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

MEMORANDUM

April 3, 2015

To:	Jonathan McDowell, SDS Group Leader
From:	Glenn E. Allen, SDS
Subject:	`acis_process_events` spec
Revision:	3.10
URL:	http://space.mit.edu/CXC/docs/docs.html#ape
File:	/nfs/inconceivable/d0/SDS/SPECS/acis_process_events/ape_spec_3.10.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. `infile`:
   (a) Existence:
   If the `infile` does not exist, then `acis_process_events` exits with an error message.
   (b) Permission:
   If the `infile` exists, but the file permissions do not allow it to be read, then `acis_process_events` exits with an error message.
   (c) Validation:

i. CONTENT:
If the infile does not have an HDU $h_{\rm in}$ with the keyword

$$\begin{aligned} \texttt{CONTENT} &= \text{EVT0 or} \quad (1)\\ \texttt{CONTENT} &= \text{EVT1 or} \quad (2)\\ \texttt{CONTENT} &= \text{TGEVT1 or} \quad (3)\\ \texttt{CONTENT} &= \text{EVT2,} \quad (4) \end{aligned}$$

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

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

$$\begin{aligned} \texttt{DATAMODE} &\neq \text{CC33\_FAINT and} \quad (5)\\ \texttt{DATAMODE} &\neq \text{CC33\_GRADED and} \quad (6)\\ \texttt{DATAMODE} &\neq \text{FAINT and} \quad (7)\\ \texttt{DATAMODE} &\neq \text{FAINT\_BIAS and} \quad (8)\\ \texttt{DATAMODE} &\neq \text{GRADED and} \quad (9)\\ \texttt{DATAMODE} &\neq \text{VFAINT,} \quad (10) \end{aligned}$$

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

iii. TIME:
If HDU $h_{\rm in}$ 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 $\texttt{TIME}_{\rm in}$.

iv. TIME_RO:
If

$$\begin{aligned} \texttt{DATAMODE}_{\rm in} &= \text{CC33\_FAINT or} \quad (11)\\ \texttt{DATAMODE}_{\rm in} &= \text{CC33\_GRADED,} \quad (12) \end{aligned}$$

if

$$\begin{aligned} \texttt{CONTENT}_{\rm in} &= \text{EVT1 or} \quad (13)\\ \texttt{CONTENT}_{\rm in} &= \text{TGEVT1 or} \quad (14)\\ \texttt{CONTENT}_{\rm in} &= \text{EVT2,} \quad (15) \end{aligned}$$

and if HDU $h_{\rm in}$ 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 $\texttt{TIME\_RO}_{\rm in}$.

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

vi. CCD_ID:
A. If

$$\texttt{CONTENT}_{\rm in} = \text{EVT0} \quad (16)$$

and if 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

$$\texttt{CONTENT}_{\rm in} = \text{EVT1 or} \tag{17}$$
$$\texttt{CONTENT}_{\rm in} = \text{TGEVT1 or} \tag{18}$$
$$\texttt{CONTENT}_{\rm in} = \text{EVT2} \tag{19}$$

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

vii. `CCDX`:

A. If

$$\texttt{CONTENT}_{\rm in} = \text{EVT0} \tag{20}$$

and if 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 $\texttt{CCDX}_{\rm in}$.

viii. `CHIPX`:

A. If

$$\texttt{CONTENT}_{\rm in} = \text{EVT1 or} \tag{21}$$
$$\texttt{CONTENT}_{\rm in} = \text{TGEVT1 or} \tag{22}$$
$$\texttt{CONTENT}_{\rm in} = \text{EVT2} \tag{23}$$

and if 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 $\texttt{CHIPX}_{\rm in}$.

ix. `CCDY`:

A. If

$$\texttt{CONTENT}_{\rm in} = \text{EVT0,} \tag{24}$$

if

$$\texttt{DATAMODE}_{\rm in} = \text{FAINT or} \tag{25}$$
$$\texttt{DATAMODE}_{\rm in} = \text{FAINT\_BIAS or} \tag{26}$$
$$\texttt{DATAMODE}_{\rm in} = \text{GRADED or} \tag{27}$$
$$\texttt{DATAMODE}_{\rm in} = \text{VFAINT,} \tag{28}$$

and if 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 $\texttt{CCDY}_{\rm in}$.

x. `TROW`:

A. If

$$\texttt{CONTENT}_{\rm in} = \text{EVT0,} \tag{29}$$

if

$$\texttt{DATAMODE}_{\rm in} = \text{CC33\_FAINT or} \tag{30}$$
$$\texttt{DATAMODE}_{\rm in} = \text{CC33\_GRADED} \tag{31}$$

and if 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 $\texttt{TROW}_{\rm in}$.

xi. `CHIPY`:

A. If

$$\texttt{CONTENT}_{\rm in} = \rm EVT1 \ or \quad (32)$$
$$\texttt{CONTENT}_{\rm in} = \rm TGEVT1 \ or \quad (33)$$
$$\texttt{CONTENT}_{\rm in} = \rm EVT2 \quad (34)$$

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

xii. `RA_TARG`, `DEC_TARG`, `RA_NOM`, `DEC_NOM`, `RA_PNT`, `DEC_PNT`, `TIMEDEL`, `CHIPY_TG`, `CHIPY_ZO`, and `TG_M`:
If

$$\texttt{DATAMODE}_{\rm in} = \rm CC33\_FAINT \ or \quad (35)$$
$$\texttt{DATAMODE}_{\rm in} = \rm CC33\_GRADED \quad (36)$$

then

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

B. `CHIPY_TG`, `CHIPY_ZO`, and `TG_M`:
If

$$\texttt{CONTENT}_{\rm in} = \rm TGEVT1 \quad (37)$$

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

2. `stop`:

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

(b) Validation:
If

$$\texttt{stop} \neq \rm none \ and \quad (38)$$
$$\texttt{stop} \neq \rm chip \ and \quad (39)$$
$$\texttt{stop} \neq \rm tdet \ and \quad (40)$$
$$\texttt{stop} \neq \rm det \ and \quad (41)$$
$$\texttt{stop} \neq \rm tan \ and \quad (42)$$
$$\texttt{stop} \neq \rm sky, \quad (43)$$

then `acis_process_events` exits with an error message.

3. `acaofffile`:

(a) Validation for CC mode:
If

$$\texttt{DATAMODE}_{\rm in} = \rm CC33\_FAINT \ or \quad (44)$$
$$\texttt{DATAMODE}_{\rm in} = \rm CC33\_GRADED, \quad (45)$$

then

i. Setting:
If

$$\texttt{acaofffile} = \text{none or} \tag{46}$$
$$\texttt{acaofffile} = \text{NONE,} \tag{47}$$

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, but 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 $h_{\rm acaoff}$ with the keyword

$$\texttt{CONTENT} = \text{ASPSOL,} \tag{48}$$

then `acis_process_events` exits with an error message.

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

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

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

4. `doevtgrade`:

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

   (b) Validation:
   If

$$\texttt{doevtgrade} \neq \text{yes and} \tag{49}$$
$$\texttt{doevtgrade} \neq \text{no,} \tag{50}$$

   then `acis_process_events` exits with an error message.

5. `apply_cti`:

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

   (b) Validation:

   i. Setting:
   If

$$\texttt{apply\_cti} \neq \text{yes and} \tag{51}$$
$$\texttt{apply\_cti} \neq \text{no,} \tag{52}$$

   then `acis_process_events` exits with an error message.

ii. `PHAS`:
If

$$\texttt{apply\_cti} = \text{yes} \tag{53}$$

and if 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

$$\begin{aligned} \texttt{apply\_cti} &= \text{yes and} \quad (54)\\ \texttt{doevtgrade} &= \text{no,} \quad (55) \end{aligned}$$

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

6. `alignmentfile`:

(a) Validation for CC mode:
If

$$\begin{aligned} \texttt{DATAMODE}_{\text{in}} &= \text{CC33\_FAINT or} \quad (56)\\ \texttt{DATAMODE}_{\text{in}} &= \text{CC33\_GRADED,} \quad (57) \end{aligned}$$

then

i. Setting:
If

$$\begin{aligned} \texttt{alignmentfile} &= \text{none or} \quad (58)\\ \texttt{alignmentfile} &= \text{NONE,} \quad (59) \end{aligned}$$

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, but 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

$$\texttt{CONTENT} = \text{ASPSOL,} \tag{60}$$

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, but the the values `TSTART` are not in increasing order, then `acis_process_events` exits with an error message.

7. `badpixfile`:

(a) Validation:
If

$$\texttt{badpixfile} \neq \text{none and} \quad (61)$$
$$\texttt{badpixfile} \neq \text{NONE,} \quad (62)$$

then

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

ii. Permission:
If the badpixfile exists, but 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 the badpixfile does not have one or more HDUs $h_{\rm badpix}$ with the keyword

$$\texttt{CONTENT} = \text{BADPIX or} \quad (63)$$
$$\texttt{CONTENT} = \text{CDB\_ACIS\_BADPIX,} \quad (64)$$

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

iv. Keyword:
If the HDU(s) $h_{\rm badpix}$ of the badpixfile do not include the keyword CCD_ID, then badpixfile is changed to "none" and acis_process_events produces a warning message.

v. Columns:
If the HDU(s) $h_{\rm badpix}$ 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 $\texttt{CHIPX}_{\rm badpix}$, $\texttt{CHIPY}_{\rm badpix}$, $\texttt{TIME}_{\rm badpix}$, $\texttt{TIME\_STOP}_{\rm badpix}$, and $\texttt{STATUS}_{\rm badpix}$, respectively.

8. ctifile:

(a) Validation:
If

$$\texttt{ctifile} \neq \text{caldb and} \quad (65)$$
$$\texttt{ctifile} \neq \text{CALDB,} \quad (66)$$

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, but 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

$$\texttt{CONTENT} = \text{CDB\_ACIS\_CTI,} \quad (67)$$

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.

9. clobber:
   (a) Lowercase:
   The parameter string is converted to contain only lower case letters.
   (b) Validation:
      i. Setting:
      If

$$\texttt{clobber} \neq \text{yes and} \tag{68}$$
$$\texttt{clobber} \neq \text{no,} \tag{69}$$

      then clobber is changed to "no" and acis_process_events produces a warning message.
      ii. Permission:
      If

$$\texttt{clobber} = \text{yes} \tag{70}$$

      and the outfile exists, but 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

$$\texttt{clobber} = \text{no} \tag{71}$$

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

10. pix_adj:
   (a) Lowercase:
   The parameter string is converted to contain only lower case letters.
   (b) Validation:
      i. Setting:
      If

$$\texttt{pix\_adj} \neq \text{centroid and} \tag{72}$$
$$\texttt{pix\_adj} \neq \text{edser and} \tag{73}$$
$$\texttt{pix\_adj} \neq \text{none and} \tag{74}$$
$$\texttt{pix\_adj} \neq \text{randomize,} \tag{75}$$

      then pix_adj is changed to "none" and acis_process_events produces a warning message.
      ii. stop:
      If

$$\texttt{pix\_adj} = \text{centroid or} \tag{76}$$
$$\texttt{pix\_adj} = \text{edser or} \tag{77}$$
$$\texttt{pix\_adj} = \text{randomize} \tag{78}$$

and if

$$\texttt{stop} \neq \text{sky}, \tag{79}$$

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

iii. `PHAS`:
If

$$\texttt{pix\_adj} = \text{centroid} \tag{80}$$

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

iv. `FLTGRADE`:
If

$$\texttt{pix\_adj} = \text{edser} \tag{81}$$

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

11. `subpixfile`:

(a) If

$$\texttt{pix\_adj} = \text{edser}, \tag{82}$$

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, but the file permissions do not allow it to be read, then `pix_adj` is changed to “none” and `acis_process_events` produces a warning message.

iii. Validation:

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

$$\texttt{CONTENT} = \text{AXAF\_SUBPIX}, \tag{83}$$

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

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

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

1.5.2 Initializations

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

2. Zeroth-order coordinates:
   If

$$\begin{aligned} \texttt{DATAMODE}_{\rm in} &= \text{CC33\_FAINT or} &(84)\\ \texttt{DATAMODE}_{\rm in} &= \text{CC33\_GRADED}, &(85) \end{aligned}$$

   and if

$$\texttt{CONTENT}_{\rm in} = \text{TGEVT1}, \quad (86)$$

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

$$\begin{aligned} \texttt{CHIPY\_ZO}_{\rm min} &= \text{minimum}\,(\texttt{CHIPY\_ZO}_{\rm in})\,, &(87)\\ \texttt{CHIPY\_ZO}_{\rm med} &= \text{median}\,(\texttt{CHIPY\_ZO}_{\rm in})\,, \text{ and} &(88)\\ \texttt{CHIPY\_ZO}_{\rm max} &= \text{maximum}\,(\texttt{CHIPY\_ZO}_{\rm in})\,. &(89) \end{aligned}$$

   Only events in the good-time intervals are included in the computation of the values of $\texttt{CHIPY\_ZO}_{\rm min}$, $\texttt{CHIPY\_ZO}_{\rm med}$, and $\texttt{CHIPY\_ZO}_{\rm max}$.

3. acaofffile:
   If

$$\begin{aligned} \texttt{DATAMODE} &= \text{CC33\_FAINT or} &(90)\\ \texttt{DATAMODE} &= \text{CC33\_GRADED}, &(91) \end{aligned}$$

   then

   (a) $\texttt{TIME}_{\rm min}$, $\texttt{TIME}_{\rm max}$, $\texttt{RA}_{\rm c}$, and $\texttt{DEC}_{\rm c}$:
   The acaofffile data are processed to determine the earliest and latest times for which there is aspect information and to determine the right ascension and declination coordinates near the center of the dither pattern:

$$\begin{aligned} \texttt{TIME}_{\rm min} &= \min\,(\texttt{TIME}_{\rm acaoff})\,, &(92)\\ \texttt{TIME}_{\rm max} &= \max\,(\texttt{TIME}_{\rm acaoff})\,, &(93)\\ \texttt{RA}_{\rm c} &= \text{median}\,(\texttt{RA}_{\rm acaoff})\,, \text{ and} &(94)\\ \texttt{DEC}_{\rm c} &= \text{median}\,(\texttt{DEC}_{\rm acaoff})\,. &(95) \end{aligned}$$

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

$$\cos(\texttt{DEC}_{\rm acaoff})\cos(\texttt{DEC}_{\rm c})\cos(\texttt{RA}_{\rm acaoff} - \texttt{RA}_{\rm c}) + \sin(\texttt{DEC}_{\rm acaoff})\sin(\texttt{DEC}_{\rm c}) \quad (96)$$

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

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

*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.

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

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

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

$$\text{median}(\texttt{CHIPY\_TARG}) \geq 16.5 \text{ and} \tag{97}$$
$$\text{median}(\texttt{CHIPY\_TARG}) < 1008.5, \tag{98}$$

then

A. ACIS-I:
If

$$\texttt{CCD\_ID}_\text{focus} \geq 0 \text{ and} \tag{99}$$
$$\texttt{CCD\_ID}_\text{focus} \leq 3, \tag{100}$$

then

$$\texttt{RA\_ADJ}_\text{I} = \texttt{RA\_TARG}_\text{in} \text{ and} \tag{101}$$
$$\texttt{DEC\_ADJ}_\text{I} = \texttt{DEC\_TARG}_\text{in}. \tag{102}$$

B. ACIS-S:
If

$$\texttt{CCD\_ID}_\text{focus} \geq 4 \text{ and} \tag{103}$$
$$\texttt{CCD\_ID}_\text{focus} \leq 9, \tag{104}$$

then

$$\texttt{RA\_ADJ}_\text{S} = \texttt{RA\_TARG}_\text{in} \text{ and} \tag{105}$$
$$\texttt{DEC\_ADJ}_\text{S} = \texttt{DEC\_TARG}_\text{in}. \tag{106}$$

1.5.3 Loop over events

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

1. STATUS:

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

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

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

† 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.

iii. If

$$\texttt{doevtgrade} = \text{yes}, \tag{107}$$

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

(b) Does not exist:
If HDU h_{in} does not include a 32-bit column named STATUS, then

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

2. EXPNO:

(a) Read:
The value of EXPNO for an event is given by $\texttt{EXPNO}_{\text{in}}$.

(b) Validation:
If

$$\texttt{EXPNO} < 0 \text{ or} \tag{108}$$
$$\texttt{EXPNO} \geq 10^8, \tag{109}$$

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

3. CCD_ID:

(a) Read:
The value of CCD_ID for an event is given by $\texttt{CCD\_ID}_{\text{in}}$.

(b) Validation:
If

$$\texttt{CCD\_ID} < 0 \text{ or} \tag{110}$$
$$\texttt{CCD\_ID} > 9, \tag{111}$$

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

4. CHIPX:

(a) Read:

i. Level 0:
If

$$\texttt{CONTENT}_{\text{in}} = \text{EVT0}, \tag{112}$$

then the value of CHIPX for an event is given by

$$\texttt{CHIPX} = \texttt{CCDX}_{\text{in}} + 1. \tag{113}$$

ii. Level 1, 1.5, or 2:
If

$$\texttt{CONTENT}_{\text{in}} = \text{EVT1, or} \tag{114}$$
$$\texttt{CONTENT}_{\text{in}} = \text{TGEVT1, or} \tag{115}$$
$$\texttt{CONTENT}_{\text{in}} = \text{EVT2}, \tag{116}$$

then the value of CHIPX for an event is given by $\texttt{CHIPX}_{\text{in}}$.

(b) Validation:

i. Unphysical:
If

$$\texttt{CHIPX} < 1 \text{ or} \tag{117}$$
$$\texttt{CHIPX} > 1024, \tag{118}$$

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

$$\texttt{CHIPX} = 1 \text{ or} \tag{119}$$
$$\texttt{CHIPX} = 1024, \tag{120}$$

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

$$\texttt{NODE\_ID} = \text{int}\left(\frac{\texttt{CHIPX} - 1}{256}\right), \tag{121}$$

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

$$\texttt{CONTENT}_{\text{in}} = \text{EVT0}, \tag{122}$$

then

A. TE mode:
If

$$\texttt{DATAMODE}_{\text{in}} = \text{FAINT or} \tag{123}$$
$$\texttt{DATAMODE}_{\text{in}} = \text{FAINT\_BIAS or} \tag{124}$$
$$\texttt{DATAMODE}_{\text{in}} = \text{GRADED or} \tag{125}$$
$$\texttt{DATAMODE}_{\text{in}} = \text{VFAINT}, \tag{126}$$

then the value of CHIPY for an event is given by

$$\texttt{CHIPY} = \texttt{CCDY}_{\text{in}} + 1. \tag{127}$$

B. CC mode:
If

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

then the value of CHIPY for an event is given by

$$\texttt{CHIPY} = \texttt{TROW}_{\text{in}} + 1. \tag{130}$$

ii. Level 1, 1.5, or 2:
If

$$\texttt{CONTENT}_{\rm in} = \text{EVT1 or} \quad (131)$$
$$\texttt{CONTENT}_{\rm in} = \text{TGEVT1 or} \quad (132)$$
$$\texttt{CONTENT}_{\rm in} = \text{EVT2,} \quad (133)$$

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

(b) Validation:

i. Unphysical:

A. TE mode:
If

$$\texttt{DATAMODE}_{\rm in} = \text{FAINT or} \quad (134)$$
$$\texttt{DATAMODE}_{\rm in} = \text{FAINT\_BIAS or} \quad (135)$$
$$\texttt{DATAMODE}_{\rm in} = \text{GRADED or} \quad (136)$$
$$\texttt{DATAMODE}_{\rm in} = \text{VFAINT} \quad (137)$$

and if

$$\texttt{CHIPY} < 1 \text{ or} \quad (138)$$
$$\texttt{CHIPY} > 1024, \quad (139)$$

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

$$\texttt{DATAMODE}_{\rm in} = \text{CC33\_FAINT or} \quad (140)$$
$$\texttt{DATAMODE}_{\rm in} = \text{CC33\_GRADED} \quad (141)$$

and if

$$\texttt{CHIPY} < 1 \text{ or} \quad (142)$$
$$\texttt{CHIPY} > 512, \quad (143)$$

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

$$\texttt{DATAMODE}_{\rm in} = \text{FAINT or} \quad (144)$$
$$\texttt{DATAMODE}_{\rm in} = \text{FAINT\_BIAS or} \quad (145)$$
$$\texttt{DATAMODE}_{\rm in} = \text{GRADED} \quad (146)$$

and if

$$\texttt{CHIPY} = 1 \text{ or} \quad (147)$$
$$\texttt{CHIPY} = 1024, \quad (148)$$

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

B. VFAINT:
If

$$\texttt{DATAMODE}_{\rm in} = \text{VFAINT} \tag{149}$$

and if

$$\texttt{CHIPY} = 1 \text{ or} \tag{150}$$
$$\texttt{CHIPY} = 2 \text{ or} \tag{151}$$
$$\texttt{CHIPY} = 1023 \text{ or} \tag{152}$$
$$\texttt{CHIPY} = 1024, \tag{153}$$

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

$$\texttt{DATAMODE}_{\rm in} = \text{CC33\_FAINT or} \tag{154}$$
$$\texttt{DATAMODE}_{\rm in} = \text{CC33\_GRADED} \tag{155}$$

and if

$$\texttt{CHIPY} = 1 \text{ or} \tag{156}$$
$$\texttt{CHIPY} = 512, \tag{157}$$

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

$$\texttt{DATAMODE}_{\rm in} = \text{CC33\_FAINT or} \tag{158}$$
$$\texttt{DATAMODE}_{\rm in} = \text{CC33\_GRADED} \tag{159}$$

and if

$$\texttt{CONTENT}_{\rm in} = \text{TGEVT1}, \tag{160}$$

then

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

ii. Validation:

A. If

$$\texttt{TG\_M} < -99, \tag{161}$$

then

$$\texttt{TG\_M} = -99 \tag{162}$$

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

$$\texttt{TG\_M} > 99, \quad (163)$$

then

$$\texttt{TG\_M} = 99 \quad (164)$$

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

$$\texttt{DATAMODE}_{\text{in}} = \text{CC33\_FAINT or} \quad (165)$$

$$\texttt{DATAMODE}_{\text{in}} = \text{CC33\_GRADED} \quad (166)$$

and if

$$\texttt{CONTENT}_{\text{in}} = \text{TGEVT1}, \quad (167)$$

then

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

ii. Validation:

A. If

$$\texttt{TG\_M} > -99 \text{ and} \quad (168)$$

$$\texttt{TG\_M} < 99, \quad (169)$$

and if

$$\texttt{CHIPY\_TG} \leq 0 \text{ or} \quad (170)$$

$$\texttt{CHIPY\_TG} \geq 1025, \quad (171)$$

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

$$\texttt{TG\_M} > -99, \quad (172)$$

$$\texttt{TG\_M} < 99, \text{and} \quad (173)$$

$$\texttt{CHIPY\_TG} < 1, \quad (174)$$

then

$$\texttt{CHIPY\_TG} = 1. \quad (175)$$

C. If

$$\texttt{TG\_M} > -99, \quad (176)$$

$$\texttt{TG\_M} < 99, \text{and} \quad (177)$$

$$\texttt{CHIPY\_TG} > 1024, \quad (178)$$

then

$$\texttt{CHIPY\_TG} = 1024. \quad (179)$$

9. CHIPY_ZO:

   (a) CC mode with gratings:
   If

$$\mathtt{DATAMODE}_{\rm in} = \text{CC33\_FAINT or} \tag{180}$$
$$\mathtt{DATAMODE}_{\rm in} = \text{CC33\_GRADED} \tag{181}$$

   and if

$$\mathtt{CONTENT}_{\rm in} = \text{TGEVT1,} \tag{182}$$

   then

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

10. TIME_RO:

   (a) CC mode:
   If

$$\mathtt{DATAMODE}_{\rm in} = \text{CC33\_FAINT or} \tag{183}$$
$$\mathtt{DATAMODE}_{\rm in} = \text{CC33\_GRADED,} \tag{184}$$

   then

      i. Read:

         A. Level 0:
         If

$$\mathtt{CONTENT}_{\rm in} = \text{EVT0,} \tag{185}$$

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

         B. Level 1, 1.5, or 2:
         If

$$\mathtt{CONTENT}_{\rm in} = \text{EVT1, or} \tag{186}$$
$$\mathtt{CONTENT}_{\rm in} = \text{TGEVT1, or} \tag{187}$$
$$\mathtt{CONTENT}_{\rm in} = \text{EVT2,} \tag{188}$$

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

      ii. Validation:
      If

$$\mathtt{TIME\_RO} < 0 \text{ or} \tag{189}$$
$$\mathtt{TIME\_RO} \geq 3 \times 10^9, \tag{190}$$

      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

$$\begin{aligned}\texttt{DATAMODE}_{\rm in} &= \text{FAINT or} \quad (191)\\ \texttt{DATAMODE}_{\rm in} &= \text{FAINT\_BIAS or} \quad (192)\\ \texttt{DATAMODE}_{\rm in} &= \text{GRADED or} \quad (193)\\ \texttt{DATAMODE}_{\rm in} &= \text{VFAINT,} \quad (194)\end{aligned}$$

then

$$\begin{aligned}\texttt{TIME} &= \texttt{TIME}_{\rm in} \text{ and} \quad (195)\\ \texttt{CHIPY\_ADJ} &= \texttt{CHIPY}. \quad (196)\end{aligned}$$

ii. CC mode without grating data:
If

$$\begin{aligned}\texttt{DATAMODE}_{\rm in} &= \text{CC33\_FAINT or} \quad (197)\\ \texttt{DATAMODE}_{\rm in} &= \text{CC33\_GRADED} \quad (198)\end{aligned}$$

and if

$$\begin{aligned}\texttt{CONTENT}_{\rm in} &= \text{EVT0 or} \quad (199)\\ \texttt{CONTENT}_{\rm in} &= \text{EVT1 or} \quad (200)\\ \texttt{CONTENT}_{\rm in} &= \text{EVT2,} \quad (201)\end{aligned}$$

then

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

$$\texttt{TIME}' = \texttt{TIME\_RO} - (512 + 1028) \times \texttt{TIMEDEL}_{\rm in}. \quad (202)$$

B. $\texttt{CHIPY\_ADJ}'$:
If

$$\begin{aligned}\texttt{CCD\_ID}_{\rm focus} &\geq 0 \text{ and} \quad (203)\\ \texttt{CCD\_ID}_{\rm focus} &\leq 3, \quad (204)\end{aligned}$$

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

$$\begin{aligned}\texttt{CCD\_ID}_{\rm focus} &\geq 4 \text{ and} \quad (205)\\ \texttt{CCD\_ID}_{\rm focus} &\leq 9, \quad (206)\end{aligned}$$

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

$$\texttt{TIME} = \texttt{TIME\_RO} - (\texttt{CHIPY\_ADJ}' + 1028) \times \texttt{TIMEDEL}_{\rm in}. \quad (207)$$

D. CHIPY_ADJ:
If

$$\texttt{CCD\_ID}_{\rm focus} \geq 0 \text{ and} \quad (208)$$
$$\texttt{CCD\_ID}_{\rm focus} \leq 3, \quad (209)$$

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

$$\texttt{CCD\_ID}_{\rm focus} \geq 4 \text{ and} \quad (210)$$
$$\texttt{CCD\_ID}_{\rm focus} \leq 9, \quad (211)$$

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

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

$$\texttt{DATAMODE}_{\rm in} = \text{CC33\_FAINT or} \quad (212)$$
$$\texttt{DATAMODE}_{\rm in} = \text{CC33\_GRADED}, \quad (213)$$

if

$$\texttt{CONTENT}_{\rm in} = \text{TGEVT1}, \quad (214)$$

and if

$$\texttt{CCD\_ID}_{\rm focus} \geq 4 \text{ and} \quad (215)$$
$$\texttt{CCD\_ID}_{\rm focus} \leq 9, \quad (216)$$

then

A. Source events:
If

$$\texttt{TG\_M} > -99 \text{ and} \quad (217)$$
$$\texttt{TG\_M} < 99, \quad (218)$$

then

$$\texttt{CHIPY\_ADJ} = \texttt{CHIPY\_TG} \text{ and} \quad (219)$$
$$\texttt{TIME} = \texttt{TIME\_RO} - (\texttt{CHIPY\_ADJ} + 1028) \times \texttt{TIMEDEL}_{\rm in}. \quad (220)$$

If the event does not occur during a good-time interval, then $\texttt{CHIPY\_ADJ} = \texttt{CHIPY\_ZO}_{\rm med}$ instead of CHIPY_TG in equation 219.

B. Background events with zeroth order on the array:
If

$$\texttt{TG\_M} = -99 \text{ or} \quad (221)$$
$$\texttt{TG\_M} = 99 \quad (222)$$

and if

$$\texttt{CHIPY\_ZO}_{\rm min} \geq 0.5 \text{ and} \quad (223)$$
$$\texttt{CHIPY\_ZO}_{\rm max} < 1024.5, \quad (224)$$

then

$$\texttt{CHIPY\_ADJ} = \texttt{CHIPY\_ZO} \text{ and} \tag{225}$$
$$\texttt{TIME} = \texttt{TIME\_RO} - (\texttt{CHIPY\_ADJ} + 1028) \times \texttt{TIMEDEL}_{\text{in}}. \tag{226}$$

If the event does not occur during a good-time interval, then $\texttt{CHIPY\_ADJ} = \texttt{CHIPY\_ZO}_{\text{med}}$ instead of CHIPY_ZO in equation. 225.

C. Background events with zeroth order off the array:
If

$$\texttt{TG\_M} = -99 \text{ or} \tag{227}$$
$$\texttt{TG\_M} = 99 \tag{228}$$

and if

$$\texttt{CHIPY\_ZO}_{\text{max}} < 0.5 \text{ or} \tag{229}$$
$$\texttt{CHIPY\_ZO}_{\text{min}} \geq 1024.5, \tag{230}$$

then

$$\texttt{CHIPY\_ADJ} = 512 + (\texttt{CHIPY\_ZO} - \texttt{CHIPY\_ZO}_{\text{med}}) \text{ and} \tag{231}$$
$$\texttt{TIME} = \texttt{TIME\_RO} - (\texttt{CHIPY\_ADJ} + 1028) \times \texttt{TIMEDEL}_{\text{in}}. \tag{232}$$

If the event does not occur during a good-time interval, then $\texttt{CHIPY\_ADJ} = 512$ instead of $512 + \texttt{CHIPY\_ZO} - \texttt{CHIPY\_ZO}_{\text{med}}$ in equation. 231.

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

$$\texttt{DATAMODE}_{\text{in}} = \text{CC33\_FAINT or} \tag{233}$$
$$\texttt{DATAMODE}_{\text{in}} = \text{CC33\_GRADED}, \tag{234}$$

if

$$\texttt{CONTENT}_{\text{in}} = \text{TGEVT1}, \tag{235}$$

and if

$$\texttt{CCD\_ID}_{\text{focus}} \geq 0 \text{ and} \tag{236}$$
$$\texttt{CCD\_ID}_{\text{focus}} \leq 3, \tag{237}$$

then

A. TIME′:
The approximate time of arrival

$$\texttt{TIME}' = \texttt{TIME\_RO} - (512 + 1028) \times \texttt{TIMEDEL}_{\text{in}}. \tag{238}$$

B. CHIPY_ADJ′:
CHIPY_ADJ′ (the approximate value of CHIPY_ADJ) is given by the CHIPY location (on the focal-point CCD) of the coordinates $\texttt{RA\_ADJ}_{\text{I}}$ and $\texttt{DEC\_ADJ}_{\text{I}}$ at the time TIME′. If the event does not occur during a good-time interval, then $\texttt{TIME}_{\text{c}}$ is used instead of TIME′.

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

$$\texttt{TIME} = \texttt{TIME\_RO} - (\texttt{CHIPY\_ADJ}' + 1028) \times \texttt{TIMEDEL}_{\text{in}}. \tag{239}$$

D. CHIPY_ADJ:

The value of CHIPY_ADJ is given by the CHIPY location (on the focal-point CCD) of the coordinates $\mathtt{RA\_ADJ}_\mathrm{I}$ and $\mathtt{DEC\_ADJ}_\mathrm{I}$ at the time TIME. If the event does not occur during a good-time interval, then $\mathtt{TIME}_\mathrm{c}$ is used instead of TIME.

(b) Validation:

i. If

$$\begin{aligned} \mathtt{TIME} &< 0 \text{ or} && (240)\\ \mathtt{TIME} &\geq 3 \times 10^9, && (241) \end{aligned}$$

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

ii. If

$$\begin{aligned} \mathtt{CHIPY\_ADJ} &< 0.5 \text{ or} && (242)\\ \mathtt{CHIPY\_ADJ} &\geq 1024.5, && (243) \end{aligned}$$

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

$$\begin{aligned} \mathtt{badpixfile} &\neq \text{none and} && (244)\\ \mathtt{badpixfile} &\neq \text{NONE} && (245) \end{aligned}$$

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

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

$$\begin{aligned} \mathtt{CHIPX} &\geq \mathtt{CHIPX}_{\mathrm{badpix},r}[0], && (246)\\ \mathtt{CHIPX} &\leq \mathtt{CHIPX}_{\mathrm{badpix},r}[1], && (247)\\ \mathtt{TIME} &\geq \mathtt{TIME}_{\mathrm{badpix},r}, && (248)\\ \mathtt{TIME} &< \mathtt{TIME\_STOP}_{\mathrm{badpix},r} && (249) \end{aligned}$$

and where

$$\begin{aligned} \mathtt{STATUS}_{\mathrm{badpix},r}[5] &= 1 \text{ or} && (250)\\ \mathtt{STATUS}_{\mathrm{badpix},r}[6] &= 1 \text{ or} && (251)\\ \mathtt{STATUS}_{\mathrm{badpix},r}[9] &= 1, && (252) \end{aligned}$$

then

$$\mathtt{STATUS}[0] = 1 \qquad (253)$$

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

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

$$\begin{aligned} \texttt{CHIPX} &\geq \texttt{CHIPX}_{{\rm badpix},r}[0], & (254)\\ \texttt{CHIPX} &\leq \texttt{CHIPX}_{{\rm badpix},r}[1], & (255)\\ \texttt{TIME} &\geq \texttt{TIME}_{{\rm badpix},r}, & (256)\\ \texttt{TIME} &< \texttt{TIME\_STOP}_{{\rm badpix},r} & (257) \end{aligned}$$

and where

$$\begin{aligned} \texttt{STATUS}_{{\rm badpix},r}[0] &= 1 \text{ or} & (258)\\ \texttt{STATUS}_{{\rm badpix},r}[1] &= 1 \text{ or} & (259)\\ \texttt{STATUS}_{{\rm badpix},r}[7] &= 1 \text{ or} & (260)\\ \texttt{STATUS}_{{\rm badpix},r}[11] &= 1 \text{ or} & (261)\\ \texttt{STATUS}_{{\rm badpix},r}[12] &= 1 \text{ or} & (262)\\ \texttt{STATUS}_{{\rm badpix},r}[13] &= 1 \text{ or} & (263)\\ \texttt{STATUS}_{{\rm badpix},r}[14] &= 1 \text{ or} & (264)\\ \texttt{STATUS}_{{\rm badpix},r}[16] &= 1, & (265) \end{aligned}$$

then

$$\texttt{STATUS}[4] = 1 \quad (266)$$

for the event.

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

$$\begin{aligned} \texttt{CHIPX} &\geq \texttt{CHIPX}_{{\rm badpix},r}[0], & (267)\\ \texttt{CHIPX} &\leq \texttt{CHIPX}_{{\rm badpix},r}[1], & (268)\\ \texttt{TIME} &\geq \texttt{TIME}_{{\rm badpix},r}, & (269)\\ \texttt{TIME} &< \texttt{TIME\_STOP}_{{\rm badpix},r} & (270) \end{aligned}$$

and where

$$\begin{aligned} \texttt{STATUS}_{{\rm badpix},r}[8] &= 1 \text{ or} & (271)\\ \texttt{STATUS}_{{\rm badpix},r}[10] &= 1, & (272) \end{aligned}$$

then

$$\texttt{STATUS}[5] = 1 \quad (273)$$

for the event.

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

$$\begin{aligned} \texttt{CHIPX} &\geq \texttt{CHIPX}_{{\rm badpix},r}[0], & (274)\\ \texttt{CHIPX} &\leq \texttt{CHIPX}_{{\rm badpix},r}[1], & (275)\\ \texttt{TIME} &\geq \texttt{TIME}_{{\rm badpix},r}, & (276)\\ \texttt{TIME} &< \texttt{TIME\_STOP}_{{\rm badpix},r} & (277) \end{aligned}$$

and where

$$\texttt{STATUS}_{{\rm badpix},r}[3] = 1, \quad (278)$$

then

$$\texttt{STATUS}[6] = 1 \tag{279}$$

for the event.

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

$$\begin{aligned} \texttt{CHIPX} &\geq \texttt{CHIPX}_{{\rm badpix},r}[0], & (280)\\ \texttt{CHIPX} &\leq \texttt{CHIPX}_{{\rm badpix},r}[1], & (281)\\ \texttt{TIME} &\geq \texttt{TIME}_{{\rm badpix},r}, & (282)\\ \texttt{TIME} &< \texttt{TIME\_STOP}_{{\rm badpix},r} & (283) \end{aligned}$$

and where

$$\begin{aligned} \texttt{STATUS}_{{\rm badpix},r}[2] &= 1 \text{ or} & (284)\\ \texttt{STATUS}_{{\rm badpix},r}[4] &= 1, & (285) \end{aligned}$$

then

$$\texttt{STATUS}[8] = 1 \tag{286}$$

for the event.

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

$$\begin{aligned} \texttt{CHIPX} &\geq \texttt{CHIPX}_{{\rm badpix},r}[0], & (287)\\ \texttt{CHIPX} &\leq \texttt{CHIPX}_{{\rm badpix},r}[1], & (288)\\ \texttt{TIME} &\geq \texttt{TIME}_{{\rm badpix},r}, & (289)\\ \texttt{TIME} &< \texttt{TIME\_STOP}_{{\rm badpix},r} & (290) \end{aligned}$$

and where

$$\texttt{STATUS}_{{\rm badpix},r}[15] = 1, \tag{291}$$

then

$$\texttt{STATUS}[16] = 1 \tag{292}$$

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, if the parameter `apply_cti` = yes, and if 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

$$\Delta_x[j] = 0, \tag{293}$$
$$\Delta_y[j] = 0, \text{ and} \tag{294}$$
$$\texttt{PHAS\_ADJ}[j] = \texttt{PHAS}[j] \tag{295}$$

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

$$n = 1. \tag{296}$$

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

$$\Delta'_x[j] = \Delta_x[j], \tag{297}$$
$$\Delta'_y[j] = \Delta_y[j], \text{ and} \tag{298}$$
$$\texttt{PHAS\_ADJ}'[j] = \texttt{PHAS\_ADJ}[j] \tag{299}$$

for each element j.

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

$$\Delta_x[0] = c_x[0]s_x\rho_x[0]V_x[0], \tag{300}$$
$$\Delta_x[1] = c_x[1]s_x\rho_x[1]V_x[1] - c'_x[0]s_x\rho_x[0]V_x[0], \tag{301}$$
$$\Delta_x[2] = c_x[2]s_x\rho_x[2]V_x[2] - c'_x[1]s_x\rho_x[1]V_x[1], \tag{302}$$
$$\Delta_x[3] = c_x[3]s_x\rho_x[3]V_x[3], \tag{303}$$

$$\Delta_x[4] = c_x[4]s_x\rho_x[4]V_x[4] - c'_x[3]s_x\rho_x[3]V_x[3], \quad (304)$$
$$\Delta_x[5] = c_x[5]s_x\rho_x[5]V_x[5] - c'_x[4]s_x\rho_x[4]V_x[4], \quad (305)$$
$$\Delta_x[6] = c_x[6]s_x\rho_x[6]V_x[6], \quad (306)$$
$$\Delta_x[7] = c_x[7]s_x\rho_x[7]V_x[7] - c'_x[6]s_x\rho_x[6]V_x[6], \text{ and} \quad (307)$$
$$\Delta_x[8] = c_x[8]s_x\rho_x[8]V_x[8] - c'_x[7]s_x\rho_x[7]V_x[7]. \quad (308)$$

where

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

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

$$s_x = 1 + \texttt{TCTIX}\,(T - \texttt{FP\_TEMP0})\,, \quad (309)$$

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

$$T = \left(\frac{t' - t'_k}{t'_{k+1} - t'_k}\right)(\texttt{FP\_TEMP}_{k+1} - \texttt{FP\_TEMP}_k) + \texttt{FP\_TEMP}_k, \quad (310)$$

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

$$t' = t + \texttt{TIMEDEL}_{\rm in}\,(\texttt{TIMEPIXR}_{\rm evt} - 0.5)\,, \quad (311)$$

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

$$t'_k = \texttt{TIME}_k + \texttt{TIMEDEL}_{\rm mtl}\,(\texttt{TIMEPIXR}_{\rm mtl} - 0.5)\,, \quad (312)$$

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

$$t'_{k+1} = \texttt{TIME}_{k+1} + \texttt{TIMEDEL}_{\text{mtl}}\left(\texttt{TIMEPIXR}_{\text{mtl}} - 0.5\right), \quad (313)$$

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

$$\rho_x[j] = \text{serial trap density}, \quad (314)$$

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

$$V_x[j] = \left(\frac{\texttt{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] - \texttt{PHA}_l}{\texttt{PHA}_{l+1} - \texttt{PHA}_l}\right)(\texttt{VOLUME\_X}_{l+1} - \texttt{VOLUME\_X}_l) + \texttt{VOLUME\_X}_l, \quad (315)$$

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

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

$$\Delta_x[0] = c_x[0]s_x\rho_x[0]V_x[0] - c'_x[1]s_x\rho_x[1]V_x[1], \quad (316)$$

$$\Delta_x[1] = c_x[1]s_x\rho_x[1]V_x[1] - c'_x[2]s_x\rho_x[2]V_x[2], \quad (317)$$

$$\Delta_x[2] = c_x[2]s_x\rho_x[2]V_x[2], \quad (318)$$

$$\Delta_x[3] = c_x[3]s_x\rho_x[3]V_x[3] - c'_x[4]s_x\rho_x[4]V_x[4], \quad (319)$$

$$\Delta_x[4] = c_x[4]s_x\rho_x[4]V_x[4] - c'_x[5]s_x\rho_x[5]V_x[5], \quad (320)$$

$$\Delta_x[5] = c_x[5]s_x\rho_x[5]V_x[5], \quad (321)$$

$$\Delta_x[6] = c_x[6]s_x\rho_x[6]V_x[6] - c'_x[7]s_x\rho_x[7]V_x[7], \quad (322)$$

$$\Delta_x[7] = c_x[7]s_x\rho_x[7]V_x[7] - c'_x[8]s_x\rho_x[8]V_x[8], \text{ and} \quad (323)$$

$$\Delta_x[8] = c_x[8]s_x\rho_x[8]V_x[8]. \quad (324)$$

where

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

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

and s_x, T, t', t'_k, t'_{k+1}, $\rho_x[j]$, and $V_x[j]$ are given by equations. 309, 310, 311, 312, 313, 314, and 315, 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

$$\Delta_y[0] = c_y[0] s_y \rho_y[0] V_y[0], \quad (325)$$

$$\Delta_y[1] = c_y[1] s_y \rho_y[1] V_y[1], \quad (326)$$

$$\Delta_y[2] = c_y[2] s_y \rho_y[2] V_y[2], \quad (327)$$

$$\Delta_y[3] = c_y[3] s_y \rho_y[3] V_y[3] - c'_y[0] s_y \rho_y[0] V_y[0], \quad (328)$$

$$\Delta_y[4] = c_y[4] s_y \rho_y[4] V_y[4] - c'_y[1] s_y \rho_y[1] V_y[1], \quad (329)$$

$$\Delta_y[5] = c_y[5] s_y \rho_y[5] V_y[5] - c'_y[2] s_y \rho_y[2] V_y[2], \quad (330)$$

$$\Delta_y[6] = c_y[6] s_y \rho_y[6] V_y[6] - c'_y[3] s_y \rho_y[3] V_y[3], \quad (331)$$

$$\Delta_y[7] = c_y[7] s_y \rho_y[7] V_y[7] - c'_y[4] s_y \rho_y[4] V_y[4], \quad (332)$$

$$\Delta_y[8] = c_y[8] s_y \rho_y[8] V_y[8] - c'_y[5] s_y \rho_y[5] V_y[5], \quad (333)$$

where

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

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

$$
s_y = 1 + \texttt{TCTIY}\,(T - \texttt{FP\_TEMPO})\,, \tag{334}
$$

$$
\left\{ \begin{array}{l} s_y \text{ is a temperature dependent scaling factor,} \\ \texttt{TCTIY} \text{ is the } \texttt{CCD\_ID} \text{ dependent value in the column } \texttt{TCTIY} \text{ of the} \\ \qquad \texttt{ctifile}, \\ \texttt{FP\_TEMPO} \text{ is the name of a keyword in the } \texttt{ctifile}, \end{array} \right.
$$

$$
\rho_y[j] = \text{parallel trap density,} \tag{335}
$$

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

$$
V_y[j] = \left(\frac{\texttt{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] - \texttt{PHA}_l}{\texttt{PHA}_{l+1} - \texttt{PHA}_l} \right) (\texttt{VOLUME\_Y}_{l+1} - \texttt{VOLUME\_Y}_l) + \texttt{VOLUME\_Y}_l, \tag{336}
$$

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

and T, t', t'_k, and t'_{k+1}, are given by equations. 310, 311, 312, and 313, respectively.

vi. The CTI-adjusted pulse heights

$$\texttt{PHAS\_ADJ}[j] = \texttt{PHAS}[j] + \Delta_x[j] + \Delta_y[j] \tag{337}$$

for all j.

vii. A. If

$$|\texttt{PHAS\_ADJ}'[j] - \texttt{PHAS\_ADJ}[j]| < \texttt{cticonverge} \text{ (for all } j\text{) and} \tag{338}$$
$$n \leq \texttt{max\_cti\_iter}, \tag{339}$$

then the computation of PHAS_ADJ is complete for the event.

B. If

$$|\texttt{PHAS\_ADJ}'[j] - \texttt{PHAS\_ADJ}[j]| \geq \texttt{cticonverge} \text{ (for one or more } j\text{) and} \tag{340}$$
$$n < \texttt{max\_cti\_iter}, \tag{341}$$

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

C. If

$$|\texttt{PHAS\_ADJ}'[j] - \texttt{PHAS\_ADJ}[j]| \geq \texttt{cticonverge} \text{ (for one or more } j\text{) and} \tag{342}$$
$$n \geq \texttt{max\_cti\_iter}, \tag{343}$$

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

$$\texttt{DATAMODE}_{\rm in} = \text{CC33\_FAINT and} \tag{344}$$
$$\texttt{apply\_cti} = \text{yes,} \tag{345}$$

then

$$\texttt{FLTGRADE} = c_{\rm f}[0] + 2c_{\rm f}[1] + 4c_{\rm f}[2] + 8c_{\rm f}[3] + 16c_{\rm f}[5] + 32c_{\rm f}[6] + 64c_{\rm f}[7] + 128c_{\rm f}[8], \tag{346}$$

where

$$c_{\rm f}[j] = \begin{cases} 0 & \text{if } \texttt{PHAS\_ADJ}[j] < \text{split threshold} \\ 1 & \text{otherwise,} \end{cases} \tag{347}$$

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

(b) If

$$\texttt{DATAMODE}_{\rm in} = \text{CC33\_FAINT and} \tag{348}$$
$$\texttt{apply\_cti} = \text{no,} \tag{349}$$

then

$$\texttt{FLTGRADE} = c_{\rm f}[0] + 2c_{\rm f}[1] + 4c_{\rm f}[2] + 8c_{\rm f}[3] + 16c_{\rm f}[5] + 32c_{\rm f}[6] + 64c_{\rm f}[7] + 128c_{\rm f}[8], \tag{350}$$

where

$$c_{\rm f}[j] = \begin{cases} 0 & \text{if } \texttt{PHAS}[j] < \text{split threshold} \\ 0 & \text{if } \texttt{PHAS}[j] > 4095 \\ 0 & \text{if } \texttt{PHAS}[j] > \texttt{PHAS}[4] \text{ for } j = 0-3) \\ 0 & \text{if } \texttt{PHAS}[j] \geq \texttt{PHAS}[4] \text{ for } j = 5-8) \\ 1 & \text{otherwise.} \end{cases} \tag{351}$$

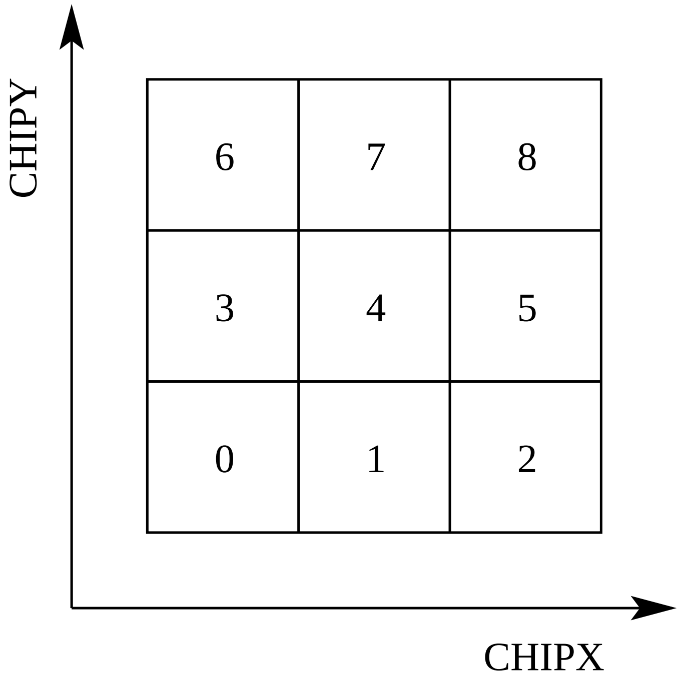

Figure 1: The relative CHIPX and CHIPY coordinates of the nine elements $j = 0$–8 of a 3 pixel × 3 pixel event island PHAS[j] or PHAS_ADJ[j].

(c) If

$$\texttt{DATAMODE}_{\rm in} \quad = \quad \text{CC33\_GRADED}, \tag{352}$$

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

$$\texttt{FLTGRADE}_{{\rm grade},i} = \texttt{FLTGRADE}, \tag{353}$$

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

iii. The GRADE of the event is given by

$$\texttt{GRADE} = \texttt{GRADE}_{{\rm grade},i}, \tag{354}$$

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

17. PHA_RO:

(a) If

$$\texttt{DATAMODE}_{\rm in} = \text{CC33\_FAINT}, \tag{355}$$

then

$$\texttt{PHA\_RO} = \sum_{j=0}^{8} \beta[j]p[j], \tag{356}$$

where

i.

$$p[j] = \texttt{PHAS}[j]. \tag{357}$$

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

iii.

$$\beta[j] = 0 \quad \text{if} \quad p[j] < \text{split threshold}. \tag{358}$$

iv.

$$\beta[j] = 0 \text{ if } \begin{cases} p[j] > p[4] \text{ (for } j = 0-3) \\ p[j] \geq p[4] \text{ (for } j = 5-8) \end{cases} \tag{359}$$

v. If CORNERS $= -1$, then

$$\beta[0] = \beta[2] = \beta[6] = \beta[8] = 0. \tag{360}$$

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

$$\beta[0] = 0 \quad \text{if} \quad \beta[1] = 0 \text{ and } \beta[3] = 0. \tag{361}$$
$$\beta[2] = 0 \quad \text{if} \quad \beta[1] = 0 \text{ and } \beta[5] = 0. \tag{362}$$
$$\beta[6] = 0 \quad \text{if} \quad \beta[3] = 0 \text{ and } \beta[7] = 0. \tag{363}$$
$$\beta[8] = 0 \quad \text{if} \quad \beta[5] = 0 \text{ and } \beta[7] = 0. \tag{364}$$

viii. If CORNERS $= 2$, then

$$\beta[0] = 0 \quad \text{if} \quad \beta[1] = 0 \text{ or } \beta[3] = 0 \text{ or } \texttt{GRADE} \neq 6. \tag{365}$$
$$\beta[2] = 0 \quad \text{if} \quad \beta[1] = 0 \text{ or } \beta[5] = 0 \text{ or } \texttt{GRADE} \neq 6. \tag{366}$$
$$\beta[6] = 0 \quad \text{if} \quad \beta[3] = 0 \text{ or } \beta[7] = 0 \text{ or } \texttt{GRADE} \neq 6. \tag{367}$$
$$\beta[8] = 0 \quad \text{if} \quad \beta[5] = 0 \text{ or } \beta[7] = 0 \text{ or } \texttt{GRADE} \neq 6. \tag{368}$$

(b) If

$$\texttt{DATAMODE}_{\text{in}} = \text{CC33\_GRADED}, \tag{369}$$

then

i. If

$$\texttt{CONTENT}_{\text{in}} = \text{EVT0}, \tag{370}$$

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

ii. If

$$\texttt{CONTENT}_{\text{in}} = \text{EVT1, TGEVT1, or EVT2}, \tag{371}$$

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

18. PHA including time-dependent gain:

(a) If

$$\texttt{DATAMODE}_{\text{in}} = \text{CC33\_FAINT}, \tag{372}$$

then

$$\texttt{PHA} = \sum_{j=0}^{8} \beta[j]p[j], \tag{373}$$

where

i.

$$p[j] = \begin{cases} \texttt{PHAS\_ADJ}[j] & \text{if } \texttt{apply\_cti} = \text{yes} \\ \texttt{PHAS}[j] & \text{if } \texttt{apply\_cti} = \text{no} \end{cases} \tag{374}$$

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

iii.

$$\beta[j] = 0 \quad \text{if} \quad p[j] < \text{split threshold}. \tag{375}$$

iv. If the CTI adjustment is not performed, then

$$\beta[j] = 0 \text{ if } \begin{cases} p[j] > p[4] \text{ (for } j = 0-3) \\ p[j] \geq p[4] \text{ (for } j = 5-8) \end{cases} \tag{376}$$

v. If CORNERS $= -1$, then

$$\beta[0] = \beta[2] = \beta[6] = \beta[8] = 0. \tag{377}$$

vi. If CORNERS $= 1$, then

$$\beta[0] = 0 \quad \text{if} \quad \beta[1] = 0 \text{ and } \beta[3] = 0. \tag{378}$$

$$\beta[2] = 0 \quad \text{if} \quad \beta[1] = 0 \text{ and } \beta[5] = 0. \tag{379}$$

$$\beta[6] = 0 \quad \text{if} \quad \beta[3] = 0 \text{ and } \beta[7] = 0. \tag{380}$$

$$\beta[8] = 0 \quad \text{if} \quad \beta[5] = 0 \text{ and } \beta[7] = 0. \tag{381}$$

vii. If CORNERS $= 2$, then

$$\beta[0] = 0 \quad \text{if} \quad \beta[1] = 0 \text{ or } \beta[3] = 0 \text{ or } \texttt{GRADE} \neq 6. \tag{382}$$

$$\beta[2] = 0 \quad \text{if} \quad \beta[1] = 0 \text{ or } \beta[5] = 0 \text{ or } \texttt{GRADE} \neq 6. \tag{383}$$

$$\beta[6] = 0 \quad \text{if} \quad \beta[3] = 0 \text{ or } \beta[7] = 0 \text{ or } \texttt{GRADE} \neq 6. \tag{384}$$

$$\beta[8] = 0 \quad \text{if} \quad \beta[5] = 0 \text{ or } \beta[7] = 0 \text{ or } \texttt{GRADE} \neq 6. \tag{385}$$

(b) If

$$\texttt{DATAMODE}_{\text{in}} = \text{CC33\_GRADED}, \tag{386}$$

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

(c) If

$$\texttt{apply\_tgain} = \text{yes}, \tag{387}$$

then

$$\texttt{PHA} = \texttt{PHA} + \text{int}\left[\left(\frac{\texttt{TIME} - \texttt{EPOCH1}}{\texttt{EPOCH2} - \texttt{EPOCH1}}\right)(\delta_2 - \delta_1) + \delta_1 + \epsilon\right], \tag{388}$$

where

$$\text{int} = \text{the integer portion of (i.e. truncate or round down)}, \tag{389}$$

$$\texttt{TIME} = \text{the time of the event}, \tag{390}$$

$$\texttt{EPOCH1} = \text{a keyword in the } \texttt{tgainfile}, \tag{391}$$

$$\texttt{EPOCH2} = \text{a keyword in the } \texttt{tgainfile}, \tag{392}$$

$$\delta_1 = \left(\frac{\texttt{PHA} - \texttt{PHA}_m[r]}{\texttt{PHA}_{m+1}[r] - \texttt{PHA}_m[r]}\right)(\texttt{DELTPHA1}_{m+1}[r] - \texttt{DELTPHA1}_m[r]) + \tag{393}$$

$$\texttt{DELTPHA1}_m[r], \tag{394}$$

$$
\begin{cases}
r \text{ is the row of the } \texttt{tgainfile} \text{ where} \\
\quad \begin{cases} \texttt{CCD\_ID}[r] = \texttt{CCD\_ID}, \\ \texttt{CHIPX\_LO}[r] \le \texttt{CHIPX}, \\ \texttt{CHIPX\_HI}[r] \ge \texttt{CHIPX}, \\ \texttt{CHIPY\_LO}[r] \le \mathrm{nint}(\texttt{CHIPY\_ADJ}), \text{ and} \\ \texttt{CHIPY\_HI}[r] \ge \mathrm{nint}(\texttt{CHIPY\_ADJ}). \end{cases} \\
m \text{ is the element of row } r \text{ where} \\
\quad \begin{cases} \texttt{PHA}_m[r] \le \texttt{PHA} \text{ and} \\ \texttt{PHA}_{m+1}[r] > \texttt{PHA}. \\ \text{If } \texttt{PHA} < \texttt{PHA}_m[r] \text{ for } m = 0, \text{ then } m = 0. \\ \text{If } \texttt{PHA} \ge \texttt{PHA}_m[r] \text{ for } m = M \text{ and } M \text{ is the last element of } \texttt{PHA}[r], \\ \qquad \text{then } m = M - 1. \end{cases} \\
\text{The } \texttt{tgainfile} \text{ includes a binary table with columns named} \\
\qquad \texttt{CCD\_ID}, \texttt{CHIPX\_LO}, \texttt{CHIPX\_HI}, \texttt{CHIPY\_LO}, \texttt{CHIPY\_HI}, \texttt{PHA}, \texttt{DELTPHA1}, \text{ and} \\
\qquad \texttt{DELTPHA2}.
\end{cases} \tag{395}
$$

$$
\delta_2 = \left(\frac{\texttt{PHA} - \texttt{PHA}_m[r]}{\texttt{PHA}_{m+1}[r] - \texttt{PHA}_m[r]} \right) (\texttt{DELTPHA2}_{m+1}[r] - \texttt{DELTPHA2}_m[r]) + \tag{396}
$$

$$
\texttt{DELTPHA2}_m[r], \tag{397}
$$

$$
\epsilon = \text{is a uniform random deviate in the range } [0, 1), \tag{398}
$$

$$
\{ \text{ If } \texttt{rand\_pha} = \text{no}, \text{ then } \epsilon = 0. \tag{399}
$$

(d) If

$$
\texttt{PHA} \ge 32767, \tag{400}
$$

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

19. CORN_PHA:

(a) If

$$
\texttt{DATAMODE}_{\text{in}} = \text{CC33\_GRADED}, \tag{401}
$$

then the value of CORN_PHA is read from the infile.

20. ENERGY:

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

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

$$
\texttt{CCD\_ID} = \texttt{CCD\_ID}_{\text{gain},i}, \tag{402}
$$

$$
\texttt{CHIPX\_MIN}_{\text{gain},i} \le \texttt{CHIPX} \le \texttt{CHIPX\_MAX}_{\text{gain},i}, \qquad \text{and} \tag{403}
$$

$$
\texttt{CHIPY\_MIN}_{\text{gain},i} \le \mathrm{nint}(\texttt{CHIPY\_ADJ}) \le \texttt{CHIPY\_MAX}_{\text{gain},i}, \tag{404}
$$

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

$$
\texttt{PHA}_{\text{gain},i}[j] \le (\texttt{PHA} + \Delta p) < \texttt{PHA}_{\text{gain},i}[j+1], \tag{405}
$$

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 $\texttt{PHA}_{\text{gain},i}[\texttt{NPOINTS} - 2] \le \texttt{PHA} + \Delta p$, 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:

$$\texttt{ENERGY} = \left(\frac{\texttt{PHA} + \Delta p - \texttt{PHA}_{\text{gain},i}[j]}{\texttt{PHA}_{\text{gain},i}[j+1] - \texttt{PHA}_{\text{gain},i}[j]}\right)(\texttt{ENERGY}_{\text{gain},i}[j+1] - \texttt{ENERGY}_{\text{gain},i}[j]) + \texttt{ENERGY}_{\text{gain},i}[j], \quad (406)$$

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

v. If ENERGY < 0, then ENERGY $= 0$.

(b) If the parameter calculate_pi = yes, if the parameter gainfile is specified, and if PHA ≤ 0, then ENERGY $= 0$.

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

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

ii. If the infile does not include the ENERGY of an event, then ENERGY $= 0$.

21. PI:

(a) If

$$\texttt{calculate\_pi} = \text{yes}, \quad (407)$$

then

i.

$$\texttt{PI} = \text{int}\left(\frac{\texttt{ENERGY}}{\texttt{pi\_bin\_width}}\right) + 1, \quad (408)$$

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

ii. If

$$\texttt{PI} < 1, \quad (409)$$

then PI $= 1$.

iii. If

$$\texttt{PI} > \texttt{pi\_num\_bins}, \quad (410)$$

then PI = pi_num_bins.

(b) If

$$\texttt{calculate\_pi} = \text{no} \quad (411)$$

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

22. pix_adj:

(a)

$$\texttt{CHIPX\_ADJ} = \texttt{CHIPX}. \quad (412)$$

(b) If

$$\texttt{pix\_adj} = \text{centroid}, \quad (413)$$

then

$$\texttt{CHIPX\_ADJ} = \texttt{CHIPX\_ADJ} - w'[0] + w'[2] - w'[3] + w'[5] - w'[6] + w'[8] \quad (414)$$

and if

$$\begin{aligned} \texttt{DATAMODE} &= \text{FAINT or} && (415)\\ \texttt{DATAMODE} &= \text{FAINT\_BIAS or} && (416)\\ \texttt{DATAMODE} &= \text{GRADED or} && (417)\\ \texttt{DATAMODE} &= \text{VFAINT,} && (418) \end{aligned}$$

then

$$\texttt{CHIPY\_ADJ} = \texttt{CHIPY\_ADJ} - w'[0] - w'[1] - w'[2] + w'[6] + w'[7] + w'[8] \quad (419)$$

and if

$$\begin{aligned} \texttt{DATAMODE} &= \text{CC33\_FAINT or} && (420)\\ \texttt{DATAMODE} &= \text{CC33\_GRADED,} && (421) \end{aligned}$$

then

$$\texttt{TIME} = \texttt{TIME} + (w'[0] + w'[1] + w'[2] - w'[6] - w'[7] - w'[8]) \times \texttt{TIMEDEL}_{\text{in}}, \quad (422)$$

where

$$w'[j] = \frac{w[j]}{\sum_{j=0}^{8} w[j]}, \quad (423)$$

$$w[j] = \begin{cases} p[j] & \text{if the pixel is valid} \\ 0 & \text{if the pixel is invalid,} \end{cases} \quad (424)$$

$$p[j] = \begin{cases} \texttt{PHAS\_ADJ}[j] & \text{if } \texttt{apply\_cti} = \text{yes} \\ \texttt{PHAS}[j] & \text{if } \texttt{apply\_cti} = \text{no,} \end{cases} \quad (425)$$

and the pixel is invalid if

$$\begin{aligned} \beta[j] &= 0 \text{ or} && (426)\\ \texttt{STATUS}[0] &= 1 \text{ or} && (427)\\ \texttt{STATUS}[1] &= 1 \text{ or} && (428)\\ \texttt{STATUS}[2] &= 1 \text{ or} && (429)\\ \texttt{STATUS}[3] &= 1 \text{ or} && (430)\\ \texttt{STATUS}[4] &= 1 \text{ or} && (431)\\ \texttt{STATUS}[11] &= 1 \text{ or} && (432)\\ \texttt{STATUS}[13] &= 1 \text{ or} && (433)\\ \texttt{STATUS}[14] &= 1 \text{ or} && (434)\\ \texttt{STATUS}[15] &= 1 \text{ or} && (435)\\ \texttt{STATUS}[16] &= 1. && (436) \end{aligned}$$

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.

(c) If

$$\texttt{pix\_adj} = \text{edser}, \quad (437)$$

then

$$\texttt{CHIPX\_ADJ} = \texttt{CHIPX\_ADJ} + \left(\frac{\texttt{ENERGY} - E[k]}{E[k+1] - E[k]}\right)(\Delta X[k+1] - \Delta X[k]) + \Delta X[k] \quad (438)$$

and if

$$\texttt{DATAMODE} = \text{FAINT or} \tag{439}$$
$$\texttt{DATAMODE} = \text{FAINT\_BIAS or} \tag{440}$$
$$\texttt{DATAMODE} = \text{GRADED or} \tag{441}$$
$$\texttt{DATAMODE} = \text{VFAINT,} \tag{442}$$

then

$$\texttt{CHIPY\_ADJ} = \texttt{CHIPY\_ADJ} + \left(\frac{\texttt{ENERGY} - E[k]}{E[k+1] - E[k]}\right)(\Delta Y[k+1] - \Delta Y[k]) + \Delta Y[k] \tag{443}$$

and if

$$\texttt{DATAMODE} = \text{CC33\_FAINT or} \tag{444}$$
$$\texttt{DATAMODE} = \text{CC33\_GRADED,} \tag{445}$$

then

$$\texttt{TIME} = \texttt{TIME} - \left(\left(\frac{\texttt{ENERGY} - E[k]}{E[k+1] - E[k]}\right)(\Delta Y[k+1] - \Delta Y[k]) + \Delta Y[k]\right) \times \texttt{TIMEDEL}_{\text{in}}, \tag{446}$$

where $E[k]$ and $E[k+1]$, $X[k]$ and $X[k+1]$, and $Y[k]$ and $Y[k+1]$ are the k and $(k+1)^{th}$ elements of the vector columns $\texttt{ENERGY}_{\text{subpix}}$, $\texttt{CHIPX\_OFFSET}_{\text{subpix}}$, and $\texttt{CHIPY\_OFFSET}_{\text{subpix}}$, 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

$$\texttt{ENERGY} \geq E[k] \text{ and} \tag{447}$$
$$\texttt{ENERGY} < E[k+1]. \tag{448}$$

Note that if

$$\texttt{ENERGY} \leq E[0], \tag{449}$$

then $k = 0$. Similarly, if

$$\texttt{ENERGY} \geq E[\texttt{NPOINTS}_{\text{subpix}} - 2], \tag{450}$$

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

(d) If

$$\texttt{pix\_adj} = \text{none}, \tag{451}$$

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

(e) If

$$\texttt{pix\_adj} = \text{randomize}, \tag{452}$$

then

$$\texttt{CHIPX\_ADJ} = \texttt{CHIPX\_ADJ} + \epsilon_x \tag{453}$$

and if

$$\texttt{DATAMODE} = \text{FAINT or} \tag{454}$$
$$\texttt{DATAMODE} = \text{FAINT\_BIAS or} \tag{455}$$
$$\texttt{DATAMODE} = \text{GRADED or} \tag{456}$$
$$\texttt{DATAMODE} = \text{VFAINT,} \tag{457}$$

then

$$\texttt{CHIPY\_ADJ} = \texttt{CHIPY\_ADJ} + \epsilon_y \tag{458}$$

and if

$$\texttt{DATAMODE} = \text{CC33\_FAINT or} \tag{459}$$
$$\texttt{DATAMODE} = \text{CC33\_GRADED,} \tag{460}$$

then

$$\texttt{TIME} = \texttt{TIME} - \epsilon_y \times \texttt{TIMEDEL}_{\text{in}}, \tag{461}$$

where ϵ_x and ϵ_y are uniform random deviates in the range $[-0.5, +0.5)$ pixel.

(f) If

$$\texttt{CHIPX\_ADJ} < 0.5, \tag{462}$$

then

$$\texttt{CHIPX\_ADJ} = 1. \tag{463}$$

(g) If

$$\texttt{CHIPX\_ADJ} \geq 1024.5, \tag{464}$$

then

$$\texttt{CHIPX\_ADJ} = 1024. \tag{465}$$

(h) If

$$\texttt{CHIPY\_ADJ} < 0.5, \tag{466}$$

then

$$\texttt{CHIPY\_ADJ} = 1. \tag{467}$$

(i) If

$$\texttt{CHIPY\_ADJ} \geq 1024.5, \tag{468}$$

then

$$\texttt{CHIPY\_ADJ} = 1024. \tag{469}$$

23. TDETX and TDETY:

(a) If

$$\texttt{stop} = \text{tdet or} \tag{470}$$
$$\texttt{stop} = \text{det or} \tag{471}$$
$$\texttt{stop} = \text{tan or} \tag{472}$$
$$\texttt{stop} = \text{sky,} \tag{473}$$

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

24. DETX and DETY:

   (a) If

$$\texttt{stop} = \text{det or} \tag{474}$$
$$\texttt{stop} = \text{tan or} \tag{475}$$
$$\texttt{stop} = \text{sky,} \tag{476}$$

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

25. X and Y:

   (a) If

$$\texttt{stop} = \text{sky,} \tag{477}$$

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

26. SKY_1D:

   (a) If

$$\texttt{DATAMODE}_{\text{in}} = \text{CC33\_FAINT or} \tag{478}$$
$$\texttt{DATAMODE}_{\text{in}} = \text{CC33\_GRADED} \tag{479}$$

   and if

$$\texttt{stop} = \text{sky,} \tag{480}$$

   then the value of SKY_1D is computed.

1.5.4 Write outfile

1. PIX_ADJ:

   (a) If

$$\texttt{pix\_adj} = \text{centroid,} \tag{481}$$

   then

$$\texttt{PIX\_ADJ} = \text{CENTROID,} \tag{482}$$

   (b) If

$$\texttt{pix\_adj} = \text{edser,} \tag{483}$$

   then

$$\texttt{PIX\_ADJ} = \text{EDSER,} \tag{484}$$

   (c) If

$$\texttt{pix\_adj} = \text{none,} \tag{485}$$

   then

$$\texttt{PIX\_ADJ} = \text{NONE,} \tag{486}$$

(d) If

$$\texttt{pix\_adj} = \text{randomize,} \tag{487}$$

then

$$\texttt{PIX\_ADJ} = \text{RANDOMIZE,} \tag{488}$$

2. RAND_SKY:

(a) If

$$\texttt{pix\_adj} = \text{centroid,} \tag{489}$$

then

$$\texttt{RAND\_SKY} = 0.0, \tag{490}$$

(b) If

$$\texttt{pix\_adj} = \text{edser,} \tag{491}$$

then

$$\texttt{RAND\_SKY} = 0.0, \tag{492}$$

(c) If

$$\texttt{pix\_adj} = \text{none,} \tag{493}$$

then

$$\texttt{RAND\_SKY} = 0.0, \tag{494}$$

(d) If

$$\texttt{pix\_adj} = \text{randomize,} \tag{495}$$

then

$$\texttt{RAND\_SKY} = 0.5, \tag{496}$$

3. TIME_ADJ:

(a) If

$$\texttt{DATAMODE}_{\text{in}} = \text{FAINT or} \tag{497}$$
$$\texttt{DATAMODE}_{\text{in}} = \text{FAINT\_BIAS or} \tag{498}$$
$$\texttt{DATAMODE}_{\text{in}} = \text{GRADED or} \tag{499}$$
$$\texttt{DATAMODE}_{\text{in}} = \text{VFAINT,} \tag{500}$$

then

$$\texttt{TIME\_ADJ} = \text{NONE.} \tag{501}$$

(b) i. If

$$\begin{aligned} \texttt{DATAMODE}_{\rm in} &= \text{CC33\_FAINT or} && (502)\\ \texttt{DATAMODE}_{\rm in} &= \text{CC33\_GRADED,} && (503)\end{aligned}$$

if

$$\begin{aligned} \texttt{CONTENT}_{\rm in} &= \text{EVT0 or} && (504)\\ \texttt{CONTENT}_{\rm in} &= \text{EVT1 or} && (505)\\ \texttt{CONTENT}_{\rm in} &= \text{EVT2,} && (506)\end{aligned}$$

if

$$\begin{aligned} \texttt{CCD\_ID}_{\rm focus} &\geq 0 \text{ and} && (507)\\ \texttt{CCD\_ID}_{\rm focus} &\leq 3, && (508)\end{aligned}$$

and if

$$\begin{aligned} &\cos(\texttt{DEC\_ADJ}_{\rm I})\cos(\texttt{DEC\_TARG}_{\rm in})\cos(\texttt{RA\_ADJ}_{\rm I} - \texttt{RA\_TARG}_{\rm in}) + && (509)\\ &\sin(\texttt{DEC\_ADJ}_{\rm I})\sin(\texttt{DEC\_TARG}_{\rm in}) < && (510)\\ &4.855 \times 10^{-11}, && (511)\end{aligned}$$

then

$$\texttt{TIME\_ADJ} = \text{TARGET.} \qquad (512)$$

ii. If

$$\begin{aligned} \texttt{DATAMODE}_{\rm in} &= \text{CC33\_FAINT or} && (513)\\ \texttt{DATAMODE}_{\rm in} &= \text{CC33\_GRADED,} && (514)\end{aligned}$$

if

$$\begin{aligned} \texttt{CONTENT}_{\rm in} &= \text{EVT0 or} && (515)\\ \texttt{CONTENT}_{\rm in} &= \text{EVT1 or} && (516)\\ \texttt{CONTENT}_{\rm in} &= \text{EVT2,} && (517)\end{aligned}$$

if

$$\begin{aligned} \texttt{CCD\_ID}_{\rm focus} &\geq 4 \text{ and} && (518)\\ \texttt{CCD\_ID}_{\rm focus} &\leq 9, && (519)\end{aligned}$$

and if

$$\begin{aligned} &\cos(\texttt{DEC\_ADJ}_{\rm S})\cos(\texttt{DEC\_TARG}_{\rm in})\cos(\texttt{RA\_ADJ}_{\rm S} - \texttt{RA\_TARG}_{\rm in}) + && (520)\\ &\sin(\texttt{DEC\_ADJ}_{\rm S})\sin(\texttt{DEC\_TARG}_{\rm in}) < && (521)\\ &4.855 \times 10^{-11}, && (522)\end{aligned}$$

then

$$\texttt{TIME\_ADJ} = \text{TARGET.} \qquad (523)$$

(c) i. If

$$\texttt{DATAMODE}_{\rm in} = \text{CC33\_FAINT or} \quad (524)$$
$$\texttt{DATAMODE}_{\rm in} = \text{CC33\_GRADED,} \quad (525)$$

if

$$\texttt{CONTENT}_{\rm in} = \text{EVT0 or} \quad (526)$$
$$\texttt{CONTENT}_{\rm in} = \text{EVT1 or} \quad (527)$$
$$\texttt{CONTENT}_{\rm in} = \text{EVT2,} \quad (528)$$

if

$$\texttt{CCD\_ID}_{\rm focus} \geq 0 \text{ and} \quad (529)$$
$$\texttt{CCD\_ID}_{\rm focus} \leq 3, \quad (530)$$

and if

$$\cos(\texttt{DEC\_ADJ}_{\rm I})\cos(\texttt{DEC\_TARG}_{\rm in})\cos(\texttt{RA\_ADJ}_{\rm I} - \texttt{RA\_TARG}_{\rm in}) + \quad (531)$$
$$\sin(\texttt{DEC\_ADJ}_{\rm I})\sin(\texttt{DEC\_TARG}_{\rm in}) \geq \quad (532)$$
$$4.855 \times 10^{-11}, \quad (533)$$

then

$$\texttt{TIME\_ADJ} = \text{AIMPOINT.} \quad (534)$$

ii. If

$$\texttt{DATAMODE}_{\rm in} = \text{CC33\_FAINT or} \quad (535)$$
$$\texttt{DATAMODE}_{\rm in} = \text{CC33\_GRADED,} \quad (536)$$

if

$$\texttt{CONTENT}_{\rm in} = \text{EVT0 or} \quad (537)$$
$$\texttt{CONTENT}_{\rm in} = \text{EVT1 or} \quad (538)$$
$$\texttt{CONTENT}_{\rm in} = \text{EVT2,} \quad (539)$$

if

$$\texttt{CCD\_ID}_{\rm focus} \geq 4 \text{ and} \quad (540)$$
$$\texttt{CCD\_ID}_{\rm focus} \leq 9, \quad (541)$$

and if

$$\cos(\texttt{DEC\_ADJ}_{\rm S})\cos(\texttt{DEC\_TARG}_{\rm in})\cos(\texttt{RA\_ADJ}_{\rm S} - \texttt{RA\_TARG}_{\rm in}) + \quad (542)$$
$$\sin(\texttt{DEC\_ADJ}_{\rm S})\sin(\texttt{DEC\_TARG}_{\rm in}) \geq \quad (543)$$
$$4.855 \times 10^{-11}, \quad (544)$$

then

$$\texttt{TIME\_ADJ} = \text{AIMPOINT.} \quad (545)$$

(d) If

$$\texttt{DATAMODE}_{\rm in} = \rm CC33\_FAINT\ or \quad (546)$$
$$\texttt{DATAMODE}_{\rm in} = \rm CC33\_GRADED \quad (547)$$

if

$$\texttt{CONTENT}_{\rm in} = \rm TGEVT1 \quad (548)$$

and if

$$\texttt{CCD\_ID}_{\rm focus} \geq 4 \text{ and} \quad (549)$$
$$\texttt{CCD\_ID}_{\rm focus} \leq 9 \quad (550)$$

then

$$\texttt{TIME\_ADJ} = \rm GRATING. \quad (551)$$

(e) If

$$\texttt{DATAMODE}_{\rm in} = \rm CC33\_FAINT\ or \quad (552)$$
$$\texttt{DATAMODE}_{\rm in} = \rm CC33\_GRADED \quad (553)$$

if

$$\texttt{CONTENT}_{\rm in} = \rm TGEVT1 \quad (554)$$

if

$$\texttt{CCD\_ID}_{\rm focus} \geq 0 \text{ and} \quad (555)$$
$$\texttt{CCD\_ID}_{\rm focus} \leq 3 \quad (556)$$

and if

$$\cos(\texttt{DEC\_ADJ}_{\rm I})\cos(\texttt{DEC\_TARG}_{\rm in})\cos(\texttt{RA\_ADJ}_{\rm I} - \texttt{RA\_TARG}_{\rm in}) + \quad (557)$$
$$\sin(\texttt{DEC\_ADJ}_{\rm I})\sin(\texttt{DEC\_TARG}_{\rm in}) < \quad (558)$$
$$4.855 \times 10^{-11}, \quad (559)$$

then

$$\texttt{TIME\_ADJ} = \rm TARGET. \quad (560)$$

(f) If

$$\texttt{DATAMODE}_{\rm in} = \rm CC33\_FAINT\ or \quad (561)$$
$$\texttt{DATAMODE}_{\rm in} = \rm CC33\_GRADED \quad (562)$$

if

$$\texttt{CONTENT}_{\rm in} = \rm TGEVT1 \quad (563)$$

if

$$\texttt{CCD\_ID}_{\rm focus} \geq 0 \text{ and} \quad (564)$$
$$\texttt{CCD\_ID}_{\rm focus} \leq 3 \quad (565)$$

and if

$$\cos\left(\texttt{DEC\_ADJ}_{\rm I}\right)\cos\left(\texttt{DEC\_TARG}_{\rm in}\right)\cos\left(\texttt{RA\_ADJ}_{\rm I} - \texttt{RA\_TARG}_{\rm in}\right) + \quad (566)$$
$$\sin\left(\texttt{DEC\_ADJ}_{\rm I}\right)\sin\left(\texttt{DEC\_TARG}_{\rm in}\right) \geq \quad (567)$$
$$4.855 \times 10^{-11}, \quad (568)$$

then

$$\texttt{TIME\_ADJ} = \text{AIMPOINT}. \quad (569)$$

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`?