4 exposure_map

Data Product Summary

ASC Data Product	exposure_map
Instrument(s)	HRC, ACIS (imaging mode)
Level	2
Scientist/SDS	D. Huenemoerder
Filetype	FITS 3D image
Created by tool	exp_make_map
Used by tool(s)	TBD
Sample file	TBD

The exposure map file for imaging mode is a 3-dimensional FITS image in which two of the dimensions are the sky X, Y spatial dimensions and the third axis is of energy. Hence, one X, Y plane is an image of the exposure vs. position, where exposure is in units of [cm^2 s]. Choosing one spatial cell and traversing then energy axis yields the effective area as a function of energy (weighted by exposure time). The map may alternatively be calculated for unit mirror and/or detector efficiencies, and will hence map only exposure time onto the sky, bounded by detector geometry. These differences will be specified by the `BUNIT` and/or `HDUCLASS` keywords.

4.1 File Structure

The following table describes the file structure by Header-Data Unit number, type, extension name, content, and HDU classes. An asterisk (*) denotes the ASC principal HDU.

HDU	Type	EXTNAME	CONTENT	HDUCLASS	Description
1 (*)	IMAGE	-	EXPMAP	ASC, IMAGE, STANDARD, EXP	Effective exposure [cm^2 sec] vs sky position vs energy, weighted by mirror and detector efficiency, unless HDUCLASSes indicate otherwise.
2	BINTABLE	EBOUNDS		OGIP, RESPONSE (TBR)	Energy grid for exposure map 3rd axis.

4.2 Column/Image Descriptions

Axes for *Principal Image HDU*

NAXIS	Comment
1	Sky spatial X coordinate, right-ascension offset.
2	Sky spatial Y coordinate, declination offset.
3	Energy

Columns for *Auxiliary EBOUNDS HDU*

TTYPE	TUNIT	TFORM	TLMIN	TLMAX	TDBIN	TNULL	Comment
CHANNEL	bin	1I	1	16384	1	0	energy bin number
E_MIN	keV	1E	0.0	20.	0.001	NaN	minimum energy of bin
E_MAX	keV	1E	0.0	20.	0.001	NaN	maximum energy of bin

4.3 Special Header Keywords

The principal IMAGE HDU spatial coordinates requre additional coordinate system attached as shown in the following table.

```
CTYPE1  = 'RA---TAN'           / Axis type for dim 1 (e.g. RA---TAN)
CTYPE2  = 'DEC--TAN'           / Axis type for dim 2 (e.g. DEC--TAN)
CTYPE3  = 'Energy'             / Axis type for dim 3
CRVAL1  =       3.32170013E+02 / Sky coord of 1st axis (deg)
CRVAL2  =       4.57400017E+01 / Sky coord of 2nd axis (deg)
CDELT1  =     -1.59E-04        / X degrees per pixel
CDELT2  =      1.59E-04        / Y degrees per pixel
CRPIX1  =              512.500 / X pixel of tangent point
CRPIX2  =              512.500 / Y pixel of tangent point
CUNIT1  = 'deg'                / Units  of 1st axis (deg)
CUNIT2  = 'deg'                / Units  of 2nd axis (deg)
CUNIT3  = 'bin'                / Units  of 3rd axis (deg)
```

The *Observation* and *Timing* components of the header are derived from the event-file and aspect solution header to which the map applies.

4.4 Size Estimate

The size of the exposure map product in bytes is specified by

$$NAXIS1 \times NAXIS2 \times NAXIS3 \times 4 + NAXIS3 \times 12.$$

The resolution is user-specifiable. Nominal values may be of order 64, 64, 256, for axes 1, 2, and 3, respectively, yielding a 4 MB file.

4.5 Unresolved Issues

4.6 Sample Header

```
# Draft FITS header for exposure map

# Lines initial characters and meanings are:
# '#' comment
# '*' to be reviewed
# 'x' marked for deletion

##########################################################################
# Primary HDU, Principal

# Mandatory for HDU:

  SIMPLE  =                    T / file does conform to FITS standard
  BITPIX  =                  -32 / number of bits per data pixel
  NAXIS   =                    3 / number of data axes
  NAXIS1  =                 1024 / length of data axis   1
  NAXIS2  =                 1024 / length of data axis   2
  NAXIS3  =                 1024 / length of data axis   3

# Image Coordinates:

  CTYPE1  = 'RA---TAN'           / Axis type for dim 1 (e.g. RA---TAN)
  CTYPE2  = 'DEC--TAN'           / Axis type for dim 2 (e.g. DEC--TAN)
  CTYPE3  = 'Energy'             / Axis type for dim 3
  CRVAL1  =       3.32170013E+02 / Sky coord of 1st axis (deg)
  CRVAL2  =       4.57400017E+01 / Sky coord of 2nd axis (deg)
  CDELT1  =      -1.59E-04       / X degrees per pixel
  CDELT2  =       1.59E-04       / Y degrees per pixel
  CRPIX1  =              512.500 / X pixel of tangent point
  CRPIX2  =              512.500 / Y pixel of tangent point
  CUNIT1  = 'deg'                / Units  of 1st axis (deg)
  CUNIT2  = 'deg'                / Units  of 2nd axis (deg)
  CUNIT3  = 'bin'                / Units  of 3rd axis (deg)

* COMMENT AXES mapping from axis-3 bins to energy is given by
* COMMENT  EBOUNDS extension.

* BSCALE  =       1.00000000E+00 / Real = file*BSCALE + BZERO
* BZERO   =       0.00000000E+00 /
  BUNIT   = 'cm**2 * s'

# CC-Full:

  COMMENT                                        +-------------------+
  COMMENT                                        | AXAF FITS   File |
  COMMENT                                        +-------------------+
  COMMENT              **********************************************************
  COMMENT              >    This file is written following certain AXAF-ASC    <
  COMMENT              >    conventions which are documented in ASC-FITS-1.0   <
```

```
  COMMENT              ********************************************************
  COMMENT                         / Configuration control-------------------------
  ORIGIN  = 'ASC     '
  CREATOR = 'xxx - Version 0.0'
  REVISION=                     0 / Processing system revision number
  COMMENT $Id$
  CHECKSUM= '0000000000000000'   / ASCII encoded HDU checksum
  DATASUM = '          0'         / Data unit checksum written in ASCII

  CONTENT = 'IMG     '
  HDUNAME = 'IMAGE   '            / If no EXTNAME
  HDUSPEC = 'tbd'                 / ICD reference
  HDUDOC  = 'ASC-FITS-1.0: McDowell, Rots: ASC FITS File Designers Guide'
  HDUVERS = '1.0.0   '
  HDUCLASS= 'OGIP    '
  HDUCLAS1= 'IMAGE   '
  HDUCLAS2= 'STANDARD'
* HDUCLAS3= 'tbd     '            / As needed ...

  LONGSTRN= 'OGIP 1.0'            / The OGIP long string convention may be used.
  COMMENT   This FITS file may contain long string keyword values that are
  COMMENT   continued over multiple keywords.  This convention uses the  '&'
  COMMENT   character at the end of a string which is then continued
  COMMENT   on subsequent keywords whose name = 'CONTINUE'.


# Timing, Full

  DATE    = '1998-01-01T00:00:00'  / Date and time of file creation (UTC)
  DATE-OBS= '1998-01-01T00:00:00'  / TT, with clock correction if CLOCKAPP
  DATE-END= '1998-01-01T00:00:00'  / TT, with clock correction if CLOCKAPP
  TIMESYS = 'TT      '            / AXAF time will be TT (Terrestrial Time)
  MJDREF  =                 50814 / 1998-01-01T00:00:00 (TT) expressed in MJD (TT)
                                  / MJD = JD - 2400000.5
  TIMEZERO=                   0.0 / 0.0 is the cumulative clock correction
  TIMEUNIT= 's       '
  TIMEREF = 'LOCAL   '            / No pathlength corrections
* TASSIGN = '        '            / ???
* CLOCKAPP=                     T / Clock correction applied
* TIERRELA=                1.0E-9 / Short-term clock stability
* TIERABSO=                1.0E-4 / Absolute precision of clock correction
* TIMVERSN= 'ASC-FITS-1.0'        / AXAF FITS design document
  TSTART  =                   0.0 / As in the "TIME" column: raw space craft clock;
  TSTOP   =                   0.0 /   add TIMEZERO and MJDREF for absolute TT
* STARTMJF=                     0 / Major frame count at start
* STARTMNF=                     0 / Minor frame count at start
* STOPMJF =                     0 / Major frame count at stop
* STOPMNF =                     0 / Minor frame count at stop
* TIMEPIXR=                   0.0 / Time stamp refers to start of bin
* TIMEDEL =                   0.0 / Time resolution of data (in seconds)
```

```
# Observation, Full
                                 / Observation information block------------------
  OBSERVER= '        '           / Name of Principal Investigator/Guest Observer
  OBS_ID  = 'xxxxxxxxxxxxxxx'    / Whatever the convention is ...
  MISSION = 'AXAF    '           / Mission is AXAF
  TELESCOP= 'AXAF    '           / Telescope is AXAF
  INSTRUME= 'ACIS    '           / HRC, ACIS, EPHIN, S/C subsystems
  DETNAM  = 'ACIS-I  '           / Detector name
  GRATING = 'NONE    '           / Grating
  OBS_MODE= 'POINTING'           / Pointing, slew, or scan
  DATAMODE= '        '           / Datamode (varies only for science instr. data)
  SIM_X   =           0.0        / Position of SIM in mm
  SIM_Y   =           0.0        /
  SIM_Z   =        -237.4        /
  FOC_LEN =       10065.0        / Assumed focal length, mm
  ONTIME  =         100.0        / Sum of GTIs
  LIVETIME=          98.0        / Ontime multiplied by DTCOR
* DTCOR   =           0.98       / Dead time correction
                                 / Source information block-----------------------
  OBJECT  = '        '           / Source name
  RA_NOM  =              -100.0 / Nominal pointing
  DEC_NOM =              -100.0 / Nominal pointing
  ROLL_NOM=               -40.0 / Nominal roll angle, deg
  EQUINOX =              2000.0 / J2000.0
  RADECSYS= 'ICRS    '           / Julian coordinate reference frame
  DATACLAS= 'SIMULATED'          / If fake data,
                                / include this (default is DATACLAS='OBSERVED')
END


#########################################################################
# Ebounds extension for Energy grid

# Mandatory for HDU:

  XTENSION= 'BINTABLE'           / binary table extension
  BITPIX  =                    8 / 8-bit bytes
  NAXIS   =                    2 / 2-dimensional binary table
  NAXIS1  =                   12 / width of table in bytes
  NAXIS2  =                 1024 / number of rows in table
  PCOUNT  =                    0 / size of special data area
  GCOUNT  =                    1 / one data group (required keyword)

# Short CC

  EXTNAME = 'EBOUNDS '           / name of this binary table extension
  ORIGIN  = 'ASC     '
  CREATOR = 'xxx - Version 0.0'
  CHECKSUM= '0000000000000000'   / ASCII encoded HDU checksum
  DATASUM = '         0'         / Data unit checksum written in ASCII
```

```
  CONTENT = '        '           / What data product
  HDUNAME = '        '           / If no EXTNAME
  HDUDOC  = 'ASC-FITS-1.0: McDowell, Rots: ASC FITS File Designers Guide'
  HDUVERS = '1.0.0   '
* HDUCLASS= 'ASC     '           / format conforms to OGIP standard
* HDUCLAS1= 'RESPONSE'           / dataset relates to spectral response
* HDUVERS1= '1.0.0   '           / Version of family of formats
  HDUCLAS2= 'EBOUNDS '           / nominal energies of energy chan boundaries
  HDUCLAS3= '        '           / As needed ...
* HDUVERS2= '1.1.0   '           / Version of format (OGIP memo CAL/GEN/92-002a)

# Short Timing

  DATE    = '1997-01-01T00:00:00'  / Date and time of file creation (UTC)
  DATE-OBS= '1997-01-01T00:00:00'  / TT, with clock correction if CLOCKAPP
  DATE-END= '1997-01-01T00:00:00'  / TT, with clock correction if CLOCKAPP
  TIMESYS = 'TT      '           / AXAF time will be TT (Terrestrial Time)
  CLOCKAPP=                    T / Clock correction applied (if false)
  TIMEZERO=                  0.0 / Clock correction (if not zero)
  TIMEUNIT= 's       '
  MJDREF  =                50814 / 1998-01-01T00:00:00 (TT) expressed in MJD (TT)
                                 / MJD = JD - 2400000.5
  TSTART  =                  0.0 / As in the "TIME" column: raw space craft clock;
  TSTOP   =                  0.0 /   add TIMEZERO and MJDREF for absolute TT

#  Short Observation

  OBS_ID  = 'xxxxxxxxxxxxxxxx'   / Whatever the convention is ...
  MISSION = 'AXAF    '           / Mission is AXAF
  TELESCOP= 'AXAF    '           / Telescope is AXAF?
  INSTRUME= 'ACIS-I  '           / HRC, ACIS, EPHIN, S/C subsystems

# Table Coords

COMMENT    This table maps the channels in the Principal HDU axis 3
COMMENT    Aeff-image to energy.

TTYPE1  = 'CHANNEL '           / label for field   1
TFORM1  = 'I       '           / data format of the field
TTYPE2  = 'E_MIN   '           / label for field   2
TFORM2  = 'E       '           / data format of the field: 4-byte REAL
TUNIT2  = 'keV     '           / physical unit of field
TTYPE3  = 'E_MAX   '           / label for field   3
TFORM3  = 'E       '           / data format of the field: 4-byte REAL
TUNIT3  = 'keV     '           / physical unit of field

END
########################################################################
```