FITS REGION Binary Table Design
ASC-FITS-REGION-1.0

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1 Definition

This document contains the specification of the REGION table which is the spatial equivalent of the (temporal) GTI table. Like the GTI table, the REGION table is a FITS binary table. It is recognized as a REGION table by the presence of HDUCLAS1='REGION'. The REGION table defines regions of an image that are to be included or excluded from certain operations, specified by means of geometrical shapes. Each row specifies an *element* of a certain shape that traces a specified area in the image; elements are grouped in *components*; and one or more components make up a *region*. As in soccer, the boundary lines are considered part of the element they circumscribe.

The logic of combining elements and components is governed by three rules:

- A region consists of the union of one or more components (logical OR operation).
- A component consists of the intersection of one or more elements (logical AND operation).
- Elements for which the value in the SHAPE column is preceded by an exclamation mark ("!") are interpreted as: the entire image, excluding the region traced by the element and its boundary (*i.e.*, logical NOT operation).

2 Columns

At the present time, the REGION table is defined for a two-dimensional space. The following columns are mandatory.

- Two spatial coordinate columns, which we shall designate here as X and Y, each containing a vector of length sufficient to describe the geometrical shapes specified in the table. The numbers may be floating point, double, or integer. The names of the columns (TTYPE*i*) indicate the coordinate system in use, in the usual way, and these coordinate names are to be identified in the MFORM1 keyword (MFORM1='X,Y'); the mandatory keyword MTYPE1 provides a name for the coordinate pair. It is recommended that the (X,Y) pixel coordinate system be tied to absolute (WCS) coordinates following the convention for pixel lists in OGIP/94-006.

The following columns are optional, although they are recommended and may be required depending on the contents of other columns.

- SHAPE (*r*A): specifies the geometrical shape of the element. At the present time the following shapes are defined: point (default), circle, ellipse, annulus, elliptannulus, box, rotbox, rectangle, rotrectangle, polygon, pie=sector, diamond=rhombus, rotdiamond=rotrhombus. The recommended value for *r* is 16. For shape identification, only the first 15 characters will be significant while case will *not* be significant. The shape name may be preceded by an exclamation mark (*e.g.,* "!Circle"), which shall be interpreted as "include the entire image, except for the specified element and its boundary".
- R (radius): for elements that require a radius parameter for their definition; like X and Y, this column needs to contain vectors of sufficient length.
- ROTANG (rotation angle): for rotated elements; like X and Y, this column needs to contain vectors of sufficient length.

The following column is optional, although it is recommended for more sophisticated use of regions:

- COMPONENT (I): component number that the element is to be associated with; default: 1.

Additional columns may be included to allow selective use of regions. In the example below, we have added the columns SOURCE and GRATING as useful selection criteria for ACIS.

3 Header Keywords

In the following example header, all keywords are mandatory except for the ones marked "r" (recommended or required by certain shapes) or "o" (truly optional). As noted above, it is recommended that the `(X,Y)` pixel coordinate system used be tied to absolute coordinates, *e.g.*, `(RA---TAN,DEC--TAN)` following the convention for pixel lists in OGIP/94-006.

```
XTENSION= 'BINTABLE'           / HDU 1=======================================
BITPIX  =                    8 / 8-bit bytes
```

```
  NAXIS   =                    2 / 2-dimensional Binary Table
  NAXIS1  =                  228 / Number of bytes per row
  NAXIS2  =                    1 / Count the rows!
  PCOUNT  =                    0 / No group parameters (required keyword)
  GCOUNT  =                    1 / One data group (required keyword)
  TFIELDS =                    8 / Number of columns

  COMMENT                    This table contains an inclusion/exclusion region spec

  EXTNAME = 'REGION  '           / Region specification table
  EXTVER  =                    1
  EXTLEVEL=                    1 / Level in DB hierarchy: Data table
  CHECKSUM= '0000000000000000'   / ASCII encoded HDU checksum
  DATASUM = '         0'         / Data unit checksum written in ASCII
  ORIGIN  = 'ASC     '
  CREATOR = 'me      '
  CONTENT = 'REGION  '
  HDUDOC  = 'ASC-FITS-1.0: McDowell, Rots: ASC FITS File Designers Guide'
  HDUVERS = '1.0.0   '
  HDUCLASS= 'ASC     '
  HDUCLAS1= 'REGION  '
  HDUCLAS2= 'STANDARD'
o LONGSTRN= 'OGIP 1.0'           / The OGIP long string convention may be used.
o COMMENT   This FITS file may contain long string keyword values that are
o COMMENT   continued over multiple keywords.  This convention uses the  '&'
o COMMENT   character at the end of a string which is then continued
o COMMENT   on subsequent keywords whose name = 'CONTINUE'.

  DATE    = '1998-02-05'         / Time information block------------------------
o DATE-OBS= '1998-01-01T00:00:00'/ TT, with clock correction
o DATE-END= '1998-01-01T00:00:01'/ TT, with clock correction
o TIMESYS = 'TT      '           / AXAF time will be TT (Terrestrial Time)
o MJDREF  =                50814 / 1998.0(TT)
o                                / MJD = JD - 2400000.5
o TIMEZERO=                  0.0 / Clock correction
o TIMEUNIT= 's       '
o TIMEREF = 'LOCAL   '           / No pathlength corrections
o TASSIGN = 'ASC     '           / ASC
o CLOCKAPP=                    T / Clock correction applied
o TIERRELA=              1.0E-9 / Short-term clock stability
o TIERABSO=              1.0E-6 / Absolute precision of clock correction
o TIMVERSN= 'ASC-FITS-1.0'       / AXAF FITS design document
o TSTART  =                  0.0 / As in the "TIME" column: raw space craft clock;
o TSTOP   =                  1.0 /   add TIMEZERO and MJDREF for absolute TT

  MTYPE1  = 'pos     '
```

```
  MFORM1   = 'X,Y     '
r RADECSYS= 'ICRS    '            / The following keywords tie the REGION
r EQUINOX =                2000.0 / coordinates to WCS
r TCTYP2   = 'RA---TAN'           / RA
r TCRPX2   =                  512
r TCRPX2   =             123.4567
r TCDLT2   =               0.0001
r TCUNI2   = 'deg     '
r TCTYP3   = 'DEC--TAN'           / Dec
r TCRPX3   =                  512
r TCRPX3   =              45.6789
r TCDLT3   =               0.0001
r TCUNI3   = 'deg     '
r TCROT3   =                 30.0


r TTYPE1   = 'SHAPE   '           / Shape of element
r TFORM1   = '16A     '
r TUNIT1   = '        '

  TTYPE2   = 'X       '           / X-coordinate vector
  TFORM2   = '12E     '
  TUNIT2   = 'pixel   '

  TTYPE3   = 'Y       '           / Y-coordinate vector
  TFORM3   = '12E     '
  TUNIT3   = 'pixel   '

r TTYPE4   = 'R       '           / Radius vector
r TFORM4   = '12E     '
r TUNIT4   = 'pixel   '

r TTYPE5   = 'ROTANG  '           / Rotation angle vector
r TFORM5   = '12E     '
r TUNIT5   = 'deg     '

r TTYPE6   = 'COMPONENT'          / Component number that shape belongs to
r TFORM6   = 'I       '           /   default: 1
r TUNIT6   = '        '

o TTYPE7   = 'SOURCE  '           / Source number
o TFORM7   = 'I       '
o TUNIT7   = '        '

o TTYPE8   = 'GRATING '           / Applicable grating (default 'NONE')
o TFORM8   = '16A     '
```

```
o TUNIT8  = '          '

  END
```

To summarize, only the X, and Y columns are required, although a SHAPE column is likely indispensible; whether R and ROTANG are needed depends on the contents of the SHAPE column. The COMPONENT column is recommended for more sophisticated use. The SOURCE and GRATING columns are implementation-dependent: any columns, like these, may be added for filtering purposes.

4 SHAPEs

The value of SHAPE (default: point) defines the precise meaning of the X, Y, R (radius), ROTANG columns and the minimum number of elements required in their vectors. The following table enumerates the currently defined values for SHAPE and the meaning of the related columns. Note the optional use of an exclamation mark preceding the SHAPE value, as described above.

Table 1: REGION Table SHAPEs

SHAPE	**X**	**Y**	**R**	**ROTANG**
Point	X	Y		
Circle	X_{cen}	Y_{cen}	R	
Ellipse	X_{cen}	Y_{cen}	R_{maj}, R_{min}	$Angle$
Annulus	X_{cen}	Y_{cen}	R_{in}, R_{out}	
Elliptannulus	X_{cen}	Y_{cen}	$R_{inmaj}, R_{inmin}, R_{outmaj}, R_{outmin}$	Ang_{in}, Ang_{out}
Box	X_{cen}	Y_{cen}	X_{size}, Y_{size}	
Rotbox	X_{cen}	Y_{cen}	X_{size}, Y_{size}	$Angle$
Rectangle	X_{min}, X_{max}	Y_{min}, Y_{max}		
Rotrectangle	X_{min}, X_{max}	Y_{min}, Y_{max}		$Angle$
Polygon	$X_0, X_1, ...X_n$	$Y_0, Y_1, ...Y_n$		
Pie	X_{cen}	Y_{cen}		Ang_{min}, Ang_{max}
Sector (=pie)	X_{cen}	Y_{cen}		Ang_{min}, Ang_{max}
Diamond	X_{cen}	Y_{cen}	X_{size}, Y_{size}	
Rhombus (=diamond)	X_{cen}	Y_{cen}	X_{size}, Y_{size}	
Rotdiamond	X_{cen}	Y_{cen}	X_{size}, Y_{size}	$Angle$
Rotrhombus (=rotdiamond)	X_{cen}	Y_{cen}	X_{size}, Y_{size}	$Angle$

The value of SHAPE (point, circle, ellipse, rectangle, rotbox, polygon; default: point) defines the precise meaning of the X, Y, R (radius), ROTANG columns and the minimum number of elements required in their vectors; *e.g.*

- *point:* first element of X, Y vectors specifies point to be included.

- *circle:* first element of X, Y, R vectors specifies center and radius.
- *ellipse:* first X, Y (center), ROTANG (counter-clockwise rotation of major axis with repect to X axis), first two R (semi axes).
- *annulus:* first X, Y (center), first two R (inner and outer radius).
- *elliptannulus:* (area between two concentric ellipses: first X, Y (center), first four R (major, minor semi-axes inner ellipse, major, minor semi-axes outer ellipse), first two ROTANG (inner and outer ellipse rotation).
- *box:* first X, Y (center), first two R (size in X, Y).
- *rotbox:* first X, Y (center), first two R (size in X, Y), first ROTANG (counter-clockwise rotation).
- *rectangle:* first two elements of X, Y (bottom left and top right corners).
- *rotrectangle:* first two elements of X, Y (bottom left and top right corners of rectangle), first element of ROTANG (counter-clockwise rotation of the rectangle with respect to X and Y axes).
- *polygon:* m X and Y elements (vertices), where m is the smallest positive number $< n$ for which ((X[m] == X[0]) && (Y[m] == Y[0])) or, if none satisfies, n; in the above example, $n = 12$.
- *pie* or *sector:* first X, Y (center), first two elements of ROTANG (sector from first to second, counted counter-clockwise from positive X-axis).
- *diamond* or *rhombus:* first X, Y (center), first two R (size in X, Y, between vertices in X, Y axis).
- *rotdiamond* or *rotrhombus:* first X, Y (center), first two R (size in X, Y, between vertices in X, Y axis), first ROTANG (counter-clockwise rotation).

The (X,Y) coordinate system is specified in the usual way. The length of the X, Y, R, and ROTANG vectors is arbitrary, as long as it is long enough to accommodate the geometric shapes used in the table. The R and ROTANG columns are optional if not required by the shapes used in the table. The names of the coordinate axes on which the regions are defined need to be given in the keyword MFORM1.