MIT Kavli Institute   Chandra X-Ray Center

MEMORANDUM

July 7, 2016

To: Jonathan McDowell, SDS Group Leader

From: Glenn E. Allen, SDS

Subject: `acis_process_events` spec

Revision: 4.15

URL: http://space.mit.edu/CXC/docs/docs.html#ape

File: /nfs/inconceivable/d0/sds/specs/acis_process_events/ape_spec_4.15.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. If

        $$\mathtt{obsfile} \;=\; \mathrm{NONE}, \tag{1}$$

        then `obsfile` is changed to "none".

        ii. Existence:
        If

        $$\mathtt{obsfile} \;\neq\; \mathrm{none} \tag{2}$$

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

iii. Permission:
   If

$$obsfile \neq none \tag{3}$$

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.

iv. OBS_MODE:
   If

$$obsfile \neq none \tag{4}$$

then
   A. If the `obsfile` does not include the keyword OBS_MODE, then OBS_MODE_{in} is set to "none".
   B. If the `obsfile` includes the keyword OBS_MODE then OBS_MODE_{in} is set to OBS_MODE.
   C. If

$$OBS\_MODE_{in} = POINTING, \tag{5}$$

   then OBS_MODE_{in} is set to "pointing".
   D. If

$$OBS\_MODE_{in} = SECONDARY, \tag{6}$$

   then OBS_MODE_{in} is set to "secondary".
   E. If

$$OBS\_MODE_{in} \neq none \text{ and} \tag{7}$$
$$OBS\_MODE_{in} \neq pointing \text{ and} \tag{8}$$
$$OBS\_MODE_{in} \neq secondary, \tag{9}$$

   then OBS_MODE_{in} is set to "none" and `acis_process_events` produces a warning message.

2. `acaofffile`:

   (a) Validation:
      If

$$OBS\_MODE_{in} = pointing, \tag{10}$$

   then
      i. If

$$acaofffile = NONE, \tag{11}$$

   then `acaofffile` is set to "none."
      ii. Setting:
         If

$$acaofffile = none, \tag{12}$$

   then `acis_process_events` produces a warning message.

iii. Existence:
If

$$\texttt{acaofffile} \quad \neq \quad \text{none} \tag{13}$$

and the `acaofffile` does not exist, then `acis_process_events` produces a warning and `acaofffile` is set to "none."

iv. Permission:
If the `acaofffile` exists and the file permissions do not allow it to be read, then `acis_process_events` produces a warning message and `acaofffile` is set to "none."

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

$$\texttt{CONTENT} \quad = \quad \text{ASPSOL or} \tag{14}$$
$$\texttt{CONTENT} \quad = \quad \text{OBCSOL,} \tag{15}$$

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

vi. Keyword:
If HDU h_{acaoff} of the `acaofffile` does not include the keyword `TSTART`, then `acis_process_events` produces a warning message and `acaofffile` is set to "none."

vii. Columns:
If HDU h_{acaoff} of the `acaofffile` does not include the columns `TIME`, `RA`, `DEC`, and `ROLL` then `acis_process_events` produces a warning message and `acaofffile` is set to "none." Hereafter, these columns are referred to as $\text{TIME}_{\text{acaoff}}$, $\text{RA}_{\text{acaoff}}$, $\text{DEC}_{\text{acaoff}}$, and $\text{ROLL}_{\text{acaoff}}$.

viii. Sequential:
If more than one valid `acaofffile` is specified and the the values `TSTART` are not in increasing order, then `acis_process_events` produces a warning message and `acaofffile` is set to "none."

3. `alignmentfile`:

   (a) Validation:
   If

$$\texttt{OBS\_MODE}_{\text{in}} \quad = \quad \text{pointing,} \tag{16}$$

   then

   i. If

$$\texttt{alignmentfile} \quad = \quad \text{NONE,} \tag{17}$$

   then `alignmentfile` is changed to "none."

   ii. Setting:
   If

$$\texttt{alignmentfile} \quad = \quad \text{none,} \tag{18}$$

   then `acis_process_events` produces a warning message.

   iii. Existence:
   If

$$\texttt{alignmentfile} \quad \neq \quad \text{none} \tag{19}$$

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

iv. Permission:
If the `alignmentfile` exists and the file permissions do not allow it to be read, then `acis_process_events` produces a warning message and `alignmentfile` is set to "none.".

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

$$\text{CONTENT} \quad = \quad \text{ASPSOL or} \tag{20}$$
$$\text{CONTENT} \quad = \quad \text{OBCSOL}, \tag{21}$$

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

vi. Keyword:
If HDU $h_{\text{alignment}}$ of the `alignmentfile` does not include the keyword `TSTART`, then `acis_process_events` produces a warning message and `alignmentfile` is set to "none.".

vii. Columns:
If HDU $h_{\text{alignment}}$ of the `alignmentfile` does not include the columns `DY`, `DZ`, and `DTHETA` then `acis_process_events` produces a warning message and `alignmentfile` is set to "none.".

viii. Sequential:
If more than one valid `alignmentfile` is specified and the values `TSTART` are not in increasing order, then `acis_process_events` produces a warning message and `alignmentfile` is set to "none.".

4. `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 $\text{OBS\_MODE}_{\text{in}}$ = none and HDU h_{in} of the `infile` includes the keyword `OBS_MODE`, then
A. $\text{OBS\_MODE}_{\text{in}}$ is set to `OBS_MODE`.
B. If

$$\text{OBS\_MODE}_{\text{in}} \quad = \quad \text{POINTING}, \tag{22}$$

then $\text{OBS\_MODE}_{\text{in}}$ is set to "pointing".
C. If

$$\text{OBS\_MODE}_{\text{in}} \quad = \quad \text{SECONDARY}, \tag{23}$$

then $\text{OBS\_MODE}_{\text{in}}$ is set to "secondary".
D. If

$$\text{OBS\_MODE}_{\text{in}} \quad \neq \quad \text{none and} \tag{24}$$
$$\text{OBS\_MODE}_{\text{in}} \quad \neq \quad \text{pointing and} \tag{25}$$
$$\text{OBS\_MODE}_{\text{in}} \quad \neq \quad \text{secondary}, \tag{26}$$

then $\text{OBS\_MODE}_{\text{in}}$ 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

$$\text{DATAMODE} \neq \text{CC33\_FAINT and} \tag{27}$$
$$\text{DATAMODE} \neq \text{CC33\_GRADED and} \tag{28}$$
$$\text{DATAMODE} \neq \text{FAINT and} \tag{29}$$
$$\text{DATAMODE} \neq \text{FAINT\_BIAS and} \tag{30}$$
$$\text{DATAMODE} \neq \text{GRADED and} \tag{31}$$
$$\text{DATAMODE} \neq \text{VFAINT,} \tag{32}$$

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

iii. `CONTENT`:

If the `infile` does not have an HDU h_{in} with the keyword

$$\text{CONTENT} = \text{EVT0 or} \tag{33}$$
$$\text{CONTENT} = \text{EVT1 or} \tag{34}$$
$$\text{CONTENT} = \text{TGEVT1 or} \tag{35}$$
$$\text{CONTENT} = \text{EVT2,} \tag{36}$$

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

iv. `TIME`:

If

$$\text{DATAMODE}_{\text{in}} = \text{CC33\_FAINT or} \tag{37}$$
$$\text{DATAMODE}_{\text{in}} = \text{CC33\_GRADED} \tag{38}$$

and 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 TIME_{in}.

v. `TIME_RO`:

If

$$\text{DATAMODE}_{\text{in}} = \text{CC33\_FAINT or} \tag{39}$$
$$\text{DATAMODE}_{\text{in}} = \text{CC33\_GRADED} \tag{40}$$

and

$$\text{CONTENT}_{\text{in}} = \text{EVT1 or} \tag{41}$$
$$\text{CONTENT}_{\text{in}} = \text{TGEVT1 or} \tag{42}$$
$$\text{CONTENT}_{\text{in}} = \text{EVT2} \tag{43}$$

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 $\text{TIME\_RO}_{\text{in}}$.

vi. `CCD_ID`:

A. If

$$\text{CONTENT}_{\text{in}} = \text{EVT0} \tag{44}$$

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

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B. If

$$\text{CONTENT}_{\text{in}} \quad = \quad \text{EVT1 or} \tag{45}$$
$$\text{CONTENT}_{\text{in}} \quad = \quad \text{TGEVT1 or} \tag{46}$$
$$\text{CONTENT}_{\text{in}} \quad = \quad \text{EVT2} \tag{47}$$

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

vii. CCDX:
  A. If

$$\text{CONTENT}_{\text{in}} \quad = \quad \text{EVT0} \tag{48}$$

and HDU h_{in} of the `infile` does not include the column CCDX and does not include the column CHIPX, then `acis_process_events` exits with an error message. Hereafter, these columns are referred to as CCDX_{in} and CHIPX_{in}, respectively.

viii. CHIPX:
  A. If

$$\text{CONTENT}_{\text{in}} \quad = \quad \text{EVT1 or} \tag{49}$$
$$\text{CONTENT}_{\text{in}} \quad = \quad \text{TGEVT1 or} \tag{50}$$
$$\text{CONTENT}_{\text{in}} \quad = \quad \text{EVT2} \tag{51}$$

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

ix. CCDY:
  A. If

$$\text{CONTENT}_{\text{in}} \quad = \quad \text{EVT0} \tag{52}$$

and

$$\text{DATAMODE}_{\text{in}} \quad = \quad \text{FAINT or} \tag{53}$$
$$\text{DATAMODE}_{\text{in}} \quad = \quad \text{FAINT\_BIAS or} \tag{54}$$
$$\text{DATAMODE}_{\text{in}} \quad = \quad \text{GRADED or} \tag{55}$$
$$\text{DATAMODE}_{\text{in}} \quad = \quad \text{VFAINT} \tag{56}$$

and HDU h_{in} of the `infile` does not include the column CCDY and does not include the column CHIPY, then `acis_process_events` exits with an error message. Hereafter, these columns are referred to as CCDY_{in} and CHIPY_{in}, respectively.

x. TROW:
  A. If

$$\text{CONTENT}_{\text{in}} \quad = \quad \text{EVT0} \tag{57}$$

and

$$\text{DATAMODE}_{\text{in}} \quad = \quad \text{CC33\_FAINT or} \tag{58}$$
$$\text{DATAMODE}_{\text{in}} \quad = \quad \text{CC33\_GRADED} \tag{59}$$

and HDU h_{in} of the `infile` does not include the column TROW and does not include the column CHIPY, then `acis_process_events` exits with an error message. Hereafter, these columns are referred to as TROW_{in} and CHIPY_{in}, respectively.

xi. CHIPY:
   A. If

$$CONTENT_{in} = EVT1 \text{ or} \tag{60}$$
$$CONTENT_{in} = TGEVT1 \text{ or} \tag{61}$$
$$CONTENT_{in} = EVT2 \tag{62}$$

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$_{in}$.

xii. TIMEDEL:
   If

$$DATAMODE_{in} = CC33\_FAINT \text{ or} \tag{63}$$
$$DATAMODE_{in} = CC33\_GRADED \tag{64}$$

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 TIMEDEL$_{in}$.

xiii. RA_TARG, DEC_TARG, RA_NOM, DEC_NOM, RA_PNT, DEC_PNT, CHIPY_TG, and TG_M:
   If

$$OBS\_MODE_{in} = \text{pointing} \tag{65}$$

and

$$DATAMODE_{in} = CC33\_FAINT \text{ or} \tag{66}$$
$$DATAMODE_{in} = CC33\_GRADED, \tag{67}$$

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 RA_TARG$_{in}$, DEC_TARG$_{in}$, RA_NOM$_{in}$, DEC_NOM$_{in}$, RA_PNT$_{in}$, and DEC_PNT$_{in}$, respectively.
   B. CHIPY_TG and TG_M:
      If

$$CONTENT_{in} = TGEVT1 \tag{68}$$

and HDU h_{in} of the `infile` does not include the columns CHIPY_TGand TG_M, then `acis_process_events` exits with an error message. Hereafter these columns are referred to as CHIPY_TG$_{in}$ and TG_M$_{in}$, respectively.

xiv. TGAINCOR:
   If HDU h_{in} of the `infile` does not include the keyword TGAINCOR, then this keyword is set to zero (i.e. FALSE). Hereafter, this keyword is referred to as TGAINCOR$_{in}$.

5. `stop`:

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

   (b) Validation:

i. Setting:
   If

$$\begin{aligned}
\texttt{stop} &\neq \text{none and} & (69) \\
\texttt{stop} &\neq \text{chip and} & (70) \\
\texttt{stop} &\neq \text{tdet and} & (71) \\
\texttt{stop} &\neq \text{det and} & (72) \\
\texttt{stop} &\neq \text{tan and} & (73) \\
\texttt{stop} &\neq \text{sky,} & (74)
\end{aligned}$$

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

ii. OBS_MODE:
   If

$$\begin{aligned}
\texttt{OBS\_MODE}_{\text{in}} &\neq \text{pointing and} & (75) \\
\texttt{stop} &\neq \text{none and} & (76) \\
\texttt{stop} &\neq \text{chip and} & (77) \\
\texttt{stop} &\neq \text{tdet,} & (78)
\end{aligned}$$

then `stop` is changed to "tdet" and `acis_process_events` produces a warning message.

iii. acaofffile:
   If

$$\begin{aligned}
\texttt{OBS\_MODE}_{\text{in}} &= \text{pointing and} & (79) \\
\texttt{acaofffile} &= \text{none and} & (80) \\
\texttt{stop} &\neq \text{none and} & (81) \\
\texttt{stop} &\neq \text{chip and} & (82) \\
\texttt{stop} &\neq \text{tdet,} & (83)
\end{aligned}$$

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

iv. alignmentfile:
   If

$$\begin{aligned}
\texttt{OBS\_MODE}_{\text{in}} &= \text{pointing and} & (84) \\
\texttt{alignmentfile} &= \text{none and} & (85) \\
\texttt{stop} &\neq \text{none and} & (86) \\
\texttt{stop} &\neq \text{chip and} & (87) \\
\texttt{stop} &\neq \text{tdet,} & (88)
\end{aligned}$$

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

6. doevtgrade:

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

   (b) Validation:
   If

$$\begin{aligned}
\texttt{doevtgrade} &\neq \text{yes and} & (89) \\
\texttt{doevtgrade} &\neq \text{no,} & (90)
\end{aligned}$$

then `acis_process_events` exits with an error message.

7. `apply_cti`:

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

   (b) Validation:

     i. Setting:
If

$$\text{apply\_cti} \quad \neq \quad \text{yes and} \tag{91}$$
$$\text{apply\_cti} \quad \neq \quad \text{no,} \tag{92}$$

then `acis_process_events` exits with an error message.

     ii. `PHAS`:
If

$$\text{apply\_cti} \quad = \quad \text{yes} \tag{93}$$

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

$$\text{apply\_cti} \quad = \quad \text{yes and} \tag{94}$$
$$\text{doevtgrade} \quad = \quad \text{no,} \tag{95}$$

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

8. `gradefile`:

   (a) Validation:

     i. If

$$\text{gradefile} \quad = \quad \text{NONE,} \tag{96}$$

then `gradefile` is changed to "none."

     ii. Existence:
If

$$\text{gradefile} \quad \neq \quad \text{none} \tag{97}$$

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

     iii. Permission:
If

$$\text{gradefile} \quad \neq \quad \text{none} \tag{98}$$

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

     iv. HDU:
If the `gradefile` does not have an HDU that includes the keyword `CBD10001` and where the keyword includes $\text{DATAMODE}_{\text{in}}$, then `gradefile` is changed to "none" and `acis_process_events` produces a warning message. Hereafter this HDU is referred to as h_{grade}.

v. Columns:
If

$$\texttt{gradefile} \;\neq\; \text{none} \tag{99}$$

and HDU h_{grade} of the gradefile does not include the columns FLTGRADE and GRADE, then gradefile is changed to "none" and acis_process_events produces a warning message. Hereafter these columns are referred to as FLTGRADE$_{\text{grade}}$ and GRADE$_{\text{grade}}$, respectively.

9. badpixfile:

   (a) Validation:

      i. If

$$\texttt{badpixfile} \;=\; \text{NONE}, \tag{100}$$

then badpixfile is changed to "none."

      ii. Existence:
          If

$$\texttt{badpixfile} \;\neq\; \text{none} \tag{101}$$

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

      iii. Permission:
           If

$$\texttt{badpixfile} \;\neq\; \text{none} \tag{102}$$

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.

      iv. CONTENT:
          If

$$\texttt{badpixfile} \;\neq\; \text{none} \tag{103}$$

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

$$\texttt{CONTENT} \;=\; \text{BADPIX or} \tag{104}$$
$$\texttt{CONTENT} \;=\; \text{CDB\_ACIS\_BADPIX}, \tag{105}$$

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

      v. Keyword:
         If

$$\texttt{badpixfile} \;\neq\; \text{none} \tag{106}$$

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 CCD_ID$_{\text{badpix}}$.

vi. Columns:
   If

$$badpixfile \neq none \tag{107}$$

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 CHIPX$_{\mathrm{badpix}}$, CHIPY$_{\mathrm{badpix}}$, TIME$_{\mathrm{badpix}}$, TIME_STOP$_{\mathrm{badpix}}$, and STATUS$_{\mathrm{badpix}}$, respectively.

10. ctifile:

   (a) Validation:
      If

$$ctifile \neq caldb \ and \tag{108}$$
$$ctifile \neq CALDB, \tag{109}$$

   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_{cti} with the keyword

$$CONTENT = CDB\_ACIS\_CTI, \tag{110}$$

         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.

11. clobber:

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

$$clobber \neq yes \ and \tag{111}$$
$$clobber \neq no, \tag{112}$$

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

$$clobber = yes \tag{113}$$

      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

$$\texttt{clobber} \quad = \quad \text{no} \tag{114}$$

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

12. `pix_adj`:

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

   (b) Validation:

      i. Setting:
         If

$$
\begin{aligned}
\texttt{pix\_adj} \quad &\neq \quad \text{centroid and} \tag{115} \\
\texttt{pix\_adj} \quad &\neq \quad \text{edser and} \tag{116} \\
\texttt{pix\_adj} \quad &\neq \quad \text{none and} \tag{117} \\
\texttt{pix\_adj} \quad &\neq \quad \text{randomize,} \tag{118}
\end{aligned}
$$

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

      ii. `OBS_MODE`:
         If

$$
\begin{aligned}
\texttt{OBS\_MODE}_{\text{in}} \quad &\neq \quad \text{pointing and} \tag{119} \\
\texttt{pix\_adj} \quad &\neq \quad \text{none,} \tag{120}
\end{aligned}
$$

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

      iii. `acaofffile`:
         If

$$\texttt{pix\_adj} \quad \neq \quad \text{none} \tag{121}$$

         and

$$
\begin{aligned}
\texttt{DATAMODE}_{\text{in}} \quad &= \quad \text{CC33\_FAINT or} \tag{122} \\
\texttt{DATAMODE}_{\text{in}} \quad &= \quad \text{CC33\_GRADED} \tag{123}
\end{aligned}
$$

         and

$$\texttt{acaofffile} \quad = \quad \text{none,} \tag{124}$$

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

      iv. `alignmentfile`:
         If

$$\texttt{pix\_adj} \quad \neq \quad \text{none} \tag{125}$$

         and

$$
\begin{aligned}
\texttt{DATAMODE}_{\text{in}} \quad &= \quad \text{CC33\_FAINT or} \tag{126} \\
\texttt{DATAMODE}_{\text{in}} \quad &= \quad \text{CC33\_GRADED} \tag{127}
\end{aligned}
$$

         and

$$\texttt{alignmentfile} \quad = \quad \text{none,} \tag{128}$$

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

12

    v. `stop`:
      If

$$\texttt{pix\_adj} = \text{centroid or} \tag{129}$$
$$\texttt{pix\_adj} = \text{edser or} \tag{130}$$
$$\texttt{pix\_adj} = \text{randomize} \tag{131}$$

and

$$\texttt{stop} \neq \text{sky}, \tag{132}$$

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

    vi. `PHAS`:
      If

$$\texttt{pix\_adj} = \text{centroid} \tag{133}$$

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

    vii. `FLTGRADE`:
      If

$$\texttt{pix\_adj} = \text{edser} \tag{134}$$

and

$$\texttt{DATAMODE} = \text{CC33\_GRADED or} \tag{135}$$
$$\texttt{DATAMODE} = \text{GRADED} \tag{136}$$

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

13. `subpixfile`:

  (a) If

$$\texttt{pix\_adj} = \text{edser}, \tag{137}$$

then

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

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

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

$$\texttt{CONTENT} = \text{AXAF\_SUBPIX}, \tag{138}$$

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

1.5.2 Initializations

1. Focal-point CCD:

If

$$\mathtt{OBS\_MODE}_{\mathrm{in}} \quad = \quad \text{pointing} \tag{139}$$

and

$$\mathtt{DATAMODE}_{\mathrm{in}} \quad = \quad \text{CC33\_FAINT or} \tag{140}$$
$$\mathtt{DATAMODE}_{\mathrm{in}} \quad = \quad \text{CC33\_GRADED,} \tag{141}$$

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

2. $\mathtt{TIME}_{\mathrm{min}}$ and $\mathtt{TIME}_{\mathrm{max}}$:

If

$$\mathtt{OBS\_MODE}_{\mathrm{in}} \quad = \quad \text{pointing and} \tag{142}$$
$$\mathtt{acaofffile} \quad \neq \quad \text{none and} \tag{143}$$
$$\mathtt{alignmentfile} \quad \neq \quad \text{none,} \tag{144}$$

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

$$\mathtt{TIME}_{\mathrm{min}} \quad = \quad \min\left(\mathtt{TIME}_{\mathrm{acaoff}}\right) \text{ and} \tag{145}$$
$$\mathtt{TIME}_{\mathrm{max}} \quad = \quad \max\left(\mathtt{TIME}_{\mathrm{acaoff}}\right). \tag{146}$$

3. $\mathtt{CHIPX\_TARG}_{\mathrm{acaoff,med}}$, $\mathtt{CHIPY\_TARG}_{\mathrm{acaoff,med}}$:

If

$$\mathtt{OBS\_MODE}_{\mathrm{in}} \quad = \quad \text{pointing} \tag{147}$$

and

$$\mathtt{DATAMODE}_{\mathrm{in}} \quad = \quad \text{CC33\_FAINT or} \tag{148}$$
$$\mathtt{DATAMODE}_{\mathrm{in}} \quad = \quad \text{CC33\_GRADED} \tag{149}$$

and

$$\mathtt{acaofffile} \quad \neq \quad \text{none and} \tag{150}$$
$$\mathtt{alignmentfile} \quad \neq \quad \text{none,} \tag{151}$$

---

[*]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.

then the values of CHIPX_TARG$_\text{acaoff}$ and CHIPY_TARG$_\text{acaoff}$ are computed from the values of RA_TARG and DEC_TARG using the orientation of the telescope (i.e. RA, DEC, and ROLL) and the orientation of the SIM (i.e. DY, DZ, and DTHETA) and the TIMEs in the acaofffile. The values of CHIPX_TARG$_\text{acaoff}$ and CHIPY_TARG$_\text{acaoff}$ are processed to obtain the median values:

$$\text{CHIPX\_TARG}_\text{acaoff,med} = \text{median}(\text{CHIPX\_TARG}_\text{acaoff}) \text{ and} \tag{152}$$
$$\text{CHIPY\_TARG}_\text{acaoff,med} = \text{median}(\text{CHIPY\_TARG}_\text{acaoff}). \tag{153}$$

1.5.3 Loop over events

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

1. STATUS:

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

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

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

      iii. If

   $$\text{doevtgrade} = \text{yes}, \tag{154}$$

   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:

      i. If HDU h_in of the infile includes the EXPNO, hereafter referred to as EXPNO$_\text{in}$, then

   $$\text{EXPNO} = \text{EXPNO}_\text{in}. \tag{155}$$

      ii. If HDU h_in of the infile does not include the EXPNO, then

   $$\text{EXPNO} = \text{NULL}. \tag{156}$$

   (b) Validation:
   If

   $$\text{EXPNO} \neq \text{NULL} \tag{157}$$

   and

   $$\text{EXPNO} < 0 \text{ or} \tag{158}$$
   $$\text{EXPNO} \geq 10^8, \tag{159}$$

   then acis_process_events produces a warning upon completion with a count of the total number of events for which equation 157 and either equation 158 or 159 is true. These conditions should not occur.

3. `CCD_ID`:

   (a) Read:
       The value of `CCD_ID` for an event is given by CCD_ID_{in}.

   (b) Validation:
       If

$$CCD\_ID \quad < \quad 0 \text{ or} \tag{160}$$
$$CCD\_ID \quad > \quad 9, \tag{161}$$

   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. If the `infile` includes the column `CHIPX`, then the value of `CHIPX` for an event is given by

$$CHIPX \quad = \quad CHIPX_{in}. \tag{162}$$

       ii. If the `infile` does not include the column `CHIPX`, then the value of `CHIPX` for an event is
           given by

$$CHIPX \quad = \quad CCDX_{in} + 1. \tag{163}$$

5. `CHIPX_ADJ`:

   (a) Initialize:

$$CHIPX\_ADJ \quad = \quad CHIPX. \tag{164}$$

   (b) Validation:

       i. Unphysical:
          If

$$CHIPX\_ADJ \quad < \quad 1, \tag{165}$$

       then

$$CHIPX\_ADJ \quad = \quad 1. \tag{166}$$

       If

$$CHIPX\_ADJ \quad > \quad 1024, \tag{167}$$

       then

$$CHIPX\_ADJ \quad = \quad 1024. \tag{168}$$

       ii. Unexpected:
           If

$$CHIPX\_ADJ \quad = \quad 1 \text{ or} \tag{169}$$
$$CHIPX\_ADJ \quad = \quad 1024, \tag{170}$$

   then `acis_process_events` sets `STATUS` bit 0 (of 0–31) to one and increments a counter for
   the number of unexpected `CHIPX` values. These values should not occur.

6. NODE_ID:

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

   $$\text{NODE\_ID} \;=\; \text{int}\left(\frac{\text{CHIPX\_ADJ} - 1}{256}\right), \tag{171}$$

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

7. CHIPY:

   (a) Read:

      i. If the infile includes the column CHIPY, then the value of CHIPY for an event is given by

      $$\text{CHIPY} \;=\; \text{CHIPY}_{\text{in}}. \tag{172}$$

      ii. If the infile does not include the column CHIPY and

      $$\begin{aligned}
      \text{DATAMODE}_{\text{in}} &\;=\; \text{FAINT or} \tag{173} \\
      \text{DATAMODE}_{\text{in}} &\;=\; \text{FAINT\_BIAS or} \tag{174} \\
      \text{DATAMODE}_{\text{in}} &\;=\; \text{GRADED or} \tag{175} \\
      \text{DATAMODE}_{\text{in}} &\;=\; \text{VFAINT,} \tag{176}
      \end{aligned}$$

      then the value of CHIPY for an event is given by

      $$\text{CHIPY} \;=\; \text{CCDY}_{\text{in}} + 1. \tag{177}$$

      iii. If the infile does not include the column CHIPY and

      $$\begin{aligned}
      \text{DATAMODE}_{\text{in}} &\;=\; \text{CC33\_FAINT or} \tag{178} \\
      \text{DATAMODE}_{\text{in}} &\;=\; \text{CC33\_GRADED,} \tag{179}
      \end{aligned}$$

      then the value of CHIPY for an event is given by

      $$\text{CHIPY} \;=\; \text{TROW}_{\text{in}} + 1. \tag{180}$$

8. CHIPY_ADJ:

   (a) Initialize:

   $$\text{CHIPY\_ADJ} \;=\; \text{CHIPY}. \tag{181}$$

   (b) Validation:

      i. Unphysical:
         A. Minimum:
            If

            $$\text{CHIPY\_ADJ} \;<\; 1, \tag{182}$$

         then

            $$\text{CHIPY\_ADJ} \;=\; 1 \tag{183}$$

      and acis_process_events sets STATUS bit 0 (of 0–31) to one and increments a counter for the number of unexpected CHIPY values. These values should not occur.

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B. Timed exposure mode maximum:
   If

$$\text{DATAMODE}_{\text{in}} = \text{FAINT or} \tag{184}$$
$$\text{DATAMODE}_{\text{in}} = \text{FAINT\_BIAS or} \tag{185}$$
$$\text{DATAMODE}_{\text{in}} = \text{GRADED or} \tag{186}$$
$$\text{DATAMODE}_{\text{in}} = \text{VFAINT} \tag{187}$$

and

$$\text{CHIPY\_ADJ} > 1024, \tag{188}$$

then

$$\text{CHIPY\_ADJ} = 1024 \tag{189}$$

and `acis_process_events` sets `STATUS` bit 0 (of 0–31) to one and increments a counter for the number of unexpected `CHIPY` values. These values should not occur.

C. Continuous-clocking mode maximum:
   If

$$\text{DATAMODE}_{\text{in}} = \text{CC33\_FAINT or} \tag{190}$$
$$\text{DATAMODE}_{\text{in}} = \text{CC33\_GRADED} \tag{191}$$

and

$$\text{CHIPY\_ADJ} > 512, \tag{192}$$

then

$$\text{CHIPY\_ADJ} = 512 \tag{193}$$

and `acis_process_events` sets `STATUS` bit 0 (of 0–31) to one and increments a counter for the number of unexpected `CHIPY` values. These values should not occur.

ii. Unexpected:
A. VFAINT:
   If

$$\text{DATAMODE}_{\text{in}} = \text{VFAINT} \tag{194}$$

and

$$\text{CHIPY\_ADJ} = 2 \text{ or} \tag{195}$$
$$\text{CHIPY\_ADJ} = 1023, \tag{196}$$

then `acis_process_events` sets `STATUS` bit 0 (of 0–31) to one and increments a counter for the number of unexpected `CHIPY` values. These values should not occur.

9. `TIME_RO`:

   (a) Timed exposure mode:
       If

$$\text{DATAMODE} = \text{FAINT or} \tag{197}$$
$$\text{DATAMODE} = \text{FAINT\_BIAS or} \tag{198}$$
$$\text{DATAMODE} = \text{GRADED or} \tag{199}$$
$$\text{DATAMODE} = \text{VFAINT,} \tag{200}$$

then

$$\texttt{TIME\_RO} \quad = \quad \text{NaN.} \tag{201}$$

(b) Continuous-clocking mode:
   If

$$\texttt{DATAMODE}_{\text{in}} \quad = \quad \text{CC33\_FAINT or} \tag{202}$$
$$\texttt{DATAMODE}_{\text{in}} \quad = \quad \text{CC33\_GRADED,} \tag{203}$$

then
   i. Read:
      A. Level 0:
         If

$$\texttt{CONTENT}_{\text{in}} \quad = \quad \text{EVT0,} \tag{204}$$

   then the value of $\texttt{TIME\_RO}$ for an event is given by $\texttt{TIME}_{\text{in}}$.
      B. Level 1, 1.5, or 2:
         If

$$\texttt{CONTENT}_{\text{in}} \quad = \quad \text{EVT1 or} \tag{205}$$
$$\texttt{CONTENT}_{\text{in}} \quad = \quad \text{TGEVT1 or} \tag{206}$$
$$\texttt{CONTENT}_{\text{in}} \quad = \quad \text{EVT2} \tag{207}$$

      and

$$\texttt{TIME\_RO}_{\text{in}} \quad > \quad 0, \tag{208}$$

      then

$$\texttt{TIME\_RO} \quad = \quad \texttt{TIME\_RO}_{\text{in}}. \tag{209}$$

      If

$$\texttt{CONTENT}_{\text{in}} \quad = \quad \text{EVT1 or} \tag{210}$$
$$\texttt{CONTENT}_{\text{in}} \quad = \quad \text{TGEVT1 or} \tag{211}$$
$$\texttt{CONTENT}_{\text{in}} \quad = \quad \text{EVT2} \tag{212}$$

      and

$$\texttt{TIME\_RO}_{\text{in}} \quad = \quad 0, \tag{213}$$

      then

$$\texttt{TIME\_RO} \quad = \quad \texttt{TIME}_{\text{in}}. \tag{214}$$

   ii. Validation:
      If

$$\texttt{TIME\_RO} \quad < \quad 0 \text{ or} \tag{215}$$
$$\texttt{TIME\_RO} \quad \geq \quad 3 \times 10^{9}, \tag{216}$$

   then `acis_process_events` produces a warning upon completion with a count of the total number of events for which either equation 215 or 216 is true. These conditions should not occur.

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10. $\text{CHIPX\_TARG}_{\text{evt}}$, $\text{CHIPY\_TARG}_{\text{evt}}$, and $\text{CHIPY\_TARG}_{\text{eff}}$:
    The coordinate $\text{CHIPY\_TARG}_{\text{eff}}$ is used to compute the coordinates X, Y, and SKY_1D.

    (a) Approximate:
        If

$$\text{DATAMODE}_{\text{in}} \quad = \quad \text{CC33\_FAINT or} \tag{217}$$
$$\text{DATAMODE}_{\text{in}} \quad = \quad \text{CC33\_GRADED} \tag{218}$$

and

$$\texttt{acaofffile} \quad \neq \quad \text{none}, \tag{219}$$

then:

    i. Initial values:
    The values of $\text{CHIPX\_TARG}_{\text{evt}}$ and $\text{CHIPY\_TARG}_{\text{evt}}$ are computed from the values of RA_TARG and DEC_TARG using the value of $\text{CCD\_ID}_{\text{focus}}$ and using the orientation of the telescope (i.e. RA, DEC, and ROLL) and the orientation of the SIM (i.e. DY, DZ, and DTHETA) at the time given by $\text{TIME\_RO} - (\text{CHIPY\_TARG}_{\text{acaoff,med}} + 1028) \times \text{TIMEDEL}$. The value of $\text{CHIPY\_TARG}_{\text{evt}}$ can be negative.

    ii. ACIS-I0 or -I2:
    If

$$\text{CCD\_ID}_{\text{focus}} \quad = \quad \text{0 or} \tag{220}$$
$$\text{CCD\_ID}_{\text{focus}} \quad = \quad 2, \tag{221}$$

then

A. If

$$\text{CCD\_ID} \quad = \quad \text{0 or} \tag{222}$$
$$\text{CCD\_ID} \quad = \quad 2, \tag{223}$$

then

$$\text{CHIPY\_TARG}_{\text{eff}} \quad = \quad \text{CHIPY\_TARG}_{\text{evt}}. \tag{224}$$

B. If

$$\text{CCD\_ID} \quad = \quad \text{1 or} \tag{225}$$
$$\text{CCD\_ID} \quad = \quad 3, \tag{226}$$

then

$$\text{CHIPY\_TARG}_{\text{eff}} \quad = \quad 512 - (\text{CHIPY\_TARG}_{\text{evt}} - \text{CHIPY\_TARG}_{\text{acaoff,med}}). \tag{227}$$

C. If

$$\text{CCD\_ID} \quad \geq \quad 4, \tag{228}$$

then

$$\text{CHIPY\_TARG}_{\text{eff}} \quad = \quad 512 - (\text{CHIPX\_TARG}_{\text{evt}} - \text{CHIPX\_TARG}_{\text{acaoff,med}}). \tag{229}$$

iii. ACIS-I1 or -I3:
If

$$\text{CCD\_ID}_{\text{focus}} \quad = \quad 1 \text{ or} \tag{230}$$
$$\text{CCD\_ID}_{\text{focus}} \quad = \quad 3, \tag{231}$$

then
A. If

$$\text{CCD\_ID} \quad = \quad 0 \text{ or} \tag{232}$$
$$\text{CCD\_ID} \quad = \quad 2, \tag{233}$$

then

$$\text{CHIPY\_TARG}_{\text{eff}} \quad = \quad 512 - (\text{CHIPY\_TARG}_{\text{evt}} - \text{CHIPY\_TARG}_{\text{acaoff,med}}). \tag{234}$$

B. If

$$\text{CCD\_ID} \quad = \quad 1 \text{ or} \tag{235}$$
$$\text{CCD\_ID} \quad = \quad 3, \tag{236}$$

then

$$\text{CHIPY\_TARG}_{\text{eff}} \quad = \quad \text{CHIPY\_TARG}_{\text{evt}}. \tag{237}$$

C. If

$$\text{CCD\_ID} \quad \geq \quad 4, \tag{238}$$

then

$$\text{CHIPY\_TARG}_{\text{eff}} \quad = \quad 512 + (\text{CHIPX\_TARG}_{\text{evt}} - \text{CHIPX\_TARG}_{\text{acaoff,med}}). \tag{239}$$

iv. ACIS-S:
If

$$\text{CCD\_ID}_{\text{focus}} \quad \geq \quad 4, \tag{240}$$

then
A. If

$$\text{CCD\_ID} \quad = \quad 0 \text{ or} \tag{241}$$
$$\text{CCD\_ID} \quad = \quad 2, \tag{242}$$

then

$$\text{CHIPY\_TARG}_{\text{eff}} \quad = \quad 512 + (\text{CHIPX\_TARG}_{\text{evt}} - \text{CHIPX\_TARG}_{\text{acaoff,med}}). \tag{243}$$

B. If

$$\text{CCD\_ID} \quad = \quad 1 \text{ or} \tag{244}$$
$$\text{CCD\_ID} \quad = \quad 3, \tag{245}$$

then

$$\text{CHIPY\_TARG}_{\text{eff}} \quad = \quad 512 - (\text{CHIPX\_TARG}_{\text{evt}} - \text{CHIPX\_TARG}_{\text{acaoff,med}}). \tag{246}$$

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C. If

$$CCD\_ID \geq 4, \tag{247}$$

then

$$\text{CHIPY\_TARG}_{\text{eff}} = \text{CHIPY\_TARG}_{\text{evt}}. \tag{248}$$

(b) Validation:
   If

$$\text{CHIPY\_TARG}_{\text{eff}} < -256 \text{ or} \tag{249}$$
$$\text{CHIPY\_TARG}_{\text{eff}} \geq 1280, \tag{250}$$

then `acis_process_events` produces a warning message.

11. `TG_M`:

   (a) Continuous-clocking mode with gratings:
      If

$$\text{OBS\_MODE}_{\text{in}} = \text{pointing} \tag{251}$$

and

$$\text{DATAMODE}_{\text{in}} = \text{CC33\_FAINT or} \tag{252}$$
$$\text{DATAMODE}_{\text{in}} = \text{CC33\_GRADED} \tag{253}$$

and

$$\text{CONTENT}_{\text{in}} = \text{TGEVT1}, \tag{254}$$

then
   i. Read:
      The value of `TG_M` for an event is given by TG_M_{in}.
   ii. Validation:

      A. If

$$\text{TG\_M} < -99, \tag{255}$$

      then

$$\text{TG\_M} = -99 \tag{256}$$

      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

$$\text{TG\_M} > 99, \tag{257}$$

      then

$$\text{TG\_M} = 99 \tag{258}$$

      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.

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12. `CHIPY_TG`:

    (a) Continuous-clocking mode with gratings:
       If

$$\text{OBS\_MODE}_{\text{in}} \quad = \quad \text{pointing} \tag{259}$$

       and

$$\text{DATAMODE}_{\text{in}} \quad = \quad \text{CC33\_FAINT or} \tag{260}$$
$$\text{DATAMODE}_{\text{in}} \quad = \quad \text{CC33\_GRADED} \tag{261}$$

       and

$$\text{CONTENT}_{\text{in}} \quad = \quad \text{TGEVT1,} \tag{262}$$

       then

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

          A. If

$$\text{TG\_M} \quad > \quad -99 \text{ and} \tag{263}$$
$$\text{TG\_M} \quad < \quad 99 \text{ and} \tag{264}$$
$$\text{CHIPY\_TG} \quad \neq \quad \text{NaN} \tag{265}$$

            and

$$\text{CHIPY\_TG} \quad \leq \quad 0 \text{ or} \tag{266}$$
$$\text{CHIPY\_TG} \quad \geq \quad 1025, \tag{267}$$

          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

$$\text{TG\_M} \quad > \quad -99 \text{ and} \tag{268}$$
$$\text{TG\_M} \quad < \quad 99 \text{ and} \tag{269}$$
$$\text{CHIPY\_TG} \quad \neq \quad \text{NaN and} \tag{270}$$
$$\text{CHIPY\_TG} \quad < \quad 1, \tag{271}$$

            then

$$\text{CHIPY\_TG} \quad = \quad 1. \tag{272}$$

          C. If

$$\text{TG\_M} \quad > \quad -99 \text{ and} \tag{273}$$
$$\text{TG\_M} \quad < \quad 99 \text{ and} \tag{274}$$
$$\text{CHIPY\_TG} \quad \neq \quad \text{NaN and} \tag{275}$$
$$\text{CHIPY\_TG} \quad > \quad 1024, \tag{276}$$

            then

$$\text{CHIPY\_TG} \quad = \quad 1024. \tag{277}$$

13. TIME and CHIPY_ADJ:

For continuous-clocking mode observations, the value of CHIPY_ADJ is used to compute the TIME, pulse heights, and the coordinates TDETX, TDETY, DETX, and DETY.

(a) Calculate:

    i. Timed exposure mode:

      If

$$
\begin{aligned}
\text{DATAMODE}_{\text{in}} &= \text{FAINT or} & (278)\\
\text{DATAMODE}_{\text{in}} &= \text{FAINT\_BIAS or} & (279)\\
\text{DATAMODE}_{\text{in}} &= \text{GRADED or} & (280)\\
\text{DATAMODE}_{\text{in}} &= \text{VFAINT,} & (281)
\end{aligned}
$$

      then

$$
\text{TIME} = \text{TIME}_{\text{in}}. \tag{282}
$$

    ii. Continuous-clocking mode:

      If

$$
\begin{aligned}
\text{DATAMODE}_{\text{in}} &= \text{CC33\_FAINT or} & (283)\\
\text{DATAMODE}_{\text{in}} &= \text{CC33\_GRADED} & (284)
\end{aligned}
$$

      then

      A. Set

$$
\begin{aligned}
\text{CHIPY\_ADJ} &= 512 \text{ and} & (285)\\
\text{TIME}' &= \text{TIME\_RO} - (\text{CHIPY\_ADJ} + 1028) \times \text{TIMEDEL}. & (286)
\end{aligned}
$$

      B. If

$$
\text{acaofffile} \neq \text{none,} \tag{287}
$$

      then

$$
\begin{aligned}
\text{CHIPY\_ADJ}' &= \text{CHIPY\_TARG}_{\text{eff}} \text{ and} & (288)\\
\text{TIME}' &= \text{TIME\_RO} - (\text{CHIPY\_ADJ}' + 1028) \times \text{TIMEDEL,} & (289)
\end{aligned}
$$

and CHIPY_ADJ is computed from the values of RA_TARG and DEC_TARG using the orientation of the telescope (i.e. RA, DEC, and ROLL) and the orientation of the SIM (i.e. DY, DZ, and DTHETA) at the time TIME′. At this step, the value of CHIPY_ADJ can be negative.

      C. If

$$
\begin{aligned}
\text{CONTENT}_{\text{in}} &= \text{TGEVT1 and} & (290)\\
\text{TG\_M} &> -99 \text{ and} & (291)\\
\text{TG\_M} &< 99 \text{ and} & (292)\\
\text{CHIPY\_TG} &\neq \text{NaN,} & (293)
\end{aligned}
$$

      then

$$
\text{CHIPY\_ADJ} = \text{CHIPY\_TG}. \tag{294}
$$

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D. If

$$\text{CONTENT}_{\text{in}} \quad = \quad \text{TGEVT1} \tag{295}$$

and

$$\text{TG\_M} \quad = \quad -99 \text{ or} \tag{296}$$
$$\text{TG\_M} \quad = \quad 99, \tag{297}$$

then

$$\text{CHIPY\_ADJ} \quad = \quad 512. \tag{298}$$

E. If

$$\text{acaofffile} \quad \neq \quad \text{none} \tag{299}$$

and

$$\text{TIME}' \quad < \quad \text{TIME}_{\text{min}} \text{ or} \tag{300}$$
$$\text{TIME}' \quad \geq \quad \text{TIME}_{\text{max}}, \tag{301}$$

then

$$\text{CHIPY\_ADJ} \quad = \quad 512. \tag{302}$$

F. If

$$\text{acaofffile} \quad \neq \quad \text{none} \tag{303}$$

and

$$\text{TIME}' \quad < \quad \text{TIME}_{\text{min}} \text{ or} \tag{304}$$
$$\text{TIME}' \quad \geq \quad \text{TIME}_{\text{max}}, \tag{305}$$

and

$$\text{CCD\_ID}_{\text{focus}} \quad = \quad 0 \text{ or} \tag{306}$$
$$\text{CCD\_ID}_{\text{focus}} \quad = \quad 2 \tag{307}$$

and

$$\text{CCD\_ID} \quad = \quad 0 \text{ or} \tag{308}$$
$$\text{CCD\_ID} \quad = \quad 2, \tag{309}$$

then

$$\text{CHIPY\_ADJ} \quad = \quad \text{CHIPY\_TARG}_{\text{acaoff,med}}. \tag{310}$$

G. If

$$\text{acaofffile} \quad \neq \quad \text{none} \tag{311}$$

and

$$\text{TIME}' \quad < \quad \text{TIME}_{\text{min}} \text{ or} \tag{312}$$
$$\text{TIME}' \quad \geq \quad \text{TIME}_{\text{max}}, \tag{313}$$

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and

$$CCD\_ID_{focus} \quad = \quad 1 \text{ or} \tag{314}$$
$$CCD\_ID_{focus} \quad = \quad 3 \tag{315}$$

and

$$CCD\_ID \quad = \quad 1 \text{ or} \tag{316}$$
$$CCD\_ID \quad = \quad 3, \tag{317}$$

then

$$CHIPY\_ADJ \quad = \quad CHIPY\_TARG_{acaoff,med}. \tag{318}$$

H. If

$$\texttt{acaofffile} \quad \neq \quad none \tag{319}$$

and

$$TIME' \quad < \quad TIME_{min} \text{ or} \tag{320}$$
$$TIME' \quad \geq \quad TIME_{max}, \tag{321}$$

and

$$CCD\_ID_{focus} \quad \geq \quad 4 \text{ and} \tag{322}$$
$$CCD\_ID \quad \geq \quad 4, \tag{323}$$

then

$$CHIPY\_ADJ \quad = \quad CHIPY\_TARG_{acaoff,med}. \tag{324}$$

I. If

$$\texttt{acaofffile} \quad = \quad none \tag{325}$$

and

$$CONTENT_{in} \quad \neq \quad TGEVT1, \tag{326}$$

then

$$CHIPY\_ADJ \quad = \quad 512. \tag{327}$$

J. If

$$CCD\_ID_{focus} \quad \leq \quad 3 \text{ and} \tag{328}$$
$$CCD\_ID \quad \geq \quad 4, \tag{329}$$

then

$$CHIPY\_ADJ \quad = \quad 512. \tag{330}$$

K. If

$$CCD\_ID_{focus} \quad \geq \quad 4 \text{ and} \tag{331}$$
$$CCD\_ID \quad \leq \quad 3, \tag{332}$$

then

$$CHIPY\_ADJ \quad = \quad 512. \tag{333}$$

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L. If

$$\text{OBS\_MODE}_{\text{in}} \quad = \quad \text{secondary,} \tag{334}$$

then

$$\text{CHIPY\_ADJ} \quad = \quad 512. \tag{335}$$

M. If

$$\text{CHIPY\_ADJ} \quad < \quad 0.5 \text{ or} \tag{336}$$
$$\text{CHIPY\_ADJ} \quad \geq \quad 1024.5 \tag{337}$$

then

$$\text{CHIPY\_ADJ} \quad = \quad 512. \tag{338}$$

N. Set

$$\text{TIME} \quad = \quad \text{TIME\_RO} - (\text{CHIPY\_ADJ} + 1028) \times \text{TIMEDEL}. \tag{339}$$

In continuous-clocking mode, the coordinate CHIPY_ADJ is used to compute the time, the pulse heights, and the coordinates (except for X, Y, and SKY_1D).

(b) Validation:

i. If

$$\text{TIME} \quad < \quad 0 \text{ or} \tag{340}$$
$$\text{TIME} \quad \geq \quad 3 \times 10^9, \tag{341}$$

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

$$\text{CHIPY\_ADJ} \quad < \quad 0.5 \text{ or} \tag{342}$$
$$\text{CHIPY\_ADJ} \quad \geq \quad 1024.5, \tag{343}$$

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

14. Bad pixel:

(a) If

$$\text{badpixfile} \quad \neq \quad \text{none} \tag{344}$$

and the badpixfile includes a valid HDU h_{badpix} where $\text{CCD\_ID}_{\text{badpix}} = \text{CCD\_ID}$, 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 $\text{DATAMODE}_{\text{in}} = \text{CC33\_FAINT}$ or $\text{DATAMODE}_{\text{in}} = \text{CC33\_GRADED}$ and there are one or more rows r in HDU h_{badpix} where

$$\text{CHIPX} \quad \geq \quad \text{CHIPX}_{\text{badpix},r}[0] \text{ and} \tag{345}$$
$$\text{CHIPX} \quad \leq \quad \text{CHIPX}_{\text{badpix},r}[1] \text{ and} \tag{346}$$
$$\text{TIME} \quad \geq \quad \text{TIME}_{\text{badpix},r} \text{ and} \tag{347}$$
$$\text{TIME} \quad < \quad \text{TIME\_STOP}_{\text{badpix},r} \tag{348}$$

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and

$$\text{STATUS}_{\text{badpix},r}[5] \quad = \quad 1 \text{ or} \tag{349}$$
$$\text{STATUS}_{\text{badpix},r}[6] \quad = \quad 1 \text{ or} \tag{350}$$
$$\text{STATUS}_{\text{badpix},r}[9] \quad = \quad 1, \tag{351}$$

then

$$\text{STATUS}[0] = 1 \tag{352}$$

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

ii. If $\text{DATAMODE}_{\text{in}} = \text{CC33\_FAINT}$ or $\text{DATAMODE}_{\text{in}} = \text{CC33\_GRADED}$ and there are one or more rows r in HDU h_{badpix} where

$$\text{CHIPX} \quad \geq \quad \text{CHIPX}_{\text{badpix},r}[0] \text{ and} \tag{353}$$
$$\text{CHIPX} \quad \leq \quad \text{CHIPX}_{\text{badpix},r}[1] \text{ and} \tag{354}$$
$$\text{TIME} \quad \geq \quad \text{TIME}_{\text{badpix},r} \text{ and} \tag{355}$$
$$\text{TIME} \quad < \quad \text{TIME\_STOP}_{\text{badpix},r} \tag{356}$$

and

$$\text{STATUS}_{\text{badpix},r}[0] \quad = \quad 1 \text{ or} \tag{357}$$
$$\text{STATUS}_{\text{badpix},r}[1] \quad = \quad 1 \text{ or} \tag{358}$$
$$\text{STATUS}_{\text{badpix},r}[7] \quad = \quad 1 \text{ or} \tag{359}$$
$$\text{STATUS}_{\text{badpix},r}[11] \quad = \quad 1 \text{ or} \tag{360}$$
$$\text{STATUS}_{\text{badpix},r}[12] \quad = \quad 1 \text{ or} \tag{361}$$
$$\text{STATUS}_{\text{badpix},r}[13] \quad = \quad 1 \text{ or} \tag{362}$$
$$\text{STATUS}_{\text{badpix},r}[14] \quad = \quad 1 \text{ or} \tag{363}$$
$$\text{STATUS}_{\text{badpix},r}[16] \quad = \quad 1, \tag{364}$$

then

$$\text{STATUS}[4] = 1 \tag{365}$$

for the event.

iii. If $\text{DATAMODE}_{\text{in}} = \text{CC33\_FAINT}$ or $\text{DATAMODE}_{\text{in}} = \text{CC33\_GRADED}$ and there are one or more rows r in HDU h_{badpix} where

$$\text{CHIPX} \quad \geq \quad \text{CHIPX}_{\text{badpix},r}[0] \text{ and} \tag{366}$$
$$\text{CHIPX} \quad \leq \quad \text{CHIPX}_{\text{badpix},r}[1] \text{ and} \tag{367}$$
$$\text{TIME} \quad \geq \quad \text{TIME}_{\text{badpix},r} \text{ and} \tag{368}$$
$$\text{TIME} \quad < \quad \text{TIME\_STOP}_{\text{badpix},r} \tag{369}$$

and

$$\text{STATUS}_{\text{badpix},r}[8] \quad = \quad 1 \text{ or} \tag{370}$$
$$\text{STATUS}_{\text{badpix},r}[10] \quad = \quad 1, \tag{371}$$

then

$$\text{STATUS}[5] = 1 \tag{372}$$

for the event.

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iv. If $\text{DATAMODE}_{\text{in}} = \text{CC33\_FAINT}$ or $\text{DATAMODE}_{\text{in}} = \text{CC33\_GRADED}$ and there are one or more rows r in HDU h_{badpix} where

$$\text{CHIPX} \geq \text{CHIPX}_{\text{badpix},r}[0] \text{ and} \tag{373}$$
$$\text{CHIPX} \leq \text{CHIPX}_{\text{badpix},r}[1] \text{ and} \tag{374}$$
$$\text{TIME} \geq \text{TIME}_{\text{badpix},r} \text{ and} \tag{375}$$
$$\text{TIME} < \text{TIME\_STOP}_{\text{badpix},r} \tag{376}$$

and

$$\text{STATUS}_{\text{badpix},r}[3] = 1, \tag{377}$$

then

$$\text{STATUS}[6] = 1 \tag{378}$$

for the event.

v. If $\text{DATAMODE}_{\text{in}} = \text{CC33\_FAINT}$ or $\text{DATAMODE}_{\text{in}} = \text{CC33\_GRADED}$ and there are one or more rows r in HDU h_{badpix} where

$$\text{CHIPX} \geq \text{CHIPX}_{\text{badpix},r}[0] \text{ and} \tag{379}$$
$$\text{CHIPX} \leq \text{CHIPX}_{\text{badpix},r}[1] \text{ and} \tag{380}$$
$$\text{TIME} \geq \text{TIME}_{\text{badpix},r} \text{ and} \tag{381}$$
$$\text{TIME} < \text{TIME\_STOP}_{\text{badpix},r} \tag{382}$$

and

$$\text{STATUS}_{\text{badpix},r}[2] = 1 \text{ or} \tag{383}$$
$$\text{STATUS}_{\text{badpix},r}[4] = 1, \tag{384}$$

then

$$\text{STATUS}[8] = 1 \tag{385}$$

for the event.

vi. If $\text{DATAMODE}_{\text{in}} = \text{CC33\_FAINT}$ or $\text{DATAMODE}_{\text{in}} = \text{CC33\_GRADED}$ and there are one or more rows r in HDU h_{badpix} where

$$\text{CHIPX} \geq \text{CHIPX}_{\text{badpix},r}[0] \text{ and} \tag{386}$$
$$\text{CHIPX} \leq \text{CHIPX}_{\text{badpix},r}[1] \text{ and} \tag{387}$$
$$\text{TIME} \geq \text{TIME}_{\text{badpix},r} \text{ and} \tag{388}$$
$$\text{TIME} < \text{TIME\_STOP}_{\text{badpix},r} \tag{389}$$

and

$$\text{STATUS}_{\text{badpix},r}[15] = 1, \tag{390}$$

then

$$\text{STATUS}[16] = 1 \tag{391}$$

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.

15. PHAS:

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

(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 $\text{PHAS}[4] <$ the split threshold, then $\text{STATUS}[k] = 1$ for bit $k = 1$.

   iii. If $\text{PHAS}[4] < \text{PHAS}[j]$ for one or more $j = 0\text{--}3$, then $\text{STATUS}[k] = 1$ for bit $k = 1$.

   iv. If $\text{PHAS}[4] \leq \text{PHAS}[j]$ for one or more $j = 5\text{--}8$, then $\text{STATUS}[k] = 1$ for bit $k = 1$.

   v. If $\text{PHAS}[j] > 4095$ for one or more $j = 0\text{--}8$, then $\text{STATUS}[k] = 1$ for bit $k = 2$.

16. FLTGRADE_RO:

(a) If HDU h_{in} of the infile includes the column PHAS and

$$\text{doevtgrade} \quad = \quad \text{yes}, \tag{392}$$

then

$$\text{FLTGRADE\_RO} \quad = \quad c_{\text{fro}}[0] + 2c_{\text{fro}}[1] + 4c_{\text{fro}}[2] + 8c_{\text{fro}}[3] + \tag{393}$$
$$16c_{\text{fro}}[5] + 32c_{\text{fro}}[6] + 64c_{\text{fro}}[7] + 128c_{\text{fro}}[8]. \tag{394}$$

The values of $c_{\text{fro}}[j]$ are determined as follows.

   i. Each value of $c_{\text{fro}}[j]$ is initialized such that

$$c_{\text{fro}}[j] \quad = \quad 1. \tag{395}$$

   ii. If

$$\text{PHAS}[j] \quad < \quad \text{split threshold or} \tag{396}$$
$$\text{PHAS}[j] \quad > \quad 4095, \tag{397}$$
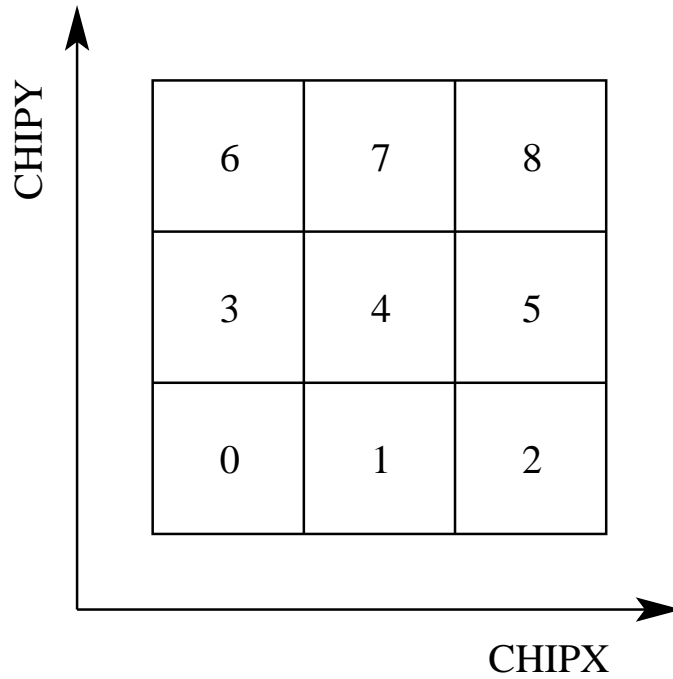
then

$$c_{\text{fro}}[j] \quad = \quad 0. \tag{398}$$

Figure 1: The relative `CHIPX` and `CHIPY` coordinates of the nine elements $j = 0\text{–}8$ of a 3 pixel $\times$ 3 pixel event island $\mathtt{PHAS}[j]$ or $\mathtt{PHAS\_ADJ}[j]$.

iii. If

$$
\begin{align}
j &\geq 0 \text{ and} \tag{399}\\
j &\leq 3 \text{ and} \tag{400}\\
\mathtt{PHAS}[j] &> \mathtt{PHAS}[4], \tag{401}
\end{align}
$$

then

$$
c_{\mathrm{fro}}[j] = 0. \tag{402}
$$

iv. If

$$
\begin{align}
j &\geq 5 \text{ and} \tag{403}\\
j &\leq 8 \text{ and} \tag{404}\\
\mathtt{PHAS}[j] &\geq \mathtt{PHAS}[4], \tag{405}
\end{align}
$$

then

$$
c_{\mathrm{fro}}[j] = 0. \tag{406}
$$

The elements $j = 0\text{–}8$ of `PHAS` are depicted in Figure 1.

(b) If HDU h_{in} of the **infile** does not include the column `PHAS` or

$$
\mathtt{doevtgrade} = \text{no}, \tag{407}
$$

then

$$
\mathtt{FLTGRADE\_RO} = \text{NULL}. \tag{408}
$$

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17. GRADE_RO:

(a) If

$$\text{FLTGRADE\_RO} \quad \neq \quad \text{NULL and} \qquad (409)$$
$$\text{gradefile} \quad \neq \quad \text{none and} \qquad (410)$$

HDU h_{grade} of the **gradefile** has a row r, where

$$\text{FLTGRADE}_{\text{grade}}[r] \quad = \quad \text{FLTGRADE\_RO}, \qquad (411)$$

then

$$\text{GRADE\_RO} \quad = \quad \text{GRADE}_{\text{grade}}[r]. \qquad (412)$$

(b) If

$$\text{FLTGRADE\_RO} \quad = \quad \text{NULL or} \qquad (413)$$
$$\text{gradefile} \quad = \quad \text{none or} \qquad (414)$$

HDU h_{grade} of the **gradefile** does not have a row r, where

$$\text{FLTGRADE}_{\text{grade}}[r] \quad = \quad \text{FLTGRADE\_RO}, \qquad (415)$$

then

$$\text{GRADE\_RO} \quad = \quad \text{NULL}. \qquad (416)$$

18. PHA_RO:

(a) If HDU h_{in} of the **infile** includes the column PHAS and

$$\text{doevtgrade} \quad = \quad \text{yes and} \qquad (417)$$
$$\text{GRADE\_RO} \quad \neq \quad \text{NULL}, \qquad (418)$$

then

$$\text{PHA\_RO} \quad = \quad \sum_{j=0}^{8} c_{\text{pro}}[j]\text{PHAS}[j]. \qquad (419)$$

The values of $c_{\text{pro}}[j]$ are determined as follows.

   i. Each value of $c_{\text{pro}}[j]$ is initialized such that

$$c_{\text{pro}}[j] \quad = \quad 1. \qquad (420)$$

   ii. If

$$\text{PHAS}[j] \quad < \quad \text{split threshold}, \qquad (421)$$

then

$$c_{\text{pro}}[j] \quad = \quad 0. \qquad (422)$$

32

iii. If

$$j \geq 0 \text{ and} \tag{423}$$
$$j \leq 3 \text{ and} \tag{424}$$
$$\texttt{PHAS}[j] > \texttt{PHAS}[4], \tag{425}$$

then

$$c_{\text{pro}}[j] = 0. \tag{426}$$

iv. If

$$j \geq 5 \text{ and} \tag{427}$$
$$j \leq 8 \text{ and} \tag{428}$$
$$\texttt{PHAS}[j] \geq \texttt{PHAS}[4], \tag{429}$$

then

$$c_{\text{pro}}[j] = 0. \tag{430}$$

v. If

$$\texttt{CORNERS} = -1, \tag{431}$$

then

$$c_{\text{pro}}[0] = 0 \text{ and} \tag{432}$$
$$c_{\text{pro}}[2] = 0 \text{ and} \tag{433}$$
$$c_{\text{pro}}[6] = 0 \text{ and} \tag{434}$$
$$c_{\text{pro}}[8] = 0. \tag{435}$$

vi. If

$$\texttt{CORNERS} = 0, \tag{436}$$

then there are no additional constraints on $c_{\text{pro}}[0]$, $c_{\text{pro}}[2]$, $c_{\text{pro}}[6]$, and $c_{\text{pro}}[8]$.

vii. If

$$\texttt{CORNERS} = 1, \tag{437}$$

then

A. If

$$c_{\text{pro}}[1] = 0 \text{ and} \tag{438}$$
$$c_{\text{pro}}[3] = 0, \tag{439}$$

then

$$c_{\text{pro}}[0] = 0. \tag{440}$$

B. If

$$c_{\text{pro}}[1] = 0 \text{ and} \tag{441}$$
$$c_{\text{pro}}[5] = 0, \tag{442}$$

then

$$c_{\text{pro}}[2] = 0. \tag{443}$$

33

C. If

$$c_{\mathrm{pro}}[3] \quad = \quad 0 \text{ and} \tag{444}$$
$$c_{\mathrm{pro}}[7] \quad = \quad 0, \tag{445}$$

then

$$c_{\mathrm{pro}}[6] \quad = \quad 0. \tag{446}$$

D. If

$$c_{\mathrm{pro}}[5] \quad = \quad 0 \text{ and} \tag{447}$$
$$c_{\mathrm{pro}}[7] \quad = \quad 0, \tag{448}$$

then

$$c_{\mathrm{pro}}[8] \quad = \quad 0. \tag{449}$$

viii. If

$$\texttt{CORNERS} \quad = \quad 2, \tag{450}$$

then

A. If

$$c_{\mathrm{pro}}[1] \quad = \quad 0 \text{ or} \tag{451}$$
$$c_{\mathrm{pro}}[3] \quad = \quad 0 \text{ or} \tag{452}$$
$$\texttt{GRADE\_RO} \quad \neq \quad 6, \tag{453}$$

then

$$c_{\mathrm{pro}}[0] \quad = \quad 0. \tag{454}$$

B. If

$$c_{\mathrm{pro}}[1] \quad = \quad 0 \text{ or} \tag{455}$$
$$c_{\mathrm{pro}}[5] \quad = \quad 0 \text{ or} \tag{456}$$
$$\texttt{GRADE\_RO} \quad \neq \quad 6, \tag{457}$$

then

$$c_{\mathrm{pro}}[2] \quad = \quad 0. \tag{458}$$

C. If

$$c_{\mathrm{pro}}[3] \quad = \quad 0 \text{ or} \tag{459}$$
$$c_{\mathrm{pro}}[7] \quad = \quad 0 \text{ or} \tag{460}$$
$$\texttt{GRADE\_RO} \quad \neq \quad 6, \tag{461}$$

then

$$c_{\mathrm{pro}}[6] \quad = \quad 0. \tag{462}$$

D. If

$$c_{\mathrm{pro}}[5] \quad = \quad 0 \text{ or} \tag{463}$$
$$c_{\mathrm{pro}}[7] \quad = \quad 0 \text{ or} \tag{464}$$
$$\texttt{GRADE\_RO} \quad \neq \quad 6, \tag{465}$$

then

$$c_{\mathrm{pro}}[8] \quad = \quad 0. \tag{466}$$

The elements $j = 0$–8 of $\texttt{PHAS}$ are depicted in Figure 1.

(b) If HDU h_{in} of the $\texttt{infile}$ does not include the column $\texttt{PHAS}$ or

$$\texttt{doevtgrade} \quad = \quad \text{no or} \tag{467}$$
$$\texttt{GRADE\_RO} \quad = \quad \text{NULL}, \tag{468}$$

then

i. If HDU h_{in} of the $\texttt{infile}$ includes the column $\texttt{PHA\_RO}$, then

$$\texttt{PHA\_RO} \quad = \quad \texttt{PHA\_RO}_{\mathrm{in}}. \tag{469}$$

ii. If HDU h_{in} of the $\texttt{infile}$ does not include the column $\texttt{PHA\_RO}$, then
   A. If HDU h_{in} of the $\texttt{infile}$ includes the column $\texttt{PHA}$ and HDU h_{in} of the $\texttt{infile}$ includes the keyword $\texttt{TGAINCOR}$ and

$$\texttt{TGAINCOR} \quad = \quad 0, \tag{470}$$

   then

$$\texttt{PHA\_RO} \quad = \quad \texttt{PHA}_{\mathrm{in}}. \tag{471}$$

   B. If HDU h_{in} of the $\texttt{infile}$ includes the column $\texttt{PHA}$ and HDU h_{in} of the $\texttt{infile}$ includes the keyword $\texttt{TGAINCOR}$ and

$$\texttt{TGAINCOR} \quad \neq \quad 0, \tag{472}$$

   then

$$\texttt{PHA\_RO} \quad = \quad \text{NULL}. \tag{473}$$

   C. If HDU h_{in} of the $\texttt{infile}$ includes the column $\texttt{PHA}$ and HDU h_{in} of the $\texttt{infile}$ does not include the keyword $\texttt{TGAINCOR}$ then

$$\texttt{PHA\_RO} \quad = \quad \texttt{PHA}_{\mathrm{in}}. \tag{474}$$

   D. If HDU h_{in} of the $\texttt{infile}$ does not include the column $\texttt{PHA}$, then

$$\texttt{PHA\_RO} \quad = \quad \text{NULL}. \tag{475}$$

19. $\texttt{PHAS\_ADJ}$:

(a) If HDU 1 of the $\texttt{infile}$ includes $\texttt{DATAMODE}_{\mathrm{in}} = \text{CC33\_FAINT}$ and the parameter $\texttt{apply\_cti} = \text{yes}$ and the $\texttt{ctifile}$ and $\texttt{mtlfile}$ are specified, then the CTI-adjusted pulse heights are computed as follows.

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

$$
\begin{align}
\Delta_x[j] &= 0, && (476)\\
\Delta_y[j] &= 0, \text{ and} && (477)\\
\texttt{PHAS\_ADJ}[j] &= \texttt{PHAS}[j] && (478)
\end{align}
$$

for every element $j = 0\text{--}8$, 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

$$
n = 1. \qquad (479)
$$

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

$$
\begin{align}
\Delta'_x[j] &= \Delta_x[j], && (480)\\
\Delta'_y[j] &= \Delta_y[j], \text{ and} && (481)\\
\texttt{PHAS\_ADJ}'[j] &= \texttt{PHAS\_ADJ}[j] && (482)
\end{align}
$$

for each element j.

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

$$
\begin{align}
\Delta_x[0] &= c_x[0]s_x\rho_x[0]V_x[0], && (483)\\
\Delta_x[1] &= c_x[1]s_x\rho_x[1]V_x[1] - c'_x[0]s_x\rho_x[0]V_x[0], && (484)\\
\Delta_x[2] &= c_x[2]s_x\rho_x[2]V_x[2] - c'_x[1]s_x\rho_x[1]V_x[1], && (485)\\
\Delta_x[3] &= c_x[3]s_x\rho_x[3]V_x[3], && (486)\\
\Delta_x[4] &= c_x[4]s_x\rho_x[4]V_x[4] - c'_x[3]s_x\rho_x[3]V_x[3], && (487)\\
\Delta_x[5] &= c_x[5]s_x\rho_x[5]V_x[5] - c'_x[4]s_x\rho_x[4]V_x[4], && (488)\\
\Delta_x[6] &= c_x[6]s_x\rho_x[6]V_x[6], && (489)\\
\Delta_x[7] &= c_x[7]s_x\rho_x[7]V_x[7] - c'_x[6]s_x\rho_x[6]V_x[6], \text{ and} && (490)\\
\Delta_x[8] &= c_x[8]s_x\rho_x[8]V_x[8] - c'_x[7]s_x\rho_x[7]V_x[7], && (491)
\end{align}
$$

where

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

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

$$s_x = 1 + \text{TCTIX}\,(T - \text{FP\_TEMP0}), \tag{492}$$

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

$$T = \left(\frac{t' - t'_k}{t'_{k+1} - t'_k}\right)(\text{FP\_TEMP}_{k+1} - \text{FP\_TEMP}_k) + \text{FP\_TEMP}_k, \tag{493}$$

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

$$t' = t + \text{TIMEDEL}_{\text{in}}\,(\text{TIMEPIXR}_{\text{evt}} - 0.5), \tag{494}$$

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

$$t'_k = \text{TIME}_k + \text{TIMEDEL}_{\text{mtl}}\,(\text{TIMEPIXR}_{\text{mtl}} - 0.5), \tag{495}$$

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

$$t'_{k+1} = \text{TIME}_{k+1} + \text{TIMEDEL}_{\text{mtl}}\,(\text{TIMEPIXR}_{\text{mtl}} - 0.5), \tag{496}$$

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

$$\rho_x[j] = \text{serial trap density,} \tag{497}$$

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

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

$$\text{VOLUME\_X}_l, \tag{498}$$

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

B. If there is a serial CTI trap-density map in the $\texttt{ctifile}$ for $\texttt{CCD\_ID}$ and $\texttt{NODE\_ID} = 1$ or 3, then the values of Δ_x are given by

$$
\begin{array}{rcll}
\Delta_x[0] & = & c_x[0]s_x\rho_x[0]V_x[0] - c'_x[1]s_x\rho_x[1]V_x[1], & (499) \\
\Delta_x[1] & = & c_x[1]s_x\rho_x[1]V_x[1] - c'_x[2]s_x\rho_x[2]V_x[2], & (500) \\
\Delta_x[2] & = & c_x[2]s_x\rho_x[2]V_x[2], & (501) \\
\Delta_x[3] & = & c_x[3]s_x\rho_x[3]V_x[3] - c'_x[4]s_x\rho_x[4]V_x[4], & (502) \\
\Delta_x[4] & = & c_x[4]s_x\rho_x[4]V_x[4] - c'_x[5]s_x\rho_x[5]V_x[5], & (503) \\
\Delta_x[5] & = & c_x[5]s_x\rho_x[5]V_x[5], & (504) \\
\Delta_x[6] & = & c_x[6]s_x\rho_x[6]V_x[6] - c'_x[7]s_x\rho_x[7]V_x[7], & (505) \\
\Delta_x[7] & = & c_x[7]s_x\rho_x[7]V_x[7] - c'_x[8]s_x\rho_x[8]V_x[8], \text{ and} & (506) \\
\Delta_x[8] & = & c_x[8]s_x\rho_x[8]V_x[8], & (507)
\end{array}
$$

where

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

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

and s_x, T, t', t'_k, t'_{k+1}, $\rho_x[j]$, and $V_x[j]$ are given by equations. 492, 493, 494, 495, 496, 497, and 498, 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

$$\Delta_y[0] = c_y[0]s_y\rho_y[0]V_y[0], \tag{508}$$
$$\Delta_y[1] = c_y[1]s_y\rho_y[1]V_y[1], \tag{509}$$
$$\Delta_y[2] = c_y[2]s_y\rho_y[2]V_y[2], \tag{510}$$
$$\Delta_y[3] = c_y[3]s_y\rho_y[3]V_y[3] - c'_y[0]s_y\rho_y[0]V_y[0], \tag{511}$$
$$\Delta_y[4] = c_y[4]s_y\rho_y[4]V_y[4] - c'_y[1]s_y\rho_y[1]V_y[1], \tag{512}$$
$$\Delta_y[5] = c_y[5]s_y\rho_y[5]V_y[5] - c'_y[2]s_y\rho_y[2]V_y[2], \tag{513}$$
$$\Delta_y[6] = c_y[6]s_y\rho_y[6]V_y[6] - c'_y[3]s_y\rho_y[3]V_y[3], \tag{514}$$
$$\Delta_y[7] = c_y[7]s_y\rho_y[7]V_y[7] - c'_y[4]s_y\rho_y[4]V_y[4], \text{ and} \tag{515}$$
$$\Delta_y[8] = c_y[8]s_y\rho_y[8]V_y[8] - c'_y[5]s_y\rho_y[5]V_y[5], \tag{516}$$

where

$$c_y[j] = \begin{cases} 0 & \begin{cases} \texttt{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] < \text{ split threshold} \\ \qquad (\text{for all } j), \end{cases} \\[1.5em] \texttt{FRCTRLY} & \begin{cases} \texttt{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] \geq \text{ split threshold and} \\ \texttt{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] < \\ \qquad \texttt{PHAS}[j-3] + \Delta'_x[j-3] + \Delta'_y[j-3] \\ \qquad (\text{for } j = 3, 4, 5, 6, 7, 8), \end{cases} \\[1.5em] 1 & \begin{cases} \texttt{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] \geq \text{ split threshold} \\ \qquad (\text{for } j = 0, 1, 2) \\ \texttt{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] \geq \text{ split threshold and} \\ \texttt{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] \geq \\ \qquad \texttt{PHAS}[j-3] + \Delta'_x[j-3] + \Delta'_y[j-3] \\ \qquad (\text{for } j = 3, 4, 5, 6, 7, 8), \end{cases} \end{cases}$$

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

$$s_y = 1 + \texttt{TCTIY}\,(T - \texttt{FP\_TEMP0}), \tag{517}$$

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

$$\rho_y[j] = \text{parallel trap density,} \tag{518}$$

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

$$V_y[j] = \left(\frac{\texttt{PHAS}[j] + \Delta_x'[j] + \Delta_y'[j] - \texttt{PHA}_l}{\texttt{PHA}_{l+1} - \texttt{PHA}_l} \right) (\texttt{VOLUME\_Y}_{l+1} - \texttt{VOLUME\_Y}_l) +$$
$$\texttt{VOLUME\_Y}_l, \tag{519}$$

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

and T, t', t_k', and t_{k+1}', are given by equations. 493, 494, 495, and 496, respectively.

vi. The CTI-adjusted pulse heights

$$\texttt{PHAS\_ADJ}[j] = \texttt{PHAS}[j] + \Delta_x[j] + \Delta_y[j] \tag{520}$$

for all j.

vii. A. If

$$|\texttt{PHAS\_ADJ}'[j] - \texttt{PHAS\_ADJ}[j]| < \texttt{cticonverge} \text{ (for all } j) \text{ and} \tag{521}$$
$$n \leq \texttt{max\_cti\_iter}, \tag{522}$$

then the computation of $\texttt{PHAS\_ADJ}$ is complete for the event.

B. If

$$|\text{PHAS\_ADJ}'[j] - \text{PHAS\_ADJ}[j]| \geq \text{cticonverge} \text{ (for one or more } j\text{) and} \quad (523)$$
$$n < \text{max\_cti\_iter}, \quad (524)$$

then $n = n + 1$ and steps 1.5.19(a)iii–1.5.19(a)vii are repeated.

C. If

$$|\text{PHAS\_ADJ}'[j] - \text{PHAS\_ADJ}[j]| \geq \text{cticonverge} \text{ (for one or more } j\text{) and} \quad (525)$$
$$n \geq \text{max\_cti\_iter}, \quad (526)$$

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.

20. FLTGRADE:

(a) If HDU h_{in} of the infile includes the column PHAS and

$$\text{apply\_cti} = \text{yes and} \quad (527)$$
$$\text{doevtgrade} = \text{yes}, \quad (528)$$

then

$$\text{FLTGRADE} = c_{\text{f}}[0] + 2c_{\text{f}}[1] + 4c_{\text{f}}[2] + 8c_{\text{f}}[3] + \quad (529)$$
$$16c_{\text{f}}[5] + 32c_{\text{f}}[6] + 64c_{\text{f}}[7] + 128c_{\text{f}}[8]. \quad (530)$$

The values of $c_{\text{f}}[j]$ are determined as follows.

i. Each value of $c_{\text{f}}[j]$ is initialized such that

$$c_{\text{f}}[j] = 1. \quad (531)$$

ii. If

$$\text{PHAS\_ADJ}[j] < \text{split threshold}, \quad (532)$$

then

$$c_{\text{f}}[j] = 0. \quad (533)$$

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

(b) If HDU h_{in} of the infile includes the column PHAS and

$$\text{apply\_cti} = \text{no and} \quad (534)$$
$$\text{doevtgrade} = \text{yes}, \quad (535)$$

then

$$\text{FLTGRADE} = \text{FLTGRADE\_RO}. \quad (536)$$

(c) If HDU h_{in} of the infile does not include the column PHAS or

$$\text{doevtgrade} = \text{no}, \quad (537)$$

then

i. If HDU h_{in} of the `infile` includes the column `FLTGRADE`, then

$$\text{FLTGRADE} \quad = \quad \text{FLTGRADE}_{\mathrm{in}}. \tag{538}$$

ii. If HDU h_{in} of the `infile` does not include the column `FLTGRADE`, then

$$\text{FLTGRADE} \quad = \quad \text{NULL}. \tag{539}$$

21. `GRADE`:

    (a) If

$$\begin{aligned}
\text{FLTGRADE} \quad &\neq \quad \text{NULL and} \tag{540} \\
\text{gradefile} \quad &\neq \quad \text{none and} \tag{541}
\end{aligned}$$

    HDU h_{grade} of the `gradefile` has a row r, where

$$\text{FLTGRADE}_{\mathrm{grade}}[r] \quad = \quad \text{FLTGRADE}, \tag{542}$$

    then

$$\text{GRADE} \quad = \quad \text{GRADE}_{\mathrm{grade}}[r]. \tag{543}$$

    (b) If

$$\begin{aligned}
\text{FLTGRADE} \quad &= \quad \text{NULL or} \tag{544} \\
\text{gradefile} \quad &= \quad \text{none or} \tag{545}
\end{aligned}$$

    HDU h_{grade} of the `gradefile` does not have a row r, where

$$\text{FLTGRADE}_{\mathrm{grade}}[r] \quad = \quad \text{FLTGRADE}, \tag{546}$$

    then

$$\text{GRADE} \quad = \quad \text{NULL}. \tag{547}$$

22. `PHA`, including time-dependent gain:

    (a) If HDU h_{in} of the `infile` includes the column `PHAS` and

$$\begin{aligned}
\text{apply\_cti} \quad &= \quad \text{yes and} \tag{548} \\
\text{doevtgrade} \quad &= \quad \text{yes and} \tag{549} \\
\text{GRADE} \quad &\neq \quad \text{NULL}, \tag{550}
\end{aligned}$$

    then

$$\text{PHA} \quad = \quad \sum_{j=0}^{8} c_{\mathrm{p}}[j]\text{PHAS\_ADJ}[j]. \tag{551}$$

    The values of $c_{\mathrm{p}}[j]$ are determined as follows.

    i. Each value of $c_{\mathrm{p}}[j]$ is initialized such that

$$c_{\mathrm{p}}[j] \quad = \quad 1. \tag{552}$$

ii. If
$$\texttt{PHAS\_ADJ}[j] \quad < \quad \text{split threshold,} \tag{553}$$
then
$$c_\mathrm{p}[j] \quad = \quad 0. \tag{554}$$

iii. If
$$\texttt{CORNERS} \quad = \quad -1, \tag{555}$$
then
$$c_\mathrm{p}[0] \quad = \quad 0 \text{ and} \tag{556}$$
$$c_\mathrm{p}[2] \quad = \quad 0 \text{ and} \tag{557}$$
$$c_\mathrm{p}[6] \quad = \quad 0 \text{ and} \tag{558}$$
$$c_\mathrm{p}[8] \quad = \quad 0. \tag{559}$$

iv. If
$$\texttt{CORNERS} \quad = \quad 0, \tag{560}$$
then there are no additional constraints on $c_\mathrm{p}[0]$, $c_\mathrm{p}[2]$, $c_\mathrm{p}[6]$, and $c_\mathrm{p}[8]$.

v. If
$$\texttt{CORNERS} \quad = \quad 1, \tag{561}$$
then

A. If
$$c_\mathrm{p}[1] \quad = \quad 0 \text{ and} \tag{562}$$
$$c_\mathrm{p}[3] \quad = \quad 0, \tag{563}$$
then
$$c_\mathrm{p}[0] \quad = \quad 0. \tag{564}$$

B. If
$$c_\mathrm{p}[1] \quad = \quad 0 \text{ and} \tag{565}$$
$$c_\mathrm{p}[5] \quad = \quad 0, \tag{566}$$
then
$$c_\mathrm{p}[2] \quad = \quad 0. \tag{567}$$

C. If
$$c_\mathrm{p}[3] \quad = \quad 0 \text{ and} \tag{568}$$
$$c_\mathrm{p}[7] \quad = \quad 0, \tag{569}$$
then
$$c_\mathrm{p}[6] \quad = \quad 0. \tag{570}$$

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D. If

$$c_{\mathrm{p}}[5] \quad = \quad 0 \text{ and} \tag{571}$$
$$c_{\mathrm{p}}[7] \quad = \quad 0, \tag{572}$$

then

$$c_{\mathrm{p}}[8] \quad = \quad 0. \tag{573}$$

vi. If

$$\texttt{CORNERS} \quad = \quad 2, \tag{574}$$

then
A. If

$$c_{\mathrm{p}}[1] \quad = \quad 0 \text{ or} \tag{575}$$
$$c_{\mathrm{p}}[3] \quad = \quad 0 \text{ or} \tag{576}$$
$$\texttt{GRADE} \quad \neq \quad 6, \tag{577}$$

then

$$c_{\mathrm{p}}[0] \quad = \quad 0. \tag{578}$$

B. If

$$c_{\mathrm{p}}[1] \quad = \quad 0 \text{ or} \tag{579}$$
$$c_{\mathrm{p}}[5] \quad = \quad 0 \text{ or} \tag{580}$$
$$\texttt{GRADE} \quad \neq \quad 6, \tag{581}$$

then

$$c_{\mathrm{p}}[2] \quad = \quad 0. \tag{582}$$

C. If

$$c_{\mathrm{p}}[3] \quad = \quad 0 \text{ or} \tag{583}$$
$$c_{\mathrm{p}}[7] \quad = \quad 0 \text{ or} \tag{584}$$
$$\texttt{GRADE} \quad \neq \quad 6, \tag{585}$$

then

$$c_{\mathrm{p}}[6] \quad = \quad 0. \tag{586}$$

D. If

$$c_{\mathrm{p}}[5] \quad = \quad 0 \text{ or} \tag{587}$$
$$c_{\mathrm{p}}[7] \quad = \quad 0 \text{ or} \tag{588}$$
$$\texttt{GRADE} \quad \neq \quad 6, \tag{589}$$

then

$$c_{\mathrm{p}}[8] \quad = \quad 0. \tag{590}$$

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

(b) If HDU h_{in} of the infile does not include the column PHAS or

$$\texttt{apply\_cti} \quad = \quad \text{no or} \tag{591}$$

$$\texttt{doevtgrade} \quad = \quad \text{no or} \tag{592}$$

$$\texttt{GRADE} \quad = \quad \text{NULL}, \tag{593}$$

then

$$\texttt{PHA} \quad = \quad \texttt{PHA\_RO}. \tag{594}$$

(c) If

$$\texttt{apply\_tgain} = \text{yes}, \tag{595}$$

then

$$\texttt{PHA} = \texttt{PHA} - \text{int}\left[\left(\frac{\texttt{TIME} - \texttt{EPOCH1}}{\texttt{EPOCH2} - \texttt{EPOCH1}}\right)(\delta_2 - \delta_1) + \delta_1 - \epsilon\right], \tag{596}$$

where

$$\text{int} \quad = \quad \text{the integer portion of (i.e. truncate or round down)}, \tag{597}$$

$$\texttt{TIME} \quad = \quad \text{the time of the event}, \tag{598}$$

$$\texttt{EPOCH1} \quad = \quad \text{a keyword in the tgainfile}, \tag{599}$$

$$\texttt{EPOCH2} \quad = \quad \text{a keyword in the tgainfile}, \tag{600}$$

$$\delta_1 \quad = \quad \left(\frac{\texttt{PHA} - \texttt{PHA}_m[r]}{\texttt{PHA}_{m+1}[r] - \texttt{PHA}_m[r]}\right)(\texttt{DELTPHA1}_{m+1}[r] - \texttt{DELTPHA1}_m[r]) + \tag{601}$$

$$\texttt{DELTPHA1}_m[r], \tag{602}$$

r is the row of the tgainfile where
  - $\texttt{CCD\_ID}[r] = \texttt{CCD\_ID}$,
  - $\texttt{CHIPX\_LO}[r] \leq \text{nint}(\texttt{CHIPX\_ADJ})$,
  - $\texttt{CHIPX\_HI}[r] \geq \text{nint}(\texttt{CHIPX\_ADJ})$,
  - $\texttt{CHIPY\_LO}[r] \leq \text{nint}(\texttt{CHIPY\_ADJ})$, and
  - $\texttt{CHIPY\_HI}[r] \geq \text{nint}(\texttt{CHIPY\_ADJ})$.

m is the element of row r where
  - $\texttt{PHA}_m[r] \leq \texttt{PHA}$ and
  - $\texttt{PHA}_{m+1}[r] > \texttt{PHA}$.
  - If $\texttt{PHA} < \texttt{PHA}_m[r]$ for $m = 0$, then $m = 0$.
  - If $\texttt{PHA} \geq \texttt{PHA}_m[r]$ for $m = M$ and M is the last element of $\texttt{PHA}[r]$,
    then $m = M - 1$.

The tgainfile includes a binary table with columns named
  $\texttt{CCD\_ID}, \texttt{CHIPX\_LO}, \texttt{CHIPX\_HI}, \texttt{CHIPY\_LO}, \texttt{CHIPY\_HI}, \texttt{PHA}, \texttt{DELTPHA1}$, and
  $\texttt{DELTPHA2}$. $\tag{603}$

$$\delta_2 \quad = \quad \left(\frac{\texttt{PHA} - \texttt{PHA}_m[r]}{\texttt{PHA}_{m+1}[r] - \texttt{PHA}_m[r]}\right)(\texttt{DELTPHA2}_{m+1}[r] - \texttt{DELTPHA2}_m[r]) + \tag{604}$$

$$\texttt{DELTPHA2}_m[r], \tag{605}$$

$$\epsilon \quad = \quad \text{is a uniform random deviate in the range } [0, 1), \tag{606}$$

$$\left\{ \text{ If } \texttt{rand\_pha} = \text{no, then } \epsilon = 0. \right. \tag{607}$$

(d) If

$$\texttt{PHA} \geq 32767, \tag{608}$$

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

23. CORN_PHA:

(a) If
$$DATAMODE_{in} = CC33\_GRADED, \tag{609}$$
then the value of CORN_PHA is read from the infile.

24. 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
$$CCD\_ID = CCD\_ID_{gain,i}, \tag{610}$$
$$CHIPX\_MIN_{gain,i} \leq \text{nint}(CHIPX\_ADJ) \leq CHIPX\_MAX_{gain,i}, \quad \text{and} \tag{611}$$
$$CHIPY\_MIN_{gain,i} \leq \text{nint}(CHIPY\_ADJ) \leq CHIPY\_MAX_{gain,i}, \tag{612}$$
   where CCD_ID_{gain}, $CHIPX\_MIN_{gain}$, $CHIPX\_MAX_{gain}$, $CHIPY\_MIN_{gain}$, and $CHIPY\_MAX_{gain}$ 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 PHA_{gain} is identified such that
$$PHA_{gain,i}[j] \leq (PHA + \Delta p) < PHA_{gain,i}[j+1], \tag{613}$$
   where PHA_{gain} is a vector column in the gainfile. If $PHA + \Delta p < PHA_{gain,i}[0]$, then $j = 0$. If $PHA_{gain,i}[NPOINTS - 2] \leq PHA + \Delta p$, then $j = NPOINTS - 2$, where NPOINTS is a column in the gainfile.

   iv. The ENERGY of an event is computed from the PHA of the event:
$$ENERGY = \left(\frac{PHA + \Delta p - PHA_{gain,i}[j]}{PHA_{gain,i}[j+1] - PHA_{gain,i}[j]} \right) (ENERGY_{gain,i}[j+1] - ENERGY_{gain,i}[j]) +$$
$$ENERGY_{gain,i}[j], \tag{614}$$
   where $ENERGY_{gain}$ is a vector column in the gainfile.

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

(b) If the parameter calculate_pi = yes and the parameter gainfile is specified and PHA $\leq$ 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.

25. PI:

(a) If
$$calculate\_pi = yes, \tag{615}$$
then

   i.
$$PI = \text{int} \left(\frac{ENERGY}{pi\_bin\_width} \right) + 1, \tag{616}$$
   where "int" indicates the integer portion of what is in parentheses (i.e. the value is truncated or rounded down).

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ii. If
$$PI < 1, \tag{617}$$

then $PI = 1$.

iii. If
$$PI > \texttt{pi\_num\_bins}, \tag{618}$$

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

(b) If
$$\texttt{calculate\_pi} = \text{no} \tag{619}$$

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

26. `pix_adj`:

(a) centroid:

i. If
$$\texttt{pix\_adj} = \text{centroid} \tag{620}$$

and

$$
\begin{aligned}
\texttt{DATAMODE}_{\text{in}} &= \text{CC33\_FAINT or} & (621)\\
\texttt{DATAMODE}_{\text{in}} &= \text{FAINT or} & (622)\\
\texttt{DATAMODE}_{\text{in}} &= \text{FAINT\_BIAS or} & (623)\\
\texttt{DATAMODE}_{\text{in}} &= \text{VFAINT,} & (624)
\end{aligned}
$$

then

$$
\begin{aligned}
\texttt{CHIPX\_ADJ} &= \texttt{CHIPX\_ADJ} - w'[0] + w'[2] - w'[3] + w'[5] - w'[6] + w'[8] \text{ and} & (625)\\
\texttt{CHIPY\_ADJ} &= \texttt{CHIPY\_ADJ} - w'[0] - w'[1] - w'[2] + w'[6] + w'[7] + w'[8], & (626)
\end{aligned}
$$

where
$$w'[j] = \frac{w[j]}{\sum_{j=0}^{8} w[j]}, \tag{627}$$

$$w[j] = \begin{cases} p[j] & \text{if the pixel is valid} \\ 0 & \text{if the pixel is invalid,} \end{cases} \tag{628}$$

$$p[j] = \begin{cases} \texttt{PHAS\_ADJ}[j] & \text{if } \texttt{apply\_cti} = \text{yes} \\ \texttt{PHAS}[j] & \text{if } \texttt{apply\_cti} = \text{no,} \end{cases} \tag{629}$$

and the pixel is invalid if

$$
\begin{aligned}
\beta[j] &= 0 \text{ or} & (630)\\
\texttt{STATUS}[0] &= 1 \text{ or} & (631)\\
\texttt{STATUS}[1] &= 1 \text{ or} & (632)\\
\texttt{STATUS}[2] &= 1 \text{ or} & (633)\\
\texttt{STATUS}[3] &= 1 \text{ or} & (634)\\
\texttt{STATUS}[4] &= 1 \text{ or} & (635)\\
\texttt{STATUS}[11] &= 1 \text{ or} & (636)\\
\texttt{STATUS}[13] &= 1 \text{ or} & (637)\\
\texttt{STATUS}[14] &= 1 \text{ or} & (638)\\
\texttt{STATUS}[15] &= 1 \text{ or} & (639)\\
\texttt{STATUS}[16] &= 1. & (640)
\end{aligned}
$$

ii. If

$$\text{pix\_adj} = \text{centroid and} \tag{641}$$
$$\text{DATAMODE}_{\text{in}} = \text{CC33\_FAINT,} \tag{642}$$

then

$$\text{TIME} = \text{TIME} + (w'[0] + w'[1] + w'[2] - w'[6] - w'[7] - w'[8]) \times \text{TIMEDEL}_{\text{in}}. \tag{643}$$

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

(b) edser:

i. If

$$\text{pix\_adj} = \text{edser} \tag{644}$$

and

$$\text{DATAMODE}_{\text{in}} = \text{CC33\_FAINT or} \tag{645}$$
$$\text{DATAMODE}_{\text{in}} = \text{CC33\_GRADED or} \tag{646}$$
$$\text{DATAMODE}_{\text{in}} = \text{FAINT or} \tag{647}$$
$$\text{DATAMODE}_{\text{in}} = \text{FAINT\_BIAS or} \tag{648}$$
$$\text{DATAMODE}_{\text{in}} = \text{GRADED or} \tag{649}$$
$$\text{DATAMODE}_{\text{in}} = \text{VFAINT,} \tag{650}$$

then
A. If

$$\text{ENERGY} \neq \text{NaN and} \tag{651}$$
$$\text{ENERGY} > 0, \tag{652}$$

then

$$\text{CHIPX\_ADJ} = \text{CHIPX\_ADJ} + \left(\frac{\text{ENERGY} - E[k]}{E[k+1] - E[k]} \right) (\Delta X[k+1] - \Delta X[k]) + \Delta X[k] \tag{653}$$

and

$$\text{CHIPY\_ADJ} = \text{CHIPY\_ADJ} + \left(\frac{\text{ENERGY} - E[k]}{E[k+1] - E[k]} \right) (\Delta Y[k+1] - \Delta Y[k]) + \Delta Y[k] \tag{654}$$

where $E[k]$ and $E[k+1]$, $\Delta X[k]$ and $\Delta X[k+1]$, and $\Delta Y[k]$ and $\Delta Y[k+1]$ are the k and $(k+1)^{th}$ elements of the vector columns ENERGY$_{\text{subpix}}$, CHIPX_OFFSET$_{\text{subpix}}$, and 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 FLTGRADE$_{\text{subpix}}$ = FLTGRADE. The values of k are the ones where

$$\text{ENERGY} \geq E[k] \text{ and} \tag{655}$$
$$\text{ENERGY} < E[k+1]. \tag{656}$$

Note that if

$$\text{ENERGY} \leq E[0], \tag{657}$$

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then $k = 0$. Similarly, if

$$\texttt{ENERGY} \ \geq \ E[\texttt{NPOINTS}_{\text{subpix}} - 2], \tag{658}$$

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

  B. If

$$\texttt{ENERGY} \ = \ \text{NaN or} \tag{659}$$
$$\texttt{ENERGY} \ \leq \ 0, \tag{660}$$

then the `CHIPX_ADJ` and `CHIPY_ADJ` coordinates are not modified.

ii. If

$$\texttt{pix\_adj} = \text{edser} \tag{661}$$

and

$$\texttt{DATAMODE}_{\text{in}} \ = \ \text{CC33\_FAINT or} \tag{662}$$
$$\texttt{DATAMODE}_{\text{in}} \ = \ \text{CC33\_GRADED,} \tag{663}$$

then

  A. If

$$\texttt{ENERGY} \ \neq \ \text{NaN and} \tag{664}$$
$$\texttt{ENERGY} \ > \ 0, \tag{665}$$

then

$$\texttt{TIME} \ = \ \texttt{TIME} - \left(\left(\frac{\texttt{ENERGY} - E[k]}{E[k+1] - E[k]} \right) (\Delta Y[k+1] - \Delta Y[k]) + \Delta Y[k] \right) \times \texttt{TIMEDEL}_{\text{in}} \tag{666}$$

  B. If

$$\texttt{ENERGY} \ = \ \text{NaN or} \tag{667}$$
$$\texttt{ENERGY} \ \leq \ 0, \tag{668}$$

then the `TIME` is not modified.

(c) none:

  If

$$\texttt{pix\_adj} = \text{none,} \tag{669}$$

then

$$\texttt{CHIPX\_ADJ} \ = \ \texttt{CHIPX\_ADJ} \ \text{and} \tag{670}$$
$$\texttt{CHIPY\_ADJ} \ = \ \texttt{CHIPY\_ADJ} \ \text{and} \tag{671}$$
$$\texttt{TIME} \ = \ \texttt{TIME.} \tag{672}$$

No sub-pixel adjustments are applied to the values of `CHIPX_ADJ` and `CHIPY_ADJ` (for timed exposure mode) or `CHIPX_ADJ` and `TIME` (for continuous-clocking mode).

(d) randomize:

  i. If

$$\texttt{pix\_adj} = \text{randomize,} \tag{673}$$

then

$$\texttt{CHIPX\_ADJ} \ = \ \texttt{CHIPX\_ADJ} + \epsilon_x \ \text{and} \tag{674}$$
$$\texttt{CHIPY\_ADJ} \ = \ \texttt{CHIPY\_ADJ} + \epsilon_y, \tag{675}$$

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

ii. If

$$\text{DATAMODE}_{\text{in}} \quad = \quad \text{CC33\_FAINT or} \tag{676}$$

$$\text{DATAMODE}_{\text{in}} \quad = \quad \text{CC33\_GRADED,} \tag{677}$$

then

$$\text{TIME} \quad = \quad \text{TIME} - \epsilon_y \times \text{TIMEDEL}_{\text{in}}. \tag{678}$$

(e) If

$$\text{CHIPX\_ADJ} \quad < \quad 0.5, \tag{679}$$

then

$$\text{CHIPX\_ADJ} \quad = \quad 1. \tag{680}$$

(f) If

$$\text{CHIPX\_ADJ} \quad \geq \quad 1024.5, \tag{681}$$

then

$$\text{CHIPX\_ADJ} \quad = \quad 1024. \tag{682}$$

(g) If

$$\text{CHIPY\_ADJ} \quad < \quad 0.5, \tag{683}$$

then

$$\text{CHIPY\_ADJ} \quad = \quad 1. \tag{684}$$

(h) If

$$\text{CHIPY\_ADJ} \quad \geq \quad 1024.5, \tag{685}$$

then

$$\text{CHIPY\_ADJ} \quad = \quad 1024. \tag{686}$$

27. X and Y:

(a) If

$$\text{stop} \quad = \quad \text{sky,} \tag{687}$$

then

i. If

$$\text{DATAMODE}_{\text{in}} \quad = \quad \text{FAINT or} \tag{688}$$

$$\text{DATAMODE}_{\text{in}} \quad = \quad \text{FAINT\_BIAS or} \tag{689}$$

$$\text{DATAMODE}_{\text{in}} \quad = \quad \text{GRADED or} \tag{690}$$

$$\text{DATAMODE}_{\text{in}} \quad = \quad \text{VFAINT,} \tag{691}$$

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

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ii. If

$$\text{DATAMODE}_{\text{in}} \quad = \quad \text{CC33\_FAINT or} \tag{692}$$
$$\text{DATAMODE}_{\text{in}} \quad = \quad \text{CC33\_GRADED,} \tag{693}$$

then the values of X and Y are computed using the real-valued coordinates CHIPX_ADJ and CHIPY_TARG$_{\text{eff}}$ and the orientation of the telescope (i.e. RA, DEC, and ROLL) at the time TIME.

iii. If

$$\text{acaofffile} \quad \neq \quad \text{none} \tag{694}$$

and

$$\text{CONTENT}_{\text{in}} \quad \neq \quad \text{TGEVT1} \tag{695}$$

and

$$\text{TIME} \quad < \quad \text{TIME}_{\text{min}} \text{ or} \tag{696}$$
$$\text{TIME} \quad \geq \quad \text{TIME}_{\text{max}}, \tag{697}$$

then

$$\text{X} \quad = \quad \text{NaN and} \tag{698}$$
$$\text{Y} \quad = \quad \text{NaN.} \tag{699}$$

iv. If

$$\text{acaofffile} \quad \neq \quad \text{none} \tag{700}$$

and

$$\text{CONTENT}_{\text{in}} \quad = \quad \text{TGEVT1 and} \tag{701}$$
$$\text{CHIPY\_TG} \quad = \quad \text{NaN,} \tag{702}$$

then

$$\text{X} \quad = \quad \text{NaN and} \tag{703}$$
$$\text{Y} \quad = \quad \text{NaN.} \tag{704}$$

28. SKY_1D:

(a) If

$$\text{stop} \quad = \quad \text{sky} \tag{705}$$

and

$$\text{DATAMODE}_{\text{in}} \quad = \quad \text{CC33\_FAINT or} \tag{706}$$
$$\text{DATAMODE}_{\text{in}} \quad = \quad \text{CC33\_GRADED,} \tag{707}$$

then

i. The value of SKY_1D is computed using the real-valued coordinates CHIPX_ADJ and CHIPY_TARG$_{\text{eff}}$ and the orientation of the telescope (i.e. RA, DEC, and ROLL) at the time TIME.

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ii. If

$$\text{acaofffile} \neq \text{none} \tag{708}$$

and

$$\text{CONTENT}_{\text{in}} \neq \text{TGEVT1} \tag{709}$$

and

$$\text{TIME} < \text{TIME}_{\text{min}} \text{ or} \tag{710}$$
$$\text{TIME} \geq \text{TIME}_{\text{max}}, \tag{711}$$

then

$$\text{SKY\_1D} = \text{NaN}. \tag{712}$$

iii. If

$$\text{acaofffile} \neq \text{none} \tag{713}$$

and

$$\text{CONTENT}_{\text{in}} = \text{TGEVT1 and} \tag{714}$$
$$\text{CHIPY\_TG} = \text{NaN}, \tag{715}$$

then

$$\text{SKY\_1D} = \text{NaN}. \tag{716}$$

29. DETX and DETY:

(a) If

$$\text{stop} = \text{det or} \tag{717}$$
$$\text{stop} = \text{tan or} \tag{718}$$
$$\text{stop} = \text{sky}, \tag{719}$$

then

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

ii. If

$$\text{acaofffile} \neq \text{none} \tag{720}$$

and

$$\text{CONTENT}_{\text{in}} \neq \text{TGEVT1} \tag{721}$$

and

$$\text{TIME} < \text{TIME}_{\text{min}} \text{ or} \tag{722}$$
$$\text{TIME} \geq \text{TIME}_{\text{max}}, \tag{723}$$

then

$$\text{DETX} = \text{NaN and} \tag{724}$$
$$\text{DETY} = \text{NaN}. \tag{725}$$

iii. If

$$\text{acaofffile} \neq \text{none} \tag{726}$$

and

$$\begin{aligned}
\text{CONTENT}_{\text{in}} &= \text{TGEVT1 and} \tag{727} \\
\text{CHIPY\_TG} &= \text{NaN,} \tag{728}
\end{aligned}$$

then

$$\begin{aligned}
\text{DETX} &= \text{NaN and} \tag{729} \\
\text{DETY} &= \text{NaN.} \tag{730}
\end{aligned}$$

30. TDETX and TDETY:

   (a) If

$$\begin{aligned}
\text{stop} &= \text{tdet or} \tag{731} \\
\text{stop} &= \text{det or} \tag{732} \\
\text{stop} &= \text{tan or} \tag{733} \\
\text{stop} &= \text{sky} \tag{734}
\end{aligned}$$

   then

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

   ii. If

$$\text{acaofffile} \neq \text{none} \tag{735}$$

   and

$$\begin{aligned}
\text{DATAMODE}_{\text{in}} &= \text{CC33\_FAINT or} \tag{736} \\
\text{DATAMODE}_{\text{in}} &= \text{CC33\_GRADED} \tag{737}
\end{aligned}$$

   and

$$\text{CONTENT}_{\text{in}} \neq \text{TGEVT1} \tag{738}$$

   and

$$\begin{aligned}
\text{TIME} &< \text{TIME}_{\text{min}} \text{ or} \tag{739} \\
\text{TIME} &\geq \text{TIME}_{\text{max}}, \tag{740}
\end{aligned}$$

   then

$$\begin{aligned}
\text{TDETX} &= \text{NULL and} \tag{741} \\
\text{TDETY} &= \text{NULL.} \tag{742}
\end{aligned}$$

   iii. If

$$\text{acaofffile} \neq \text{none} \tag{743}$$

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and

$$\text{DATAMODE}_{\text{in}} = \text{CC33\_FAINT or} \tag{744}$$
$$\text{DATAMODE}_{\text{in}} = \text{CC33\_GRADED} \tag{745}$$

and

$$\text{CONTENT}_{\text{in}} = \text{TGEVT1 and} \tag{746}$$
$$\text{CHIPY\_TG} = \text{NaN,} \tag{747}$$

then

$$\text{TDETX} = \text{NULL and} \tag{748}$$
$$\text{TDETY} = \text{NULL.} \tag{749}$$

1.5.4 Write `outfile`

1. Unexpected `CHIPX` values:
   If the counter associated with equations 169 and 170 is greater than zero, then `acis_process_events` produces a warning message that includes the number of events that have unexpected `CHIPX` values.

2. Unexpected `CHIPY` values:
   If the counter associated with equations 195 and 196 is greater than zero, then `acis_process_events` produces a warning message that includes the number of events that have unexpected `CHIPY` values.

3. `PIX_ADJ`:

   (a) If

   $$\text{pix\_adj} = \text{centroid,} \tag{750}$$

   then

   $$\text{PIX\_ADJ} = \text{CENTROID.} \tag{751}$$

   (b) If

   $$\text{pix\_adj} = \text{edser,} \tag{752}$$

   then

   $$\text{PIX\_ADJ} = \text{EDSER.} \tag{753}$$

   (c) If

   $$\text{pix\_adj} = \text{none,} \tag{754}$$

   then

   $$\text{PIX\_ADJ} = \text{NONE.} \tag{755}$$

   (d) If

   $$\text{pix\_adj} = \text{randomize,} \tag{756}$$

   then

   $$\text{PIX\_ADJ} = \text{RANDOMIZE.} \tag{757}$$

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4. `RAND_SKY`:

   (a) If

   $$\texttt{pix\_adj} \quad = \quad \text{centroid}, \tag{758}$$

   then

   $$\texttt{RAND\_SKY} \quad = \quad 0.0. \tag{759}$$

   (b) If

   $$\texttt{pix\_adj} \quad = \quad \text{edser}, \tag{760}$$

   then

   $$\texttt{RAND\_SKY} \quad = \quad 0.0. \tag{761}$$

   (c) If

   $$\texttt{pix\_adj} \quad = \quad \text{none}, \tag{762}$$

   then

   $$\texttt{RAND\_SKY} \quad = \quad 0.0. \tag{763}$$

   (d) If

   $$\texttt{pix\_adj} \quad = \quad \text{randomize}, \tag{764}$$

   then

   $$\texttt{RAND\_SKY} \quad = \quad 0.5. \tag{765}$$

5. `TIME_ADJ`:

   (a) Timed-exposure mode:
       If

   $$\texttt{DATAMODE}_{\text{in}} \quad = \quad \text{FAINT or} \tag{766}$$
   $$\texttt{DATAMODE}_{\text{in}} \quad = \quad \text{FAINT\_BIAS or} \tag{767}$$
   $$\texttt{DATAMODE}_{\text{in}} \quad = \quad \text{GRADED or} \tag{768}$$
   $$\texttt{DATAMODE}_{\text{in}} \quad = \quad \text{VFAINT}, \tag{769}$$

   then

   $$\texttt{TIME\_ADJ} \quad = \quad \text{NONE}. \tag{770}$$

   (b) Continuous-clocking mode:
       i. Set

   $$\texttt{TIME\_ADJ} \quad = \quad \text{MIDCHIP}. \tag{771}$$

ii. If

$$\text{OBS\_MODE}_{\text{in}} \quad = \quad \text{pointing and} \tag{772}$$
$$\texttt{acaofffile} \quad \neq \quad \text{none} \tag{773}$$

then

$$\text{TIME\_ADJ} \quad = \quad \text{TARGET.} \tag{774}$$

iii. If

$$\text{OBS\_MODE}_{\text{in}} \quad = \quad \text{pointing and} \tag{775}$$
$$\text{CONTENT}_{\text{in}} \quad = \quad \text{TGEVT1,} \tag{776}$$

then

$$\text{TIME\_ADJ} \quad = \quad \text{GRATING.} \tag{777}$$

2 TBD

- Add the graded mode cti adjustment.

- Include all timed exposure mode processing.

- Should CONTENTs other than EVT0, EVT1, TGEVT1, and EVT2 be included?

- Should CONTENT = EVT2 be dropped?

- Should DATAMODEs other than CC33_FAINT, CC33_GRADED, FAINT, FAINT_BIAS, GRADED, and VFAINT be included?

- Are the β in PHA_RO the same as the β in PHA?

- Should something be done about SKY_1D?