rgsangles

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Abstract

This task corrects CCD pixel positions of an event for changes in the spacecraft pointing. The correction depends on the position of the source which must be supplied to the task.

Revision no.	Date	Comments
3.0	2001-07-16	updates of task description to account for changes of the parameter interface of version 4.0
2.1	2001-07-16	minor updates of task description after delivery of version 3.1
2.0	2001-03-23	updated parameters to match task SOC-SPR-1575 add definitions of RGS FOV angles
1.4	2000-12-12	fix doc typo SOC-SPR-1645
0.48	05/04/00	parameter referenceframe renamed to referenceattitude
0.45	02/03/00	ready for re-submition
0.6	02/02/00	first version rgsangles (previously called rgswavelength)
0.5	07/12/98	updated based on SSC and SOC comments
0.4	19/11/98	submitted for task approval (as rgswavelength)

1 Instruments/Modes

Instrument	Mode
RGS	Spectroscopy , High-time resolution

2 Use

pipeline processing	yes
interactive analysis	yes

3 Description

The main purpose of this task is the correction for attitude drifts using the dispersion coordinate system. The dispersion coordinates are defined based on the position and on the orientation of the RGA, and have two components: the dispersion angle `BETA` and the cross dispersion angle `XDSP`. Under the assumption

that the relative movement between the RGA and the RFC is negligible (stable telescope tube), these angles can be calculated per event solely from the pixel locations of the event on the RFC and from the relative alignment of RGA and RFC. This calculation is performed by a CAL call (using the coordinate converter modes) in **rgsevents**, which adds `BETA` and `XDSP` to the event list. Each event is therefore associated with a position in dispersion coordinates.

The measured position of an event (`BETA`, `XDSP`) depends on the wavelength of the photon and the position of the X-ray source in the field of view (FOV) of the telescope. A drift of the telescope changes the position of the source in the FOV which results in a blurred wavelength spectrum.

While the aspect drift correction in the cross-dispersion coordinate is straightforward and similar to an imaging instrument, the approach in the dispersion direction is to absorb the aspect drift correction in the calculation of the dispersion coordinate from the RGA-RFC geometry. This approach of the drift correction is described in the following.

The following description is given in RGS FOV coordinates (ϕ,ψ), which relate to the angles (θ',ϕ') of the `TELCOORD` system in the following way:

$$\begin{aligned} \phi &= -\theta \cos\phi' \ , \\ \psi &= -\theta \sin\phi' \ . \end{aligned} \tag{1}$$

Hence ϕ describes the angualr component of an off-axis source parallel to the dispersion direction, and ψ its componenta anti-parallel to the cross-dispersion.

X-rays from a source which is at angles (ϕ,ψ) have the following angle of incidence α on the gratings of the RGA:

$$\alpha = \alpha_0 + \phi \, \frac{F}{L} \ , \tag{2}$$

with the nominal angle of incidence for an on-axis source α_0, the focal length F, and the distance between RGA and prime focus L (nominal: $F = 7500\,\mathrm{mm}$, $L = 6700\,\mathrm{mm}$; exact values depend on the distances of the reference points of the RGA and of the RFC, and are provided by the CAL. Aspect drift is described by adding its amount along the dispersion direction $\Delta\phi$ to ϕ. Note that for non-negligible drift in roll, $\Delta\phi$ also is a function of roll drift and source off-axis angle, because ϕ and $\Delta\phi$ are angles in the RGA frame (i.e. along the dispersion direction).

From the dispersion relation

$$\cos\beta = \frac{m\lambda}{d} + \cos\alpha \ , \tag{3}$$

with the grating incidence angle α (measured from the grating surface), the grating exit angle β, grating line density d and order m for a given wavelength λ. It follows from (3) for variations of α & β by differentiation

$$\Delta\beta \sin\beta = \Delta\alpha \sin\alpha \ , \tag{4}$$

or

$$\Delta\beta = \frac{\sin\alpha}{\sin\beta}\Delta\alpha \ . \tag{5}$$

Using (2) and the aspect drift $\Delta\phi$, this becomes

$$\Delta\beta = \frac{\sin(\alpha_0 + \phi\ F/L)}{\sin\beta}\ \Delta\phi\ \frac{F}{L} \tag{6}$$

With this formulation, the drift of attitude is described as corrections in dispersion coordinates. This effectively means that the RFC moves in β-space and has the side effect that the same correction has to be used for the calculation of the exposure maps. For this reason the evaluation of these equations are part of **rgslib**.

It can also be seen from (6) that the amount of correction of the dispersion angle is dependent in the position of the source in the FOV (through ϕ). In order to achieve best possible accuracy, this correction should be performed per source that is to be considered in the RGS FOV. Hence the dependence on the source index in the RGS `SRCLIST` table.

The absolute values of ϕ and $\Delta\phi$ have to be determined for a given starting value of the pointing of the telescope. This is called *reference attitude* and basically means that this is the on-axis sky position to which the telescope points after the attitude drift correction was performed. Different choices of reference attitudes will cause absolute offsets of the amounts of $\Delta\phi$ accordingly, and it is therefore optimal to choose a center of reference that is close to the actual pointing.

The reference attitude is provided by the `SRCLIST` table. The reference attitude is added to the `EVENTS` table with the keywords `RA_PNT`, `DEC_PNT` and `APOS_PNT`.

The source position, from which ϕ is calculated with respect to the center of the reference attitude, is read from the `SRCLIST` table, too. The source position that is used in correction described in equation (6) is added to the `EVENTS` table with the keywords `RA_OBJ` and `DEC_OBJ`. The row number of the source in the `SRCLIST` table is written to the `EVENTS` header with keyword `SOURCEID`.

It has been described before that ϕ and $\Delta\phi$ have to be available in instrument specific coordinates, namely along the dispersion direction. The following steps have to be performed in order to obtain the components of the source position along dispersion (ϕ) and cross dispersion (ψ) direction (implemented in **rgslib**).[1]

The calculation of the components of the source position with respect to the reference attitude is performed as follows. First the reference attitude matrix is calculated from the reference pointing as specified by $(Ra_{\rm ref}, Dec_{\rm ref}, Pa_{\rm ref})$ with

$$RefAtt = \texttt{OAL_toAttitudeMatrix}(Ra_{\rm ref}, Dec_{\rm ref}, Pa_{\rm ref}) \tag{7}$$

The reference attitude is multiplied by the instrument specific BoreSight matrix, such that *RefAtt* holds the instrument specific attitude matrix.

Next the source position (Ra,Dec) is converted to a Cartesian sky vector with

$$Src_{\rm SkyVect} = \texttt{unitCartesian}(Src_{\rm Ra}, Src_{\rm Dec})\ , \tag{8}$$

and the Cartesian position of the source for the reference attitude is obtained in the instrument specific FOV coordinates $Src_{\rm cart}$ by

[1] Please note that the calling interface to the described functions and subroutines of the OAL and of the CAL is not accurate, but is specified as pseudo-code for illustrative purposes only. The documentation of the OAL and CAL has to be consulted to find the actual calling sequence.

$$Src_{\rm cart}(t=0) = RefAtt \otimes Src_{\rm SkyVect} \ . \tag{9}$$

The angles ϕ in the dispersion direction and ψ in the cross-dispersion direction are obtained straightforwardly from the Cartesian components

$$\begin{aligned} \phi &= \arctan(Src_{\rm cart,Z}/Src_{\rm cart,X}) \\ \psi &= \arctan(Src_{\rm cart,Y}/Src_{\rm cart,X}) \end{aligned} \tag{10}$$

The calculations of equations (7)–(10) are performed by the **rgslib** function `offAxisAngles(referenceAttitude,sourcePos)`.

Attitude drifts cause variations ($\Delta\phi$, $\Delta\psi$) to ϕ and ψ as calculated in equation (10) and are calculated in instrument FOV coordinates as well as variations from the reference pointing. First ϕ and ψ are evaluated equivalent to the steps described above (equations (8)–(10)), but instead of the the source pointing the pointing of the reference attitude is used. This yields $Ref_{\rm SkyVect}(t=0)$ together with the starting values for ϕ_0 and ψ_0 to be used for the calculation of $\Delta\phi$ and $\Delta\psi$.[2] Then ϕ and ψ are calculated for each available attitude, and the angles of the drift ($\Delta\phi$, $\Delta\psi$) are just the differences between those obtained for the reference attitude and the time dependent attitude. Let *VarAtt* be the attitude of the instrument as a function of time, then

$$VarAtt(t) = \texttt{OAL_getAttitude}(t) \otimes BoreSight \ . \tag{11}$$

The multiplication with the BoreSight here is necessary, as `OAL_getAttitude` returns the attitude of the star tracker as a function of time. Similar as above in (9), the position of the reference pointing in the (drifted) FOV in Cartesian coordinates is obtained by multiplication, and

$$Ref_{\rm cart}(t) = VarAtt(t) \otimes Ref_{\rm SkyVect}(t=0) \ , \tag{12}$$

and the components of the drift then follow with equation (10) according to

$$\begin{aligned} \Delta\phi &= \arctan(Ref_{\rm cart,Z}(t)/Ref_{\rm cart,X}(t)) - \phi_0 \\ \Delta\psi &= \arctan(Ref_{\rm cart,Y}(t)/Ref_{\rm cart,X}(t)) - \phi_0 \end{aligned} \tag{13}$$

The calculations of equations (11)–(13) are performed by the **rgslib** function `gratingAspectAngles(time, referenceAttitude)`, which returns an array holding $(\Delta\phi, \Delta\psi)$, and also includes the calculation of ϕ_0 and ψ_0 according to equations (7)–(10), but for the reference pointing. The values of $\Delta\phi$ and $\Delta\psi$ are added to the `EXPOSUO`n table as columns `ASPCDSP` and `ASPCXDSP` respectively.

For each event the aspect correction $\Delta\beta$ is calculated using equation (6). The drift independent term $F/L\sin(\alpha_0+\phi\ F/L)$ is written as keyword `ASPFACT1` to the EVENTS header for use by task **rgsexposure**.

The drift corrected columns `BETA_CORR` `XDSP_CORR` are binned into int16 channel columns `BETA_CHANNEL` and `XDSP_CHANNEL`. The binning can be specified either by the number of bins together with the ranges in `BETA_CORR` and `XDSP_CORR`, or by specifying the bin-size and a reference value for the first channel. Keywords `TCRVL` (formerly `BETA_REF`, `XDSP_REF`) and `TCDLT` (formerly `BETA_WID`, `XDSP_WID`) specify the

[2] This of course evaluates = 0. However the implementation in **rgslib** is such that `gratingAspectAngles` calculates these angles with respect to an imaginary central grating of the RGA, and hence ϕ_0 and ψ_0 are the angles of incidence on this grating corresponding to an on-axis source.

midpoint of the first bin and the bin width used for the binning. Depending on the data range and binning, channel numbers could become negative. Channel values outside the integer 16 range will cause a fatal error condition.

In order to secure against wrong values of `BETA_CORR` and `XDSP_CORR` which could arise from a bad choice of the reference attitude, a range check is performed on these values, and a warning is generated when unreasonable values are encountered.

The following optional columns can be added to the event table for investigation of the intermediate results:

- The spacecraft pointing in (rad) `SC_POINTING_RA SC_POINTING_DEC SC_POINTING_POS`: this is the pointing as a function of time as provided by the OAL, without aspect drift correction (this is provided for debugging purposes for subsequent tasks, which do not use the OAL).
- `M_LAMBDA` order wavelength product from dispersion relation (3) using corrected β and ϕ_0 as inputs.

4 Parameters

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

Parameter	Mand	Type	Default	Constraints
mergedset	yes	e		

Input/output data set containing RGS raw events

srclist	yes	e	rgssources.ds	

Input data set containing RGS source list

nbetabins	no	i	3000	> 0

number of beta bins.

betabinning	no	s	Range	Range|binSize

Specify channels either as range and number of channels, or as first channel, channel-width and number of channels

betamin	no	r	3.e-2	

lower boundary of first beta bin (rad); used when betabinning='Range'

betamax	no	r	8.e-2	

upper boudary of last beta bin (rad); used when betabinning='Range'

betabinref	no	r	3.577e-2	

midpoint of the bin for which `BETA_CHANNEL` = 1 (rad); used when betabinning='binSize'

betabinwidth	no	r	4e-6	

width of BETA_CHANNEL bin (rad); used when betabinning='binSize'

nxdispbins	no	integer	100	> 0

number of cross-dispersion bins.

xdispbinning	no	s	Range	Range|binSize

Specify channels either as range and number of channels, or as first channel, channel-width and number of channels

xdispmin	no	r	-1.e-3	

lower boundary of first cross-dispersion bin (rad); used when xdispbinning='Range'

xdispmax	no	r	+1.e-3	

upper boundary of last cross-dispersion bin (rad); used when xdispbinning='Range'

xdispbinref	no	r	-7.92e-4	

midpoint of the bin for which `XDSP_CHANNEL` = 1 (rad); used when xdispbinning='binSize'

xdispbinwidth	no	r	3.6e-6	

width of XDSP_CHANNEL bin (rad); used when xdispbinning='binSize'

withpointingcolumn	no	b	Yes	

Produce columns SC_POINTING_* with Spacecraft Pointing RA DEC POS

withmlambdacolumn	no	b	Yes	

Produce column with $m * \lambda$ based on geometry and given source position. (Å)

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.

noPointing *(warning)*
pointing_mod: No pointing available from OAL for requested time. *Generated by* ***rgslib***.
corrective action:

RGSLIB_getsourcepos *(error)*
requested source index number is not valid in SRCLIST table. *Generated by* ***rgslib***.

6 Input Files

1. event list as produced by **rgsevents**.
2. RGS source list as generated by task **rgssources**

7 Output Files

1. in event list data set: expanded `EVENTS` & `EXPOSUO`n table

8 Algorithm

```
Set state CAL/OAL

get columns from EVENTS table
setup new columns in EVENTS table

Get source position from RGS SRCLIST table

Get reference attitude from RGS SRCLIST table

loop over EXPOSU0n tables
   call processFramesTable to fill ASPCDSP and ASPCXDSP columns of
                           EXPOSU0n table
                using gratingAspectAngles(time, referenceAttitude)
end loop

loop over all times to find elements with available attitude

call processEvents to correct BETA, XDSP with attitude drift
                using phi0=offAxisAngles(referenceAttitude, sourcePos)

     processEvents{
           Calculate corrected beta
           beta_corr = betaraw + (Qfactor * ASPCDSP / sin(betaraw))

           if (cross dispersion) xdsp_corr =  xdspRaw + ASPCXDSP
     }

store factor ASPFACT1 in header EVENTS table
       Qfactor = FoverL * sin(alpha0 + phi0dsp*FoverL)

bin BETA_CORR into BETA_CHANNEL
bin XDSP_CORR into XDSP_CHANNEL
```

9 Comments

- This task operates on the `EXPOSU0n` and `EVENTS` tables of the merged event list
- High-time resolution mode will not produce any cross dispersion columns. Keywords related to cross dispersion values are not produced in that case
- There is no internal looping over multiple sources. The caller (meta task) should do the source loop.

References