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

MEMORANDUM

June 9, 2015

To:	Jonathan McDowell, SDS Group Leader
From:	Glenn E. Allen, SDS
Subject:	`acis_process_events` spec
Revision:	3.26
URL:	http://space.mit.edu/CXC/docs/docs.html#ape
File:	/nfs/inconceivable/d0/sds/specs/acis_process_events/ape_spec_3.26.tex

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

$$\texttt{obsfile} \neq \text{none and} \quad (1)$$
$$\texttt{obsfile} \neq \text{NONE} \quad (2)$$

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

ii. Permission:
If

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

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

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

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

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

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

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

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_{in} keyword of the same name. Hereafter this keyword is referred to as `OBS_MODE`.

B. If the HDU h_{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

$$\texttt{CONTENT}_{\rm in} = \rm EVT0 \quad (34)$$

and HDU $h_{\rm in}$ 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 $\texttt{CCD\_ID}_{\rm in}$.

B. If

$$\texttt{CONTENT}_{\rm in} = \rm EVT1 \ or \quad (35)$$
$$\texttt{CONTENT}_{\rm in} = \rm TGEVT1 \ or \quad (36)$$
$$\texttt{CONTENT}_{\rm in} = \rm EVT2 \quad (37)$$

and HDU $h_{\rm in}$ 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 $\texttt{CCD\_ID}_{\rm in}$.

viii. CCDX:

A. If

$$\texttt{CONTENT}_{\rm in} = \rm EVT0 \quad (38)$$

and HDU $h_{\rm in}$ 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 $\texttt{CCDX}_{\rm in}$.

ix. CHIPX:

A. If

$$\texttt{CONTENT}_{\rm in} = \rm EVT1 \ or \quad (39)$$
$$\texttt{CONTENT}_{\rm in} = \rm TGEVT1 \ or \quad (40)$$
$$\texttt{CONTENT}_{\rm in} = \rm EVT2 \quad (41)$$

and HDU $h_{\rm in}$ 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 $\texttt{CHIPX}_{\rm in}$.

x. CCDY:

A. If

$$\texttt{CONTENT}_{\rm in} = \rm EVT0 \quad (42)$$

and

$$\texttt{DATAMODE}_{\rm in} = \rm FAINT \ or \quad (43)$$
$$\texttt{DATAMODE}_{\rm in} = \rm FAINT\_BIAS \ or \quad (44)$$
$$\texttt{DATAMODE}_{\rm in} = \rm GRADED \ or \quad (45)$$
$$\texttt{DATAMODE}_{\rm in} = \rm VFAINT \quad (46)$$

and HDU $h_{\rm in}$ 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 $\texttt{CCDY}_{\rm in}$.

xi. TROW:

A. If

$$\texttt{CONTENT}_{\rm in} = \rm EVT0 \quad (47)$$

and

$$\texttt{DATAMODE}_{\rm in} = \rm CC33\_FAINT \ or \quad (48)$$
$$\texttt{DATAMODE}_{\rm in} = \rm CC33\_GRADED \quad (49)$$

and HDU $h_{\rm in}$ 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 $\texttt{TROW}_{\rm in}$.

xii. CHIPY:

A. If

$$\text{CONTENT}_{\text{in}} = \text{EVT1 or} \tag{50}$$
$$\text{CONTENT}_{\text{in}} = \text{TGEVT1 or} \tag{51}$$
$$\text{CONTENT}_{\text{in}} = \text{EVT2} \tag{52}$$

and HDU h_{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 CHIPY_{in}.

xiii. TIMEDEL:

If

$$\text{DATAMODE}_{\text{in}} = \text{CC33\_FAINT or} \tag{53}$$
$$\text{DATAMODE}_{\text{in}} = \text{CC33\_GRADED} \tag{54}$$

and HDU h_{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 $\text{TIMEDEL}_{\text{in}}$.

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

If

$$\text{OBS\_MODE} = \text{pointing or} \tag{55}$$
$$\text{OBS\_MODE} = \text{POINTING} \tag{56}$$

and

$$\text{DATAMODE}_{\text{in}} = \text{CC33\_FAINT or} \tag{57}$$
$$\text{DATAMODE}_{\text{in}} = \text{CC33\_GRADED}, \tag{58}$$

then

A. RA_TARG, DEC_TARG, RA_NOM, DEC_NOM, RA_PNT, DEC_PNT:
If HDU h_{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 $\text{RA\_TARG}_{\text{in}}$, $\text{DEC\_TARG}_{\text{in}}$, $\text{RA\_NOM}_{\text{in}}$, $\text{DEC\_NOM}_{\text{in}}$, $\text{RA\_PNT}_{\text{in}}$, and $\text{DEC\_PNT}_{\text{in}}$, respectively.

B. CHIPY_TG, CHIPY_ZO, and TG_M:
If

$$\text{CONTENT}_{\text{in}} = \text{TGEVT1} \tag{59}$$

and HDU h_{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 $\text{CHIPY\_TG}_{\text{in}}$, $\text{CHIPY\_ZO}_{\text{in}}$, and TG_M_{in}, respectively.

3. stop:

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

(b) Validation:

i. Setting:
If

$$\texttt{stop} \neq \text{none and} \tag{60}$$

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

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

ii. `OBS_MODE`:
If

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

and

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

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

4. `acaofffile`:

(a) Validation for CC mode:
If

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

and

$$\begin{aligned}
\texttt{DATAMODE}_{\text{in}} &= \text{CC33_FAINT or} \quad (73)\\
\texttt{DATAMODE}_{\text{in}} &= \text{CC33_GRADED,} \quad (74)
\end{aligned}$$

then

i. Setting:
If

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

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

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

then `acis_process_events` exits with an error message.

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

vi. Columns:
If HDU h_{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 $\mathtt{TIME}_{\mathrm{acaoff}}$, $\mathtt{RA}_{\mathrm{acaoff}}$, $\mathtt{DEC}_{\mathrm{acaoff}}$, and $\mathtt{ROLL}_{\mathrm{acaoff}}$.

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

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

   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

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

   then `acis_process_events` exits with an error message.

   ii. `PHAS`:
   If

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

   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

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

   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

$$\texttt{badpixfile} \neq \text{none and} \quad (94)$$
$$\texttt{badpixfile} \neq \text{NONE} \quad (95)$$

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

$$\texttt{badpixfile} \neq \text{none and} \quad (96)$$
$$\texttt{badpixfile} \neq \text{NONE} \quad (97)$$

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

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

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

iv. Keyword:
If

$$\texttt{badpixfile} \neq \text{none and} \quad (100)$$
$$\texttt{badpixfile} \neq \text{NONE} \quad (101)$$

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

$$\texttt{badpixfile} \neq \text{none and} \quad (102)$$
$$\texttt{badpixfile} \neq \text{NONE} \quad (103)$$

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

$$\texttt{ctifile} \neq \text{caldb and} \quad (104)$$
$$\texttt{ctifile} \neq \text{CALDB}, \quad (105)$$

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

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

and

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

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

iii. stop:
If

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

and

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

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

iv. PHAS:
If

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

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

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

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

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

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

$$\texttt{CONTENT} = \mathrm{AXAF\_SUBPIX}, \quad (125)$$

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 $\texttt{FLTGRADE}_{\mathrm{subpix}}$, $\texttt{NPOINTS}_{\mathrm{subpix}}$, $\texttt{ENERGY}_{\mathrm{subpix}}$, $\texttt{CHIPX\_OFFSET}_{\mathrm{subpix}}$, and $\texttt{CHIPY\_OFFSET}_{\mathrm{subpix}}$, respectively.

1.5.2 Initializations

1. Focal-point CCD:
   If

$$\texttt{OBS\_MODE} = \text{pointing or} \quad (126)$$
$$\texttt{OBS\_MODE} = \text{POINTING} \quad (127)$$

   and

$$\texttt{DATAMODE}_{\mathrm{in}} = \text{CC33\_FAINT or} \quad (128)$$
$$\texttt{DATAMODE}_{\mathrm{in}} = \text{CC33\_GRADED}, \quad (129)$$

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

2. `acaofffile`:
   If

$$\texttt{OBS\_MODE} = \text{pointing or} \quad (130)$$
$$\texttt{OBS\_MODE} = \text{POINTING} \quad (131)$$

   and

$$\texttt{DATAMODE} = \text{CC33\_FAINT or} \quad (132)$$
$$\texttt{DATAMODE} = \text{CC33\_GRADED}, \quad (133)$$

   then

   (a) $\texttt{TIME}_{\mathrm{min}}$, $\texttt{TIME}_{\mathrm{max}}$, $\texttt{RA}_{\mathrm{c}}$, and $\texttt{DEC}_{\mathrm{c}}$:
   The `acaofffile` data are processed to determine the earliest and latest times for which there

*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.

is aspect information and to determine the right ascension and declination coordinates near the center of the dither pattern:

$$\begin{aligned} \mathtt{TIME}_{\rm min} &= \min\left(\mathtt{TIME}_{\rm acaoff}\right), && (134)\\ \mathtt{TIME}_{\rm max} &= \max\left(\mathtt{TIME}_{\rm acaoff}\right), && (135)\\ \mathtt{RA}_{\rm c} &= \mathrm{median}\left(\mathtt{RA}_{\rm acaoff}\right), \text{ and} && (136)\\ \mathtt{DEC}_{\rm c} &= \mathrm{median}\left(\mathtt{DEC}_{\rm acaoff}\right). && (137) \end{aligned}$$

(b) $\mathtt{TIME}_{\rm c}$:
The `acaofffile` data are processed to determine the time $\mathtt{TIME}_{\rm c}$ at which the quantity

$$\cos\left(\mathtt{DEC}_{\rm acaoff}\right)\cos\left(\mathtt{DEC}_{\rm c}\right)\cos\left(\mathtt{RA}_{\rm acaoff}-\mathtt{RA}_{\rm c}\right)+\sin\left(\mathtt{DEC}_{\rm acaoff}\right)\sin\left(\mathtt{DEC}_{\rm c}\right) \quad (138)$$

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

(c) $\mathtt{RA\_ADJ}_{\rm I}$, $\mathtt{DEC\_ADJ}_{\rm I}$, $\mathtt{RA\_ADJ}_{\rm S}$, $\mathtt{DEC\_ADJ}_{\rm S}$:
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`.

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

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

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

$$\begin{aligned} \mathrm{median}\left(\mathtt{CHIPY\_TARG}\right) &\geq 16.5 \text{ and} && (139)\\ \mathrm{median}\left(\mathtt{CHIPY\_TARG}\right) &< 1008.5, && (140) \end{aligned}$$

then

A. ACIS-I:
If

$$\begin{aligned} \mathtt{CCD\_ID}_{\rm focus} &\geq 0 \text{ and} && (141)\\ \mathtt{CCD\_ID}_{\rm focus} &\leq 3, && (142) \end{aligned}$$

then

$$\begin{aligned} \mathtt{RA\_ADJ}_{\rm I} &= \mathtt{RA\_TARG}_{\rm in} \text{ and} && (143)\\ \mathtt{DEC\_ADJ}_{\rm I} &= \mathtt{DEC\_TARG}_{\rm in}. && (144) \end{aligned}$$

B. ACIS-S:
If

$$\begin{aligned} \mathtt{CCD\_ID}_{\rm focus} &\geq 4 \text{ and} && (145)\\ \mathtt{CCD\_ID}_{\rm focus} &\leq 9, && (146) \end{aligned}$$

† 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.

‡ 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.

then

$$\texttt{RA\_ADJ}_{\rm S} = \texttt{RA\_TARG}_{\rm in} \text{ and} \tag{147}$$
$$\texttt{DEC\_ADJ}_{\rm S} = \texttt{DEC\_TARG}_{\rm in}. \tag{148}$$

3. Zeroth-order coordinates:
   If

$$\texttt{OBS\_MODE} = \text{pointing or} \tag{149}$$
$$\texttt{OBS\_MODE} = \text{POINTING} \tag{150}$$

   and

$$\texttt{DATAMODE}_{\rm in} = \text{CC33\_FAINT or} \tag{151}$$
$$\texttt{DATAMODE}_{\rm in} = \text{CC33\_GRADED} \tag{152}$$

   and

$$\texttt{CONTENT}_{\rm in} = \text{TGEVT1}, \tag{153}$$

   then the $\texttt{CHIPY\_ZO}_{\rm in}$ coordinates are processed to obtain the minimum, median, and maximum values:

$$\texttt{CHIPY\_ZO}_{\rm min} = \text{minimum}\,(\texttt{CHIPY\_ZO}_{\rm in})\,, \tag{154}$$
$$\texttt{CHIPY\_ZO}_{\rm med} = \text{median}\,(\texttt{CHIPY\_ZO}_{\rm in})\,,\ \text{and} \tag{155}$$
$$\texttt{CHIPY\_ZO}_{\rm max} = \text{maximum}\,(\texttt{CHIPY\_ZO}_{\rm in})\,. \tag{156}$$

   The calculation of these three CHIPY_ZO statistics is performed using only the events for which

$$\texttt{CHIPY\_ZO} \neq \text{NaN and} \tag{157}$$
$$\texttt{TIME\_RO} - (\texttt{CHIPY\_ZO} + 1028) \times \texttt{TIMEDEL}_{\rm in} \geq \texttt{TIME}_{\rm min} \text{ and} \tag{158}$$
$$\texttt{TIME\_RO} - (\texttt{CHIPY\_ZO} + 1028) \times \texttt{TIMEDEL}_{\rm in} < \texttt{TIME}_{\rm max} \text{ and} \tag{159}$$

   $\texttt{TIME\_RO} - (\texttt{CHIPY\_ZO} + 1028) \times \texttt{TIMEDEL}_{\rm in}$ is in a good-time interval.

1.5.3 Loop over events

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

1. STATUS:
   (a) Exists:
       If HDU $h_{\rm in}$ 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

$$\texttt{doevtgrade} = \text{yes}, \tag{160}$$

       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 $h_{\rm in}$ does not include a 32-bit column named STATUS, then

   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 $\mathtt{EXPNO}_{\rm in}$.
   (b) Validation:
   If

$$\mathtt{EXPNO} < 0 \text{ or} \tag{161}$$
$$\mathtt{EXPNO} \geq 10^8, \tag{162}$$

   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 $\mathtt{CCD\_ID}_{\rm in}$.
   (b) Validation:
   If

$$\mathtt{CCD\_ID} < 0 \text{ or} \tag{163}$$
$$\mathtt{CCD\_ID} > 9, \tag{164}$$

   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

$$\mathtt{CONTENT}_{\rm in} = \text{EVT0}, \tag{165}$$

      then the value of CHIPX for an event is given by

$$\mathtt{CHIPX} = \mathtt{CCDX}_{\rm in} + 1. \tag{166}$$

      ii. Level 1, 1.5, or 2:
      If

$$\mathtt{CONTENT}_{\rm in} = \text{EVT1 or} \tag{167}$$
$$\mathtt{CONTENT}_{\rm in} = \text{TGEVT1 or} \tag{168}$$
$$\mathtt{CONTENT}_{\rm in} = \text{EVT2}, \tag{169}$$

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

i. Unphysical:
If

$$\texttt{CHIPX} < 1 \text{ or} \tag{170}$$
$$\texttt{CHIPX} > 1024, \tag{171}$$

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

$$\texttt{CHIPX} = 1 \text{ or} \tag{172}$$
$$\texttt{CHIPX} = 1024, \tag{173}$$

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

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

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

$$\texttt{CONTENT}_{\text{in}} = \text{EVT0}, \tag{175}$$

then

A. TE mode:
If

$$\texttt{DATAMODE}_{\text{in}} = \text{FAINT or} \tag{176}$$
$$\texttt{DATAMODE}_{\text{in}} = \text{FAINT\_BIAS or} \tag{177}$$
$$\texttt{DATAMODE}_{\text{in}} = \text{GRADED or} \tag{178}$$
$$\texttt{DATAMODE}_{\text{in}} = \text{VFAINT}, \tag{179}$$

then the value of CHIPY for an event is given by

$$\texttt{CHIPY} = \texttt{CCDY}_{\text{in}} + 1. \tag{180}$$

B. CC mode:
If

$$\texttt{DATAMODE}_{\text{in}} = \text{CC33\_FAINT or} \tag{181}$$
$$\texttt{DATAMODE}_{\text{in}} = \text{CC33\_GRADED}, \tag{182}$$

then the value of CHIPY for an event is given by

$$\texttt{CHIPY} = \texttt{TROW}_{\text{in}} + 1. \tag{183}$$

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

$$\texttt{DATAMODE}_{\rm in} = \text{VFAINT} \quad (202)$$

and

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

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

$$\texttt{DATAMODE}_{\rm in} = \text{CC33\_FAINT or} \quad (207)$$
$$\texttt{DATAMODE}_{\rm in} = \text{CC33\_GRADED} \quad (208)$$

and

$$\texttt{CHIPY} = 1 \text{ or} \quad (209)$$
$$\texttt{CHIPY} = 512, \quad (210)$$

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

$$\texttt{OBS\_MODE} = \text{pointing or} \quad (211)$$
$$\texttt{OBS\_MODE} = \text{POINTING} \quad (212)$$

and

$$\texttt{DATAMODE}_{\rm in} = \text{CC33\_FAINT or} \quad (213)$$
$$\texttt{DATAMODE}_{\rm in} = \text{CC33\_GRADED} \quad (214)$$

and

$$\texttt{CONTENT}_{\rm in} = \text{TGEVT1}, \quad (215)$$

then

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

ii. Validation:

A. If

$$\texttt{TG\_M} < -99, \quad (216)$$

then

$$\texttt{TG\_M} = -99 \quad (217)$$

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

$$\texttt{TG\_M} > 99, \quad (218)$$

then

$$\texttt{TG\_M} = 99 \quad (219)$$

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

$$\texttt{OBS\_MODE} = \text{pointing or} \quad (220)$$
$$\texttt{OBS\_MODE} = \text{POINTING} \quad (221)$$

and

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

and

$$\texttt{CONTENT}_{\text{in}} = \text{TGEVT1}, \quad (224)$$

then

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

ii. Validation:

A. If

$$\texttt{TG\_M} > -99 \text{ and} \quad (225)$$
$$\texttt{TG\_M} < 99 \text{ and} \quad (226)$$
$$\texttt{CHIPY\_TG} \neq \text{NaN} \quad (227)$$

and

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

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

$$\begin{aligned} \texttt{TG\_M} &> -99 \text{ and} && (230)\\ \texttt{TG\_M} &< 99 \text{ and} && (231)\\ \texttt{CHIPY\_TG} &\neq \text{NaN and} && (232)\\ \texttt{CHIPY\_TG} &< 1, && (233) \end{aligned}$$

then

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

C. If

$$\begin{aligned} \texttt{TG\_M} &> -99 \text{ and} && (235)\\ \texttt{TG\_M} &< 99 \text{ and} && (236)\\ \texttt{CHIPY\_TG} &\neq \text{NaN and} && (237)\\ \texttt{CHIPY\_TG} &> 1024, && (238) \end{aligned}$$

then

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

9. CHIPY_ZO:

   (a) CC mode with gratings:
   If

$$\begin{aligned} \texttt{OBS\_MODE} &= \text{pointing or} && (240)\\ \texttt{OBS\_MODE} &= \text{POINTING} && (241) \end{aligned}$$

   and

$$\begin{aligned} \texttt{DATAMODE}_{\text{in}} &= \text{CC33\_FAINT or} && (242)\\ \texttt{DATAMODE}_{\text{in}} &= \text{CC33\_GRADED} && (243) \end{aligned}$$

   and

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

   then

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

10. TIME_RO:

   (a) CC mode:
   If

$$\begin{aligned} \texttt{DATAMODE}_{\text{in}} &= \text{CC33\_FAINT or} && (245)\\ \texttt{DATAMODE}_{\text{in}} &= \text{CC33\_GRADED}, && (246) \end{aligned}$$

   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

$$\texttt{TIME} = \texttt{TIME}_{\rm in} \text{ and} \quad (264)$$
$$\texttt{CHIPY\_ADJ} = \texttt{CHIPY}. \quad (265)$$

ii. Pointing CC mode without grating data:
If

$$\texttt{OBS\_MODE} = \text{pointing or} \quad (266)$$
$$\texttt{OBS\_MODE} = \text{POINTING} \quad (267)$$

and

$$\texttt{DATAMODE}_{\rm in} = \text{CC33\_FAINT or} \quad (268)$$
$$\texttt{DATAMODE}_{\rm in} = \text{CC33\_GRADED} \quad (269)$$

and

$$\texttt{CONTENT}_{\rm in} = \text{EVT0 or} \quad (270)$$
$$\texttt{CONTENT}_{\rm in} = \text{EVT1 or} \quad (271)$$
$$\texttt{CONTENT}_{\rm in} = \text{EVT2}, \quad (272)$$

then

A. TIME′:
The approximate time of arrival

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

B. CHIPY_ADJ′:
If

$$\texttt{CCD\_ID}_{\rm focus} \geq 0 \text{ and} \quad (274)$$
$$\texttt{CCD\_ID}_{\rm focus} \leq 3, \quad (275)$$

then CHIPY_ADJ′ (the approximate value of CHIPY_ADJ) is given by the CHIPY location (on the focal-point CCD) of the coordinates $\texttt{RA\_ADJ}_{\rm I}$ and $\texttt{DEC\_ADJ}_{\rm I}$ 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 $\texttt{TIME}' < \texttt{TIME}_{\rm min}$ or $\texttt{TIME}' \geq \texttt{TIME}_{\rm max}$, then $\texttt{TIME}_{\rm c}$ is used instead of TIME′. If

$$\texttt{CCD\_ID}_{\rm focus} \geq 4 \text{ and} \quad (276)$$
$$\texttt{CCD\_ID}_{\rm focus} \leq 9, \quad (277)$$

then CHIPY_ADJ′ is given by the CHIPY location (on the focal-point CCD) of the coordinates $\texttt{RA\_ADJ}_{\rm S}$ and $\texttt{DEC\_ADJ}_{\rm S}$ 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 $\texttt{TIME}' < \texttt{TIME}_{\rm min}$ or $\texttt{TIME}' \geq \texttt{TIME}_{\rm max}$, then $\texttt{TIME}_{\rm c}$ is used instead of TIME′.

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

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

D. CHIPY_ADJ:
If

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

then the value of CHIPY_ADJ is given by the CHIPY location (on the focal-point CCD) of the coordinates $\mathtt{RA\_ADJ}_{\mathrm{I}}$ and $\mathtt{DEC\_ADJ}_{\mathrm{I}}$ 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 $\mathtt{TIME} < \mathtt{TIME}_{\mathrm{min}}$ or $\mathtt{TIME} \geq \mathtt{TIME}_{\mathrm{max}}$, then $\mathtt{TIME}_{\mathrm{c}}$ is used instead of TIME. If

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

then the value of CHIPY_ADJ is given by the CHIPY location (on the focal-point CCD) of the coordinates $\mathtt{RA\_ADJ}_{\mathrm{S}}$ and $\mathtt{DEC\_ADJ}_{\mathrm{S}}$ 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 $\mathtt{TIME} < \mathtt{TIME}_{\mathrm{min}}$ or $\mathtt{TIME} \geq \mathtt{TIME}_{\mathrm{max}}$, then $\mathtt{TIME}_{\mathrm{c}}$ 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

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

and

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

and

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

then

A. Source events in GTIs:
If

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

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

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

B. Source events not in GTIs:
If

$$\texttt{TG\_M} > -99 \text{ and} \tag{297}$$
$$\texttt{TG\_M} < 99 \text{ and} \tag{298}$$
$$\texttt{CHIPY\_TG} \neq \text{NaN} \tag{299}$$

and

$$\texttt{TIME\_RO} - (\texttt{CHIPY\_TG} + 1028) \times \texttt{TIMEDEL}_{\text{in}} < \texttt{TIME}_{\text{min}} \text{ or} \tag{300}$$
$$\texttt{TIME\_RO} - (\texttt{CHIPY\_TG} + 1028) \times \texttt{TIMEDEL}_{\text{in}} \geq \texttt{TIME}_{\text{max}} \tag{301}$$

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

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

C. Background events with zeroth order on the array in GTIs:
If

$$\texttt{TG\_M} = -99 \text{ or} \tag{304}$$
$$\texttt{TG\_M} = 99 \tag{305}$$

and

$$\texttt{CHIPY\_ZO} \neq \text{NaN and} \tag{306}$$
$$\texttt{CHIPY\_ZO}_{\text{min}} \geq 0.5 \text{ and} \tag{307}$$
$$\texttt{CHIPY\_ZO}_{\text{max}} < 1024.5 \tag{308}$$

and

$$\texttt{TIME\_RO} - (\texttt{CHIPY\_ZO} + 1028) \times \texttt{TIMEDEL}_{\text{in}} \geq \texttt{TIME}_{\text{min}} \text{ and} \tag{309}$$
$$\texttt{TIME\_RO} - (\texttt{CHIPY\_ZO} + 1028) \times \texttt{TIMEDEL}_{\text{in}} < \texttt{TIME}_{\text{max}} \tag{310}$$

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

$$\texttt{CHIPY\_ADJ} = \texttt{CHIPY\_ZO} \text{ and} \tag{311}$$
$$\texttt{TIME} = \texttt{TIME\_RO} - (\texttt{CHIPY\_ADJ} + 1028) \times \texttt{TIMEDEL}_{\text{in}}. \tag{312}$$

D. Background events with zeroth order on the array not in GTIs:
If

$$\texttt{TG\_M} = -99 \text{ or} \tag{313}$$
$$\texttt{TG\_M} = 99 \tag{314}$$

and

$$\texttt{CHIPY\_ZO} \neq \text{NaN and} \tag{315}$$
$$\texttt{CHIPY\_ZO}_{\text{min}} \geq 0.5 \text{ and} \tag{316}$$
$$\texttt{CHIPY\_ZO}_{\text{max}} < 1024.5 \tag{317}$$

and

$$\texttt{TIME\_RO} - (\texttt{CHIPY\_ZO} + 1028) \times \texttt{TIMEDEL}_{\text{in}} < \texttt{TIME}_{\text{min}} \text{ or} \tag{318}$$
$$\texttt{TIME\_RO} - (\texttt{CHIPY\_ZO} + 1028) \times \texttt{TIMEDEL}_{\text{in}} \geq \texttt{TIME}_{\text{max}} \tag{319}$$

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

$$\texttt{CHIPY\_ADJ} = \texttt{CHIPY\_ZO}_{\rm med} \text{ and} \quad (320)$$
$$\texttt{TIME} = \texttt{TIME\_RO} - (\texttt{CHIPY\_ADJ} + 1028) \times \texttt{TIMEDEL}_{\rm in}. \quad (321)$$

E. Background events with zeroth order off the array in GTIs:
If

$$\texttt{TG\_M} = -99 \text{ or} \quad (322)$$
$$\texttt{TG\_M} = 99 \quad (323)$$

and

$$\texttt{CHIPY\_ZO} \neq \text{NaN} \quad (324)$$

and

$$\texttt{CHIPY\_ZO}_{\rm max} < 0.5 \text{ or} \quad (325)$$
$$\texttt{CHIPY\_ZO}_{\rm min} \geq 1024.5 \quad (326)$$

and

$$\texttt{TIME\_RO} - (\texttt{CHIPY\_ZO}_{\rm med} + 1028) \times \texttt{TIMEDEL}_{\rm in} \geq \texttt{TIME}_{\rm min} \text{ and} \quad (327)$$
$$\texttt{TIME\_RO} - (\texttt{CHIPY\_ZO}_{\rm med} + 1028) \times \texttt{TIMEDEL}_{\rm in} < \texttt{TIME}_{\rm max} \quad (328)$$

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

$$\texttt{CHIPY\_ADJ} = \texttt{CHIPY\_ZO}_{\rm med} \text{ and} \quad (329)$$
$$\texttt{TIME} = \texttt{TIME\_RO} - (\texttt{CHIPY\_ADJ} + 1028) \times \texttt{TIMEDEL}_{\rm in}. \quad (330)$$

F. Background events with zeroth order off the array not in GTIs:
If

$$\texttt{TG\_M} = -99 \text{ or} \quad (331)$$
$$\texttt{TG\_M} = 99 \quad (332)$$

and

$$\texttt{CHIPY\_ZO} \neq \text{NaN} \quad (333)$$

and

$$\texttt{CHIPY\_ZO}_{\rm max} < 0.5 \text{ or} \quad (334)$$
$$\texttt{CHIPY\_ZO}_{\rm min} \geq 1024.5 \quad (335)$$

and

$$\texttt{TIME\_RO} - (\texttt{CHIPY\_ZO}_{\rm med} + 1028) \times \texttt{TIMEDEL}_{\rm in} < \texttt{TIME}_{\rm min} \text{ or} \quad (336)$$
$$\texttt{TIME\_RO} - (\texttt{CHIPY\_ZO}_{\rm med} + 1028) \times \texttt{TIMEDEL}_{\rm in} \geq \texttt{TIME}_{\rm max} \quad (337)$$

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

$$\texttt{CHIPY\_ADJ} = \texttt{CHIPY\_ZO}_{\rm med} \text{ and} \quad (338)$$
$$\texttt{TIME} = \texttt{TIME\_RO} - (\texttt{CHIPY\_ADJ} + 1028) \times \texttt{TIMEDEL}_{\rm in}. \quad (339)$$

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

$$\texttt{OBS\_MODE} = \text{pointing or} \tag{340}$$
$$\texttt{OBS\_MODE} = \text{POINTING} \tag{341}$$

and

$$\texttt{DATAMODE}_{\text{in}} = \text{CC33\_FAINT or} \tag{342}$$
$$\texttt{DATAMODE}_{\text{in}} = \text{CC33\_GRADED} \tag{343}$$

and

$$\texttt{CONTENT}_{\text{in}} = \text{TGEVT1} \tag{344}$$

and

$$\texttt{CCD\_ID}_{\text{focus}} \geq 0 \text{ and} \tag{345}$$
$$\texttt{CCD\_ID}_{\text{focus}} \leq 3, \tag{346}$$

then

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

$$\texttt{TIME}' = \texttt{TIME\_RO} - (512 + 1028) \times \texttt{TIMEDEL}_{\text{in}}. \tag{347}$$

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

C. TIME:
The value of $\texttt{CHIPY\_ADJ}'$ is used to obtain a better estimate of the time of arrival

$$\texttt{TIME} = \texttt{TIME\_RO} - (\texttt{CHIPY\_ADJ}' + 1028) \times \texttt{TIMEDEL}_{\text{in}}. \tag{348}$$

D. CHIPY_ADJ:
The value of CHIPY_ADJ is given by the CHIPY location (on the focal-point CCD) of the coordinates $\texttt{RA\_ADJ}_{\text{I}}$ and $\texttt{DEC\_ADJ}_{\text{I}}$ 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 $\texttt{TIME} < \texttt{TIME}_{\text{min}}$ or $\texttt{TIME} \geq \texttt{TIME}_{\text{max}}$, then $\texttt{TIME}_{\text{c}}$ is used instead of TIME.

v. Secondary CC mode:
If

$$\texttt{OBS\_MODE} \neq \text{pointing and} \tag{349}$$
$$\texttt{OBS\_MODE} \neq \text{POINTING}, \tag{350}$$

then

A. TIME:

$$\texttt{TIME} = \texttt{TIME\_RO} - (512 + 1028) \times \texttt{TIMEDEL}_{\text{in}}. \tag{351}$$

B. CHIPY_ADJ:

$$\texttt{CHIPY\_ADJ} = 512. \quad (352)$$

(b) Validation:

i. If

$$\texttt{TIME} < 0 \text{ or} \quad (353)$$
$$\texttt{TIME} \geq 3 \times 10^9, \quad (354)$$

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

$$\texttt{CHIPY\_ADJ} < 0.5 \text{ or} \quad (355)$$
$$\texttt{CHIPY\_ADJ} \geq 1024.5, \quad (356)$$

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

$$\texttt{badpixfile} \neq \text{none and} \quad (357)$$
$$\texttt{badpixfile} \neq \text{NONE} \quad (358)$$

and the badpixfile includes a valid HDU $h_{\rm badpix}$ where $\texttt{CCD\_ID}_{\rm badpix} = \texttt{CCD\_ID}$, 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 $\texttt{DATAMODE}_{\rm in}$ = CC33_FAINT or $\texttt{DATAMODE}_{\rm in}$ = CC33_GRADED and there are one or more rows r in HDU $h_{\rm badpix}$ where

$$\texttt{CHIPX} \geq \texttt{CHIPX}_{{\rm badpix},r}[0] \text{ and} \quad (359)$$
$$\texttt{CHIPX} \leq \texttt{CHIPX}_{{\rm badpix},r}[1] \text{ and} \quad (360)$$
$$\texttt{TIME} \geq \texttt{TIME}_{{\rm badpix},r} \text{ and} \quad (361)$$
$$\texttt{TIME} < \texttt{TIME\_STOP}_{{\rm badpix},r} \quad (362)$$

and

$$\texttt{STATUS}_{{\rm badpix},r}[5] = 1 \text{ or} \quad (363)$$
$$\texttt{STATUS}_{{\rm badpix},r}[6] = 1 \text{ or} \quad (364)$$
$$\texttt{STATUS}_{{\rm badpix},r}[9] = 1, \quad (365)$$

then

$$\texttt{STATUS}[0] = 1 \quad (366)$$

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

$$\begin{aligned}\texttt{CHIPX} &\geq \texttt{CHIPX}_{\text{badpix},r}[0] \text{ and} && (367)\\ \texttt{CHIPX} &\leq \texttt{CHIPX}_{\text{badpix},r}[1] \text{ and} && (368)\\ \texttt{TIME} &\geq \texttt{TIME}_{\text{badpix},r} \text{ and} && (369)\\ \texttt{TIME} &< \texttt{TIME\_STOP}_{\text{badpix},r} && (370)\end{aligned}$$

and

$$\begin{aligned}\texttt{STATUS}_{\text{badpix},r}[0] &= 1 \text{ or} && (371)\\ \texttt{STATUS}_{\text{badpix},r}[1] &= 1 \text{ or} && (372)\\ \texttt{STATUS}_{\text{badpix},r}[7] &= 1 \text{ or} && (373)\\ \texttt{STATUS}_{\text{badpix},r}[11] &= 1 \text{ or} && (374)\\ \texttt{STATUS}_{\text{badpix},r}[12] &= 1 \text{ or} && (375)\\ \texttt{STATUS}_{\text{badpix},r}[13] &= 1 \text{ or} && (376)\\ \texttt{STATUS}_{\text{badpix},r}[14] &= 1 \text{ or} && (377)\\ \texttt{STATUS}_{\text{badpix},r}[16] &= 1, && (378)\end{aligned}$$

then

$$\texttt{STATUS}[4] = 1 \quad (379)$$

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

$$\begin{aligned}\texttt{CHIPX} &\geq \texttt{CHIPX}_{\text{badpix},r}[0] \text{ and} && (380)\\ \texttt{CHIPX} &\leq \texttt{CHIPX}_{\text{badpix},r}[1] \text{ and} && (381)\\ \texttt{TIME} &\geq \texttt{TIME}_{\text{badpix},r} \text{ and} && (382)\\ \texttt{TIME} &< \texttt{TIME\_STOP}_{\text{badpix},r} && (383)\end{aligned}$$

and

$$\begin{aligned}\texttt{STATUS}_{\text{badpix},r}[8] &= 1 \text{ or} && (384)\\ \texttt{STATUS}_{\text{badpix},r}[10] &= 1, && (385)\end{aligned}$$

then

$$\texttt{STATUS}[5] = 1 \quad (386)$$

for the event.

iv. 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

$$\begin{aligned}\texttt{CHIPX} &\geq \texttt{CHIPX}_{\text{badpix},r}[0] \text{ and} && (387)\\ \texttt{CHIPX} &\leq \texttt{CHIPX}_{\text{badpix},r}[1] \text{ and} && (388)\\ \texttt{TIME} &\geq \texttt{TIME}_{\text{badpix},r} \text{ and} && (389)\\ \texttt{TIME} &< \texttt{TIME\_STOP}_{\text{badpix},r} && (390)\end{aligned}$$

and

$$\texttt{STATUS}_{\text{badpix},r}[3] = 1, \quad (391)$$

then

$$\texttt{STATUS}[6] = 1 \tag{392}$$

for the event.

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

$$\begin{aligned} \texttt{CHIPX} &\geq \texttt{CHIPX}_{{\rm badpix},r}[0] \text{ and} & (393)\\ \texttt{CHIPX} &\leq \texttt{CHIPX}_{{\rm badpix},r}[1] \text{ and} & (394)\\ \texttt{TIME} &\geq \texttt{TIME}_{{\rm badpix},r} \text{ and} & (395)\\ \texttt{TIME} &< \texttt{TIME\_STOP}_{{\rm badpix},r} & (396)\end{aligned}$$

and

$$\begin{aligned} \texttt{STATUS}_{{\rm badpix},r}[2] &= 1 \text{ or} & (397)\\ \texttt{STATUS}_{{\rm badpix},r}[4] &= 1, & (398)\end{aligned}$$

then

$$\texttt{STATUS}[8] = 1 \tag{399}$$

for the event.

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

$$\begin{aligned} \texttt{CHIPX} &\geq \texttt{CHIPX}_{{\rm badpix},r}[0] \text{ and} & (400)\\ \texttt{CHIPX} &\leq \texttt{CHIPX}_{{\rm badpix},r}[1] \text{ and} & (401)\\ \texttt{TIME} &\geq \texttt{TIME}_{{\rm badpix},r} \text{ and} & (402)\\ \texttt{TIME} &< \texttt{TIME\_STOP}_{{\rm badpix},r} & (403)\end{aligned}$$

and

$$\texttt{STATUS}_{{\rm badpix},r}[15] = 1, \tag{404}$$

then

$$\texttt{STATUS}[16] = 1 \tag{405}$$

for the event.

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.

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

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

$$\Delta_x[j] = 0, \tag{406}$$
$$\Delta_y[j] = 0, \text{ and} \tag{407}$$
$$\texttt{PHAS\_ADJ}[j] = \texttt{PHAS}[j] \tag{408}$$

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

$$n = 1. \tag{409}$$

iii. The temporary variables Δ'_x, Δ'_y, and PHAS_ADJ$'$ are set such that

$$\Delta'_x[j] = \Delta_x[j], \tag{410}$$
$$\Delta'_y[j] = \Delta_y[j], \text{ and} \tag{411}$$
$$\texttt{PHAS\_ADJ}'[j] = \texttt{PHAS\_ADJ}[j] \tag{412}$$

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

$$\Delta_x[0] = c_x[0]s_x\rho_x[0]V_x[0], \tag{413}$$
$$\Delta_x[1] = c_x[1]s_x\rho_x[1]V_x[1] - c'_x[0]s_x\rho_x[0]V_x[0], \tag{414}$$
$$\Delta_x[2] = c_x[2]s_x\rho_x[2]V_x[2] - c'_x[1]s_x\rho_x[1]V_x[1], \tag{415}$$
$$\Delta_x[3] = c_x[3]s_x\rho_x[3]V_x[3], \tag{416}$$

$$
\begin{aligned}
\Delta_x[4] &= c_x[4]s_x\rho_x[4]V_x[4] - c'_x[3]s_x\rho_x[3]V_x[3], && (417)\\
\Delta_x[5] &= c_x[5]s_x\rho_x[5]V_x[5] - c'_x[4]s_x\rho_x[4]V_x[4], && (418)\\
\Delta_x[6] &= c_x[6]s_x\rho_x[6]V_x[6], && (419)\\
\Delta_x[7] &= c_x[7]s_x\rho_x[7]V_x[7] - c'_x[6]s_x\rho_x[6]V_x[6], \text{ and} && (420)\\
\Delta_x[8] &= c_x[8]s_x\rho_x[8]V_x[8] - c'_x[7]s_x\rho_x[7]V_x[7], && (421)
\end{aligned}
$$

where

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

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

$$
\begin{aligned}
s_x &= 1 + \texttt{TCTIX}\,(T - \texttt{FP\_TEMP0})\,, && (422)\\
& \begin{cases} s_x \text{ is a temperature dependent scaling factor,} \\ \texttt{TCTIX} \text{ is the } \texttt{CCD\_ID} \text{ dependent value in the column } \texttt{TCTIX} \text{ of the} \\ \quad \texttt{ctifile}, \\ \texttt{FP\_TEMP0} \text{ is the name of a keyword in the } \texttt{ctifile}, \end{cases} \\
T &= \left(\frac{t' - t'_k}{t'_{k+1} - t'_k}\right)(\texttt{FP\_TEMP}_{k+1} - \texttt{FP\_TEMP}_k) + \texttt{FP\_TEMP}_k, && (423)\\
& \left\{ T \text{ is the time dependent focal plane temperature,} \right. \\
t' &= t + \texttt{TIMEDEL}_{\rm in}\,(\texttt{TIMEPIXR}_{\rm evt} - 0.5)\,, && (424)\\
& \begin{cases} t \text{ is the } \texttt{TIME} \text{ of the event,} \\ \texttt{TIMEPIXR}_{\rm evt} \text{ is a keyword in the } \texttt{infile}, \end{cases} \\
t'_k &= \texttt{TIME}_k + \texttt{TIMEDEL}_{\rm mtl}\,(\texttt{TIMEPIXR}_{\rm mtl} - 0.5)\,, && (425)
\end{aligned}
$$

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

$$t'_{k+1} = \texttt{TIME}_{k+1} + \texttt{TIMEDEL}_{\text{mtl}} \left(\texttt{TIMEPIXR}_{\text{mtl}} - 0.5\right), \tag{426}$$

$$\left\{\begin{array}{l}\texttt{TIME}_{k+1} \text{ is the } (k+1)^{\text{th}} \text{ element of the column } \texttt{TIME} \text{ in the } \texttt{mtlfile}, \\ t'_{k+1} > t', \\ \text{If } t' > t'_k \text{ for } k = n, \text{ where } n \text{ is the last element, then } k = n, \\ \texttt{FP\_TEMP}_{k+1} \text{ is the } (k+1)^{\text{th}} \text{ element of the column } \texttt{FP\_TEMP} \text{ in the} \\ \quad \texttt{mtlfile},\end{array}\right.$$

$$\rho_x[j] = \text{serial trap density}, \tag{427}$$

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

$$V_x[j] = \left(\frac{\texttt{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] - \texttt{PHA}_l}{\texttt{PHA}_{l+1} - \texttt{PHA}_l}\right)\left(\texttt{VOLUME\_X}_{l+1} - \texttt{VOLUME\_X}_l\right) + \texttt{VOLUME\_X}_l, \tag{428}$$

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

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

$$\Delta_x[0] = c_x[0] s_x \rho_x[0] V_x[0] - c'_x[1] s_x \rho_x[1] V_x[1], \tag{429}$$

$$\Delta_x[1] = c_x[1] s_x \rho_x[1] V_x[1] - c'_x[2] s_x \rho_x[2] V_x[2], \tag{430}$$

$$\Delta_x[2] = c_x[2] s_x \rho_x[2] V_x[2], \tag{431}$$

$$\Delta_x[3] = c_x[3] s_x \rho_x[3] V_x[3] - c'_x[4] s_x \rho_x[4] V_x[4], \tag{432}$$

$$\Delta_x[4] = c_x[4] s_x \rho_x[4] V_x[4] - c'_x[5] s_x \rho_x[5] V_x[5], \tag{433}$$

$$\Delta_x[5] = c_x[5] s_x \rho_x[5] V_x[5], \tag{434}$$

$$\Delta_x[6] = c_x[6] s_x \rho_x[6] V_x[6] - c'_x[7] s_x \rho_x[7] V_x[7], \tag{435}$$

$$\Delta_x[7] = c_x[7] s_x \rho_x[7] V_x[7] - c'_x[8] s_x \rho_x[8] V_x[8], \text{ and} \tag{436}$$

$$\Delta_x[8] = c_x[8] s_x \rho_x[8] V_x[8], \tag{437}$$

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. 422, 423, 424, 425, 426, 427, and 428, 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

$$\Delta_y[0] = c_y[0] s_y \rho_y[0] V_y[0], \tag{438}$$
$$\Delta_y[1] = c_y[1] s_y \rho_y[1] V_y[1], \tag{439}$$
$$\Delta_y[2] = c_y[2] s_y \rho_y[2] V_y[2], \tag{440}$$
$$\Delta_y[3] = c_y[3] s_y \rho_y[3] V_y[3] - c'_y[0] s_y \rho_y[0] V_y[0], \tag{441}$$
$$\Delta_y[4] = c_y[4] s_y \rho_y[4] V_y[4] - c'_y[1] s_y \rho_y[1] V_y[1], \tag{442}$$
$$\Delta_y[5] = c_y[5] s_y \rho_y[5] V_y[5] - c'_y[2] s_y \rho_y[2] V_y[2], \tag{443}$$
$$\Delta_y[6] = c_y[6] s_y \rho_y[6] V_y[6] - c'_y[3] s_y \rho_y[3] V_y[3], \tag{444}$$
$$\Delta_y[7] = c_y[7] s_y \rho_y[7] V_y[7] - c'_y[4] s_y \rho_y[4] V_y[4], \text{ and} \tag{445}$$
$$\Delta_y[8] = c_y[8] s_y \rho_y[8] V_y[8] - c'_y[5] s_y \rho_y[5] V_y[5], \tag{446}$$

where

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

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

$$s_y = 1 + \texttt{TCTIY}\,(T - \texttt{FP\_TEMPO})\,, \tag{447}$$

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

$$\rho_y[j] = \text{parallel trap density}, \tag{448}$$

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

$$V_y[j] = \left(\frac{\texttt{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] - \texttt{PHA}_l}{\texttt{PHA}_{l+1} - \texttt{PHA}_l}\right)(\texttt{VOLUME\_Y}_{l+1} - \texttt{VOLUME\_Y}_l) + \texttt{VOLUME\_Y}_l, \tag{449}$$

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

and T, t', t'_k, and t'_{k+1}, are given by equations. 423, 424, 425, and 426, respectively.

vi. The CTI-adjusted pulse heights

$$\texttt{PHAS\_ADJ}[j] = \texttt{PHAS}[j] + \Delta_x[j] + \Delta_y[j] \tag{450}$$

for all j.

vii. A. If

$$|\texttt{PHAS\_ADJ}'[j] - \texttt{PHAS\_ADJ}[j]| < \texttt{cticonverge} \text{ (for all } j\text{) and} \tag{451}$$
$$n \leq \texttt{max\_cti\_iter}, \tag{452}$$

then the computation of PHAS_ADJ is complete for the event.

B. If

$$|\texttt{PHAS\_ADJ}'[j] - \texttt{PHAS\_ADJ}[j]| \geq \texttt{cticonverge} \text{ (for one or more } j\text{) and} \tag{453}$$
$$n < \texttt{max\_cti\_iter}, \tag{454}$$

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

C. If

$$|\texttt{PHAS\_ADJ}'[j] - \texttt{PHAS\_ADJ}[j]| \geq \texttt{cticonverge} \text{ (for one or more } j\text{) and} \tag{455}$$
$$n \geq \texttt{max\_cti\_iter}, \tag{456}$$

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

$$\texttt{DATAMODE}_{\text{in}} = \text{CC33\_FAINT and} \tag{457}$$
$$\texttt{apply\_cti} = \text{yes,} \tag{458}$$

then

$$\texttt{FLTGRADE} = c_{\text{f}}[0] + 2c_{\text{f}}[1] + 4c_{\text{f}}[2] + 8c_{\text{f}}[3] + 16c_{\text{f}}[5] + 32c_{\text{f}}[6] + 64c_{\text{f}}[7] + 128c_{\text{f}}[8], \tag{459}$$

where

$$c_{\text{f}}[j] = \begin{cases} 0 & \text{if } \texttt{PHAS\_ADJ}[j] < \text{split threshold} \\ 1 & \text{otherwise,} \end{cases} \tag{460}$$

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

(b) If

$$\texttt{DATAMODE}_{\text{in}} = \text{CC33\_FAINT and} \tag{461}$$
$$\texttt{apply\_cti} = \text{no,} \tag{462}$$

then

$$\texttt{FLTGRADE} = c_{\text{f}}[0] + 2c_{\text{f}}[1] + 4c_{\text{f}}[2] + 8c_{\text{f}}[3] + 16c_{\text{f}}[5] + 32c_{\text{f}}[6] + 64c_{\text{f}}[7] + 128c_{\text{f}}[8], \tag{463}$$

where

$$c_{\text{f}}[j] = \begin{cases} 0 & \text{if } \texttt{PHAS}[j] < \text{split threshold} \\ 0 & \text{if } \texttt{PHAS}[j] > 4095 \\ 0 & \text{if } \texttt{PHAS}[j] > \texttt{PHAS}[4] \text{ for } j = 0 - 3) \\ 0 & \text{if } \texttt{PHAS}[j] \geq \texttt{PHAS}[4] \text{ for } j = 5 - 8) \\ 1 & \text{otherwise.} \end{cases} \tag{464}$$

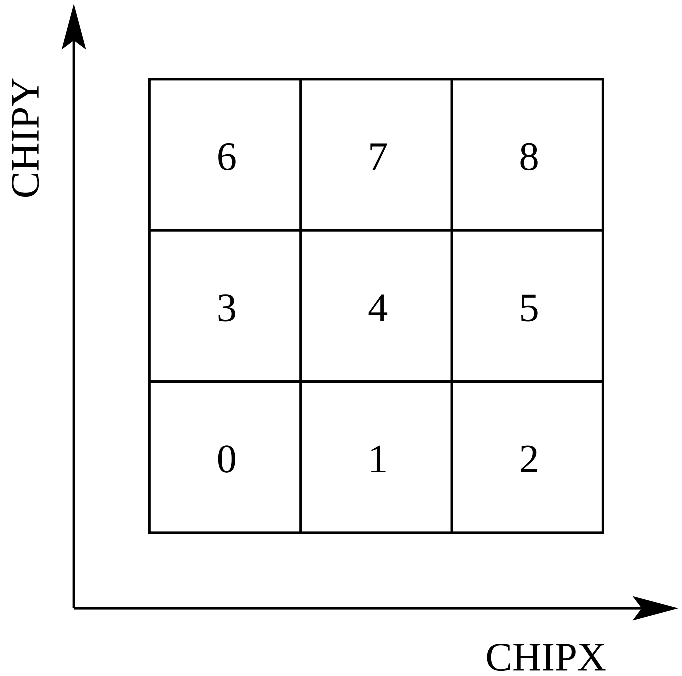

Figure 1: The relative CHIPX and CHIPY coordinates of the nine elements $j = 0$–8 of a 3 pixel × 3 pixel event island PHAS$[j]$ or PHAS_ADJ$[j]$.

(c) If

$$\texttt{DATAMODE}_{\rm in} \quad = \quad \text{CC33\_GRADED}, \tag{465}$$

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

$$\texttt{FLTGRADE}_{{\rm grade},i} = \texttt{FLTGRADE}, \tag{466}$$

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

iii. The GRADE of the event is given by

$$\texttt{GRADE} = \texttt{GRADE}_{{\rm grade},i}, \tag{467}$$

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

17. PHA_RO:

(a) If

$$\texttt{DATAMODE}_{\rm in} = \text{CC33\_FAINT}, \tag{468}$$

then

$$\texttt{PHA\_RO} = \sum_{j=0}^{8} \beta[j]p[j], \tag{469}$$

where

i.

$$p[j] = \texttt{PHAS}[j]. \tag{470}$$

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

iii.

$$\beta[j] = 0 \quad \text{if} \quad p[j] < \text{split threshold}. \tag{471}$$

iv.

$$\beta[j] = 0 \text{ if } \begin{cases} p[j] > p[4] \text{ (for } j = 0\text{–}3) \\ p[j] \geq p[4] \text{ (for } j = 5\text{–}8) \end{cases} \tag{472}$$

v. If CORNERS $= -1$, then

$$\beta[0] = \beta[2] = \beta[6] = \beta[8] = 0. \tag{473}$$

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

$$\beta[0] = 0 \quad \text{if} \quad \beta[1] = 0 \text{ and } \beta[3] = 0. \tag{474}$$
$$\beta[2] = 0 \quad \text{if} \quad \beta[1] = 0 \text{ and } \beta[5] = 0. \tag{475}$$
$$\beta[6] = 0 \quad \text{if} \quad \beta[3] = 0 \text{ and } \beta[7] = 0. \tag{476}$$
$$\beta[8] = 0 \quad \text{if} \quad \beta[5] = 0 \text{ and } \beta[7] = 0. \tag{477}$$

viii. If CORNERS $= 2$, then

$$\beta[0] = 0 \quad \text{if} \quad \beta[1] = 0 \text{ or } \beta[3] = 0 \text{ or } \texttt{GRADE} \neq 6. \tag{478}$$
$$\beta[2] = 0 \quad \text{if} \quad \beta[1] = 0 \text{ or } \beta[5] = 0 \text{ or } \texttt{GRADE} \neq 6. \tag{479}$$
$$\beta[6] = 0 \quad \text{if} \quad \beta[3] = 0 \text{ or } \beta[7] = 0 \text{ or } \texttt{GRADE} \neq 6. \tag{480}$$
$$\beta[8] = 0 \quad \text{if} \quad \beta[5] = 0 \text{ or } \beta[7] = 0 \text{ or } \texttt{GRADE} \neq 6. \tag{481}$$

(b) If

$$\texttt{DATAMODE}_{\text{in}} = \text{CC33\_GRADED}, \tag{482}$$

then

i. If

$$\texttt{CONTENT}_{\text{in}} = \text{EVT0}, \tag{483}$$

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

ii. If

$$\texttt{CONTENT}_{\text{in}} = \text{EVT1 or} \tag{484}$$
$$\texttt{CONTENT}_{\text{in}} = \text{TGEVT1 or} \tag{485}$$
$$\texttt{CONTENT}_{\text{in}} = \text{EVT2}, \tag{486}$$

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

$$\texttt{DATAMODE}_{\rm in} = \text{CC33\_FAINT}, \tag{487}$$

then

$$\texttt{PHA} = \sum_{j=0}^{8} \beta[j] p[j], \tag{488}$$

where

i.

$$p[j] = \begin{cases} \texttt{PHAS\_ADJ}[j] & \text{if } \texttt{apply\_cti} = \text{yes} \\ \texttt{PHAS}[j] & \text{if } \texttt{apply\_cti} = \text{no} \end{cases} \tag{489}$$

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

iii.

$$\beta[j] = 0 \quad \text{if} \quad p[j] < \text{split threshold}. \tag{490}$$

iv. If the CTI adjustment is not performed, then

$$\beta[j] = 0 \text{ if } \begin{cases} p[j] > p[4] \text{ (for } j = 0\text{–}3) \\ p[j] \geq p[4] \text{ (for } j = 5\text{–}8) \end{cases} \tag{491}$$

v. If CORNERS $= -1$, then

$$\beta[0] = \beta[2] = \beta[6] = \beta[8] = 0. \tag{492}$$

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

$$\beta[0] = 0 \quad \text{if} \quad \beta[1] = 0 \text{ and } \beta[3] = 0. \tag{493}$$

$$\beta[2] = 0 \quad \text{if} \quad \beta[1] = 0 \text{ and } \beta[5] = 0. \tag{494}$$

$$\beta[6] = 0 \quad \text{if} \quad \beta[3] = 0 \text{ and } \beta[7] = 0. \tag{495}$$

$$\beta[8] = 0 \quad \text{if} \quad \beta[5] = 0 \text{ and } \beta[7] = 0. \tag{496}$$

viii. If CORNERS $= 2$, then

$$\beta[0] = 0 \quad \text{if} \quad \beta[1] = 0 \text{ or } \beta[3] = 0 \text{ or } \texttt{GRADE} \neq 6. \tag{497}$$

$$\beta[2] = 0 \quad \text{if} \quad \beta[1] = 0 \text{ or } \beta[5] = 0 \text{ or } \texttt{GRADE} \neq 6. \tag{498}$$

$$\beta[6] = 0 \quad \text{if} \quad \beta[3] = 0 \text{ or } \beta[7] = 0 \text{ or } \texttt{GRADE} \neq 6. \tag{499}$$

$$\beta[8] = 0 \quad \text{if} \quad \beta[5] = 0 \text{ or } \beta[7] = 0 \text{ or } \texttt{GRADE} \neq 6. \tag{500}$$

(b) If

$$\texttt{DATAMODE}_{\rm in} = \text{CC33\_GRADED}, \tag{501}$$

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

(c) If

$$\texttt{apply\_tgain} = \text{yes}, \tag{502}$$

then

$$\texttt{PHA} = \texttt{PHA} - \text{int}\left[\left(\frac{\texttt{TIME} - \texttt{EPOCH1}}{\texttt{EPOCH2} - \texttt{EPOCH1}}\right)(\delta_2 - \delta_1) + \delta_1 - \epsilon\right], \tag{503}$$

where

$$\text{int} = \text{the integer portion of (i.e. truncate or round down)}, \quad (504)$$

$$\texttt{TIME} = \text{the time of the event}, \quad (505)$$

$$\texttt{EPOCH1} = \text{a keyword in the } \texttt{tgainfile}, \quad (506)$$

$$\texttt{EPOCH2} = \text{a keyword in the } \texttt{tgainfile}, \quad (507)$$

$$\delta_1 = \left(\frac{\texttt{PHA} - \texttt{PHA}_m[r]}{\texttt{PHA}_{m+1}[r] - \texttt{PHA}_m[r]}\right)(\texttt{DELTPHA1}_{m+1}[r] - \texttt{DELTPHA1}_m[r]) + \quad (508)$$

$$\texttt{DELTPHA1}_m[r], \quad (509)$$

$$\left\{\begin{array}{l} r \text{ is the row of the } \texttt{tgainfile} \text{ where} \\ \left\{\begin{array}{l} \texttt{CCD\_ID}[r] = \texttt{CCD\_ID}, \\ \texttt{CHIPX\_LO}[r] \leq \texttt{CHIPX}, \\ \texttt{CHIPX\_HI}[r] \geq \texttt{CHIPX}, \\ \texttt{CHIPY\_LO}[r] \leq \text{nint}(\texttt{CHIPY\_ADJ}), \text{ and} \\ \texttt{CHIPY\_HI}[r] \geq \text{nint}(\texttt{CHIPY\_ADJ}). \end{array}\right. \\ m \text{ is the element of row } r \text{ where} \\ \left\{\begin{array}{l} \texttt{PHA}_m[r] \leq \texttt{PHA} \text{ and} \\ \texttt{PHA}_{m+1}[r] > \texttt{PHA}. \\ \text{If } \texttt{PHA} < \texttt{PHA}_m[r] \text{ for } m = 0, \text{ then } m = 0. \\ \text{If } \texttt{PHA} \geq \texttt{PHA}_m[r] \text{ for } m = M \text{ and } M \text{ is the last element of } \texttt{PHA}[r], \\ \quad \text{then } m = M - 1. \end{array}\right. \\ \text{The } \texttt{tgainfile} \text{ includes a binary table with columns named} \\ \quad \texttt{CCD\_ID}, \texttt{CHIPX\_LO}, \texttt{CHIPX\_HI}, \texttt{CHIPY\_LO}, \texttt{CHIPY\_HI}, \texttt{PHA}, \texttt{DELTPHA1}, \text{ and} \\ \quad \texttt{DELTPHA2}. \end{array}\right. \quad (510)$$

$$\delta_2 = \left(\frac{\texttt{PHA} - \texttt{PHA}_m[r]}{\texttt{PHA}_{m+1}[r] - \texttt{PHA}_m[r]}\right)(\texttt{DELTPHA2}_{m+1}[r] - \texttt{DELTPHA2}_m[r]) + \quad (511)$$

$$\texttt{DELTPHA2}_m[r], \quad (512)$$

$$\epsilon = \text{is a uniform random deviate in the range } [0, 1), \quad (513)$$

$$\{ \text{ If } \texttt{rand\_pha} = \text{no}, \text{ then } \epsilon = 0. \quad (514)$$

(d) If

$$\texttt{PHA} \geq 32767, \quad (515)$$

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

19. CORN_PHA:

(a) If

$$\texttt{DATAMODE}_{\text{in}} = \text{CC33\_GRADED}, \quad (516)$$

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

$$\texttt{CCD\_ID} = \texttt{CCD\_ID}_{\text{gain},i}, \quad (517)$$

$$\texttt{CHIPX\_MIN}_{\text{gain},i} \leq \texttt{CHIPX} \leq \texttt{CHIPX\_MAX}_{\text{gain},i}, \qquad \text{and} \quad (518)$$

$$\texttt{CHIPY\_MIN}_{\text{gain},i} \leq \text{nint}(\texttt{CHIPY\_ADJ}) \leq \texttt{CHIPY\_MAX}_{\text{gain},i}, \quad (519)$$

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 $\texttt{PHA}_{\text{gain}}$ is identified such that

$$\texttt{PHA}_{\text{gain},i}[j] \leq (\texttt{PHA} + \Delta p) < \texttt{PHA}_{\text{gain},i}[j+1], \tag{520}$$

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

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

$$\begin{aligned}\texttt{ENERGY} \;=\;& \left(\frac{\texttt{PHA} + \Delta p - \texttt{PHA}_{\text{gain},i}[j]}{\texttt{PHA}_{\text{gain},i}[j+1] - \texttt{PHA}_{\text{gain},i}[j]}\right)(\texttt{ENERGY}_{\text{gain},i}[j+1] - \texttt{ENERGY}_{\text{gain},i}[j]) + \\ & \texttt{ENERGY}_{\text{gain},i}[j],\end{aligned} \tag{521}$$

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

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

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

(c) If the parameter $\texttt{calculate\_pi} = \text{no}$ 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 $\texttt{ENERGY} = 0$.

21. `PI`:

(a) If

$$\texttt{calculate\_pi} = \text{yes}, \tag{522}$$

then

i.

$$\texttt{PI} = \text{int}\left(\frac{\texttt{ENERGY}}{\texttt{pi\_bin\_width}}\right) + 1, \tag{523}$$

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

ii. If

$$\texttt{PI} < 1, \tag{524}$$

then $\texttt{PI} = 1$.

iii. If

$$\texttt{PI} > \texttt{pi\_num\_bins}, \tag{525}$$

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

(b) If

$$\texttt{calculate\_pi} = \text{no} \tag{526}$$

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

$$\texttt{pix\_adj} = \text{centroid}, \tag{527}$$

then

$$\texttt{CHIPX\_ADJ} = \texttt{CHIPX\_ADJ} - w'[0] + w'[2] - w'[3] + w'[5] - w'[6] + w'[8], \tag{528}$$

where

$$w'[j] = \frac{w[j]}{\sum_{j=0}^{8} w[j]}, \tag{529}$$

$$w[j] = \begin{cases} p[j] & \text{if the pixel is valid} \\ 0 & \text{if the pixel is invalid,} \end{cases} \tag{530}$$

$$p[j] = \begin{cases} \texttt{PHAS\_ADJ}[j] & \text{if } \texttt{apply\_cti} = \text{yes} \\ \texttt{PHAS}[j] & \text{if } \texttt{apply\_cti} = \text{no,} \end{cases} \tag{531}$$

and the pixel is invalid if

$$\beta[j] = 0 \text{ or} \tag{532}$$
$$\texttt{STATUS}[0] = 1 \text{ or} \tag{533}$$
$$\texttt{STATUS}[1] = 1 \text{ or} \tag{534}$$
$$\texttt{STATUS}[2] = 1 \text{ or} \tag{535}$$
$$\texttt{STATUS}[3] = 1 \text{ or} \tag{536}$$
$$\texttt{STATUS}[4] = 1 \text{ or} \tag{537}$$
$$\texttt{STATUS}[11] = 1 \text{ or} \tag{538}$$
$$\texttt{STATUS}[13] = 1 \text{ or} \tag{539}$$
$$\texttt{STATUS}[14] = 1 \text{ or} \tag{540}$$
$$\texttt{STATUS}[15] = 1 \text{ or} \tag{541}$$
$$\texttt{STATUS}[16] = 1. \tag{542}$$

If

$$\texttt{DATAMODE} = \text{CC33\_FAINT or} \tag{543}$$
$$\texttt{DATAMODE} = \text{CC33\_GRADED or} \tag{544}$$
$$\texttt{DATAMODE} = \text{FAINT or} \tag{545}$$
$$\texttt{DATAMODE} = \text{FAINT\_BIAS or} \tag{546}$$
$$\texttt{DATAMODE} = \text{GRADED or} \tag{547}$$
$$\texttt{DATAMODE} = \text{VFAINT,} \tag{548}$$

then

$$\texttt{CHIPY\_ADJ} = \texttt{CHIPY\_ADJ} - w'[0] - w'[1] - w'[2] + w'[6] + w'[7] + w'[8]. \tag{549}$$

If

$$\texttt{DATAMODE} = \text{CC33\_FAINT or} \tag{550}$$
$$\texttt{DATAMODE} = \text{CC33\_GRADED,} \tag{551}$$

then

$$\texttt{TIME} = \texttt{TIME} + (w'[0] + w'[1] + w'[2] - w'[6] - w'[7] - w'[8]) \times \texttt{TIMEDEL}_{\text{in}}. \tag{552}$$

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

$$\texttt{pix\_adj} = \text{edser}, \tag{553}$$

then

$$\texttt{CHIPX\_ADJ} = \texttt{CHIPX\_ADJ} + \left(\frac{\texttt{ENERGY} - E[k]}{E[k+1] - E[k]}\right)(\Delta X[k+1] - \Delta X[k]) + \Delta X[k], \tag{554}$$

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

$$\texttt{ENERGY} \geq E[k] \text{ and} \tag{555}$$

$$\texttt{ENERGY} < E[k+1]. \tag{556}$$

Note that if

$$\texttt{ENERGY} \leq E[0], \tag{557}$$

then $k = 0$. Similarly, if

$$\texttt{ENERGY} \geq E[\texttt{NPOINTS}_{\text{subpix}} - 2], \tag{558}$$

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

$$\texttt{DATAMODE} = \text{CC33\_FAINT or} \tag{559}$$

$$\texttt{DATAMODE} = \text{CC33\_GRADED or} \tag{560}$$

$$\texttt{DATAMODE} = \text{FAINT or} \tag{561}$$

$$\texttt{DATAMODE} = \text{FAINT\_BIAS or} \tag{562}$$

$$\texttt{DATAMODE} = \text{GRADED or} \tag{563}$$

$$\texttt{DATAMODE} = \text{VFAINT}, \tag{564}$$

then

$$\texttt{CHIPY\_ADJ} = \texttt{CHIPY\_ADJ} + \left(\frac{\texttt{ENERGY} - E[k]}{E[k+1] - E[k]}\right)(\Delta Y[k+1] - \Delta Y[k]) + \Delta Y[k], \tag{565}$$

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

$$\texttt{DATAMODE} = \text{CC33\_FAINT or} \tag{566}$$

$$\texttt{DATAMODE} = \text{CC33\_GRADED}, \tag{567}$$

then

$$\texttt{TIME} = \texttt{TIME} - \left(\left(\frac{\texttt{ENERGY} - E[k]}{E[k+1] - E[k]}\right)(\Delta Y[k+1] - \Delta Y[k]) + \Delta Y[k]\right) \times \texttt{TIMEDEL}_{\text{in}}. \tag{568}$$

(c) none:
If

$$\texttt{pix\_adj} = \text{none}, \tag{569}$$

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

(d) randomize:
If

$$\texttt{pix\_adj} = \text{randomize}, \tag{570}$$

then

$$\texttt{CHIPX\_ADJ} = \texttt{CHIPX\_ADJ} + \epsilon_x, \tag{571}$$

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

$$\texttt{DATAMODE} = \text{CC33\_FAINT or} \tag{572}$$
$$\texttt{DATAMODE} = \text{CC33\_GRADED or} \tag{573}$$
$$\texttt{DATAMODE} = \text{FAINT or} \tag{574}$$
$$\texttt{DATAMODE} = \text{FAINT\_BIAS or} \tag{575}$$
$$\texttt{DATAMODE} = \text{GRADED or} \tag{576}$$
$$\texttt{DATAMODE} = \text{VFAINT}, \tag{577}$$

then

$$\texttt{CHIPY\_ADJ} = \texttt{CHIPY\_ADJ} + \epsilon_y, \tag{578}$$

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

$$\texttt{DATAMODE} = \text{CC33\_FAINT or} \tag{579}$$
$$\texttt{DATAMODE} = \text{CC33\_GRADED}, \tag{580}$$

then

$$\texttt{TIME} = \texttt{TIME} - \epsilon_y \times \texttt{TIMEDEL}_{\text{in}}. \tag{581}$$

(e) If

$$\texttt{CHIPX\_ADJ} < 0.5, \tag{582}$$

then

$$\texttt{CHIPX\_ADJ} = 1. \tag{583}$$

(f) If

$$\texttt{CHIPX\_ADJ} \geq 1024.5, \tag{584}$$

then

$$\texttt{CHIPX\_ADJ} = 1024. \tag{585}$$

(g) If

$$\texttt{CHIPY\_ADJ} < 0.5, \tag{586}$$

then

$$\texttt{CHIPY\_ADJ} = 1. \tag{587}$$

(h) If

$$\texttt{CHIPY\_ADJ} \geq 1024.5, \quad (588)$$

then

$$\texttt{CHIPY\_ADJ} = 1024. \quad (589)$$

23. TDETX and TDETY:

(a) If

$$\texttt{stop} = \text{tdet or} \quad (590)$$
$$\texttt{stop} = \text{det or} \quad (591)$$
$$\texttt{stop} = \text{tan or} \quad (592)$$
$$\texttt{stop} = \text{sky} \quad (593)$$

then

i. If

$$\texttt{TIME} \geq \texttt{TIME}_{\text{min}} \text{ and} \quad (594)$$
$$\texttt{TIME} < \texttt{TIME}_{\text{max}} \quad (595)$$

and TIME is in a good-time interval, then

A. If

$$\texttt{CONTENT} = \text{EVT0 or} \quad (596)$$
$$\texttt{CONTENT} = \text{EVT1 or} \quad (597)$$
$$\texttt{CONTENT} = \text{EVT2}, \quad (598)$$

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

B. If

$$\texttt{CONTENT} = \text{TGEVT1}, \quad (599)$$

then the values of TDETX and TDETY are computed using values of nint(CHIPX_ADJ) and nint(CHIPY_ZO).[§]

ii. If

$$\texttt{TIME} < \texttt{TIME}_{\text{min}} \text{ or} \quad (600)$$
$$\texttt{TIME} \geq \texttt{TIME}_{\text{max}} \quad (601)$$

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

$$\texttt{stop} = \text{det or} \quad (602)$$
$$\texttt{stop} = \text{tan or} \quad (603)$$
$$\texttt{stop} = \text{sky}, \quad (604)$$

then

[§]As requested, the TDETX, TDETY, DETX, DETY, X, and Y coordinates for gratings observations are computed using the CHIPY location of zeroth order, not the CHIPY location of the gratings arms.

i. If

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

and TIME is in a good-time interval, then

A. If

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

then the values of DETX and DETY are computed using the real-valued coordinates CHIPX_ADJ and CHIPY_ADJ.

B. If

$$\texttt{CONTENT} = \text{TGEVT1,} \tag{610}$$

then the values of DETX and DETY are computed using the real-valued coordinates CHIPX_ADJ and CHIPY_ZO.§

The computation of the DET coordinates uses the orientation of the SIM (i.e. DY, DZ, and DTHETA) at the time TIME.

ii. If

$$\texttt{TIME} < \texttt{TIME}_{\mathrm{min}} \text{ or} \tag{611}$$
$$\texttt{TIME} \geq \texttt{TIME}_{\mathrm{max}} \tag{612}$$

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

$$\texttt{stop} = \text{sky,} \tag{613}$$

then

i. If

$$\texttt{TIME} \geq \texttt{TIME}_{\mathrm{min}} \text{ and} \tag{614}$$
$$\texttt{TIME} < \texttt{TIME}_{\mathrm{max}} \tag{615}$$

and TIME is in a good-time interval, then

A. If

$$\texttt{CONTENT} = \text{EVT0 or} \tag{616}$$
$$\texttt{CONTENT} = \text{EVT1 or} \tag{617}$$
$$\texttt{CONTENT} = \text{EVT2,} \tag{618}$$

then the values of X and Y are computed using the real-valued coordinates CHIPX_ADJ and CHIPY_ADJ.

B. If

$$\texttt{CONTENT} = \text{TGEVT1,} \tag{619}$$

then the values of X and Y are computed using the real-valued coordinates CHIPX_ADJ and CHIPY_ZO.§

The computation of the sky coordinates uses the orientation of the telescope (i.e. RA, DEC, and ROLL) at the time TIME.

ii. If

$$\texttt{TIME} < \texttt{TIME}_{\text{min}} \text{ or} \quad (620)$$
$$\texttt{TIME} \geq \texttt{TIME}_{\text{max}} \quad (621)$$

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

SKY_1D:

(a) If

$$\texttt{DATAMODE}_{\text{in}} = \text{CC33\_FAINT or} \quad (622)$$
$$\texttt{DATAMODE}_{\text{in}} = \text{CC33\_GRADED} \quad (623)$$

and

$$\texttt{stop} = \text{sky}, \quad (624)$$

then

i. If

$$\texttt{TIME} \geq \texttt{TIME}_{\text{min}} \text{ and} \quad (625)$$
$$\texttt{TIME} < \texttt{TIME}_{\text{max}} \quad (626)$$

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

$$\texttt{TIME} < \texttt{TIME}_{\text{min}} \text{ or} \quad (627)$$
$$\texttt{TIME} \geq \texttt{TIME}_{\text{max}} \quad (628)$$

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

$$\texttt{pix\_adj} = \text{centroid}, \quad (629)$$

then

$$\texttt{PIX\_ADJ} = \text{CENTROID}. \quad (630)$$

(b) If

$$\texttt{pix\_adj} = \text{edser}, \quad (631)$$

then

$$\texttt{PIX\_ADJ} = \text{EDSER}. \quad (632)$$

(c) If

$$\texttt{pix\_adj} = \text{none}, \tag{633}$$

then

$$\texttt{PIX\_ADJ} = \text{NONE}. \tag{634}$$

(d) If

$$\texttt{pix\_adj} = \text{randomize}, \tag{635}$$

then

$$\texttt{PIX\_ADJ} = \text{RANDOMIZE}. \tag{636}$$

2. RAND_SKY:

(a) If

$$\texttt{pix\_adj} = \text{centroid}, \tag{637}$$

then

$$\texttt{RAND\_SKY} = 0.0. \tag{638}$$

(b) If

$$\texttt{pix\_adj} = \text{edser}, \tag{639}$$

then

$$\texttt{RAND\_SKY} = 0.0. \tag{640}$$

(c) If

$$\texttt{pix\_adj} = \text{none}, \tag{641}$$

then

$$\texttt{RAND\_SKY} = 0.0. \tag{642}$$

(d) If

$$\texttt{pix\_adj} = \text{randomize}, \tag{643}$$

then

$$\texttt{RAND\_SKY} = 0.5. \tag{644}$$

3. TIME_ADJ:

(a) TE mode:
If

$$\texttt{DATAMODE}_{\text{in}} = \text{FAINT or} \tag{645}$$
$$\texttt{DATAMODE}_{\text{in}} = \text{FAINT\_BIAS or} \tag{646}$$
$$\texttt{DATAMODE}_{\text{in}} = \text{GRADED or} \tag{647}$$
$$\texttt{DATAMODE}_{\text{in}} = \text{VFAINT}, \tag{648}$$

then

$$\texttt{TIME\_ADJ} = \text{NONE}. \tag{649}$$

(b) Pointing CC mode without grating data:

i. If

$$\begin{aligned} \texttt{OBS\_MODE} &= \text{pointing or} \quad (650)\\ \texttt{OBS\_MODE} &= \text{POINTING} \quad (651)\end{aligned}$$

and

$$\begin{aligned} \texttt{DATAMODE}_{\text{in}} &= \text{CC33\_FAINT or} \quad (652)\\ \texttt{DATAMODE}_{\text{in}} &= \text{CC33\_GRADED} \quad (653)\end{aligned}$$

and

$$\begin{aligned} \texttt{CONTENT}_{\text{in}} &= \text{EVT0 or} \quad (654)\\ \texttt{CONTENT}_{\text{in}} &= \text{EVT1 or} \quad (655)\\ \texttt{CONTENT}_{\text{in}} &= \text{EVT2} \quad (656)\end{aligned}$$

and

$$\begin{aligned} \texttt{CCD\_ID}_{\text{focus}} &\geq 0 \text{ and} \quad (657)\\ \texttt{CCD\_ID}_{\text{focus}} &\leq 3 \quad (658)\end{aligned}$$

and

$$\begin{aligned} &\cos(\texttt{DEC\_ADJ}_{\text{I}})\cos(\texttt{DEC\_TARG}_{\text{in}})\cos(\texttt{RA\_ADJ}_{\text{I}} - \texttt{RA\_TARG}_{\text{in}}) + \quad (659)\\ &\sin(\texttt{DEC\_ADJ}_{\text{I}})\sin(\texttt{DEC\_TARG}_{\text{in}}) < \quad (660)\\ &4.855 \times 10^{-11}, \quad (661)\end{aligned}$$

then

$$\texttt{TIME\_ADJ} = \text{TARGET.} \quad (662)$$

ii. If

$$\begin{aligned} \texttt{OBS\_MODE} &= \text{pointing or} \quad (663)\\ \texttt{OBS\_MODE} &= \text{POINTING} \quad (664)\end{aligned}$$

and

$$\begin{aligned} \texttt{DATAMODE}_{\text{in}} &= \text{CC33\_FAINT or} \quad (665)\\ \texttt{DATAMODE}_{\text{in}} &= \text{CC33\_GRADED} \quad (666)\end{aligned}$$

and

$$\begin{aligned} \texttt{CONTENT}_{\text{in}} &= \text{EVT0 or} \quad (667)\\ \texttt{CONTENT}_{\text{in}} &= \text{EVT1 or} \quad (668)\\ \texttt{CONTENT}_{\text{in}} &= \text{EVT2} \quad (669)\end{aligned}$$

and

$$\begin{aligned} \texttt{CCD\_ID}_{\text{focus}} &\geq 4 \text{ and} \quad (670)\\ \texttt{CCD\_ID}_{\text{focus}} &\leq 9 \quad (671)\end{aligned}$$

and

$$\cos(\texttt{DEC\_ADJ}_{\rm S})\cos(\texttt{DEC\_TARG}_{\rm in})\cos(\texttt{RA\_ADJ}_{\rm S} - \texttt{RA\_TARG}_{\rm in}) + \quad (672)$$
$$\sin(\texttt{DEC\_ADJ}_{\rm S})\sin(\texttt{DEC\_TARG}_{\rm in}) < \quad (673)$$
$$4.855 \times 10^{-11}, \quad (674)$$

then

$$\texttt{TIME\_ADJ} = \text{TARGET}. \quad (675)$$

iii. If

$$\texttt{OBS\_MODE} = \text{pointing or} \quad (676)$$
$$\texttt{OBS\_MODE} = \text{POINTING} \quad (677)$$

and

$$\texttt{DATAMODE}_{\rm in} = \text{CC33\_FAINT or} \quad (678)$$
$$\texttt{DATAMODE}_{\rm in} = \text{CC33\_GRADED} \quad (679)$$

and

$$\texttt{CONTENT}_{\rm in} = \text{EVT0 or} \quad (680)$$
$$\texttt{CONTENT}_{\rm in} = \text{EVT1 or} \quad (681)$$
$$\texttt{CONTENT}_{\rm in} = \text{EVT2} \quad (682)$$

and

$$\texttt{CCD\_ID}_{\rm focus} \geq 0 \text{ and} \quad (683)$$
$$\texttt{CCD\_ID}_{\rm focus} \leq 3 \quad (684)$$

and

$$\cos(\texttt{DEC\_ADJ}_{\rm I})\cos(\texttt{DEC\_TARG}_{\rm in})\cos(\texttt{RA\_ADJ}_{\rm I} - \texttt{RA\_TARG}_{\rm in}) + \quad (685)$$
$$\sin(\texttt{DEC\_ADJ}_{\rm I})\sin(\texttt{DEC\_TARG}_{\rm in}) \geq \quad (686)$$
$$4.855 \times 10^{-11}, \quad (687)$$

then

$$\texttt{TIME\_ADJ} = \text{AIMPOINT}. \quad (688)$$

iv. If

$$\texttt{OBS\_MODE} = \text{pointing or} \quad (689)$$
$$\texttt{OBS\_MODE} = \text{POINTING} \quad (690)$$

and

$$\texttt{DATAMODE}_{\rm in} = \text{CC33\_FAINT or} \quad (691)$$
$$\texttt{DATAMODE}_{\rm in} = \text{CC33\_GRADED} \quad (692)$$

and

$$\texttt{CONTENT}_{\rm in} = \text{EVT0 or} \quad (693)$$
$$\texttt{CONTENT}_{\rm in} = \text{EVT1 or} \quad (694)$$
$$\texttt{CONTENT}_{\rm in} = \text{EVT2} \quad (695)$$

and

$$\texttt{CCD\_ID}_{\rm focus} \geq 4 \text{ and} \quad (696)$$
$$\texttt{CCD\_ID}_{\rm focus} \leq 9 \quad (697)$$

and

$$\cos(\texttt{DEC\_ADJ}_{\rm S})\cos(\texttt{DEC\_TARG}_{\rm in})\cos(\texttt{RA\_ADJ}_{\rm S} - \texttt{RA\_TARG}_{\rm in}) + \quad (698)$$
$$\sin(\texttt{DEC\_ADJ}_{\rm S})\sin(\texttt{DEC\_TARG}_{\rm in}) \geq \quad (699)$$
$$4.855 \times 10^{-11}, \quad (700)$$

then

$$\texttt{TIME\_ADJ} = \text{AIMPOINT}. \quad (701)$$

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

$$\texttt{OBS\_MODE} = \text{pointing or} \quad (702)$$
$$\texttt{OBS\_MODE} = \text{POINTING} \quad (703)$$

and

$$\texttt{DATAMODE}_{\rm in} = \text{CC33\_FAINT or} \quad (704)$$
$$\texttt{DATAMODE}_{\rm in} = \text{CC33\_GRADED} \quad (705)$$

and

$$\texttt{CONTENT}_{\rm in} = \text{TGEVT1} \quad (706)$$

and

$$\texttt{CCD\_ID}_{\rm focus} \geq 4 \text{ and} \quad (707)$$
$$\texttt{CCD\_ID}_{\rm focus} \leq 9, \quad (708)$$

then

$$\texttt{TIME\_ADJ} = \text{GRATING}. \quad (709)$$

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

i. If

$$\texttt{OBS\_MODE} = \text{pointing or} \quad (710)$$
$$\texttt{OBS\_MODE} = \text{POINTING} \quad (711)$$

and

$$\texttt{DATAMODE}_{\rm in} = \text{CC33\_FAINT or} \quad (712)$$
$$\texttt{DATAMODE}_{\rm in} = \text{CC33\_GRADED} \quad (713)$$

and

$$\texttt{CONTENT}_{\rm in} = \text{TGEVT1} \quad (714)$$

and

$$\begin{aligned} \texttt{CCD\_ID}_{\rm focus} &\geq 0 \text{ and} && (715)\\ \texttt{CCD\_ID}_{\rm focus} &\leq 3 && (716)\end{aligned}$$

and

$$\begin{aligned} &\cos(\texttt{DEC\_ADJ}_{\rm I})\cos(\texttt{DEC\_TARG}_{\rm in})\cos(\texttt{RA\_ADJ}_{\rm I} - \texttt{RA\_TARG}_{\rm in}) + && (717)\\ &\sin(\texttt{DEC\_ADJ}_{\rm I})\sin(\texttt{DEC\_TARG}_{\rm in}) < && (718)\\ &4.855 \times 10^{-11}, && (719)\end{aligned}$$

then

$$\texttt{TIME\_ADJ} = \text{TARGET}. \qquad (720)$$

ii. If

$$\begin{aligned} \texttt{OBS\_MODE} &= \text{pointing or} && (721)\\ \texttt{OBS\_MODE} &= \text{POINTING} && (722)\end{aligned}$$

and

$$\begin{aligned} \texttt{DATAMODE}_{\rm in} &= \text{CC33\_FAINT or} && (723)\\ \texttt{DATAMODE}_{\rm in} &= \text{CC33\_GRADED} && (724)\end{aligned}$$

and

$$\texttt{CONTENT}_{\rm in} = \text{TGEVT1} \qquad (725)$$

and

$$\begin{aligned} \texttt{CCD\_ID}_{\rm focus} &\geq 0 \text{ and} && (726)\\ \texttt{CCD\_ID}_{\rm focus} &\leq 3 && (727)\end{aligned}$$

and

$$\begin{aligned} &\cos(\texttt{DEC\_ADJ}_{\rm I})\cos(\texttt{DEC\_TARG}_{\rm in})\cos(\texttt{RA\_ADJ}_{\rm I} - \texttt{RA\_TARG}_{\rm in}) + && (728)\\ &\sin(\texttt{DEC\_ADJ}_{\rm I})\sin(\texttt{DEC\_TARG}_{\rm in}) \geq && (729)\\ &4.855 \times 10^{-11}, && (730)\end{aligned}$$

then

$$\texttt{TIME\_ADJ} = \text{AIMPOINT}. \qquad (731)$$

(e) Secondary CC mode:
If

$$\begin{aligned} \texttt{OBS\_MODE} &\neq \text{pointing and} && (732)\\ \texttt{OBS\_MODE} &\neq \text{POINTING} && (733)\end{aligned}$$

and

$$\begin{aligned} \texttt{DATAMODE}_{\rm in} &= \text{CC33\_FAINT or} && (734)\\ \texttt{DATAMODE}_{\rm in} &= \text{CC33\_GRADED}, && (735)\end{aligned}$$

then

$$\texttt{TIME\_ADJ} = \text{MIDCHIP}. \qquad (736)$$

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`?