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

MEMORANDUM

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To:	Martin Elvis, SDS Group Leader
From:	Glenn Allen, SDS
Subject:	Computation of the Coordinates X, Y, and SKY_1D and the Times of Arrival for Continuous-Clocking Event Data
Revision:	4.5
URL:	http://space.mit.edu/CXC/docs/docs.html#toa
File:	/nfs/cxc/h2/gea/sds/docs/memos/memo_acis_cc_calc_toa_4.5.tex

The event times in ACIS Level 0 continuous-clocking (CC) event-data files are associated with the times events are read, not the times of arrival of the particles that deposit charge in the detector. Therefore, analyses of the event times to search for evidence of pulsations may be complicated by the time it takes to move change from the nominal aim point to the location of the read-out electronics, the motion of the source on the detector as the telescope dither, the motion of the SIM relative to the telescope, and the use of the gratings. Analyses of the sky coordinates of continuous-clocking mode event data can be difficult if the effects of dither are not removed and if the source events are arbitrarily assumed to have CHIPY values of 512. To make it easier for users to analyze continuous-clocking mode data, acis_process_events (1) computes the times of arrival of events for a given source location, (2) removes the effects of dither and the SIM motion from the coordinates X and Y, (3) has the one-dimension image of the coordinates X and Y pass through the location associated with RA_TARG and DEC_TARG, and (4) computes the coordinate SKY_1D (described below).

1 acis_process_events

The tool acis_process_events can create columns called TIME_RO and SKY_1D for continuous-clocking event data. The contents of the column TIME_RO correspond to the times events are read (i.e. are the same as the values of TIME in Level 0 event files). The contents of the column TIME are the estimated times of arrival of events assuming the events are from a source whose celestial coordinates are given by RA_TARG and DEC_TARG. Since it is not possible to discriminate between events associated with the source and background events, all events are handled in the same manner. The coordinate SKY_1D represents the distance of an event from the location of the source (in arcseconds) in the direction perpendicular to the readout direction.

Additional Parameters

1. calc_cc_times,b,h,“yes”,,,“Estimate the times of arrival for a CC-mode observation?”

Input

1. An ACIS continuous-clocking event-data file that includes the columns TIME, CCD_ID, and CHIPX (or CCDX).
2. The associated aspect solution file.
3. The right ascension (RA_TARG) and declination (DEC_TARG) of the observed source in J2000.0 coordinates.

Output

1. An ACIS event-data file that includes the columns TIME_RO (if specified as part of the parameter eventdef) and SKY_1D.
2. If the value of the parameter calc_cc_times is "yes," the header of the output file should contain the keyword HDUCLAS3 = 'CC_CORRECTED' to confirm that the values in the column TIME are the estimated times of arrival instead of the read-out times. Otherwise, this keyword is excluded from the output file.

Processing

1. Check for input errors: Verify that the input event files are continuous-clocking mode data files and contain columns named TIME (or TIME_RO), CCD_ID, and CCDX (or CHIPX). Verify that the keywords RA_NOM, DEC_NOM, RA_TARG, DEC_TARG and TIMEDEL exist. Verify that the input aspect solution file(s) exist.
2. Read the values of the keywords RA_NOM, DEC_NOM, RA_TARG, DEC_TARG, TIMEDEL and HDUCLAS3 (if it exists) from the header in the event-data file.
3. For event i, read the values of TIME_i, $\mathrm{TIME\_RO}_i$ (if it exists), $\mathrm{CCD\_ID}_i$, CCDX_i (or CHIPX_i), and CCDY_i (or CHIPY_i). If the columns CHIPX and CHIPY do not exist, compute the values of CHIPX_i and CHIPY_i.
4. If the value of the parameter calc_cc_times is "yes," the keyword HDUCLAS3 is "CC_CORRECTED" and the column TIME_RO does not exist in the input file, set $\mathrm{TIME\_RO}_i = \mathrm{TIME}_i$. See table 1 for a list of how to handle the other possible cases.
5. If the parameter calc_cc_times is "yes" or the parameter stop is "sky," estimate the time of arrival t_i of event i. This estimate is only used to compute the value $\mathrm{CHIPY}_{\mathrm{TARG}_i}$ (see step 7). It is not used to compute the time of arrival TIME_i. If event i is the first event in the input event-data file,

   $$t_1 = \mathrm{TIME\_RO}_1 - (512 + 1028) \times \mathrm{TIMEDEL}, \tag{1}$$

   where $\mathrm{TIME\_RO}_1$ is the read-out time of the first event. For all subsequent events,

   $$t_i = \mathrm{TIME\_RO}_i - (\mathrm{CHIPY}_{\mathrm{TARG}_{i-1}} + 1028) \times \mathrm{TIMEDEL}, \tag{2}$$

   where $\mathrm{TIME\_RO}_i$ is the read-out time of the i^{th} event and $\mathrm{CHIPY}_{\mathrm{TARG}_{i-1}}$ is the CHIPY coordinate associated with RA_TARG and DEC_TARG at t_{i-1} (see step 7).
6. If the parameter calc_cc_times is "yes" or the parameter stop is "sky," find the appropriate values of RA_i, DEC_i, and ROLL_i associated with t_i in the aspect solution file(s).
7. If the parameter calc_cc_times is "yes" or the parameter stop is "sky," use the values of RA_i, DEC_i, ROLL_i RA_TARG, DEC_TARG, RA_NOM and DEC_NOM to compute the value of $\mathrm{CHIPY}_{\mathrm{TARG}_i}$, the CHIPY coordinate associated with RA_TARG and DEC_TARG at time t_i. The value of $\mathrm{CHIPY}_{\mathrm{TARG}_i}$ is used to compute the values of TIME_i,X_i, Y_i and $\mathrm{SKY\_1D}_i$.

Table 1. Possible cases

	infile			outfile		
Parameter calc_cc_times	Keyword HDUCLAS3	Column TIME	Column TIME_RO	Keyword HDUCLAS3	Column TIME	Column TIME_RO[*]
yes[†]	Not CC_CORRECTED	Exists	Doesn't exist	CC_CORRECTED	Input TIMEs + Adjustments	Input TIMEs
yes[†]	Not CC_CORRECTED	Exists	Exists	CC_CORRECTED	Input TIME_ROs + Adjustments	Input TIME_ROs
yes[†]	CC_CORRECTED	Exists	Doesn't exist	CC_CORRECTED	Input TIMEs	Zeroes
yes[†]	CC_CORRECTED	Exists	Exists	CC_CORRECTED	Input TIME_ROs + Adjustments	Input TIME_ROs
no	Not CC_CORRECTED	Exists	Doesn't exist	Doesn't exist	Input TIMEs	Zeroes
no	Not CC_CORRECTED	Exists	Exists	Doesn't exist	Input TIMEs	Input TIME_ROs
no	CC_CORRECTED	Exists	Doesn't exist	CC_CORRECTED	Input TIMEs	Zeroes
no	CC_CORRECTED	Exists	Exists	CC_CORRECTED	Input TIMEs	Input TIME_ROs

[†] If the parameter acaofffile=NONE or the file(s) specified by acaofffile do not exist, then produce a warning message and reset the parameter calc_cc_times from "yes" to "no."

[*] If the column is specified as part of the output using the parameter "eventdef."

8. If the parameter calc_cc_times is "yes," compute the time of arrival of event i:

$$\mathrm{TIME}_i = \mathrm{TIME\_RO}_i - (\mathrm{CHIPY}_{\mathrm{TARG}_i} + 1028) \times \mathrm{TIMEDEL}.$$

   Note that the contents of the column TIME contain the estimated times of arrival instead of the read-out times. The column TIME_RO contains the read-out times.

9. If the parameter stop is "sky," compute the values of X_i and Y_i using the values of TIME_i, $\mathrm{CCD\_ID}_i$, CHIPX_i and $\mathrm{CHIPY}_{\mathrm{TARG}_i}$ (not CHIPY_i). The resulting sky coordinates are free of the effects of dither and the motion of the SIM. The sky image is a thin line (only a few pixels wide) that passes through RA_TARG and DEC_TARG.

10. If the parameter stop is "sky," compute the value of SKY_1D.

11. Repeat steps 3 through 10 for each event in the input event-data file.

12. Write the results to the output event-data file. Include the column TIME_RO and the keyword HDUCLAS3, if appropriate (see table 1).

2 Acknowledgements

The development of the algorithms to compute the sky positions and times of arrival of the events relied heavily on the assistance of Ian Evans, Peter Ford, Kenny Glotfelty, David Huenemoerder, Jonathan McDowell, Herman Marshall, Joe Masters, Arnold Rots, Divas Sanwal, and Allyn Tennant. Jonathan McDowell produced much of the code to compute the sky positions of the events and Herman Marshall and Allyn Tennant provided a great deal of help with the algorithm to compute the times of arrival.