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

**MEMORANDUM**
September 9, 2002

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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:** | 4.3b |
| **URL:** | http://space.mit.edu/CXC/docs/docs.html#toa |
| **File:** | /nfs/cxc/h2/gea/sds/docs/memos/memo_acis_cc_calc_toa_4.3b.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 read out an event, 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 should be modified (1) to compute the times of arrival of events for a given source location, (2) to remove the effects of dither and the SIM motion from the coordinates X and Y, (3) to have an image of the coordinates X and Y pass throught the location associated with RA_TARG and DEC_TARG, and (4) to compute the coordinate SKY_1D(described below).

# 1 acis_process_events

The tool acis_process_events should 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 direcion.

## Additional Parameters

1. calc_cc_times,b,h,"no",,,"Estimate the times of arrival for a CC-mode observation?"

## Input

1. An ACIS continuous-clocking event-data file that includes the columns TIME (or TIME_RO), 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 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 keywords should be 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_TARG and DEC_TARG exist. Verify that the input aspect solution file(s) exist.

2. Read the values of the keywords RA_TARG, DEC_TARG, RA_NOM, DEC_NOM, and TIMEDEL from the header in the event data file.

3. Read the values of RA, DEC, and ROLL from the input aspect solution file(s).

4. Read the values of TIME, TIME_RO (if it exists), CCD_ID, CCDX (or CHIPX), and CCDY (or CHIPY) for event $i$. If the columns CHIPX and CHIPY do not exist, compute the values of these coordinates.

5. If the value of the parameter calc_cc_times is "yes" and the column TIME_RO does not exist in the input file, copy the value of TIME for event $i$ to the column TIME_RO. If the column TIME_RO exists, do not copy the value of TIME to TIME_RO (even if calc_cc_times = "yes"). If calc_cc_times = "no" and the column TIME_RO exists, copy the value of TIME_RO for event $i$ to the column TIME.

6. Estimate the time of arrival of the event. This estimate is to be used only to compute the values of $\mathrm{CCD\_ID}_{\mathrm{TARG}_i}$ and $\mathrm{CHIPY}_{\mathrm{TARG}_i}$ associated with the source location. (See step **??**.) The time of arrival that is written to the output file is the time of arrival computed in step 10 below. For the first event in the input event data file, the estimated time of arrival

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

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

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

   where $\mathrm{TIME\_RO}_i$ is the read-out time of the $i^{\mathrm{th}}$ event and $\mathrm{CHIPY}_{\mathrm{TARG}_{i-1}}$ is the CHIPY coordinate associated with the source location (RA_TARG, DEC_TARG) at the time of arrival of the $i-1^{\mathrm{th}}$ event. The value of $\mathrm{CHIPY}_{\mathrm{TARG}_{i-1}}$ is the value computed in step **??**.

7. Compute the $\mathrm{CCD\_ID}_{\mathrm{TARG}_i}$ and $\mathrm{CHIPY}_{\mathrm{TARG}_i}$ location of the source (RA_TARG, DEC_TARG) on the ACIS detector using the aspect solution at the estimated time of arrival of event $i$ ($t_i$). This computation of the value of $\mathrm{CHIPY}_{\mathrm{TARG}_i}$ for an event should include the effects of dither and the SIM motion. The coordinate $\mathrm{CHIPY}_{\mathrm{TARG}_i}$ is used to compute the values of the coordinates X, Y, and SKY_1D and to estimate the time of arrival of the $i+1^{\mathrm{th}}$ event. (See step **??**.)

8. Use the values of $\mathrm{CCD\_ID_{TARG}}_i$ and $\mathrm{CHIPY_{TARG}}_i$ to determine the value of $\mathrm{CHIPY}_i$.

   If the value of CCD_ID for event $i$ ($\mathrm{CCD\_ID}_i$) is in the range 4–9, if $4 \leq \mathrm{CCD\_ID_{TARG}}_i \leq 9$, and if $2 \leq \mathrm{CHIPY_{TARG}}_i \leq 1023$, then

$$\mathrm{CHIPY}_i = \mathrm{CHIPY_{TARG}}_i. \tag{3}$$

   If $4 \leq \mathrm{CCD\_ID} \leq 9$ and either $\mathrm{CCD\_ID_{TARG}}_i \leq 3$ or $\mathrm{CHIPY_{TARG}}_i$ is not in the range 2–1023 (or both), then

$$\begin{aligned}\mathrm{CHIPY}_i \quad = SIM??? \quad & 512 - \\ & a \sin(\mathrm{ROLL}_i)(\mathrm{RA}_i - \mathrm{RA\_NOM}) \cos(\mathrm{DEC\_NOM}) + \\ & a \cos(\mathrm{ROLL}_i)(\mathrm{DEC}_i - \mathrm{DEC\_NOM}),\end{aligned} \tag{4}$$

   where $\mathrm{RA}_i$, $\mathrm{DEC}_i$, and $\mathrm{ROLL}_i$ are the values of RA, DEC, and ROLL that have been interpolated to the time $t_i$, $a \approx 4.192 \times 10^6$ pixels rad$^{-1}$ (i.e. $360/2\pi$ deg rad$^{-1}$ $\times$ 3600 arcsec deg$^{-1}$$\div$ FP-1.1 arcsec pixel$^{-1}$) is the inverse of the ACIS plate scale, and FP-1.1 is an entry in the CALDB file "sky."

9. If the value of the parameter calc_cc_times is "yes," perform steps ??–13. Otherwise, do not compute the times of arrival of the events, do not create the column named TIME_RO, and copy the input event TIMEs to the output column TIME.

10. Compute the time of arrival of event $i$:

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

    Note that the contents of the column TIME are modified to contain the estimated times of arrival instead of the read-out times.

11. Compute the X and Y coordinates of event $i$ using $\mathrm{CCD\_ID}_i$, the coordinates $\mathrm{CHIPX}_i$ and $\mathrm{CHIPY_{TARG}}_i$, the time $\mathrm{TIME}_i$ (as computed in step 10), and the aspect solution. The resulting coordinates are free of the effects of dither and the motion of the SIM. The sky image is a thin (one or a few pixels wide) line that passes through the source location (RA_TARG, DEC_TARG). Jonathan McDowell has already developed the code to perform this computation.

12. Repeat steps ??–11 for each event in the input event data file.

13. Copy the contents of the input event file to the output event file. Add the column TIME_RO to the output file. Add appropriate HISTORY keywords to the output file if it does not exist in the input file.

## 2 Related Issues

1. Ensure that the GTI boundaries are computed using the correct set of times.

2. Create an ARD that contains the number 1028.

3. Modify the parameter eventdef.

4. Modify tg_resolve_events to compute the time of arrival offset for dispersed events.

## 3 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.