. If

$$\texttt{TG\_M} > 99, \tag{218}$$

then

$$\texttt{TG\_M} = 99 \tag{219}$$

and `acis_process_events` produces a warning upon completion with a count of the total number of events for which this condition is true. These values should not occur.

8. `CHIPY_TG`:

(a) CC mode with gratings:
If

$$\texttt{OBS\_MODE} = \text{pointing or} \tag{220}$$
$$\texttt{OBS\_MODE} = \text{POINTING} \tag{221}$$

and

$$\texttt{DATAMODE}_{\text{in}} = \text{CC33\_FAINT or} \tag{222}$$
$$\texttt{DATAMODE}_{\text{in}} = \text{CC33\_GRADED} \tag{223}$$

and

$$\texttt{CONTENT}_{\text{in}} = \text{TGEVT1}, \tag{224}$$

then

i. Read:
The value of `CHIPY_TG` for an event is given by $\texttt{CHIPY\_TG}_{\text{in}}$.

ii. Validation:

A. If

$$\texttt{TG\_M} > -99 \text{ and} \tag{225}$$
$$\texttt{TG\_M} < 99 \text{ and} \tag{226}$$
$$\texttt{CHIPY\_TG} \neq \text{NULL} \tag{227}$$

and

$$\texttt{CHIPY\_TG} \leq 0 \text{ or} \tag{228}$$
$$\texttt{CHIPY\_TG} \geq 1025, \tag{229}$$

then `acis_process_events` exits with an error message because `CHIPY_TG`-dependent computations could fail if the value of `CHIPY_TG` is unphysical.

B. If

$$\mathtt{TG\_M} > -99 \text{ and} \tag{230}$$
$$\mathtt{TG\_M} < 99 \text{ and} \tag{231}$$
$$\mathtt{CHIPY\_TG} \neq \text{NULL and} \tag{232}$$
$$\mathtt{CHIPY\_TG} < 1, \tag{233}$$

then

$$\mathtt{CHIPY\_TG} = 1. \tag{234}$$

C. If

$$\mathtt{TG\_M} > -99 \text{ and} \tag{235}$$
$$\mathtt{TG\_M} < 99 \text{ and} \tag{236}$$
$$\mathtt{CHIPY\_TG} \neq \text{NULL and} \tag{237}$$
$$\mathtt{CHIPY\_TG} > 1024, \tag{238}$$

then

$$\mathtt{CHIPY\_TG} = 1024. \tag{239}$$

9. `CHIPY_ZO`:

(a) CC mode with gratings:
If

$$\mathtt{OBS\_MODE} = \text{pointing or} \tag{240}$$
$$\mathtt{OBS\_MODE} = \text{POINTING} \tag{241}$$

and

$$\mathtt{DATAMODE}_{\text{in}} = \text{CC33\_FAINT or} \tag{242}$$
$$\mathtt{DATAMODE}_{\text{in}} = \text{CC33\_GRADED} \tag{243}$$

and

$$\mathtt{CONTENT}_{\text{in}} = \text{TGEVT1}, \tag{244}$$

then

i. Read:
The value of `CHIPY_ZO` for an event is given by $\mathtt{CHIPY\_ZO}_{\text{in}}$.

10. `TIME_RO`:

(a) CC mode:
If

$$\mathtt{DATAMODE}_{\text{in}} = \text{CC33\_FAINT or} \tag{245}$$
$$\mathtt{DATAMODE}_{\text{in}} = \text{CC33\_GRADED}, \tag{246}$$

then

i. Read:

A. Level 0:
If

$$\texttt{CONTENT}_{\rm in} = \text{EVT0}, \tag{247}$$

then the value of TIME_RO for an event is given by $\texttt{TIME}_{\rm in}$.

B. Level 1, 1.5, or 2:
If

$$\texttt{CONTENT}_{\rm in} = \text{EVT1 or} \tag{248}$$
$$\texttt{CONTENT}_{\rm in} = \text{TGEVT1 or} \tag{249}$$
$$\texttt{CONTENT}_{\rm in} = \text{EVT2} \tag{250}$$

and

$$\texttt{TIME\_RO}_{\rm in} > 0, \tag{251}$$

then

$$\texttt{TIME\_RO} = \texttt{TIME\_RO}_{\rm in}. \tag{252}$$

If

$$\texttt{CONTENT}_{\rm in} = \text{EVT1 or} \tag{253}$$
$$\texttt{CONTENT}_{\rm in} = \text{TGEVT1 or} \tag{254}$$
$$\texttt{CONTENT}_{\rm in} = \text{EVT2} \tag{255}$$

and

$$\texttt{TIME\_RO}_{\rm in} = 0, \tag{256}$$

then

$$\texttt{TIME\_RO} = \texttt{TIME}_{\rm in}. \tag{257}$$

ii. Validation:
If

$$\texttt{TIME\_RO} < 0 \text{ or} \tag{258}$$
$$\texttt{TIME\_RO} \geq 3 \times 10^9, \tag{259}$$

then acis_process_events produces a warning upon completion with a count of the total number of events for which one or the other of these conditions is true. These values should not occur.

11. TIME and CHIPY_ADJ:

(a) Read or calculate:

i. TE mode:
If

$$\texttt{DATAMODE}_{\rm in} = \text{FAINT or} \tag{260}$$
$$\texttt{DATAMODE}_{\rm in} = \text{FAINT\_BIAS or} \tag{261}$$
$$\texttt{DATAMODE}_{\rm in} = \text{GRADED or} \tag{262}$$
$$\texttt{DATAMODE}_{\rm in} = \text{VFAINT}, \tag{263}$$

then

$$\mathtt{TIME} = \mathtt{TIME}_{\rm in} \text{ and} \tag{264}$$
$$\mathtt{CHIPY\_ADJ} = \mathtt{CHIPY}. \tag{265}$$

ii. Pointing CC mode without grating data:
If

$$\mathtt{OBS\_MODE} = \text{pointing or} \tag{266}$$
$$\mathtt{OBS\_MODE} = \text{POINTING} \tag{267}$$

and

$$\mathtt{DATAMODE}_{\rm in} = \text{CC33\_FAINT or} \tag{268}$$
$$\mathtt{DATAMODE}_{\rm in} = \text{CC33\_GRADED} \tag{269}$$

and

$$\mathtt{CONTENT}_{\rm in} = \text{EVT0 or} \tag{270}$$
$$\mathtt{CONTENT}_{\rm in} = \text{EVT1 or} \tag{271}$$
$$\mathtt{CONTENT}_{\rm in} = \text{EVT2,} \tag{272}$$

then

A. TIME′:
The approximate time of arrival

$$\mathtt{TIME}' = \mathtt{TIME\_RO} - (512 + 1028) \times \mathtt{TIMEDEL}_{\rm in}. \tag{273}$$

B. CHIPY_ADJ′:
If

$$\mathtt{CCD\_ID}_{\rm focus} \geq 0 \text{ and} \tag{274}$$
$$\mathtt{CCD\_ID}_{\rm focus} \leq 3, \tag{275}$$

then CHIPY_ADJ′ (the approximate value of CHIPY_ADJ) is given by the CHIPY location (on the focal-point CCD) of the coordinates $\mathtt{RA\_ADJ}_{\rm I}$ and $\mathtt{DEC\_ADJ}_{\rm I}$ using the orientation of the telescope (i.e. RA, DEC, and ROLL) and the SIM (i.e. DY, DZ, and DTHETA) at the time TIME′. If $\mathtt{TIME}' < \mathtt{TIME}_{\rm min}$ or $\mathtt{TIME}' \geq \mathtt{TIME}_{\rm max}$, then $\mathtt{TIME}_{\rm c}$ is used instead of TIME′. If

$$\mathtt{CCD\_ID}_{\rm focus} \geq 4 \text{ and} \tag{276}$$
$$\mathtt{CCD\_ID}_{\rm focus} \leq 9, \tag{277}$$

then CHIPY_ADJ′ is given by the CHIPY location (on the focal-point CCD) of the coordinates $\mathtt{RA\_ADJ}_{\rm S}$ and $\mathtt{DEC\_ADJ}_{\rm S}$ using the orientation of the telescope (i.e. RA, DEC, and ROLL) and the SIM (i.e. DY, DZ, and DTHETA) at the time TIME′. If $\mathtt{TIME}' < \mathtt{TIME}_{\rm min}$ or $\mathtt{TIME}' \geq \mathtt{TIME}_{\rm max}$, then $\mathtt{TIME}_{\rm c}$ is used instead of TIME′.

C. TIME:
The value of CHIPY_ADJ′ is used to obtain a better estimate of the time of arrival

$$\mathtt{TIME} = \mathtt{TIME\_RO} - (\mathtt{CHIPY\_ADJ}' + 1028) \times \mathtt{TIMEDEL}_{\rm in}. \tag{278}$$

D. CHIPY_ADJ:
If

$$\mathtt{CCD\_ID}_{\rm focus} \geq 0 \text{ and} \quad (279)$$
$$\mathtt{CCD\_ID}_{\rm focus} \leq 3, \quad (280)$$

then the value of CHIPY_ADJ is given by the CHIPY location (on the focal-point CCD) of the coordinates $\mathtt{RA\_ADJ}_{\rm I}$ and $\mathtt{DEC\_ADJ}_{\rm I}$ using the orientation of the telescope (i.e. RA, DEC, and ROLL) and the SIM (i.e. DY, DZ, and DTHETA) at the time TIME. If $\mathtt{TIME} < \mathtt{TIME}_{\rm min}$ or $\mathtt{TIME} \geq \mathtt{TIME}_{\rm max}$, then $\mathtt{TIME}_{\rm c}$ is used instead of TIME. If

$$\mathtt{CCD\_ID}_{\rm focus} \geq 4 \text{ and} \quad (281)$$
$$\mathtt{CCD\_ID}_{\rm focus} \leq 9, \quad (282)$$

then the value of CHIPY_ADJ is given by the CHIPY location (on the focal-point CCD) of the coordinates $\mathtt{RA\_ADJ}_{\rm S}$ and $\mathtt{DEC\_ADJ}_{\rm S}$ using the orientation of the telescope (i.e. RA, DEC, and ROLL) and the SIM (i.e. DY, DZ, and DTHETA) at the time TIME. If $\mathtt{TIME} < \mathtt{TIME}_{\rm min}$ or $\mathtt{TIME} \geq \mathtt{TIME}_{\rm max}$, then $\mathtt{TIME}_{\rm c}$ is used instead of TIME.

iii. Pointing CC mode with ACIS-S grating data:
If

$$\mathtt{OBS\_MODE} = \text{pointing or} \quad (283)$$
$$\mathtt{OBS\_MODE} = \text{POINTING} \quad (284)$$

and

$$\mathtt{DATAMODE}_{\rm in} = \text{CC33\_FAINT or} \quad (285)$$
$$\mathtt{DATAMODE}_{\rm in} = \text{CC33\_GRADED} \quad (286)$$

and

$$\mathtt{CONTENT}_{\rm in} = \text{TGEVT1} \quad (287)$$

and

$$\mathtt{CCD\_ID}_{\rm focus} \geq 4 \text{ and} \quad (288)$$
$$\mathtt{CCD\_ID}_{\rm focus} \leq 9, \quad (289)$$

then

A. Source events in GTIs:
If

$$\mathtt{TG\_M} > -99 \text{ and} \quad (290)$$
$$\mathtt{TG\_M} < 99 \text{ and} \quad (291)$$
$$\mathtt{CHIPY\_TG} \neq \text{NULL and} \quad (292)$$
$$\mathtt{TIME\_RO} - (\mathtt{CHIPY\_TG} + 1028) \times \mathtt{TIMEDEL}_{\rm in} \geq \mathtt{TIME}_{\rm min} \text{ and} \quad (293)$$
$$\mathtt{TIME\_RO} - (\mathtt{CHIPY\_TG} + 1028) \times \mathtt{TIMEDEL}_{\rm in} < \mathtt{TIME}_{\rm max} \quad (294)$$

and $\mathtt{TIME\_RO} - (\mathtt{CHIPY\_TG} + 1028) \times \mathtt{TIMEDEL}_{\rm in}$ is in a good-time interval, then

$$\mathtt{CHIPY\_ADJ} = \mathtt{CHIPY\_TG} \text{ and} \quad (295)$$
$$\mathtt{TIME} = \mathtt{TIME\_RO} - (\mathtt{CHIPY\_ADJ} + 1028) \times \mathtt{TIMEDEL}_{\rm in}. \quad (296)$$

B. Source events not in GTIs:
If

$$\begin{aligned} \texttt{TG\_M} &> -99 \text{ and} && (297)\\ \texttt{TG\_M} &< 99 && (298)\end{aligned}$$

and

$$\begin{aligned} \texttt{CHIPY\_TG} &= \text{NULL or} && (299)\\ \texttt{TIME\_RO} - (\texttt{CHIPY\_TG} + 1028) \times \texttt{TIMEDEL}_{\text{in}} &< \texttt{TIME}_{\text{min}} \text{ or} && (300)\\ \texttt{TIME\_RO} - (\texttt{CHIPY\_TG} + 1028) \times \texttt{TIMEDEL}_{\text{in}} &\geq \texttt{TIME}_{\text{max}} && (301)\end{aligned}$$

or $\texttt{TIME\_RO} - (\texttt{CHIPY\_TG} + 1028) \times \texttt{TIMEDEL}_{\text{in}}$ is not in a good-time interval, then

$$\begin{aligned} \texttt{CHIPY\_ADJ} &= \texttt{CHIPY\_ZO}_{\text{med}} \text{ and} && (302)\\ \texttt{TIME} &= \texttt{TIME\_RO} - (\texttt{CHIPY\_ADJ} + 1028) \times \texttt{TIMEDEL}_{\text{in}}. && (303)\end{aligned}$$

C. All background events:
If

$$\begin{aligned} \texttt{TG\_M} &= -99 \text{ or} && (304)\\ \texttt{TG\_M} &= 99 && (305)\end{aligned}$$

then

$$\begin{aligned} \texttt{CHIPY\_ADJ} &= 512 \text{ and} && (306)\\ \texttt{TIME} &= \texttt{TIME\_RO} - (\texttt{CHIPY\_ADJ} + 1028) \times \texttt{TIMEDEL}_{\text{in}}. && (307)\end{aligned}$$

iv. Pointing CC mode with ACIS-I grating data:
If

$$\begin{aligned} \texttt{OBS\_MODE} &= \text{pointing or} && (308)\\ \texttt{OBS\_MODE} &= \text{POINTING} && (309)\end{aligned}$$

and

$$\begin{aligned} \texttt{DATAMODE}_{\text{in}} &= \text{CC33\_FAINT or} && (310)\\ \texttt{DATAMODE}_{\text{in}} &= \text{CC33\_GRADED} && (311)\end{aligned}$$

and

$$\texttt{CONTENT}_{\text{in}} = \text{TGEVT1} \qquad (312)$$

and

$$\begin{aligned} \texttt{CCD\_ID}_{\text{focus}} &\geq 0 \text{ and} && (313)\\ \texttt{CCD\_ID}_{\text{focus}} &\leq 3, && (314)\end{aligned}$$

then

A. $\texttt{TIME}'$:
The approximate time of arrival

$$\texttt{TIME}' = \texttt{TIME\_RO} - (512 + 1028) \times \texttt{TIMEDEL}_{\text{in}}. \qquad (315)$$

B. CHIPY_ADJ′:
CHIPY_ADJ′ (the approximate value of CHIPY_ADJ) is given by the CHIPY location (on the focal-point CCD) of the coordinates $\mathtt{RA\_ADJ}_{\rm I}$ and $\mathtt{DEC\_ADJ}_{\rm I}$ using the orientation of the telescope (i.e. RA, DEC, and ROLL) and the SIM (i.e. DY, DZ, and DTHETA) at the time TIME′. If TIME′ is not in a good-time interval or $\mathtt{TIME}' < \mathtt{TIME}_{\rm min}$ or $\mathtt{TIME}' \geq \mathtt{TIME}_{\rm max}$, then $\mathtt{TIME}_{\rm c}$ is used instead of TIME′.

C. TIME:
The value of CHIPY_ADJ′ is used to obtain a better estimate of the time of arrival

$$\mathtt{TIME} = \mathtt{TIME\_RO} - (\mathtt{CHIPY\_ADJ}' + 1028) \times \mathtt{TIMEDEL}_{\rm in}. \quad (316)$$

D. CHIPY_ADJ:
The value of CHIPY_ADJ is given by the CHIPY location (on the focal-point CCD) of the coordinates $\mathtt{RA\_ADJ}_{\rm I}$ and $\mathtt{DEC\_ADJ}_{\rm I}$ using the orientation of the telescope (i.e. RA, DEC, and ROLL) and the SIM (i.e. DY, DZ, and DTHETA) at the time TIME. If TIME is not in a good-time interval or $\mathtt{TIME} < \mathtt{TIME}_{\rm min}$ or $\mathtt{TIME} \geq \mathtt{TIME}_{\rm max}$, then $\mathtt{TIME}_{\rm c}$ is used instead of TIME.

v. Secondary CC mode:
If

$$\mathtt{OBS\_MODE} \neq \text{pointing and} \quad (317)$$
$$\mathtt{OBS\_MODE} \neq \text{POINTING}, \quad (318)$$

then

A. TIME:

$$\mathtt{TIME} = \mathtt{TIME\_RO} - (512 + 1028) \times \mathtt{TIMEDEL}_{\rm in}. \quad (319)$$

B. CHIPY_ADJ:

$$\mathtt{CHIPY\_ADJ} = 512. \quad (320)$$

(b) Validation:

i. If

$$\mathtt{TIME} < 0 \text{ or} \quad (321)$$
$$\mathtt{TIME} \geq 3 \times 10^9, \quad (322)$$

then acis_process_events produces a warning upon completion with a count of the total number of events for which one or the other of these conditions is true. These values should not occur.

ii. If

$$\mathtt{CHIPY\_ADJ} < 0.5 \text{ or} \quad (323)$$
$$\mathtt{CHIPY\_ADJ} \geq 1024.5, \quad (324)$$

then acis_process_events exits with an error message because CHIPY_ADJ-dependent computations could fail if the value of CHIPY_ADJ is unphysical.

12. Bad pixel:

(a) If

$$\mathtt{badpixfile} \neq \text{none and} \quad (325)$$
$$\mathtt{badpixfile} \neq \text{NONE} \quad (326)$$

and the badpixfile includes a valid HDU $h_{\rm badpix}$ where $\mathtt{CCD\_ID}_{\rm badpix} = \mathtt{CCD\_ID}$, then the HDU $h_{\rm badpix}$ is searched as follows to determine if the event should have one or more STATUS bits set to one.

i. If $\texttt{DATAMODE}_{\text{in}}$ = CC33_FAINT or $\texttt{DATAMODE}_{\text{in}}$ = CC33_GRADED and there are one or more rows r in HDU h_{badpix} where

$$\begin{aligned}\texttt{CHIPX} &\geq \texttt{CHIPX}_{\text{badpix},r}[0] \text{ and} &(327)\\ \texttt{CHIPX} &\leq \texttt{CHIPX}_{\text{badpix},r}[1] \text{ and} &(328)\\ \texttt{TIME} &\geq \texttt{TIME}_{\text{badpix},r} \text{ and} &(329)\\ \texttt{TIME} &< \texttt{TIME\_STOP}_{\text{badpix},r} &(330)\end{aligned}$$

and

$$\begin{aligned}\texttt{STATUS}_{\text{badpix},r}[5] &= 1 \text{ or} &(331)\\ \texttt{STATUS}_{\text{badpix},r}[6] &= 1 \text{ or} &(332)\\ \texttt{STATUS}_{\text{badpix},r}[9] &= 1, &(333)\end{aligned}$$

then

$$\texttt{STATUS}[0] = 1 \quad (334)$$

for the event. Here $\texttt{CCD\_ID}_{\text{badpix}}$ is the value of the keyword `CCD_ID` in HDU h_{badpix} of the `badpixfile`, $\texttt{CHIPX}_{\text{badpix},r}[0]$ and $\texttt{CHIPX}_{\text{badpix},r}[1]$ are the first and second values in the vector column named `CHIPX` of row r of HDU h_{badpix} of the `badpixfile`, and $\texttt{TIME}_{\text{badpix},r}$ and $\texttt{TIME\_STOP}_{\text{badpix},r}$ are the values in the columns named `TIME` and `TIME_STOP`, respectively, of row r of HDU h_{badpix} of the `badpixfile`.

ii. If $\texttt{DATAMODE}_{\text{in}}$ = CC33_FAINT or $\texttt{DATAMODE}_{\text{in}}$ = CC33_GRADED and there are one or more rows r in HDU h_{badpix} where

$$\begin{aligned}\texttt{CHIPX} &\geq \texttt{CHIPX}_{\text{badpix},r}[0] \text{ and} &(335)\\ \texttt{CHIPX} &\leq \texttt{CHIPX}_{\text{badpix},r}[1] \text{ and} &(336)\\ \texttt{TIME} &\geq \texttt{TIME}_{\text{badpix},r} \text{ and} &(337)\\ \texttt{TIME} &< \texttt{TIME\_STOP}_{\text{badpix},r} &(338)\end{aligned}$$

and

$$\begin{aligned}\texttt{STATUS}_{\text{badpix},r}[0] &= 1 \text{ or} &(339)\\ \texttt{STATUS}_{\text{badpix},r}[1] &= 1 \text{ or} &(340)\\ \texttt{STATUS}_{\text{badpix},r}[7] &= 1 \text{ or} &(341)\\ \texttt{STATUS}_{\text{badpix},r}[11] &= 1 \text{ or} &(342)\\ \texttt{STATUS}_{\text{badpix},r}[12] &= 1 \text{ or} &(343)\\ \texttt{STATUS}_{\text{badpix},r}[13] &= 1 \text{ or} &(344)\\ \texttt{STATUS}_{\text{badpix},r}[14] &= 1 \text{ or} &(345)\\ \texttt{STATUS}_{\text{badpix},r}[16] &= 1, &(346)\end{aligned}$$

then

$$\texttt{STATUS}[4] = 1 \quad (347)$$

for the event.

iii. If $\texttt{DATAMODE}_{\text{in}}$ = CC33_FAINT or $\texttt{DATAMODE}_{\text{in}}$ = CC33_GRADED and there are one or more rows r in HDU h_{badpix} where

$$\begin{aligned}\texttt{CHIPX} &\geq \texttt{CHIPX}_{\text{badpix},r}[0] \text{ and} &(348)\\ \texttt{CHIPX} &\leq \texttt{CHIPX}_{\text{badpix},r}[1] \text{ and} &(349)\\ \texttt{TIME} &\geq \texttt{TIME}_{\text{badpix},r} \text{ and} &(350)\\ \texttt{TIME} &< \texttt{TIME\_STOP}_{\text{badpix},r} &(351)\end{aligned}$$

and

$$\mathtt{STATUS}_{\mathrm{badpix},r}[8] = 1 \text{ or} \tag{352}$$
$$\mathtt{STATUS}_{\mathrm{badpix},r}[10] = 1, \tag{353}$$

then

$$\mathtt{STATUS}[5] = 1 \tag{354}$$

for the event.

iv. If $\mathtt{DATAMODE}_{\mathrm{in}}$ = CC33_FAINT or $\mathtt{DATAMODE}_{\mathrm{in}}$ = CC33_GRADED and there are one or more rows r in HDU h_{badpix} where

$$\mathtt{CHIPX} \geq \mathtt{CHIPX}_{\mathrm{badpix},r}[0] \text{ and} \tag{355}$$
$$\mathtt{CHIPX} \leq \mathtt{CHIPX}_{\mathrm{badpix},r}[1] \text{ and} \tag{356}$$
$$\mathtt{TIME} \geq \mathtt{TIME}_{\mathrm{badpix},r} \text{ and} \tag{357}$$
$$\mathtt{TIME} < \mathtt{TIME\_STOP}_{\mathrm{badpix},r} \tag{358}$$

and

$$\mathtt{STATUS}_{\mathrm{badpix},r}[3] = 1, \tag{359}$$

then

$$\mathtt{STATUS}[6] = 1 \tag{360}$$

for the event.

v. If $\mathtt{DATAMODE}_{\mathrm{in}}$ = CC33_FAINT or $\mathtt{DATAMODE}_{\mathrm{in}}$ = CC33_GRADED and there are one or more rows r in HDU h_{badpix} where

$$\mathtt{CHIPX} \geq \mathtt{CHIPX}_{\mathrm{badpix},r}[0] \text{ and} \tag{361}$$
$$\mathtt{CHIPX} \leq \mathtt{CHIPX}_{\mathrm{badpix},r}[1] \text{ and} \tag{362}$$
$$\mathtt{TIME} \geq \mathtt{TIME}_{\mathrm{badpix},r} \text{ and} \tag{363}$$
$$\mathtt{TIME} < \mathtt{TIME\_STOP}_{\mathrm{badpix},r} \tag{364}$$

and

$$\mathtt{STATUS}_{\mathrm{badpix},r}[2] = 1 \text{ or} \tag{365}$$
$$\mathtt{STATUS}_{\mathrm{badpix},r}[4] = 1, \tag{366}$$

then

$$\mathtt{STATUS}[8] = 1 \tag{367}$$

for the event.

vi. If $\mathtt{DATAMODE}_{\mathrm{in}}$ = CC33_FAINT or $\mathtt{DATAMODE}_{\mathrm{in}}$ = CC33_GRADED and there are one or more rows r in HDU h_{badpix} where

$$\mathtt{CHIPX} \geq \mathtt{CHIPX}_{\mathrm{badpix},r}[0] \text{ and} \tag{368}$$
$$\mathtt{CHIPX} \leq \mathtt{CHIPX}_{\mathrm{badpix},r}[1] \text{ and} \tag{369}$$
$$\mathtt{TIME} \geq \mathtt{TIME}_{\mathrm{badpix},r} \text{ and} \tag{370}$$
$$\mathtt{TIME} < \mathtt{TIME\_STOP}_{\mathrm{badpix},r} \tag{371}$$

and

$$\mathtt{STATUS}_{\mathrm{badpix},r}[15] = 1, \tag{372}$$

then

$$\mathtt{STATUS}[16] = 1 \tag{373}$$

for the event.

Table 1: Bad-pixel to event STATUS bit mapping

Bad-pixel STATUS bit	Event STATUS bit
0	4
1	4
2	8
3	6
4	8
5	0
6	0
7	4
8	5
9	0
10	5
11	4
12	4
13	4
14	4
15	16
16	4

vii. In summary, the mapping between a bad-pixel `STATUS` bit and the corresponding event `STATUS` bit is listed in Table 1.

13. `PHAS`:

   (a) If HDU 1 of the `infile` includes the column `PHAS`, then

      i. the values of `PHAS` for an event are read from the `infile`.
      ii. If $\texttt{PHAS}[4] <$ the split threshold, then $\texttt{STATUS}[k] = 1$ for bit $k = 1$.
      iii. If $\texttt{PHAS}[4] \leq \texttt{PHAS}[j]$ for one or more $j = 0$–3 or 5–8, then $\texttt{STATUS}[k] = 1$ for bit $k = 1$.
      iv. If $\texttt{PHAS}[j] > 4095$ for one or more $j = 0$–8, then $\texttt{STATUS}[k] = 1$ for bit $k = 2$.

14. `PHAS_ADJ`:

   (a) If HDU 1 of the `infile` includes $\texttt{DATAMODE}_{\rm in}$ = CC33_FAINT and the parameter `apply_cti` = yes and the `ctifile` and `mtlfile` are specified, then the CTI-adjusted pulse heights are computed as follows.

      i. The real-valued arrays for the serial CTI adjustment Δ_x, the parallel CTI adjustment Δ_y, and the adjusted pulse heights `PHAS_ADJ` are initialized such that

$$\Delta_x[j] = 0, \quad (374)$$
$$\Delta_y[j] = 0, \text{ and} \quad (375)$$
$$\texttt{PHAS\_ADJ}[j] = \texttt{PHAS}[j] \quad (376)$$

      for every element $j = 0$–8, where the starting point for the adjusted pulse heights are the unadjusted pulse heights `PHAS`. Note that the values of the unadjusted pulse heights `PHAS` remain unchanged to ensure that it is possible to remove the CTI adjustment or to reapply the adjustment if the algorithm or calibration data are modified.

      ii. The CTI iteration counter n is initialized such that

$$n = 1. \quad (377)$$

iii. The temporary variables Δ'_x, Δ'_y, and $\texttt{PHAS\_ADJ}'$ are set such that

$$\begin{aligned} \Delta'_x[j] &= \Delta_x[j], & (378) \\ \Delta'_y[j] &= \Delta_y[j], \text{ and} & (379) \\ \texttt{PHAS\_ADJ}'[j] &= \texttt{PHAS\_ADJ}[j] & (380) \end{aligned}$$

for each element j.

iv. A. If there is a serial CTI trap-density map in the `ctifile` for `CCD_ID` and `NODE_ID` $= 0$ or 2, then the values of Δ_x are given by

$$\begin{aligned} \Delta_x[0] &= c_x[0]s_x\rho_x[0]V_x[0], & (381) \\ \Delta_x[1] &= c_x[1]s_x\rho_x[1]V_x[1] - c'_x[0]s_x\rho_x[0]V_x[0], & (382) \\ \Delta_x[2] &= c_x[2]s_x\rho_x[2]V_x[2] - c'_x[1]s_x\rho_x[1]V_x[1], & (383) \\ \Delta_x[3] &= c_x[3]s_x\rho_x[3]V_x[3], & (384) \\ \Delta_x[4] &= c_x[4]s_x\rho_x[4]V_x[4] - c'_x[3]s_x\rho_x[3]V_x[3], & (385) \\ \Delta_x[5] &= c_x[5]s_x\rho_x[5]V_x[5] - c'_x[4]s_x\rho_x[4]V_x[4], & (386) \\ \Delta_x[6] &= c_x[6]s_x\rho_x[6]V_x[6], & (387) \\ \Delta_x[7] &= c_x[7]s_x\rho_x[7]V_x[7] - c'_x[6]s_x\rho_x[6]V_x[6], \text{ and} & (388) \\ \Delta_x[8] &= c_x[8]s_x\rho_x[8]V_x[8] - c'_x[7]s_x\rho_x[7]V_x[7], & (389) \end{aligned}$$

where

$$c_x[j] = \begin{cases} 0 & \left\{ \begin{array}{l} \texttt{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] < \text{ split threshold} \\ \quad (\text{for all } j), \end{array} \right. \\ \texttt{FRCTRLX} & \left\{ \begin{array}{l} \texttt{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] \geq \text{ split threshold and} \\ \texttt{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] < \\ \quad \texttt{PHAS}[j-1] + \Delta'_x[j-1] + \Delta'_y[j-1] \\ \quad (\text{for } j = 1,2,4,5,7,8), \end{array} \right. \\ 1 & \left\{ \begin{array}{l} \texttt{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] \geq \text{ split threshold} \\ \quad (\text{for } j = 0,3,6) \\ \texttt{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] \geq \text{ split threshold and} \\ \texttt{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] \geq \\ \quad \texttt{PHAS}[j-1] + \Delta'_x[j-1] + \Delta'_y[j-1] \\ \quad (\text{for } j = 1,2,4,5,7,8), \end{array} \right. \end{cases}$$

$$c'_x[j] = \begin{cases} 0 & \left\{ \begin{array}{l} \texttt{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] < \text{ split threshold or} \\ \texttt{PHAS}[j+1] + \Delta'_x[j+1] + \Delta'_y[j+1] < \text{ split threshold or} \\ j \rightarrow \texttt{CHIPX} = 1, 256, 513, \text{ or } 768 \\ \quad (\text{for } j = 0,1,3,4,6,7), \end{array} \right. \\ \texttt{FRCTRLX} & \left\{ \begin{array}{l} \texttt{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] > \\ \quad \texttt{PHAS}[j+1] + \Delta'_x[j+1] + \Delta'_y[j+1] \text{ and} \\ \texttt{PHAS}[j+1] + \Delta'_x[j+1] + \Delta'_y[j+1] \geq \text{ split threshold} \\ \quad (\text{for } j = 0,1,3,4,6,7), \end{array} \right. \\ 1 & \left\{ \begin{array}{l} \texttt{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] \leq \\ \quad \texttt{PHAS}[j+1] + \Delta'_x[j+1] + \Delta'_y[j+1] \text{ and} \\ \texttt{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] \geq \text{ split threshold} \\ \quad (\text{for } j = 0,1,3,4,6,7), \end{array} \right. \end{cases}$$

$$s_x = 1 + \texttt{TCTIX}\,(T - \texttt{FP\_TEMP0})\,, \qquad (390)$$

$$\left\{ \begin{array}{l} s_x \text{ is a temperature dependent scaling factor,} \\ \texttt{TCTIX} \text{ is the } \texttt{CCD\_ID} \text{ dependent value in the column } \texttt{TCTIX} \text{ of the} \\ \quad \texttt{ctifile}, \\ \texttt{FP\_TEMP0} \text{ is the name of a keyword in the } \texttt{ctifile}, \end{array} \right.$$

$$T = \left(\frac{t' - t'_k}{t'_{k+1} - t'_k}\right)(\texttt{FP\_TEMP}_{k+1} - \texttt{FP\_TEMP}_k) + \texttt{FP\_TEMP}_k, \tag{391}$$

$\{$ T is the time dependent focal plane temperature,

$$t' = t + \texttt{TIMEDEL}_{\text{in}}(\texttt{TIMEPIXR}_{\text{evt}} - 0.5), \tag{392}$$

$\{$ t is the `TIME` of the event,
$\texttt{TIMEPIXR}_{\text{evt}}$ is a keyword in the `infile`,

$$t'_k = \texttt{TIME}_k + \texttt{TIMEDEL}_{\text{mtl}}(\texttt{TIMEPIXR}_{\text{mtl}} - 0.5), \tag{393}$$

$\{$ $\texttt{TIME}_k$ is the k^{th} element of the column `TIME` in the `mtlfile`,
$t'_k \leq t'$,
If $t' < t'_k$ for $k = 0$, then $k = 0$,
$\texttt{FP\_TEMP}_k$ is the k^{th} element of the column `FP_TEMP` in the `mtlfile`,
$\texttt{TIMEDEL}_{\text{mtl}}$ is a keyword in the `mtlfile`,
$\texttt{TIMEPIXR}_{\text{mtl}}$ is a keyword in the `mtlfile`,

$$t'_{k+1} = \texttt{TIME}_{k+1} + \texttt{TIMEDEL}_{\text{mtl}}(\texttt{TIMEPIXR}_{\text{mtl}} - 0.5), \tag{394}$$

$\{$ $\texttt{TIME}_{k+1}$ is the $(k+1)^{\text{th}}$ element of the column `TIME` in the `mtlfile`,
$t'_{k+1} > t'$,
If $t' > t'_k$ for $k = n$, where n is the last element, then $k = n$,
$\texttt{FP\_TEMP}_{k+1}$ is the $(k+1)^{\text{th}}$ element of the column `FP_TEMP` in the `mtlfile`,

$$\rho_x[j] = \text{serial trap density}, \tag{395}$$

$\{$ $\rho_x[j]$ depends upon the `CCD_ID` and upon the `CHIPX` and nint(`CHIPY_ADJ`) coordinates associated with element j of `PHAS_ADJ`[j] (see Fig. 1),

$$V_x[j] = \left(\frac{\texttt{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] - \texttt{PHA}_l}{\texttt{PHA}_{l+1} - \texttt{PHA}_l}\right)(\texttt{VOLUME\_X}_{l+1} - \texttt{VOLUME\_X}_l) + \texttt{VOLUME\_X}_l, \tag{396}$$

$\{$ $\texttt{PHA}_l$ is the l^{th} element of the column `PHA` in the `ctifile`,
$\texttt{PHA}_l$ (and $\texttt{PHA}_{l+1}$) are `CCD_ID` depdendent,
$\texttt{PHA}_l \leq \texttt{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j]$,
If $\texttt{PHA}_l > \texttt{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j]$ for $l = 0$, then $l = 0$,
$\texttt{PHA}_{l+1}$ is the $(l+1)^{\text{th}}$ element of the column `PHA` in the `ctifile`,
$\texttt{PHA}_{l+1} > \texttt{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j]$,
If $\texttt{PHA}_{l+1} \leq \texttt{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j]$ for $l = n$, where n is the last element, then $l = n$,
$\texttt{VOLUME\_X}_l$ is the l^{th} element of the column `VOLUME_X` in the `ctifile`,
$\texttt{VOLUME\_X}_l$, which is `CCD_ID` depdendent, is associated with $\texttt{PHA}_l$,
$\texttt{VOLUME\_X}_{l+1}$ is the $(l+1)^{\text{th}}$ element of the column `VOLUME_X` in the `ctifile`, and
$\texttt{VOLUME\_X}_{l+1}$, which is `CCD_ID` depdendent, is associated with $\texttt{PHA}_{l+1}$

B. If there is a serial CTI trap-density map in the `ctifile` for `CCD_ID` and `NODE_ID` = 1 or 3, then the values of Δ_x are given by

$$\Delta_x[0] = c_x[0]s_x\rho_x[0]V_x[0] - c'_x[1]s_x\rho_x[1]V_x[1], \tag{397}$$
$$\Delta_x[1] = c_x[1]s_x\rho_x[1]V_x[1] - c'_x[2]s_x\rho_x[2]V_x[2], \tag{398}$$
$$\Delta_x[2] = c_x[2]s_x\rho_x[2]V_x[2], \tag{399}$$
$$\Delta_x[3] = c_x[3]s_x\rho_x[3]V_x[3] - c'_x[4]s_x\rho_x[4]V_x[4], \tag{400}$$
$$\Delta_x[4] = c_x[4]s_x\rho_x[4]V_x[4] - c'_x[5]s_x\rho_x[5]V_x[5], \tag{401}$$
$$\Delta_x[5] = c_x[5]s_x\rho_x[5]V_x[5], \tag{402}$$

$$
\begin{aligned}
\Delta_x[6] &= c_x[6]s_x\rho_x[6]V_x[6] - c'_x[7]s_x\rho_x[7]V_x[7], && (403)\\
\Delta_x[7] &= c_x[7]s_x\rho_x[7]V_x[7] - c'_x[8]s_x\rho_x[8]V_x[8], \text{ and} && (404)\\
\Delta_x[8] &= c_x[8]s_x\rho_x[8]V_x[8], && (405)
\end{aligned}
$$

where

$$
c_x[j] = \begin{cases}
0 & \begin{cases} \texttt{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] < \text{ split threshold} \\ \quad \text{(for all } j\text{),} \end{cases} \\
\texttt{FRCTRLX} & \begin{cases} \texttt{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] \geq \text{ split threshold and} \\ \texttt{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] < \\ \quad \texttt{PHAS}[j+1] + \Delta'_x[j+1] + \Delta'_y[j+1] \\ \quad \text{(for } j = 0,1,3,4,6,7\text{),} \end{cases} \\
1 & \begin{cases} \texttt{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] \geq \text{ split threshold} \\ \quad \text{(for } j = 2,5,8\text{)} \\ \texttt{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] \geq \text{ split threshold and} \\ \texttt{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] \geq \\ \quad \texttt{PHAS}[j+1] + \Delta'_x[j+1] + \Delta'_y[j+1] \\ \quad \text{(for } j = 0,1,3,4,6,7\text{),} \end{cases}
\end{cases}
$$

$$
c'_x[j] = \begin{cases}
0 & \begin{cases} \texttt{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] < \text{ split threshold or} \\ \texttt{PHAS}[j-1] + \Delta'_x[j-1] + \Delta'_y[j-1] < \text{ split threshold or} \\ j \rightarrow \texttt{CHIPX} = 257, 512, 769, \text{ or } 1024 \\ \quad \text{(for } j = 1,2,4,5,7,8\text{),} \end{cases} \\
\texttt{FRCTRLX} & \begin{cases} \texttt{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] > \\ \quad \texttt{PHAS}[j-1] + \Delta'_x[j-1] + \Delta'_y[j-1] \text{ and} \\ \texttt{PHAS}[j-1] + \Delta'_x[j-1] + \Delta'_y[j-1] \geq \text{ split threshold} \\ \quad \text{(for } j = 1,2,4,5,7,8\text{),} \end{cases} \\
1 & \begin{cases} \texttt{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] \leq \\ \quad \texttt{PHAS}[j-1] + \Delta'_x[j-1] + \Delta'_y[j-1] \text{ and} \\ \texttt{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] \geq \text{ split threshold} \\ \quad \text{(for } j = 1,2,4,5,7,8\text{),} \end{cases}
\end{cases}
$$

and s_x, T, t', t'_k, t'_{k+1}, $\rho_x[j]$, and $V_x[j]$ are given by equations. 390, 391, 392, 393, 394, 395, and 396, respectively.

v. If there is a parallel CTI trap-density map in the `ctifile` for `CCD_ID`, then the values of Δ_y are given by

$$
\begin{aligned}
\Delta_y[0] &= c_y[0]s_y\rho_y[0]V_y[0], && (406)\\
\Delta_y[1] &= c_y[1]s_y\rho_y[1]V_y[1], && (407)\\
\Delta_y[2] &= c_y[2]s_y\rho_y[2]V_y[2], && (408)\\
\Delta_y[3] &= c_y[3]s_y\rho_y[3]V_y[3] - c'_y[0]s_y\rho_y[0]V_y[0], && (409)\\
\Delta_y[4] &= c_y[4]s_y\rho_y[4]V_y[4] - c'_y[1]s_y\rho_y[1]V_y[1], && (410)\\
\Delta_y[5] &= c_y[5]s_y\rho_y[5]V_y[5] - c'_y[2]s_y\rho_y[2]V_y[2], && (411)\\
\Delta_y[6] &= c_y[6]s_y\rho_y[6]V_y[6] - c'_y[3]s_y\rho_y[3]V_y[3], && (412)\\
\Delta_y[7] &= c_y[7]s_y\rho_y[7]V_y[7] - c'_y[4]s_y\rho_y[4]V_y[4], \text{ and} && (413)\\
\Delta_y[8] &= c_y[8]s_y\rho_y[8]V_y[8] - c'_y[5]s_y\rho_y[5]V_y[5], && (414)
\end{aligned}
$$

where

$$c_y[j] = \begin{cases} 0 & \begin{cases} \texttt{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] < \text{ split threshold} \\ \quad \text{(for all } j), \end{cases} \\ \texttt{FRCTRLY} & \begin{cases} \texttt{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] \geq \text{ split threshold and} \\ \texttt{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] < \\ \quad \texttt{PHAS}[j-3] + \Delta'_x[j-3] + \Delta'_y[j-3] \\ \quad \text{(for } j = 3,4,5,6,7,8), \end{cases} \\ 1 & \begin{cases} \texttt{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] \geq \text{ split threshold} \\ \quad \text{(for } j = 0,1,2) \\ \texttt{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] \geq \text{ split threshold and} \\ \texttt{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] \geq \\ \quad \texttt{PHAS}[j-3] + \Delta'_x[j-3] + \Delta'_y[j-3] \\ \quad \text{(for } j = 3,4,5,6,7,8), \end{cases} \end{cases}$$

$$c'_y[j] = \begin{cases} 0 & \begin{cases} \texttt{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] < \text{ split threshold or} \\ \texttt{PHAS}[j+3] + \Delta'_x[j+3] + \Delta'_y[j+3] < \text{ split threshold or} \\ j \rightarrow \texttt{CHIPY} = 1\text{or } 1024 \\ \quad \text{(for } j = 1,2,3,4,5), \end{cases} \\ \texttt{FRCTRLY} & \begin{cases} \texttt{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] > \\ \quad \texttt{PHAS}[j+3] + \Delta'_x[j+3] + \Delta'_y[j+3] \text{ and} \\ \texttt{PHAS}[j+3] + \Delta'_x[j+3] + \Delta'_y[j+3] \geq \text{ split threshold} \\ \quad \text{(for } j = 0,1,2,3,4,5), \end{cases} \\ 1 & \begin{cases} \texttt{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] \leq \\ \quad \texttt{PHAS}[j+3] + \Delta'_x[j+3] + \Delta'_y[j+3] \text{ and} \\ \texttt{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] \geq \text{ split threshold} \\ \quad \text{(for } j = 0,1,2,3,4,5), \end{cases} \end{cases}$$

$$s_y = 1 + \texttt{TCTIY}\,(T - \texttt{FP\_TEMPO})\,, \tag{415}$$

$$\begin{cases} s_y \text{ is a temperature dependent scaling factor,} \\ \texttt{TCTIY} \text{ is the } \texttt{CCD\_ID} \text{ dependent value in the column } \texttt{TCTIY} \text{ of the} \\ \quad \texttt{ctifile}, \\ \texttt{FP\_TEMPO} \text{ is the name of a keyword in the } \texttt{ctifile}, \end{cases}$$

$$\rho_y[j] = \text{parallel trap density,} \tag{416}$$

$$\begin{cases} \rho_y[j] \text{ depends upon the } \texttt{CCD\_ID} \text{ and upon the } \texttt{CHIPX} \text{ and nint}(\texttt{CHIPY\_ADJ}) \\ \quad \text{coordinates associated with element } j \text{ of } \texttt{PHAS\_ADJ}[j] \text{ (see Fig. 1),} \end{cases}$$

$$V_y[j] = \left(\frac{\texttt{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] - \texttt{PHA}_l}{\texttt{PHA}_{l+1} - \texttt{PHA}_l}\right)(\texttt{VOLUME\_Y}_{l+1} - \texttt{VOLUME\_Y}_l) + \texttt{VOLUME\_Y}_l, \tag{417}$$

$$\begin{cases} \texttt{PHA}_l \text{ is the } l^{\text{th}} \text{ element of the column } \texttt{PHA} \text{ in the } \texttt{ctifile}, \\ \texttt{PHA}_l \text{ (and } \texttt{PHA}_{l+1}) \text{ are } \texttt{CCD\_ID} \text{ depdendent,} \\ \texttt{PHA}_l \leq \texttt{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j], \\ \text{If } \texttt{PHA}_l > \texttt{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] \text{ for } l = 0, \text{ then } l = 0, \\ \texttt{PHA}_{l+1} \text{ is the } (l+1)^{\text{th}} \text{ element of the column } \texttt{PHA} \text{ in the } \texttt{ctifile}, \\ \texttt{PHA}_{l+1} > \texttt{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j], \\ \text{If } \texttt{PHA}_{l+1} \leq \texttt{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] \text{ for } l = n, \text{ where } n \text{ is the last} \\ \quad \text{element, then } l = n, \\ \texttt{VOLUME\_Y}_l \text{ is the } l^{\text{th}} \text{ element of the column } \texttt{VOLUME\_Y} \text{ in the } \texttt{ctifile}, \\ \texttt{VOLUME\_Y}_l, \text{ which is } \texttt{CCD\_ID} \text{ depdendent, is associated with } \texttt{PHA}_l, \\ \texttt{VOLUME\_Y}_{l+1} \text{ is the } (l+1)^{\text{th}} \text{ element of the column } \texttt{VOLUME\_Y} \text{ in the} \\ \quad \texttt{ctifile}, \\ \texttt{VOLUME\_Y}_{l+1}, \text{ which is } \texttt{CCD\_ID} \text{ depdendent, is associated with } \texttt{PHA}_{l+1}, \end{cases}$$

and T, t', t'_k, and t'_{k+1}, are given by equations. 391, 392, 393, and 394, respectively.

vi. The CTI-adjusted pulse heights

$$\texttt{PHAS\_ADJ}[j] = \texttt{PHAS}[j] + \Delta_x[j] + \Delta_y[j] \tag{418}$$

for all j.

vii. A. If

$$|\texttt{PHAS\_ADJ}'[j] - \texttt{PHAS\_ADJ}[j]| < \texttt{cticonverge} \text{ (for all } j\text{) and} \tag{419}$$
$$n \leq \texttt{max\_cti\_iter}, \tag{420}$$

then the computation of PHAS_ADJ is complete for the event.

B. If

$$|\texttt{PHAS\_ADJ}'[j] - \texttt{PHAS\_ADJ}[j]| \geq \texttt{cticonverge} \text{ (for one or more } j\text{) and} \tag{421}$$
$$n < \texttt{max\_cti\_iter}, \tag{422}$$

then $n = n + 1$ and steps 1.5.14(a)iii–1.5.14(a)vii are repeated.

C. If

$$|\texttt{PHAS\_ADJ}'[j] - \texttt{PHAS\_ADJ}[j]| \geq \texttt{cticonverge} \text{ (for one or more } j\text{) and} \tag{423}$$
$$n \geq \texttt{max\_cti\_iter}, \tag{424}$$

then no additional iterations are performed, the values of PHAS_ADJ$[j]$ from the most recent iteration are used as are, and STATUS$[k] = 1$ for bit $k = 20$ to indicate that the CTI adjustment did not converge.

15. FLTGRADE:

(a) If

$$\texttt{DATAMODE}_{\text{in}} = \text{CC33\_FAINT and} \tag{425}$$
$$\texttt{apply\_cti} = \text{yes,} \tag{426}$$

then

$$\texttt{FLTGRADE} = c_{\text{f}}[0] + 2c_{\text{f}}[1] + 4c_{\text{f}}[2] + 8c_{\text{f}}[3] + 16c_{\text{f}}[5] + 32c_{\text{f}}[6] + 64c_{\text{f}}[7] + 128c_{\text{f}}[8], \tag{427}$$

where

$$c_{\text{f}}[j] = \begin{cases} 0 & \text{if } \texttt{PHAS\_ADJ}[j] < \text{split threshold} \\ 1 & \text{otherwise,} \end{cases} \tag{428}$$

and the elements $j = 0$–3 and 5–8 of PHAS_ADJ are depicted in Figure 1.

(b) If

$$\texttt{DATAMODE}_{\text{in}} = \text{CC33\_FAINT and} \tag{429}$$
$$\texttt{apply\_cti} = \text{no,} \tag{430}$$

then

$$\texttt{FLTGRADE} = c_{\text{f}}[0] + 2c_{\text{f}}[1] + 4c_{\text{f}}[2] + 8c_{\text{f}}[3] + 16c_{\text{f}}[5] + 32c_{\text{f}}[6] + 64c_{\text{f}}[7] + 128c_{\text{f}}[8], \tag{431}$$

where

$$c_{\text{f}}[j] = \begin{cases} 0 & \text{if } \texttt{PHAS}[j] < \text{split threshold} \\ 0 & \text{if } \texttt{PHAS}[j] > 4095 \\ 0 & \text{if } \texttt{PHAS}[j] > \texttt{PHAS}[4] \text{ for } j = 0 - 3) \\ 0 & \text{if } \texttt{PHAS}[j] \geq \texttt{PHAS}[4] \text{ for } j = 5 - 8) \\ 1 & \text{otherwise.} \end{cases} \tag{432}$$

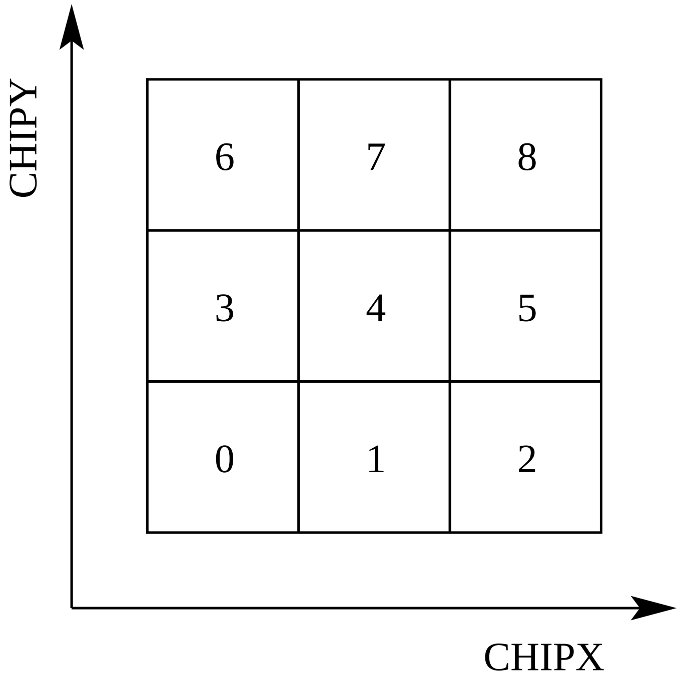

Figure 1: The relative CHIPX and CHIPY coordinates of the nine elements $j = 0$–8 of a 3 pixel × 3 pixel event island PHAS[j] or PHAS_ADJ[j].

(c) If

$$\texttt{DATAMODE}_{\rm in} \quad = \quad \text{CC33\_GRADED}, \tag{433}$$

then the FLTGRADE of an event is equal to the value of FLTGRADE for the event in the infile.

16. GRADE:

(a) If the gradefile is specified, then the GRADE of an event is determined from the FLTGRADE of the event as follows.

i. The appropriate HDU of the gradefile is identified. This HDU is the one where the header keyword CBD10001 includes the $\texttt{DATAMODE}_{\rm in}$ of HDU 1 of the infile.

ii. The row i of the appropriate HDU of the gradefile is identified. This row is the one where

$$\texttt{FLTGRADE}_{{\rm grade},i} = \texttt{FLTGRADE}, \tag{434}$$

where $\texttt{FLTGRADE}_{\rm grade}$ is a column in the gradefile.

iii. The GRADE of the event is given by

$$\texttt{GRADE} = \texttt{GRADE}_{{\rm grade},i}, \tag{435}$$

where $\texttt{GRADE}_{\rm grade}$ is a column in the gradefile.

17. PHA_RO:

(a) If

$$\texttt{DATAMODE}_{\rm in} = \text{CC33\_FAINT}, \tag{436}$$

then

$$\texttt{PHA\_RO} = \sum_{j=0}^{8} \beta[j]p[j], \tag{437}$$

where

i.

$$p[j] = \texttt{PHAS}[j]. \tag{438}$$

ii. The elements $j = 0$–8 of PHAS are depicted in Figure 1.

iii.

$$\beta[j] = 0 \quad \text{if} \quad p[j] < \text{split threshold}. \tag{439}$$

iv.

$$\beta[j] = 0 \text{ if } \begin{cases} p[j] > p[4] \text{ (for } j = 0-3) \\ p[j] \geq p[4] \text{ (for } j = 5-8) \end{cases} \tag{440}$$

v. If CORNERS $= -1$, then

$$\beta[0] = \beta[2] = \beta[6] = \beta[8] = 0. \tag{441}$$

vi. If CORNERS $= 0$, then there are no additional constraints on $\beta[0]$, $\beta[2]$, $\beta[6]$, and $\beta[8]$.

vii. If CORNERS $= 1$, then

$$\beta[0] = 0 \quad \text{if} \quad \beta[1] = 0 \text{ and } \beta[3] = 0. \tag{442}$$
$$\beta[2] = 0 \quad \text{if} \quad \beta[1] = 0 \text{ and } \beta[5] = 0. \tag{443}$$
$$\beta[6] = 0 \quad \text{if} \quad \beta[3] = 0 \text{ and } \beta[7] = 0. \tag{444}$$
$$\beta[8] = 0 \quad \text{if} \quad \beta[5] = 0 \text{ and } \beta[7] = 0. \tag{445}$$

viii. If CORNERS $= 2$, then

$$\beta[0] = 0 \quad \text{if} \quad \beta[1] = 0 \text{ or } \beta[3] = 0 \text{ or } \texttt{GRADE} \neq 6. \tag{446}$$
$$\beta[2] = 0 \quad \text{if} \quad \beta[1] = 0 \text{ or } \beta[5] = 0 \text{ or } \texttt{GRADE} \neq 6. \tag{447}$$
$$\beta[6] = 0 \quad \text{if} \quad \beta[3] = 0 \text{ or } \beta[7] = 0 \text{ or } \texttt{GRADE} \neq 6. \tag{448}$$
$$\beta[8] = 0 \quad \text{if} \quad \beta[5] = 0 \text{ or } \beta[7] = 0 \text{ or } \texttt{GRADE} \neq 6. \tag{449}$$

(b) If

$$\texttt{DATAMODE}_{\text{in}} = \text{CC33\_GRADED}, \tag{450}$$

then

i. If

$$\texttt{CONTENT}_{\text{in}} = \text{EVT0}, \tag{451}$$

then the value of PHA_RO for the event is the value of PHA in the `infile`.

ii. If

$$\texttt{CONTENT}_{\text{in}} = \text{EVT1 or} \tag{452}$$
$$\texttt{CONTENT}_{\text{in}} = \text{TGEVT1 or} \tag{453}$$
$$\texttt{CONTENT}_{\text{in}} = \text{EVT2}, \tag{454}$$

then the value of PHA_RO for the event is the value of PHA_RO in the `infile`.

18. PHA, including time-dependent gain:

(a) If

$$\texttt{DATAMODE}_{\text{in}} = \text{CC33\_FAINT}, \tag{455}$$

then

$$\texttt{PHA} = \sum_{j=0}^{8} \beta[j]p[j], \tag{456}$$

where

i.

$$p[j] = \begin{cases} \texttt{PHAS\_ADJ}[j] & \text{if } \texttt{apply\_cti} = \text{yes} \\ \texttt{PHAS}[j] & \text{if } \texttt{apply\_cti} = \text{no} \end{cases} \tag{457}$$

ii. The elements $j = 0$–8 of PHAS_ADJ (or PHAS) are depicted in Figure 1.

iii.

$$\beta[j] = 0 \quad \text{if} \quad p[j] < \text{split threshold}. \tag{458}$$

iv. If the CTI adjustment is not performed, then

$$\beta[j] = 0 \text{ if } \begin{cases} p[j] > p[4] \text{ (for } j = 0\text{–}3) \\ p[j] \geq p[4] \text{ (for } j = 5\text{–}8) \end{cases} \tag{459}$$

v. If CORNERS $= -1$, then

$$\beta[0] = \beta[2] = \beta[6] = \beta[8] = 0. \tag{460}$$

vi. If CORNERS $= 0$, then there are no additional constraints on $\beta[0]$, $\beta[2]$, $\beta[6]$, and $\beta[8]$.

vii. If CORNERS $= 1$, then

$$\beta[0] = 0 \quad \text{if} \quad \beta[1] = 0 \text{ and } \beta[3] = 0. \tag{461}$$

$$\beta[2] = 0 \quad \text{if} \quad \beta[1] = 0 \text{ and } \beta[5] = 0. \tag{462}$$

$$\beta[6] = 0 \quad \text{if} \quad \beta[3] = 0 \text{ and } \beta[7] = 0. \tag{463}$$

$$\beta[8] = 0 \quad \text{if} \quad \beta[5] = 0 \text{ and } \beta[7] = 0. \tag{464}$$

viii. If CORNERS $= 2$, then

$$\beta[0] = 0 \quad \text{if} \quad \beta[1] = 0 \text{ or } \beta[3] = 0 \text{ or } \texttt{GRADE} \neq 6. \tag{465}$$

$$\beta[2] = 0 \quad \text{if} \quad \beta[1] = 0 \text{ or } \beta[5] = 0 \text{ or } \texttt{GRADE} \neq 6. \tag{466}$$

$$\beta[6] = 0 \quad \text{if} \quad \beta[3] = 0 \text{ or } \beta[7] = 0 \text{ or } \texttt{GRADE} \neq 6. \tag{467}$$

$$\beta[8] = 0 \quad \text{if} \quad \beta[5] = 0 \text{ or } \beta[7] = 0 \text{ or } \texttt{GRADE} \neq 6. \tag{468}$$

(b) If

$$\texttt{DATAMODE}_{\text{in}} = \text{CC33\_GRADED}, \tag{469}$$

then the value of PHA for the event is read from the `infile`.

(c) If

$$\texttt{apply\_tgain} = \text{yes}, \tag{470}$$

then

$$\texttt{PHA} = \texttt{PHA} - \text{int}\left[\left(\frac{\texttt{TIME} - \texttt{EPOCH1}}{\texttt{EPOCH2} - \texttt{EPOCH1}}\right)(\delta_2 - \delta_1) + \delta_1 - \epsilon\right], \tag{471}$$

where

$$\text{int} = \text{the integer portion of (i.e. truncate or round down)}, \quad (472)$$

$$\texttt{TIME} = \text{the time of the event}, \quad (473)$$

$$\texttt{EPOCH1} = \text{a keyword in the } \texttt{tgainfile}, \quad (474)$$

$$\texttt{EPOCH2} = \text{a keyword in the } \texttt{tgainfile}, \quad (475)$$

$$\delta_1 = \left(\frac{\texttt{PHA} - \texttt{PHA}_m[r]}{\texttt{PHA}_{m+1}[r] - \texttt{PHA}_m[r]}\right)(\texttt{DELTPHA1}_{m+1}[r] - \texttt{DELTPHA1}_m[r]) + \quad (476)$$

$$\texttt{DELTPHA1}_m[r], \quad (477)$$

$$\left\{\begin{array}{l} r \text{ is the row of the } \texttt{tgainfile} \text{ where} \\ \left\{\begin{array}{l} \texttt{CCD\_ID}[r] = \texttt{CCD\_ID}, \\ \texttt{CHIPX\_LO}[r] \leq \texttt{CHIPX}, \\ \texttt{CHIPX\_HI}[r] \geq \texttt{CHIPX}, \\ \texttt{CHIPY\_LO}[r] \leq \text{nint}(\texttt{CHIPY\_ADJ}), \text{ and} \\ \texttt{CHIPY\_HI}[r] \geq \text{nint}(\texttt{CHIPY\_ADJ}). \end{array}\right. \\ m \text{ is the element of row } r \text{ where} \\ \left\{\begin{array}{l} \texttt{PHA}_m[r] \leq \texttt{PHA} \text{ and} \\ \texttt{PHA}_{m+1}[r] > \texttt{PHA}. \\ \text{If } \texttt{PHA} < \texttt{PHA}_m[r] \text{ for } m = 0, \text{ then } m = 0. \\ \text{If } \texttt{PHA} \geq \texttt{PHA}_m[r] \text{ for } m = M \text{ and } M \text{ is the last element of } \texttt{PHA}[r], \\ \quad \text{then } m = M - 1. \end{array}\right. \\ \text{The } \texttt{tgainfile} \text{ includes a binary table with columns named} \\ \quad \texttt{CCD\_ID}, \texttt{CHIPX\_LO}, \texttt{CHIPX\_HI}, \texttt{CHIPY\_LO}, \texttt{CHIPY\_HI}, \texttt{PHA}, \texttt{DELTPHA1}, \text{ and} \\ \quad \texttt{DELTPHA2}. \end{array}\right. \quad (478)$$

$$\delta_2 = \left(\frac{\texttt{PHA} - \texttt{PHA}_m[r]}{\texttt{PHA}_{m+1}[r] - \texttt{PHA}_m[r]}\right)(\texttt{DELTPHA2}_{m+1}[r] - \texttt{DELTPHA2}_m[r]) + \quad (479)$$

$$\texttt{DELTPHA2}_m[r], \quad (480)$$

$$\epsilon = \text{is a uniform random deviate in the range } [0, 1), \quad (481)$$

$$\left\{ \text{If } \texttt{rand\_pha} = \text{no}, \text{ then } \epsilon = 0. \right. \quad (482)$$

(d) If

$$\texttt{PHA} \geq 32767, \quad (483)$$

then $\texttt{STATUS}[k] = 1$ for bit $k = 3$.

19. CORN_PHA:

    (a) If

$$\texttt{DATAMODE}_{\text{in}} = \text{CC33\_GRADED}, \quad (484)$$

then the value of CORN_PHA is read from the infile.

20. ENERGY:

    (a) If the parameter calculate_pi = yes and the parameter gainfile is specified and PHA > 0, then

       i. The row i in the gainfile is identified such that

$$\texttt{CCD\_ID} = \texttt{CCD\_ID}_{\text{gain},i}, \quad (485)$$

$$\texttt{CHIPX\_MIN}_{\text{gain},i} \leq \texttt{CHIPX} \leq \texttt{CHIPX\_MAX}_{\text{gain},i}, \quad \text{and} \quad (486)$$

$$\texttt{CHIPY\_MIN}_{\text{gain},i} \leq \text{nint}(\texttt{CHIPY\_ADJ}) \leq \texttt{CHIPY\_MAX}_{\text{gain},i}, \quad (487)$$

where $\texttt{CCD\_ID}_{\text{gain}}$, $\texttt{CHIPX\_MIN}_{\text{gain}}$, $\texttt{CHIPX\_MAX}_{\text{gain}}$, $\texttt{CHIPY\_MIN}_{\text{gain}}$, and $\texttt{CHIPY\_MAX}_{\text{gain}}$ are columns in the gainfile.

ii. A uniform random deviate Δp is computed over the interval from $[-0.5, +0.5)$.

iii. The element j of row i of $\mathtt{PHA}_{\mathrm{gain}}$ is identified such that

$$\mathtt{PHA}_{\mathrm{gain},i}[j] \leq (\mathtt{PHA} + \Delta p) < \mathtt{PHA}_{\mathrm{gain},i}[j+1], \quad (488)$$

where $\mathtt{PHA}_{\mathrm{gain}}$ is a vector column in the `gainfile`. If $\mathtt{PHA} + \Delta p < \mathtt{PHA}_{\mathrm{gain},i}[0]$, then $j = 0$. If $\mathtt{PHA}_{\mathrm{gain},i}[\mathtt{NPOINTS} - 2] \leq \mathtt{PHA} + \Delta p$, then $j = \mathtt{NPOINTS} - 2$, where `NPOINTS` is a column in the `gainfile`.

iv. The `ENERGY` of an event is computed from the `PHA` of the event:

$$\begin{aligned} \mathtt{ENERGY} &= \left(\frac{\mathtt{PHA} + \Delta p - \mathtt{PHA}_{\mathrm{gain},i}[j]}{\mathtt{PHA}_{\mathrm{gain},i}[j+1] - \mathtt{PHA}_{\mathrm{gain},i}[j]}\right)(\mathtt{ENERGY}_{\mathrm{gain},i}[j+1] - \mathtt{ENERGY}_{\mathrm{gain},i}[j]) + \\ &\quad \mathtt{ENERGY}_{\mathrm{gain},i}[j], \end{aligned} \quad (489)$$

where $\mathtt{ENERGY}_{\mathrm{gain}}$ is a vector column in the `gainfile`.

v. If $\mathtt{ENERGY} < 0$, then $\mathtt{ENERGY} = 0$.

(b) If the parameter `calculate_pi` = yes and the parameter `gainfile` is specified and $\mathtt{PHA} \leq 0$, then $\mathtt{ENERGY} = 0$.

(c) If the parameter `calculate_pi` = no or if the parameter `gainfile` is not specified, then

i. If the `infile` includes the `ENERGY` of an event, then the `ENERGY` of the event is equal to the `ENERGY` in the `infile`.

ii. If the `infile` does not include the `ENERGY` of an event, then $\mathtt{ENERGY} = 0$.

21. `PI`:

(a) If

$$\mathtt{calculate\_pi} = \mathrm{yes}, \quad (490)$$

then

i.

$$\mathtt{PI} = \mathrm{int}\left(\frac{\mathtt{ENERGY}}{\mathtt{pi\_bin\_width}}\right) + 1, \quad (491)$$

where "int" indicates the integer portion of what is in parentheses (i.e. the value is truncated or rounded down).

ii. If

$$\mathtt{PI} < 1, \quad (492)$$

then $\mathtt{PI} = 1$.

iii. If

$$\mathtt{PI} > \mathtt{pi\_num\_bins}, \quad (493)$$

then $\mathtt{PI} = \mathtt{pi\_num\_bins}$.

(b) If

$$\mathtt{calculate\_pi} = \mathrm{no} \quad (494)$$

and the `infile` includes the value of `PI` for an event, then the value of `PI` is read from the `infile`.

22. `pix_adj`:

(a) centroid:
If

$$\mathtt{pix\_adj} = \mathrm{centroid}, \quad (495)$$

then

$$\texttt{CHIPX\_ADJ} = \texttt{CHIPX\_ADJ} - w'[0] + w'[2] - w'[3] + w'[5] - w'[6] + w'[8], \tag{496}$$

where

$$w'[j] = \frac{w[j]}{\sum_{j=0}^{8} w[j]}, \tag{497}$$

$$w[j] = \begin{cases} p[j] & \text{if the pixel is valid} \\ 0 & \text{if the pixel is invalid,} \end{cases} \tag{498}$$

$$p[j] = \begin{cases} \texttt{PHAS\_ADJ}[j] & \text{if } \texttt{apply\_cti} = \text{yes} \\ \texttt{PHAS}[j] & \text{if } \texttt{apply\_cti} = \text{no,} \end{cases} \tag{499}$$

and the pixel is invalid if

$$\beta[j] = 0 \text{ or} \tag{500}$$

$$\texttt{STATUS}[0] = 1 \text{ or} \tag{501}$$

$$\texttt{STATUS}[1] = 1 \text{ or} \tag{502}$$

$$\texttt{STATUS}[2] = 1 \text{ or} \tag{503}$$

$$\texttt{STATUS}[3] = 1 \text{ or} \tag{504}$$

$$\texttt{STATUS}[4] = 1 \text{ or} \tag{505}$$

$$\texttt{STATUS}[11] = 1 \text{ or} \tag{506}$$

$$\texttt{STATUS}[13] = 1 \text{ or} \tag{507}$$

$$\texttt{STATUS}[14] = 1 \text{ or} \tag{508}$$

$$\texttt{STATUS}[15] = 1 \text{ or} \tag{509}$$

$$\texttt{STATUS}[16] = 1. \tag{510}$$

If

$$\texttt{DATAMODE} = \text{CC33\_FAINT or} \tag{511}$$

$$\texttt{DATAMODE} = \text{CC33\_GRADED or} \tag{512}$$

$$\texttt{DATAMODE} = \text{FAINT or} \tag{513}$$

$$\texttt{DATAMODE} = \text{FAINT\_BIAS or} \tag{514}$$

$$\texttt{DATAMODE} = \text{GRADED or} \tag{515}$$

$$\texttt{DATAMODE} = \text{VFAINT,} \tag{516}$$

then

$$\texttt{CHIPY\_ADJ} = \texttt{CHIPY\_ADJ} - w'[0] - w'[1] - w'[2] + w'[6] + w'[7] + w'[8]. \tag{517}$$

If

$$\texttt{DATAMODE} = \text{CC33\_FAINT or} \tag{518}$$

$$\texttt{DATAMODE} = \text{CC33\_GRADED,} \tag{519}$$

then

$$\texttt{TIME} = \texttt{TIME} + (w'[0] + w'[1] + w'[2] - w'[6] - w'[7] - w'[8]) \times \texttt{TIMEDEL}_{\text{in}}. \tag{520}$$

Note that it is possible for the centroid algorithm to yield an adjustment to `CHIPX_ADJ` and/or `CHIPY_ADJ` that is greater than half a pixel. However, the adjustment cannot equal or exceed one pixel.

(b) edser:
If

$$\texttt{pix\_adj} = \text{edser}, \tag{521}$$

then

$$\texttt{CHIPX\_ADJ} = \texttt{CHIPX\_ADJ} + \left(\frac{\texttt{ENERGY} - E[k]}{E[k+1] - E[k]}\right)(\Delta X[k+1] - \Delta X[k]) + \Delta X[k], \tag{522}$$

where $E[k]$ and $E[k+1]$ and $\Delta X[k]$ and $\Delta X[k+1]$ are the k and $(k+1)^{th}$ elements of the vector columns $\texttt{ENERGY}_{\text{subpix}}$ and $\texttt{CHIPX\_OFFSET}_{\text{subpix}}$, respectively. These columns are in the HDU of the `subpixfile` where the value of the keyword `CCD_ID` is equal to the value of the `CCD_ID` of the event. The appropriate row of these columns is the one where $\texttt{FLTGRADE}_{\text{subpix}} = \texttt{FLTGRADE}$. The values of k are the ones where

$$\texttt{ENERGY} \geq E[k] \text{ and} \tag{523}$$

$$\texttt{ENERGY} < E[k+1]. \tag{524}$$

Note that if

$$\texttt{ENERGY} \leq E[0], \tag{525}$$

then $k = 0$. Similarly, if

$$\texttt{ENERGY} \geq E[\texttt{NPOINTS}_{\text{subpix}} - 2], \tag{526}$$

then $k = \texttt{NPOINTS}_{\text{subpix}} - 2$. If

$$\texttt{DATAMODE} = \text{CC33\_FAINT or} \tag{527}$$

$$\texttt{DATAMODE} = \text{CC33\_GRADED or} \tag{528}$$

$$\texttt{DATAMODE} = \text{FAINT or} \tag{529}$$

$$\texttt{DATAMODE} = \text{FAINT\_BIAS or} \tag{530}$$

$$\texttt{DATAMODE} = \text{GRADED or} \tag{531}$$

$$\texttt{DATAMODE} = \text{VFAINT}, \tag{532}$$

then

$$\texttt{CHIPY\_ADJ} = \texttt{CHIPY\_ADJ} + \left(\frac{\texttt{ENERGY} - E[k]}{E[k+1] - E[k]}\right)(\Delta Y[k+1] - \Delta Y[k]) + \Delta Y[k], \tag{533}$$

where $\Delta Y[k]$ and $\Delta Y[k+1]$ are the k and $(k+1)^{th}$ elements of the vector column $\texttt{CHIPY\_OFFSET}_{\text{subpix}}$. If

$$\texttt{DATAMODE} = \text{CC33\_FAINT or} \tag{534}$$

$$\texttt{DATAMODE} = \text{CC33\_GRADED}, \tag{535}$$

then

$$\texttt{TIME} = \texttt{TIME} - \left(\left(\frac{\texttt{ENERGY} - E[k]}{E[k+1] - E[k]}\right)(\Delta Y[k+1] - \Delta Y[k]) + \Delta Y[k]\right) \times \texttt{TIMEDEL}_{\text{in}}. \tag{536}$$

(c) none:
If

$$\texttt{pix\_adj} = \text{none}, \tag{537}$$

then the values of `CHIPX_ADJ` and `CHIPY_ADJ` remain unchanged.

(d) randomize:
If

$$\texttt{pix\_adj} = \text{randomize}, \tag{538}$$

then

$$\texttt{CHIPX\_ADJ} = \texttt{CHIPX\_ADJ} + \epsilon_x, \tag{539}$$

where ϵ_x is a uniform random deviate in the range $[-0.5, +0.5)$ pixel. If

$$\texttt{DATAMODE} = \text{CC33\_FAINT or} \tag{540}$$
$$\texttt{DATAMODE} = \text{CC33\_GRADED or} \tag{541}$$
$$\texttt{DATAMODE} = \text{FAINT or} \tag{542}$$
$$\texttt{DATAMODE} = \text{FAINT\_BIAS or} \tag{543}$$
$$\texttt{DATAMODE} = \text{GRADED or} \tag{544}$$
$$\texttt{DATAMODE} = \text{VFAINT}, \tag{545}$$

then

$$\texttt{CHIPY\_ADJ} = \texttt{CHIPY\_ADJ} + \epsilon_y, \tag{546}$$

where ϵ_y is a uniform random deviate in the range $[-0.5, +0.5)$ pixel. If

$$\texttt{DATAMODE} = \text{CC33\_FAINT or} \tag{547}$$
$$\texttt{DATAMODE} = \text{CC33\_GRADED}, \tag{548}$$

then

$$\texttt{TIME} = \texttt{TIME} - \epsilon_y \times \texttt{TIMEDEL}_{\text{in}}. \tag{549}$$

(e) If

$$\texttt{CHIPX\_ADJ} < 0.5, \tag{550}$$

then

$$\texttt{CHIPX\_ADJ} = 1. \tag{551}$$

(f) If

$$\texttt{CHIPX\_ADJ} \geq 1024.5, \tag{552}$$

then

$$\texttt{CHIPX\_ADJ} = 1024. \tag{553}$$

(g) If

$$\texttt{CHIPY\_ADJ} < 0.5, \tag{554}$$

then

$$\texttt{CHIPY\_ADJ} = 1. \tag{555}$$

(h) If

$$\texttt{CHIPY\_ADJ} \geq 1024.5, \tag{556}$$

then

$$\texttt{CHIPY\_ADJ} = 1024. \tag{557}$$

23. TDETX and TDETY:

(a) If

$$\texttt{stop} = \text{tdet or} \tag{558}$$
$$\texttt{stop} = \text{det or} \tag{559}$$
$$\texttt{stop} = \text{tan or} \tag{560}$$
$$\texttt{stop} = \text{sky} \tag{561}$$

then

i. If

$$\texttt{CONTENT} = \text{EVT0 or} \tag{562}$$
$$\texttt{CONTENT} = \text{EVT1 or} \tag{563}$$
$$\texttt{CONTENT} = \text{EVT2,} \tag{564}$$

and

$$\texttt{TIME} \geq \texttt{TIME}_{\text{min}} \text{ and} \tag{565}$$
$$\texttt{TIME} < \texttt{TIME}_{\text{max}} \tag{566}$$

and TIME is in a good-time interval, then the values of TDETX and TDETY are computed using the values of nint(CHIPX_ADJ) and nint(CHIPY_ADJ). Here, "nint" indicates that the real-valued coordinate is rounded to the nearest integer.

ii. If

$$\texttt{CONTENT} = \text{EVT0 or} \tag{567}$$
$$\texttt{CONTENT} = \text{EVT1 or} \tag{568}$$
$$\texttt{CONTENT} = \text{EVT2,} \tag{569}$$

and

$$\texttt{TIME} < \texttt{TIME}_{\text{min}} \text{ or} \tag{570}$$
$$\texttt{TIME} \geq \texttt{TIME}_{\text{max}} \tag{571}$$

or TIME is not in a good-time interval, then the values of TDETX and TDETY are set to NULL.

iii. If

$$\texttt{CONTENT} = \text{TGEVT1,} \tag{572}$$

and

$$\texttt{CHIPY\_ZO} \neq \text{NULL,} \tag{573}$$

and

$$\texttt{TIME} \geq \texttt{TIME}_{\rm min} \text{ and} \quad (574)$$
$$\texttt{TIME} < \texttt{TIME}_{\rm max} \quad (575)$$

and TIME is in a good-time interval, then the values of TDETX and TDETY are computed using the values of nint(CHIPX_ADJ) and nint(CHIPY_ZO).¶

iv. If

$$\texttt{CONTENT} = \text{TGEVT1}, \quad (576)$$

and

$$\texttt{CHIPY\_ZO} = \text{NULL or} \quad (577)$$
$$\texttt{TIME} < \texttt{TIME}_{\rm min} \text{ or} \quad (578)$$
$$\texttt{TIME} \geq \texttt{TIME}_{\rm max} \quad (579)$$

or TIME is not in a good-time interval, then the values of TDETX and TDETY are set to NULL.

24. DETX and DETY:

(a) If

$$\texttt{stop} = \text{det or} \quad (580)$$
$$\texttt{stop} = \text{tan or} \quad (581)$$
$$\texttt{stop} = \text{sky}, \quad (582)$$

then

i. If

$$\texttt{CONTENT} = \text{EVT0 or} \quad (583)$$
$$\texttt{CONTENT} = \text{EVT1 or} \quad (584)$$
$$\texttt{CONTENT} = \text{EVT2}, \quad (585)$$

and

$$\texttt{TIME} \geq \texttt{TIME}_{\rm min} \text{ and} \quad (586)$$
$$\texttt{TIME} < \texttt{TIME}_{\rm max} \quad (587)$$

and TIME is in a good-time interval, then the values of DETX and DETY are computed using the real-valued coordinates CHIPX_ADJ and CHIPY_ADJ and the orientation of the SIM (i.e. DY, DZ, and DTHETA) at the time TIME.

ii. If

$$\texttt{CONTENT} = \text{EVT0 or} \quad (588)$$
$$\texttt{CONTENT} = \text{EVT1 or} \quad (589)$$
$$\texttt{CONTENT} = \text{EVT2}, \quad (590)$$

and

$$\texttt{TIME} < \texttt{TIME}_{\rm min} \text{ or} \quad (591)$$
$$\texttt{TIME} \geq \texttt{TIME}_{\rm max} \quad (592)$$

or TIME is not in a good-time interval, then the values of DETX and DETY are set to NaN.

¶As requested, these coordinates for gratings observations are computed using the CHIPY location of zeroth order, not the CHIPY location of the gratings arms.

iii. If

$$\texttt{CONTENT} = \text{TGEVT1}, \tag{593}$$

and

$$\texttt{CHIPY\_ZO} \neq \text{NULL}, \tag{594}$$

and

$$\texttt{TIME} \geq \texttt{TIME}_{\text{min}} \text{ and} \tag{595}$$
$$\texttt{TIME} < \texttt{TIME}_{\text{max}} \tag{596}$$

and `TIME` is in a good-time interval, then the values of `DETX` and `DETY` are computed using the real-valued coordinates `CHIPX_ADJ` and `CHIPY_ZO`¶ and the orientation of the SIM (i.e. `DY`, `DZ`, and `DTHETA`) at the time `TIME`.

iv. If

$$\texttt{CONTENT} = \text{TGEVT1}, \tag{597}$$

and

$$\texttt{CHIPY\_ZO} = \text{NULL or} \tag{598}$$
$$\texttt{TIME} < \texttt{TIME}_{\text{min}} \text{ or} \tag{599}$$
$$\texttt{TIME} \geq \texttt{TIME}_{\text{max}} \tag{600}$$

or `TIME` is not in a good-time interval, then the values of `DETX` and `DETY` are set to NaN.

25. `X` and `Y`:

(a) If

$$\texttt{stop} = \text{sky}, \tag{601}$$

then

i. If

$$\texttt{CONTENT} = \text{EVT0 or} \tag{602}$$
$$\texttt{CONTENT} = \text{EVT1 or} \tag{603}$$
$$\texttt{CONTENT} = \text{EVT2}, \tag{604}$$

and

$$\texttt{TIME} \geq \texttt{TIME}_{\text{min}} \text{ and} \tag{605}$$
$$\texttt{TIME} < \texttt{TIME}_{\text{max}} \tag{606}$$

and `TIME` is in a good-time interval, then the values of `X` and `Y` are computed using the real-valued coordinates `CHIPX_ADJ` and `CHIPY_ADJ` and the orientation of the telescope (i.e. `RA`, `DEC`, and `ROLL`) at the time `TIME`.

ii. If

$$\texttt{CONTENT} = \text{EVT0 or} \tag{607}$$
$$\texttt{CONTENT} = \text{EVT1 or} \tag{608}$$
$$\texttt{CONTENT} = \text{EVT2}, \tag{609}$$

and

$$\begin{aligned} \texttt{TIME} &< \texttt{TIME}_{\rm min} \text{ or} && (610)\\ \texttt{TIME} &\geq \texttt{TIME}_{\rm max} && (611)\end{aligned}$$

or TIME is not in a good-time interval, then the values of X and Y are set to NaN.

iii. If

$$\texttt{CONTENT} = \text{TGEVT1}, \quad (612)$$

and

$$\texttt{CHIPY\_ZO} \neq \text{NULL}, \quad (613)$$

and

$$\begin{aligned} \texttt{TIME} &\geq \texttt{TIME}_{\rm min} \text{ and} && (614)\\ \texttt{TIME} &< \texttt{TIME}_{\rm max} && (615)\end{aligned}$$

and TIME is in a good-time interval, then the values of X and Y are computed using the real-valued coordinates CHIPX_ADJ and CHIPY_ZO¶ and the orientation of the telescope (i.e. RA, DEC, and ROLL) at the time TIME.

iv. If

$$\texttt{CONTENT} = \text{TGEVT1}, \quad (616)$$

and

$$\begin{aligned} \texttt{CHIPY\_ZO} &= \text{NULL or} && (617)\\ \texttt{TIME} &< \texttt{TIME}_{\rm min} \text{ or} && (618)\\ \texttt{TIME} &\geq \texttt{TIME}_{\rm max} && (619)\end{aligned}$$

or TIME is not in a good-time interval, then the values of X and Y are set to NaN.

SKY_1D:

(a) If

$$\begin{aligned} \texttt{DATAMODE}_{\rm in} &= \text{CC33\_FAINT or} && (620)\\ \texttt{DATAMODE}_{\rm in} &= \text{CC33\_GRADED} && (621)\end{aligned}$$

and

$$\texttt{stop} = \text{sky}, \quad (622)$$

then

i. If

$$\begin{aligned} \texttt{TIME} &\geq \texttt{TIME}_{\rm min} \text{ and} && (623)\\ \texttt{TIME} &< \texttt{TIME}_{\rm max} && (624)\end{aligned}$$

and TIME is in a good-time interval, then the value of SKY_1D is computed using the real-valued coordinates CHIPX_ADJ and CHIPY_ADJ and using the orientation of the telescope (i.e. RA, DEC, and ROLL) at the time TIME.

ii. If

$$\begin{aligned} \texttt{TIME} &< \texttt{TIME}_{\rm min} \text{ or} && (625)\\ \texttt{TIME} &\geq \texttt{TIME}_{\rm max} && (626)\end{aligned}$$

or TIME is not in a good-time interval, then the value of SKY_1D is set to NaN.

1.5.4 Write `outfile`

1. `PIX_ADJ`:
   (a) If
   $$\texttt{pix\_adj} = \text{centroid}, \tag{627}$$
   then
   $$\texttt{PIX\_ADJ} = \text{CENTROID}. \tag{628}$$
   (b) If
   $$\texttt{pix\_adj} = \text{edser}, \tag{629}$$
   then
   $$\texttt{PIX\_ADJ} = \text{EDSER}. \tag{630}$$
   (c) If
   $$\texttt{pix\_adj} = \text{none}, \tag{631}$$
   then
   $$\texttt{PIX\_ADJ} = \text{NONE}. \tag{632}$$
   (d) If
   $$\texttt{pix\_adj} = \text{randomize}, \tag{633}$$
   then
   $$\texttt{PIX\_ADJ} = \text{RANDOMIZE}. \tag{634}$$
2. `RAND_SKY`:
   (a) If
   $$\texttt{pix\_adj} = \text{centroid}, \tag{635}$$
   then
   $$\texttt{RAND\_SKY} = 0.0. \tag{636}$$
   (b) If
   $$\texttt{pix\_adj} = \text{edser}, \tag{637}$$
   then
   $$\texttt{RAND\_SKY} = 0.0. \tag{638}$$
   (c) If
   $$\texttt{pix\_adj} = \text{none}, \tag{639}$$
   then
   $$\texttt{RAND\_SKY} = 0.0. \tag{640}$$

(d) If

$$\texttt{pix\_adj} = \text{randomize,} \quad (641)$$

then

$$\texttt{RAND\_SKY} = 0.5. \quad (642)$$

3. TIME_ADJ:

(a) TE mode:
If

$$\texttt{DATAMODE}_{\text{in}} = \text{FAINT or} \quad (643)$$
$$\texttt{DATAMODE}_{\text{in}} = \text{FAINT\_BIAS or} \quad (644)$$
$$\texttt{DATAMODE}_{\text{in}} = \text{GRADED or} \quad (645)$$
$$\texttt{DATAMODE}_{\text{in}} = \text{VFAINT,} \quad (646)$$

then

$$\texttt{TIME\_ADJ} = \text{NONE.} \quad (647)$$

(b) Pointing CC mode without grating data:

i. If

$$\texttt{OBS\_MODE} = \text{pointing or} \quad (648)$$
$$\texttt{OBS\_MODE} = \text{POINTING} \quad (649)$$

and

$$\texttt{DATAMODE}_{\text{in}} = \text{CC33\_FAINT or} \quad (650)$$
$$\texttt{DATAMODE}_{\text{in}} = \text{CC33\_GRADED} \quad (651)$$

and

$$\texttt{CONTENT}_{\text{in}} = \text{EVT0 or} \quad (652)$$
$$\texttt{CONTENT}_{\text{in}} = \text{EVT1 or} \quad (653)$$
$$\texttt{CONTENT}_{\text{in}} = \text{EVT2} \quad (654)$$

and

$$\texttt{CCD\_ID}_{\text{focus}} \geq 0 \text{ and} \quad (655)$$
$$\texttt{CCD\_ID}_{\text{focus}} \leq 3 \quad (656)$$

and

$$\cos(\texttt{DEC\_ADJ}_{\text{I}})\cos(\texttt{DEC\_TARG}_{\text{in}})\cos(\texttt{RA\_ADJ}_{\text{I}} - \texttt{RA\_TARG}_{\text{in}}) + \quad (657)$$
$$\sin(\texttt{DEC\_ADJ}_{\text{I}})\sin(\texttt{DEC\_TARG}_{\text{in}}) < \quad (658)$$
$$4.855 \times 10^{-11}, \quad (659)$$

then

$$\texttt{TIME\_ADJ} = \text{TARGET.} \quad (660)$$

ii. If

$$\begin{aligned} \texttt{OBS\_MODE} &= \text{pointing or} \quad (661) \\ \texttt{OBS\_MODE} &= \text{POINTING} \quad (662) \end{aligned}$$

and

$$\begin{aligned} \texttt{DATAMODE}_{\text{in}} &= \text{CC33\_FAINT or} \quad (663) \\ \texttt{DATAMODE}_{\text{in}} &= \text{CC33\_GRADED} \quad (664) \end{aligned}$$

and

$$\begin{aligned} \texttt{CONTENT}_{\text{in}} &= \text{EVT0 or} \quad (665) \\ \texttt{CONTENT}_{\text{in}} &= \text{EVT1 or} \quad (666) \\ \texttt{CONTENT}_{\text{in}} &= \text{EVT2} \quad (667) \end{aligned}$$

and

$$\begin{aligned} \texttt{CCD\_ID}_{\text{focus}} &\geq 4 \text{ and} \quad (668) \\ \texttt{CCD\_ID}_{\text{focus}} &\leq 9 \quad (669) \end{aligned}$$

and

$$\begin{aligned} &\cos(\texttt{DEC\_ADJ}_{\text{S}}) \cos(\texttt{DEC\_TARG}_{\text{in}}) \cos(\texttt{RA\_ADJ}_{\text{S}} - \texttt{RA\_TARG}_{\text{in}}) + \quad (670) \\ &\sin(\texttt{DEC\_ADJ}_{\text{S}}) \sin(\texttt{DEC\_TARG}_{\text{in}}) < \quad (671) \\ &4.855 \times 10^{-11}, \quad (672) \end{aligned}$$

then

$$\texttt{TIME\_ADJ} = \text{TARGET.} \quad (673)$$

iii. If

$$\begin{aligned} \texttt{OBS\_MODE} &= \text{pointing or} \quad (674) \\ \texttt{OBS\_MODE} &= \text{POINTING} \quad (675) \end{aligned}$$

and

$$\begin{aligned} \texttt{DATAMODE}_{\text{in}} &= \text{CC33\_FAINT or} \quad (676) \\ \texttt{DATAMODE}_{\text{in}} &= \text{CC33\_GRADED} \quad (677) \end{aligned}$$

and

$$\begin{aligned} \texttt{CONTENT}_{\text{in}} &= \text{EVT0 or} \quad (678) \\ \texttt{CONTENT}_{\text{in}} &= \text{EVT1 or} \quad (679) \\ \texttt{CONTENT}_{\text{in}} &= \text{EVT2} \quad (680) \end{aligned}$$

and

$$\begin{aligned} \texttt{CCD\_ID}_{\text{focus}} &\geq 0 \text{ and} \quad (681) \\ \texttt{CCD\_ID}_{\text{focus}} &\leq 3 \quad (682) \end{aligned}$$

and

$$\cos\left(\texttt{DEC\_ADJ}_{\rm I}\right)\cos\left(\texttt{DEC\_TARG}_{\rm in}\right)\cos\left(\texttt{RA\_ADJ}_{\rm I}-\texttt{RA\_TARG}_{\rm in}\right)+ \quad (683)$$
$$\sin\left(\texttt{DEC\_ADJ}_{\rm I}\right)\sin\left(\texttt{DEC\_TARG}_{\rm in}\right)\geq \quad (684)$$
$$4.855\times 10^{-11}, \quad (685)$$

then

$$\texttt{TIME\_ADJ} = \text{AIMPOINT}. \quad (686)$$

iv. If

$$\texttt{OBS\_MODE} = \text{pointing or} \quad (687)$$
$$\texttt{OBS\_MODE} = \text{POINTING} \quad (688)$$

and

$$\texttt{DATAMODE}_{\rm in} = \text{CC33\_FAINT or} \quad (689)$$
$$\texttt{DATAMODE}_{\rm in} = \text{CC33\_GRADED} \quad (690)$$

and

$$\texttt{CONTENT}_{\rm in} = \text{EVT0 or} \quad (691)$$
$$\texttt{CONTENT}_{\rm in} = \text{EVT1 or} \quad (692)$$
$$\texttt{CONTENT}_{\rm in} = \text{EVT2} \quad (693)$$

and

$$\texttt{CCD\_ID}_{\rm focus} \geq 4 \text{ and} \quad (694)$$
$$\texttt{CCD\_ID}_{\rm focus} \leq 9 \quad (695)$$

and

$$\cos\left(\texttt{DEC\_ADJ}_{\rm S}\right)\cos\left(\texttt{DEC\_TARG}_{\rm in}\right)\cos\left(\texttt{RA\_ADJ}_{\rm S}-\texttt{RA\_TARG}_{\rm in}\right)+ \quad (696)$$
$$\sin\left(\texttt{DEC\_ADJ}_{\rm S}\right)\sin\left(\texttt{DEC\_TARG}_{\rm in}\right)\geq \quad (697)$$
$$4.855\times 10^{-11}, \quad (698)$$

then

$$\texttt{TIME\_ADJ} = \text{AIMPOINT}. \quad (699)$$

(c) Pointing CC mode with ACIS-S grating data:
If

$$\texttt{OBS\_MODE} = \text{pointing or} \quad (700)$$
$$\texttt{OBS\_MODE} = \text{POINTING} \quad (701)$$

and

$$\texttt{DATAMODE}_{\rm in} = \text{CC33\_FAINT or} \quad (702)$$
$$\texttt{DATAMODE}_{\rm in} = \text{CC33\_GRADED} \quad (703)$$

and

$$\texttt{CONTENT}_{\rm in} = \text{TGEVT1} \quad (704)$$

and

$$\texttt{CCD\_ID}_{\text{focus}} \geq 4 \text{ and} \tag{705}$$
$$\texttt{CCD\_ID}_{\text{focus}} \leq 9, \tag{706}$$

then

$$\texttt{TIME\_ADJ} = \text{GRATING.} \tag{707}$$

(d) Pointing CC mode with ACIS-I grating data:

i. If

$$\texttt{OBS\_MODE} = \text{pointing or} \tag{708}$$
$$\texttt{OBS\_MODE} = \text{POINTING} \tag{709}$$

and

$$\texttt{DATAMODE}_{\text{in}} = \text{CC33\_FAINT or} \tag{710}$$
$$\texttt{DATAMODE}_{\text{in}} = \text{CC33\_GRADED} \tag{711}$$

and

$$\texttt{CONTENT}_{\text{in}} = \text{TGEVT1} \tag{712}$$

and

$$\texttt{CCD\_ID}_{\text{focus}} \geq 0 \text{ and} \tag{713}$$
$$\texttt{CCD\_ID}_{\text{focus}} \leq 3 \tag{714}$$

and

$$\cos(\texttt{DEC\_ADJ}_{\text{I}})\cos(\texttt{DEC\_TARG}_{\text{in}})\cos(\texttt{RA\_ADJ}_{\text{I}} - \texttt{RA\_TARG}_{\text{in}}) + \tag{715}$$
$$\sin(\texttt{DEC\_ADJ}_{\text{I}})\sin(\texttt{DEC\_TARG}_{\text{in}}) < \tag{716}$$
$$4.855 \times 10^{-11}, \tag{717}$$

then

$$\texttt{TIME\_ADJ} = \text{TARGET.} \tag{718}$$

ii. If

$$\texttt{OBS\_MODE} = \text{pointing or} \tag{719}$$
$$\texttt{OBS\_MODE} = \text{POINTING} \tag{720}$$

and

$$\texttt{DATAMODE}_{\text{in}} = \text{CC33\_FAINT or} \tag{721}$$
$$\texttt{DATAMODE}_{\text{in}} = \text{CC33\_GRADED} \tag{722}$$

and

$$\texttt{CONTENT}_{\text{in}} = \text{TGEVT1} \tag{723}$$

and

$$\texttt{CCD\_ID}_{\rm focus} \geq 0 \text{ and} \quad (724)$$
$$\texttt{CCD\_ID}_{\rm focus} \leq 3 \quad (725)$$

and

$$\cos(\texttt{DEC\_ADJ}_{\rm I})\cos(\texttt{DEC\_TARG}_{\rm in})\cos(\texttt{RA\_ADJ}_{\rm I} - \texttt{RA\_TARG}_{\rm in}) + \quad (726)$$
$$\sin(\texttt{DEC\_ADJ}_{\rm I})\sin(\texttt{DEC\_TARG}_{\rm in}) \geq \quad (727)$$
$$4.855 \times 10^{-11}, \quad (728)$$

then

$$\texttt{TIME\_ADJ} = \text{AIMPOINT}. \quad (729)$$

(e) Secondary CC mode:
If

$$\texttt{OBS\_MODE} \neq \text{pointing and} \quad (730)$$
$$\texttt{OBS\_MODE} \neq \text{POINTING} \quad (731)$$

and

$$\texttt{DATAMODE}_{\rm in} = \text{CC33\_FAINT or} \quad (732)$$
$$\texttt{DATAMODE}_{\rm in} = \text{CC33\_GRADED}, \quad (733)$$

then

$$\texttt{TIME\_ADJ} = \text{MIDCHIP}. \quad (734)$$

2 TBD

- Complete the spec to include all of the timed exposure mode processing.
- Complete sections 1.1, 1.2, 1.3, and 1.4.
- Should `CONTENT`s other than EVT0, EVT1, TGEVT1, and EVT2 be included?
- Should `CONTENT` = EVT2 be dropped?
- Should `DATAMODE`s other than CC33_FAINT, CC33_GRADED, FAINT, FAINT_BIAS, GRADED, and VFAINT be included?
- Are the `RA_TARG`, `DEC_TARG`, `RA_NOM`, `DEC_NOM`, and `TIMEDEL` keywords in the output of afe (need `obsfile` sometimes)?
- What if `TIME_RO` is not in the `infile` (output of afe? EVT2 files?)?
- What if a small fraction of the values of `CHIPY_TARG` are off the chip due to bad aspect?
- Make sure that the `STATUS` bits are unset and reset properly.
- What about aoff and soff files instead of asol files?
- Are the β in `PHA_RO` the same as the β in `PHA`?
- Should something be done about `SKY_1D`?