attcalc

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Abstract

The task **attcalc** calculates linearized sky coordinates (i.e. a tangential projection on the sky) on an event-by-event basis, and stores these new coordinates in the input event list in columns `X` and `Y`, as offsets from a particular reference point.

1 Instruments/Modes

Instrument	Mode
EPIC MOS	IMAGING
EPIC MOS	TIMING
EPIC PN	IMAGING
EPIC PN	TIMING
EPIC PN	BURST

2 Use

pipeline processing	yes
interactive analysis	yes

3 Description

This task operates on event data in an event list. It computes celestial (tangentially projected) coordinates on an event-by-event basis and stores them in pre-existing empty columns `X` and `Y` (if these columns do not exist they will be created within **attcalc**).

Each calculated integer X/Y pixel position is the result of a spacecraft (S/C) aspect-corrected projection of an event's position on the detector onto a plane tangent to the celestial sphere. Thus, the task takes into account the facts that the pointing and position angle of the S/C can vary during the observation, as can in fact the boresight offsets of the individual instruments. The entire set of X/Y pixels can be thought of as representing an image of the observed region of the sky during the entire exposure.

The computed sky pixels, X and Y, shall be 'fixed' to a reference point whose equatorial coordinates (R.A. & Dec.) will be stored as standard World-Coordinate-System parameters. (Note: it should be

possible for FITS readers such as "kview", "ds9", "Ximage", "saotng" or the FTOOL "xy2sky" to compute the actual R.A./Dec. values of each individual photon.)

The reference point is user-selectable from the following alternatives, chosen via the parameter `refpointlabel`: it is taken either from the current nominal pointing direction of the S/C (`refpointlabel`=nom), from the pointing direction of the celestial object in question (`refpointlabel`=obj), from the mean pointing direction of the S/C during the observation (`refpointlabel`=pnt), or from any fixed point in the sky given as a user-supplied R.A./Dec. coordinate pair (`refpointlabel`=user). In the first two cases, the celestial coordinates of the reference point are taken respectively as the values of the `RA_NOM`,`DEC_NOM` or `RA_OBJ`,`DEC_OBJ` values in the input event file header. `RA_NOM` and `DEC_NOM` are the boresight RA/Dec values of the prime instrument (i.e. the proposed pointing), while `RA_OBJ` and `DEC_OBJ` are the coordinates of the proposed target. These values are written into the event file header by **epframes** or **emframes**. In the third case the mean or median (chosen using the parameter `withmedianpnt`) pointing direction of the spacecraft over the entire observation is used. This is actually calculated by the task **atthkgen** (which must be run earlier in the task chain), and placed by **attcalc** in the event file header as attributes `RA_PNT` and `DEC_PNT` (along with `PA_PNT`). An attribute `AVRG_PNT` is also written indicating whether the mean or median PNT values have been written. The parameter `atthkset` is used to give the name of the **atthkgen** output file. If the **atthkgen** output (default name `atthk.dat`) does not exist, a warning message is given, no PNT attributes are propagated to the event file, and, if `refpointlabel`=pnt is chosen, the `RA_NOM`, `DEC_NOM` values are used instead. A boolean parameter `withatthkset` exists to determine whether the task should access the atthkgen output file or not. In the fourth case, the coordinates of an arbitrary reference point have to be supplied by the user via parameters `nominalra` and `nominaldec`.

A string is input to the parameter `attitudelabel`, determining from which source the attitude data should be obtained. Possible values are: "ahf" (data are to be read from the attitude history file), "om" (data are to be read from OM tracking history file on the ODF) and "fixed" (no data from the ODF shall be used but the S/C's attitude is assumed to be fixed during the observation). Although the OM attitude information may be more accurate, it will not be present throughout part of the observation, and as such, the default source for the attitude data should be "ahf". If "fixed" is chosen, then the attitude information has to be specified via the parameters `fixedra`, `fixeddec` and `fixedposangle`.

The attitude information (obtained from the user, or from the ODF via an OAL call [i.e. not from the atthkgen output file]) is transformed from spherical to parallel or TAN (gnomonic) coordinates (see Greisen E.W., Calabretta M., 'Representation of celestial coordinates in FITS' 1995, adass, 4, 233). The boresight offset for the particular instrument in question is then accessed (from the Current Calibration File), and applied to the transformed attitude information. The task takes into account the fact that the pointing and the position angle of the S/C (in the ahf/om cases), and the boresight corrections of the individual detectors can vary during the observation. In cases where the OAL call gives back 'invalid pointing data', then the X/Y position of the events in question are set to NULL. The value 'INDEF' appears in the X/Y columns for these events.

This boresight-corrected attitude information can then be used to correct each events `DETX` and `DETY` into the sky co-ordinates `X` and `Y`. Note that the calculation of the boresight-corrected attitude information need only be done for each *frame*, not for each event. Though the input event file will have many events (perhaps millions), there will only be a few thousand frames, where new boresight-corrected attitude information need be calculated.

The sky coordinates, `X` and `Y` are north-oriented, i.e. the central 'line' of increasing Y-coordinate (and constant X-coordinate) points towards the celestial north pole ($+Y$ axis corresponds to increasing values of declination, $+X$ axis corresponds to decreasing values of right ascension).

If a specified event list has already been processed with the **attcalc** task, the columns `X` and `Y` shall be re-calculated and a corresponding informative message shall be reported.

In TIMING and BURST modes, attcalc works in exactly the same way: The attitude information is used,

as in IMAGING mode, to correct, via the same transformations, each events `DETX` and `DETY` into the sky co-ordinates `X` and `Y`.

4 Parameters

This section documents the parameters recognized by this task (if any).

Parameter	Mand	Type	Default	Constraints
eventset	yes	string		
input events set				
attitudelabel	no	string	ahf	ahf/fixed/om
source of attitude data				
refpointlabel	no	string	pnt	nom/obj/pnt/user
source of celestial coordinates of central reference point				
fixedra	no	real	0.0	0−360
Value specifying RA of S/C's attitude in the equatorial, earth-centred reference frame (if `attitudelabel`=fixed)				
fixeddec	no	real	0.0	-90−+90
Values specifying Dec of S/C's attitude in the equatorial, earth-centred reference frame (if `attitudelabel`=fixed)				
fixedposangle	no	real	0.0	-180−+360
Values specifying position angle of S/C's attitude in the equatorial, earth-centred reference frame (if `attitudelabel`=fixed) (see comments)				
nominalra	no	real	0.0	0−360
celestial RA coordinate of central reference point (if `refpointlabel`=user)				
nominaldec	no	real	0.0	-90−+90
celestial Dec coordinate of central reference point (if `refpointlabel`=user)				
imagesize	no	real	0.36	
half-size of final image (in degrees) (see comments)				
withatthkset	no	logical	Y	Y/N
Use **atthkgen** output file				
atthkset	no	string	atthk.dat	
atthkgen output file				
withmedianpnt	no	logical	Y	Y/N
Get median PNT values from **atthkgen** file (otherwise mean)?				

5 Errors

This section documents warnings and errors generated by this task (if any). Note that warnings and errors can also be generated in the SAS infrastructure libraries, in which case they would not be documented here. Refer to the index of all errors and warnings available in the HTML version of the SAS documentation.

badInfile *(error)*
Input file incorrect - either no EVENTS extension, or no `DETX`, `DETY` or `TIME` column

badInstrument *(error)*
Instrument not supported

badDatamode *(error)*
Data mode not supported

badPntValues *(warning)*
`PNT` values in **atthkgen** output file bad - using `NOM` values
corrective action: Continue, using `NOM` values

noEvents *(warning)*
Event file contains no events
corrective action: continue, with warning message

outOfImageRange *(warning)*
some events out of range of image
corrective action: continue, with warning message

noAtthkgenFile *(warning)*
No atthkgen file - can't get PNT values - using NOM values
corrective action: continue, with warning message, using NOM values

noPntAttributes *(warning)*
No atthkgen file - no PNT attributes propagated
corrective action: continue, with warning message

undefinedHelpVector *(warning)*
Help vector has undefined length - taking aspect solution as help point to contine
corrective action: continue, with warning message

6 Input Files

1. Input MOS or pn event list containing correct `DETX` and `DETY` coordinates (0.05 arcsecond resolution). Keywords `DATAMODE` and `TCDLT` are read, as are (depending on `refpointlabel`) `RA_NOM` and `DEC_NOM` or `RA_OBJ` and `DEC_OBJ`.

2. **atthkgen** output file (default name: `atthk.dat`), containing median and mean pointing direction over the observation (this is all that **attcalc** accesses from this file). It is not necessary for this file to exist, though, if so, no PNT attributes will be propagated to the events file. Keywords read are (depending on parameters `attitudelabel` and `withmedianpnt`) `MAHFRA`, `MAHFDEC` and `MAHFPA` or `MOMRA`, `MOMDEC` and `MOMPA` or `AAHFRA`, `AAHFDEC` and `AAHFPA` or `AOMRA`, `AOMDEC` and `AOMPA`.

7 Output Files

1. Input event list with columns X, and Y filled with attitude-corrected sky coordinate values. Keywords EQUINOX, RADECSYS, REFXCTYP, REFXCRPX, REFXCRVL, REFXCDLT, REFXLMIN, REFXLMAX, REFXDMIN, REFXDMAX, REFXCUNI, REFYCTYP, REFYCRPX, REFYCRVL, REFYCDLT, REFYLMIN, REFYLMAX, REFYDMIN, REFYDMAX, REFYCUNI, (and if applicable RA_PNT, DEC_PNT, PA_PNT and AVRG_PNT) are added to the primary header. Keywords EQUINOX, RADECSYS, REFPOINT, RAREF, DECREF, ATTSRC, and if applicable (attsrc=FIXED), ATTRA, ATTDEC and ATTPA added to events header. Also WCS keywords TCTYP, TCRPX, TCRVL, TCDLT, TLMIN, TLMAX, TDMIN, TDMAX and TCUNI (attributable to both columns X, and Y) added to events header. History information added.

8 Algorithm

```
subroutine attcalc

  * get input events
  * get instrument, mode and ccdid from events file
  * add X/Y columns to event table if they don't already exist

  * obtain CCF, set state

  * get refpointlabel (source of reference point information)
  * get RA\_PNT, DEC\_PNT and PA\_PNT from atthkset (atthkgen output file)
      if no file, use NOM values
  * set central reference point (nominalra, nominaldec)
  * get attitudelabel (source of attitude information)
  * if attitudelabel=fixed, get fixedra, fixeddec, fixedposangle
  * if attitudelabel=ahf or om, set attitudeFromAhf (AHF or OM)

  * loop through events
      if event time has changed (i.e. is frame different) then
        if (attitudelabel .ne. fixed) then
          call OAL_getAttitude  (AHF/OM attitude information)
          identify if special case (e.g. dec=0, +90, -90)
          transform from spherical to parallel coords
          repeat above for a point 1 degree more north along the local meridian
            (the 'help point'), to get the angle with the nominal meridian
        endif
        call getBoresightMatrix and apply boresight correction
      endif
      apply corrected attitude information to event DETX/DETY to get X/Y
  * end loop through events

  * add WCS parameters to events file
  * (calculation of and) adding of keywords to event file
  * add history to events file

end subroutine attcalc
```

9 Comments

- The **atthkgen** output file is accessed by **attcalc** for the mean and median pointing values over the observation (nothing else, when `attitudelabel`=ahf, **attcalc** calls the OAL anew). If this file (default name: `atthk.dat`) doesn't exist in the current directory, a warning message is given, and no PNT attributes are propagated. A boolean parameter `withatthkgen` exists to determine whether the task should use any atthkgen output file.
- It is still unclear at present how the OM tracking history file will look, and how the attitude information will be accessed from this file (perhaps through a combination of **omatt** and OAL_getAttitude).
- The parameter `imagesize` (default 0.36 degrees [= 21.6 arcminutes]) is needed to define the range of the X and Y coordinates and all the WCS attributes. For normal pointings the default value should be used. Larger numbers can be used for instance when constructing a dataset over several pointings over a large field.
- The 'position angle' used is in actuality an '*astronomical* position angle' (see XMM-MOC-TN-0109-OAD and INT-SYS-FD-TN-0004-OAD). This angle is counted from the celestial north in the mathematically positive sense around the axis pointing from the object towards the observer (i.e. anticlockwise from the observer's point of view, looking towards the sky). This is now in line with SciSim.

10 Future developments

The task does not at present work on SDF files.

In these coordinate transformations, the same method as for the ROSAT PSPC has been used. At present, the transformations appear to function correctly except *perhaps* at very specific points on the sky, though none have so far been found.

11 Examples

- *attcalc eventset=events.dat* (uses ahf attitude within the current ODF [set via the environment variable $SAS_ODF] to calculate event X/Y coordinates, referenced to PNT values in atthk.dat)
- *eventset=events.dat attitudelabel=fixed refpointlabel=obj fixedra=23.645 fixeddec=-10.034 fixedposangle=23.4* (uses fixed attitude to calculate event X/Y coordinates, referenced to the OBJ RA/Dec values in the event file).
- *attcalc eventset=events.dat attitudelabel=ahf refpointlabel=user nominalra=100.0 nominaldec=10.0 imagesize=1.0* (uses ahf attitude in the current ODF to calculate event X/Y coordinates, referenced to user defined RA/Dec. Size of effective image increased).

References