AXAF Science Center

Grating Data Products: Level 2 to ASC Archive Interface Control Document

(`http://space.mit.edu/ASC/docs/ICD_TGL2.ps.gz`)

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Document and Change Control Log

Date	Version	Section	Status
23 Apr 98	0.0	all	Initial Draft, for review by J.Houck
4 May 98 hline	1.0	all	Update for review

Unresolved Issues

The following is a list of unresolved, un-reviewed, or un-implemented items:

1. 980404: Only included spectrum file, exposure map (ARF) extension, and region extension.

   To be added: ARF (file); redistribution (RMF) (file); measurement products, summary products.

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1 Introduction

This document describes the interface to be employed in transferring the products of grating (HETG, the High Energy Transmission Grating, or LETG, the Low Energy Transmission Grating) obervations Standard Data Processing from the ASC Level 2 processing pipeline to the ASC Data Archive, according to the requirements stipulated in the "ASC Data System Requirements" (Applicable Document 3).

Formatting NOTE: Text formatted between horizontal rules (like this block) provide some historical context regarding alternative choices considered, which may still be debated.

Items boxed in the right margin (like this) are questions to be answered or TBD's to be replaced.

1.1 Purpose

TG (generically referring to HETG and LETG Transmission Grating instruments) Level 2 processing, described in Applicable Document 3, consists of processing TG Level 1.5 event files and ancillary products (which are described in Applicable Document 10 into a binned-spectral FITS file. This document describes the structure and content of the resulting files. In addition, the Level 2 pipeline produces ancillary calibration products (effective area and redistribution files), measurements (feature detection and characterization), and summary information products.

1.2 Scope

This interface shall apply to all TG-specific data products that are generated by ASC Level 2 pipelines and distributed to the ASC Data Archive (see Applicable Document 3 and the "ASC Data System Software Design," Applicable Document 4) during the course of the AXAF mission.

1.3 Applicable Documents

The Applicable Documents required for background and detail on grating Level 2 products are as follows:

1. AXAF Data Products Guide
   `http://hea-www.harvard.edu/asclocal/sds/CDR2/dp.ps`
2. AXAF Coordinate Systems
   `http://hea-www.harvard.edu/~jcm/asc/coords`
3. ASC AMO-2400 (SE03)
   ASC Data System Requirements (ASC.302.93.0008)
4. ASC AMO-2401 (DS01)
   ASC Data System Software Design (ASC.500.93.0006)
5. NOST 100-1.1, Definition of the Flexible Image Transport System (FITS)
   `http://www.cv.nrao.edu/fits/`
6. HEASARC FITS Standards:
   `http://heasarc.gsfc.nasa.gov/docs/heasarc/ofwg/ofwg_intro.html`

7. ASC FITS File Designers' Guide
   `http://hea-www.harvard.edu/~arots/asc/fits/ascfits.ps`
8. HRC Data Products Guide:
   Level 1 to ASC Archive Interface Control Document
   `http://hea-www.harvard.edu/asclocal/sds/ICD/l1icd.ps.gz`
9. ACIS Data Products Guide:
   Level 1 to ASC Archive Interface Control Document
   `http://space.mit.edu/ASC/docs/acis_l1.ps.gz`
10. Grating Data Products:
    Level 1.5 to ASC Archive Interface Control Document
    `http://space.mit.edu/ASC/docs/ICD_L1.5.ps.gz`
11. FITS File Names for the AXAF Archive:
    `http://hea-www.harvard.edu/~arots/asc/archive/files.html`
12. FITS REGION Binary Table Design (ASC-FITS-REGION-1.0)
    `http://hea-www.harvard.edu/~arots/asc/fits/region.ps`
13. The OGIP Spectral File Format (OGIP/92-007)
    `http://heasarc.gsfc.nasa.gov/docs/heasarc/TBD.html`

TBD: Get OGIP/92-007 URL

1.4 Functional Description

1.4.1 Data Content Summary

TG data sets generated by the Level 2 processing pipeline shall consist of data files conforming to the FITS format (Applicable Document 5) and further conforming to HEASARC standards (Applicable Document 6) and the ASC conventions (Applicable Document 7). These files contain header keyword entries and binary table (BINTABLE) extensions. Following rules outlined in Applicable Document 7, all these files will contain a null primary header followed by a main binary table (the "principal HDU") and auxiliary extensions ("auxiliary HDU").

Any other types of files will either be of types in common use (e.g., PostScript), or fully described here.

1.4.2 Recipients and Utilization

The primary recipients of TG Level 2 data products, via distribution from the archive, are AXAF observers, who will utilize these data products for scientific data analysis. The ASC may also make use of specific Level 2 data products for instrument calibration, instrument and/or spacecraft monitoring and trends analysis, and validation and verification of the Level 0, Level 1, Level 1.5, and Level 2 software and of the data products themselves.

1.4.3 Pertinent Relationships with Other Interfaces

Changes to the definition of Level 1.5 data products, as described in Applicable Document 10 may affect the Level 2 data products described in the current document.

1.5 Assumptions and Constraints

For each TG science event run reported in the AXAF telemetry stream, Level 2 processing shall generate a set of product files as described in Section 2.1. The products depend upon possibly time-dependent calibration data for coordinate transformations and region definitions.

The natural subdivision of TG processing prior to Level 2 is the Observation Interval (ObI). Each ObI may span several TG science runs, which are the atomic unit of the scientific instrument's telemetry. TG data prior to Level 2 will be processed by ObI. The Level 2 pipeline assumes that ObIs have been merged. This is not a necessary requirement, so each ObI (or other time-interval) can in principal produce its own Level 2 products, but the pipeline will process merged ObIs.

1.6 Products Not Covered

TG Level 2 products that are used for maintenance and diagnostic purposes (those that are not supplied to the user for scientific data analysis), or which are generic AXAF Level 2 products, are not currently included within the interface defined by this document.

2 Detailed Interface Specifications

2.1 Labeling and Identification

The data files generated by the Level 2 processing pipeline shall be assigned external names as defined by the following general convention, (specified in "FITS File Names for the AXAF Archive", Applicable Document 11):

<i><s><t><v>_[<f>_]<c><l>[<sl>].<type>

where the mnemonics are:

<i> instrument: "acis", "hrci", "hrcs", ...

<s> data source: "x", "f", "t", "b", "s", "u"

<t> TSTART (integer part): "##########"

<v> processing run (version): "N###"

<f> optional discriminator (e.g., an ACIS FEP Id)

<c> contents: "evt", "prf", "hst", "src", "win", "bias", "sum", ...

<l> processing level: single digit: "0", "1", "2"

<sl> sublevel: single lower case letter; e.g., 1.5 is "1a"

<type> superfluous: usually "fits"

Relevant default values for instrument (<i>) are `aciss` or `hrcs`; for data source (<s>) is "f" for flight (or possibly "s" for simulation). The appropriate designation for the processing level and sublevel is "2". Level 2 products are listed in Table 2.1.

*_hst2.fits	Binned spectra (**hist**ogram) file	required
*_arf.fits	spectral responses	Optional. May be included in binned spectrum file as a vector column.
*_rmf.fits	Spectral redistribution file	optional
*_reg2.fits	Spectral extraction region	Optional. By default, included in the FITS product as an extension.
*_TBD.fits	Spectral measurements.	Required. Strong features in spectrum.
*_sum.ps	Postscript summary	required
*_sum.html	Hypertext summary	TBR
*_TBD.gif	GIF summary images	TBR

Table 1: *These are required and optional grating Level 2 product files. The "*" designates an appropriate label sub-string as described in the text.*

2.2 Overview of Components

The "ASC FITS Designers' Guide" (Applicable Document 7) defines and lists general header components for the primary header and for all binary table extensions. Since grating data are always obtained with either the HRC or ACIS detectors, file content is also described in detail by the HRC and ACIS Level 1 Interface Control Documents (Applicable Documents 8 and 9). Level 1.5-added content is described in the Level 1.5 ICD (Applicable Document 10).

Spectrum: The basic product is a binned spectrum. This product is based on the OGIP Type II PHA Spectrum (see "The OGIP Spectral File Format", Applicable Document 13. New columns have been added to describe the source, spectrum part, and order. Column names have been taken from the Level 1.5 definition. The ACIS intrinsic energy region (PHA, or PI) is specified by calibration tables (named in the header) and by processing history (parameters).

Spectral Response: The spectral response is the effective area times exposure time (the exposure map). This accounts for variations in efficiency with position on the detector, including source position and position variation with time (dither) and detector gaps, as well as spectral order. It depends on the spatial/spectral extraction region (in particular the cross-dispersion aperture and the PI-order-sorting region, if ACIS), which are accounted for in the Level 2 exposure map calculation. This is traditionally referred to as an Auxiliary Response File (ARF). Since it is so source-specific for AXAF grating observations, we will by default include it as a column in the spectrum file.

> Issue: The units of an exposure map are $[\mathrm{cm}^2\,\mathrm{s}\,\text{Å}]$. Dividing counts by this, gives flux in units of $[\mathrm{photons}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}\,\text{Å}^{-1}]$. Should we instead normalize the spectrum by some exposure time (e.g., sum of global GTI)?

Spectral Redistribution: The redistribution describes the energy-dependent convolution kernel of the line-spread-function. It depends on the source position via the off-axis angle. Hence, it is in general different for every source, but varies slowly near the optical axis. It is provided as traditional OGIP Response Matrix Files (RMF), each of which may includes multiple orders.

Region: The binned spectra are selected from a spatial/spectral and PI (Pulse Invariant) region of the Level 1.5 file. The region is given in grating diffraction coordinates (one coordinate in the dispersion direction, and one in the cross-disperssion direction; see Applicable Documents 2 and 10). The spatial/spectral extraction region mask is by default encoded as a region extension (see "FITS REGION Binary Table Design (ASC-FITS-REGION-1.0)", Applicable Document 12) in the Level 2 FITS file. The PI region is not encoded explicitly, but is implicit in calibration files and processing history.

Measurements: The binned spectra have features such as emission lines, absorption lines, and edges. Standard measurement products derived from these spectra will be collected into FITS bintables. Those spectral measurements which can be done without significant scientific judgement (such as strong emission line detection and characterization) are done automatically by the Level 2 pipeline. The specific quantities will evolve with experience, and are tentatively (all TBR):

Measurement products TBD by J.Houck

- line wavelength and uncertainty
- line flux and uncertainty
- line width and uncertainty
- line ID
- continuum spectrum and uncertainty
- edge position and uncertainty
- edge depth and uncertainty

Other measurements can only be done via interactive analysis.

Summary: At the end of Level 2 processing, summary products are produced for quick-look inspection and assessment by the end-user, and also by ASC validation and verification processing. Products are tentatively: (all TBR)

- Postscript plots and tables of spectra, images, results (e.g., field image, spectral regions, PHA-position plots, binned spectra, total counts vs source, counts vs order vs source, fluxed spectra)
- HTML interface to summary products
- GIF versions of images and plots

Products may exist both as Postscript files which can be viewed or directly printed, and/or hypertext files for easy interactive viewing.

TBD by USG: summary products

2.3 Spectral Histogram Files (*_hst2.fits)

TBR: What's the right "content" string?

During Level 1.5 processing, event coordinates undergo several transformations. Given a zero-order centroid in sky coordinates, a region angle, and region width, events within each region are given several new coordinates. Proper interpretation of the spectrum requires consistent selection on several coordinates. These coordinates are carried over into the Level 2 spectrum file as attributes of the spectrum.

TG_SRCID is the source number, as output from the detection algorithm. A *TG_SRCID* of 0 means background — the photon has not been associated with a detected source.

TG_PART identifies the region of the spectrum of which the photon is a part. This can have only specific values as follows:

- **0:** zero order;
- **1:** HEG part of the spectrum;
- **2:** MEG part;
- **3:** LETG photon;
- **4–7:** LETG/HESF parts of the spectrum;
- **99:** background.

TG_M: The diffraction order, if resolved. This is a small integer, not likely to be of absolute value greater than 10 for HETG/ACIS-S. The value, 99, is used as a flag for "unresolved" or background photons.

For LETGS photons (detector is HRC, *TG_PART* is 3-7), *TG_M* will be either $+1$ or -1 (since HRC cannot resolve the orders via a pulse-height value).

The physically meaningful geometric limit set by the ACIS-S array with HETG is about ± 62. This is for a 10 keV photon observed with the aim-point at one end of the ACIS-S array, and the detected photon at the other end. It is not a likely scenario, but is used to define allowed physically conceivable data ranges.

2.3.1 Column Specifications

The contents of the FITS columns of the binned spectrum extension are given in Table 2. These generally conform to the OGIP Type II PHA definition, with some additions appropriate for AXAF grating spectra. Some columns are optional. The rest are mandatory for a Level 2 TG spectral file.

The length of the vector columns (specified by `TFORM`*n*, such as for "COUNT" or "FLUX") is given in the table as 16384. This is a *representative maximum length*! It could in principal be longer or shorter. For LETGS, for example, binning at a single resolution element per bin will give about 6700 bins, and HETGS about 3400. Analysis tools can specify arbitrary binning. Pipelines will default to 0.5-1.0 resolution-element bins.

The IEEE value, "NaN" (Not A Number) is used for missing real values. Note that this is not explicitly encoded as a TNULL keyword value in the header; it is implicit in the FITS standard.

2.3.2 Un-specified Columns

Any particular file *may* contain arbitrary additional columns, added at other stages of processing, or by a User. Though they are unspecified, they are permitted. Level 2 software (analysis tools) should ignore them or simply pass them through to output, as directed by Level 2 tool specifications. Their presence should, however, *not* invalidate the product as TG Level 2.

TTYPE	TUNIT	TFORM	TLMIN	TLMAX	TDBIN	TNULL	Comment
SPEC_NUM		1I	1	16384	1	0	spectrum number
ROWID		8A	N/A	N/A	N/A	‘’	Arbitrary string identifier
TG_M		1I	−62	62	N/A	99	order (m)
TG_PART		1I	0	99	N/A	N/A	component (HEG, MEG, LEG, . . .)
TG_SRCID		1I	1	TBD	N/A	0	source ID
ANCRFILE		64A	N/A	N/A	N/A	‘’	Ancillary response file name (ARF). Optional; by default, the response itself is included as a column.
RESPFILE		64A	N/A	N/A	N/A	‘’	Redistribution file name (RMF)
BACKFILE		64A	N/A	N/A	N/A	‘’	background file; Optional
BACKSCAL		1E	TBD	TBD	N/A	NaN	background scale factor (optional)
CORRFILE		64A	N/A	N/A	N/A	‘’	“correction” file (optional)
CORRSCAL		1E	TBD	TBD	N/A	NaN	“Correction” scale factor (optional)
CHANNEL		16384I	1	16384	1	0	vector of spectral “channel” numbers
COUNT	count	16384I	0	16384	1	TBD	count vector (a spectrum)
STAT_ERR	count	16384I	0	16384	1	TBD	statistical uncertainty (“error”) on count column
SYS_ERR	count	16384E	0.0	TBD	1	NaN	Systematic uncertainty on count vector column.
QUAL		16384I	0	16384	N/A	TBD	quality flag
GRPG		16384I	-1	1	N/A	TBD	grouping vector
BACKGND	count	16384E	0.0	TBD	1	NaN	background count vector
BINLO	angstrom	16384E	0.0	400.0	1.0E-04 (TBR)	NaN	Bin boundary, low coordinate
BINHI	angstrom	16384E	0.0	400.0	1.0E-04 (TBR)	NaN	Bin boundary, high coordinate
ARF	s cm**2 (TBR)	16384E	0.0	10000.	N/A	NaN	Effective area (TBR units: may normalize by EXPTIM)
FLUX	[photon or ergs] /s /cm**2 / [angstrom or kev]	16384E	0.0	TBD	TBD	NaN	Flux. Choice of ergs or photons per angstrom or keV.
FLUX_ERR	(same as FLUX)	16384E	0.0	TBD	TBD	NaN	Uncertainty on flux.

Table 2: *FITS spectrum data file binary table contents for extension “SPECTRUM” (one entry per spectrum). “N/A” means “Not Applicable”. The “TNULL” value of “NaN” stands for the IEEE “Not A Number” (which is not actually encoded into the header, but is implicit in the FITS convention). The “TNULL” value of “ ‘’ ” for strings represents the null-string.*

2.4 Keywords Describing Coordinate Systems

All columns either need no coordinate system, or are already in physical units. There are no `TCRPX`n, `TCRVL`n, etc., keywords required.

2.5 Keywords Describing Calibration Data

Resolution of HETGS (HETG + ACIS-S) photons into diffraction orders requires application of the calibration from wavelength to pulse-height (PI, for Pulse-Invariant signal), and information on the distribution of the response. To do this, a special table is read, which was in turn generated from the CCD response matrices (RMFs), for a given fractional enclosed energy. Subsequent processing will require knowledge of this filter, so keywords are stored in the event extension header, as defined in Table 3.

```
COMMENT Order-sorting lookup tables:
COMMENT   Tables of PI_min and PI_max vs E used for order-sorting,
COMMENT   constructed for a specific fractional enclosed probability
COMMENT Reference ICD for file definition is: TBD.
COMMENT
ACISDPIF='acis_fi_95_V0.0.fits'     /delta-PI vs energy table, FI CCD
ACISDPIB='acis_bi_95_V0.0.fits'     /delta-PI vs energy table, BI CCD
```

Table 3: *Special Keywords describing calibration files.*

TBD: Need reference ICD for order sorting table.

2.6 Grating Spectral Region Definitions (`REGION BINTABLE` extension)

During Level 1.5 processing, for each ObI, a regional mask is created for each observation, as defined by the zero-order sky coordinates output from source detection and width and angle parameters. The source regions are designed to be of generous dimensions, such that the L1.5 product is a superset of photons likely to be selected for analysis or Level 2 processing, thus avoiding re-running the L1.5 pipeline for alternate selection criteria. It is defined in sky (X, Y) coordinates (typically a right-ascension and declination tangent-plane system) and is used to filter the events for transformation to grating diffraction coordinates.

During Level 2 processing, additional filtering may be applied to sub-select within the Level 1.5 region, but more naturally in grating coordinates.

The generic definition of an ASC FITS region is given in the "FITS REGION Binary Table Design" (Applicable Document 12). The region HDU will be a single `REGION` auxiliary extension, whose header is comprised of these components:

- mandatory `REGION`-content header,
- table coordinate system and ranges,
- short configuration control,
- short timing, and
- short observation information.

The components which differ substantially from the event file's other extensions (events, GTI) are the mandatory `REGION` keywords, and the table coordinate system. A region specification is in general specific to the ObI.

The `REGION` definition for Level 1.5 spectral mask are comprised of parts described by a circle for zero-order and rotated boxes for diffracted orders. There are generally multiple components for each spectrum and possibly multiple sources per observation. Level 2 processing may apply additional filtering within the Level 1.5 region.

TTYPE	TUNIT	TFORM	TLMIN	TLMAX	Comment
`SHAPE`	-	16A	-	-	Shape of region: may be `CIRCLE`, `RECTANGLE`, `ROTBOX`, or `BOX`.
`tg_lam`	angstrom	$4E$	0	400.	Dispersion coordinate vector for `SHAPE`. Note that this *could* be any other coordinate in the dispersion direction, such as `TG_R` or `TG_MLAM`.
`TG_D`	deg	$4E$	-2.	2.	Cross-dispersion coordinate vector for `SHAPE`.
`R`	N/A	$4E$	0	2	radius vector for `SHAPE`. The interpretation of coordinates and units depends upon the `SHAPE`.
`ROTANG`	deg	$4E$	0	360	Rotation angle for SHAPE, in degrees.
`COMPONENT`	-	I	0	7	Component number that `SHAPE` belongs to (default is 1). This is equivalent to `TG_PART`.
`INCLUDE`	-	I	0	1	Inclusion (1; default) or exclusion (0).
`SOURCE`	-	I	1	TBD	Source identification number.
`TG_M`	-	I	1	62	Optional diffraction order. Different orders could be extracted from different regions.

Table 4: *FITS grating region file binary table contents.*

The interpretation of the `COMPONENT` value is shown in Table 5.

The interpretation of the coordinate vectors for grating region shapes, as given in the FITS region specification (Applicable Document 12) is:

`CIRCLE:` First element of X, Y, R vectors specifies center and radius.

`ROTBOX:` First element of each X and Y vectors specify the center of a rectangle. The first element of `ROTANG` specifies counter-clockwise rotation of the rectangle with respect to X and Y axes. The center of the rotation is the center of the rectangle (given by X, Y).

Other elements of X, Y are undefined. The first two elements of R specify the full-widths of X and Y, respectively.

GRATING	COMPONENT	Meaning
HETG	0	Zero-order (optional)
	1	HEG arm
	2	MEG arm
LETG	0	Zero-order (optional)
	3	LEG arm
	4	HESF (Drake Flat) region 1 (optional)
	5	HESF (Drake Flat) region 2 (optional)
	6	HESF (Drake Flat) region 3 (optional)
	7	HESF (Drake Flat) region 4 (optional)

Table 5: *Region table component interpretation. Zero-order regions are optional. Grating is either HETG or LETG. If Grating is LETG, then HESF parts are also optional. (Zero-order is generally not appropriate for binned spectral files.)*

For both grating types, component 0 is optional (e.g., if the zero-order was not imaged onto the detector). For the LETG, components 4–7 are optional (e.g., the source was not imaged onto the HESF (Drake Flat)).

2.7 Example: Full Region Extension Header

Insert a sample region header here.

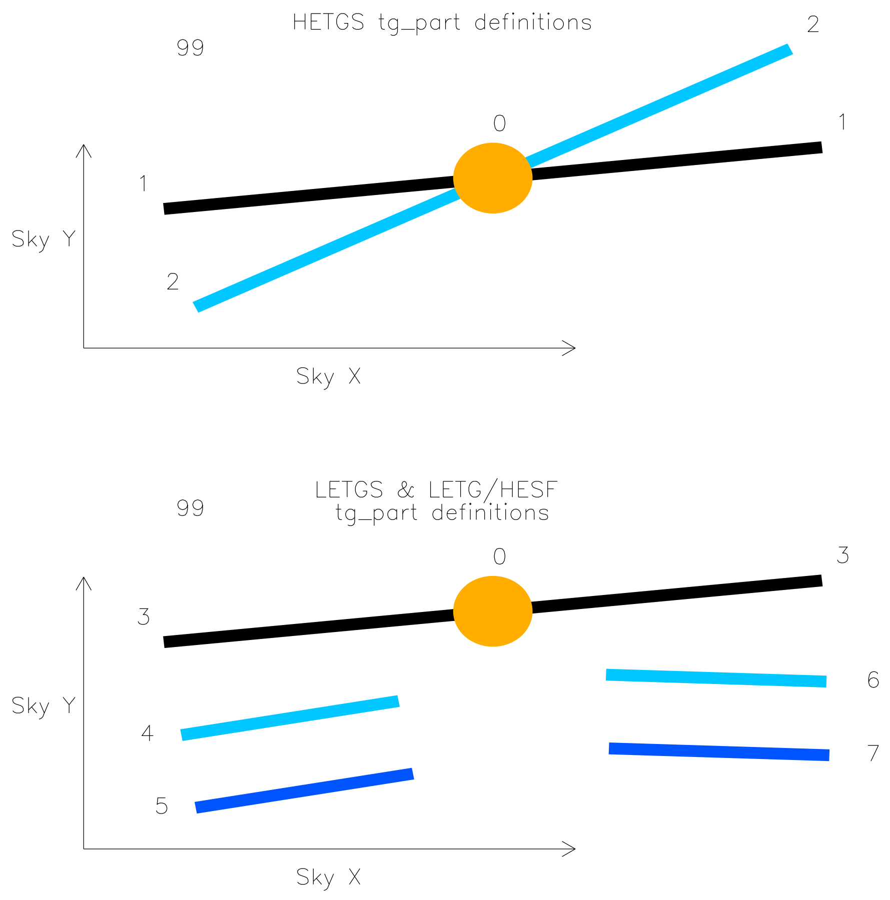

Figure 1: *This is a schematic representation of the grating region showing the different parts of the spectrum. On the top is the HETG specification, and on the bottom, LETG. For the LETG, the parts, 4–7 are optional, only being required if the HESF is in the beam. Scales are arbitrary. There has been a small rotation applied, to emphasize the fact that in sky coordinates, the spectrum can have any orientation. In Level 2 processing, region parts are obtained from a Level 1.5 event file column, and carried into the Level 2 product. Within each part, Level 1.5 processing assigns dispersion and cross-dispersion coordinates.*

2.8 Spectral Measurements Files

TBS

2.9 Redistribution Matrix File

TBS

2.10 Ancillary Response File

TBS

2.11 Summary Information Files

TBS

2.12 Volume, Size, and Frequency Estimates

TBS.

3 Example Files

labelpg:samples

```
TBS: HETG/ACIS-S 2 src FITS spectrum, region
     LETG/HRC_S 2 src
     LETG/HESF TBD.
```

3.1 Full Header: spectral histogram file

3.1.1 Primary Header

```
COMMENT                        / Mandatory for HDU -------------------------
SIMPLE  =                    T / file does conform to FITS standard
BITPIX  =                    8 / number of bits per data pixel
NAXIS   =                    2 / number of data axes
NAXIS1  =                    1 / length of data axis 1
NAXIS2  =                    1 / length of data axis 2
EXTEND  =                    T / FITS dataset may contain extensions
COMMENT   FITS (Flexible Image Transport System) format defined in Astronomy and
COMMENT   Astrophysics Supplement Series v44/p363, v44/p371, v73/p359, v73/p365.
COMMENT   Contact the NASA Science Office of Standards and Technology for the
COMMENT   FITS Definition document #100 and other FITS information.

COMMENT                        / Configuration control-------------------------
ORIGIN  = 'ASC     '
CREATOR = 'xxx     '           / - Version 0.0
CHECKSUM= 'WIFDa9CCWGCCa9CC'   / encoded HDU checksum updated on 07/04/98
DATASUM =                    0 / Data unit checksum written in ASCII
COMMENT

COMMENT                        / Time information block------------------------
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)
CLOCKAPP=                    T / Clock correction applied (if false)
TIMEZERO=                  0.0 / Clock correction (if not zero)
TIMEUNIT= 's       '           / time unit
MJDREF  =                50814 / 1998-01-01T00:00:00 (TT) expressed in MJD (TT)
TSTART  =                  0.0 / As in the "TIME" column: raw space craft clock;
TSTOP   =                  0.0 /   add TIMEZERO and MJDREF for absolute TT
COMMENT

COMMENT                        / Observation information block-----------------
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
PHAVERSN= '1992a   '           / OGIP memo number for file format
END
```

3.1.2 Spectrum Extension Header

```
COMMENT                           / Mandatory for HDU -------------------------
XTENSION= 'BINTABLE'              / binary table extension
BITPIX  =                       8 / 8-bit bytes
NAXIS   =                       2 / 2-dimensional binary table
NAXIS1  =                  140280 / width of table in bytes
NAXIS2  =                       2 / number of rows in table
PCOUNT  =                       0 / size of special data area
GCOUNT  =                       1 / one data group (required keyword)
TFIELDS =                      23 / number of fields in each row
TTYPE1  = 'SPEC_NUM'              / label for field   1
TFORM1  = 'I       '              / data format of field: 2-byte INTEGER
TUNIT1  = '        '              / physical unit of field
TTYPE2  = 'ROWID   '              / label for field   2
TFORM2  = '8A      '              / data format of field: ASCII Character
TUNIT2  = '        '              / physical unit of field
TTYPE3  = 'TG_SRCID'              / label for field   3
TFORM3  = 'I       '              / data format of field: 2-byte INTEGER
TUNIT3  = '        '              / physical unit of field
TTYPE4  = 'TG_PART '              / label for field   4
TFORM4  = 'I       '              / data format of field: 2-byte INTEGER
TUNIT4  = '        '              / physical unit of field
TTYPE5  = 'TG_M    '              / label for field   5
TFORM5  = 'I       '              / data format of field: 2-byte INTEGER
TUNIT5  = '        '              / physical unit of field
TTYPE6  = 'ANCRFILE'              / label for field   6
TFORM6  = '64A     '              / data format of field: ASCII Character
TUNIT6  = '        '              / physical unit of field
TTYPE7  = 'RESPFILE'              / label for field   7
TFORM7  = '64A     '              / data format of field: ASCII Character
TUNIT7  = '        '              / physical unit of field
TTYPE8  = 'BACKFILE'              / label for field   8
TFORM8  = '64A     '              / data format of field: ASCII Character
TUNIT8  = '        '              / physical unit of field
TTYPE9  = 'BACKSCAL'              / label for field   9
TFORM9  = '1E      '              / data format of field: 4-byte REAL
TUNIT9  = '        '              / physical unit of field
TTYPE10 = 'CORRFILE'              / label for field  10
TFORM10 = '64A     '              / data format of field: ASCII Character
TUNIT10 = '        '              / physical unit of field
TTYPE11 = 'CORRSCAL'              / label for field  11
TFORM11 = '1E      '              / data format of field: 4-byte REAL
TUNIT11 = '        '              / physical unit of field
TTYPE12 = 'CHANNEL '              / label for field  12
TFORM12 = '3500I   '              / data format of field: 2-byte INTEGER
TUNIT12 = '        '              / physical unit of field
TTYPE13 = 'COUNT   '              / label for field  13
TFORM13 = '3500I   '              / data format of field: 2-byte INTEGER
TUNIT13 = 'count   '              / physical unit of field
TTYPE14 = 'STAT_ERR'              / label for field  14
```

```
TFORM14 = '3500E   '           / data format of field: 4-byte REAL
TUNIT14 = 'count   '           / physical unit of field
TTYPE15 = 'SYS_ERR '           / label for field  15
TFORM15 = '3500E   '           / data format of field: 4-byte REAL
TUNIT15 = 'count   '           / physical unit of field
TTYPE16 = 'QUAL    '           / label for field  16
TFORM16 = '3500I   '           / data format of field: 2-byte INTEGER
TUNIT16 = '        '           / physical unit of field
TTYPE17 = 'GRPG    '           / label for field  17
TFORM17 = '3500I   '           / data format of field: 2-byte INTEGER
TUNIT17 = '        '           / physical unit of field
TTYPE18 = 'BACKGND '           / label for field  18
TFORM18 = '3500E   '           / data format of field: 4-byte REAL
TUNIT18 = 'count   '           / physical unit of field
TTYPE19 = 'BINLO   '           / label for field  19
TFORM19 = '3500E   '           / data format of field: 4-byte REAL
TUNIT19 = 'angstrom'           / physical unit of field
TTYPE20 = 'BINHI   '           / label for field  20
TFORM20 = '3500E   '           / data format of field: 4-byte REAL
TUNIT20 = 'angstrom'           / physical unit of field
TTYPE21 = 'ARF     '           / label for field  21
TFORM21 = '3500E   '           / data format of field: 4-byte REAL
TUNIT21 = 'cm**2   '           / physical unit of field
TTYPE22 = 'FLUX    '           / label for field  22
TFORM22 = '3500E   '           / data format of field: 4-byte REAL
TUNIT22 = 'photon /s /cm**2 /angstrom' / physical unit of field
TTYPE23 = 'FLUX_ERR'           / label for field  23
TFORM23 = '3500E   '           / data format of field: 4-byte REAL
TUNIT23 = 'photon /s /cm**2 /angstrom' / physical unit of field
EXTNAME = 'SPECTRUM'           / Extension name
COMMENT

COMMENT                        / Table Coordinate System Keywords--------------
COMMENT

COMMENT                        / Configuration control-------------------------
ORIGIN  = 'ASC     '
CREATOR = 'progname'           / v0.0.0
REVISION=                    0 / Processing system revision number
CHECKSUM= 'lnTamnSXlnSalnSU'   / encoded HDU checksum updated on 07/04/98
DATASUM = ' 262426642'         / data unit checksum updated on 07/04/98
CONTENT = 'SPECTRUM'           / What data product
HDUSPEC = 'LETG    '           / Level 2 Data Products ICD, Version 0.0  / ICD r
HDUDOC  = 'Arnaud  '           / et al. 1992a Legacy 2  p 65  Type: II
HDUVERS = '1.1.0   '
HDUCLASS= 'ASC     '           / format conforms to ASC Spectral standards
HDUCLAS1= 'SPECTRUM'           / Extension contains a Spectrum
HDUCLAS2= 'NET     '           / Extension contains a Spectrum
HDUCLAS3= 'RATE    '           / Extension contains rate
HDUCLAS4= 'TYPE:II '           / Multiple PHA file contained
LONGSTRN= 'OGIP    '           / 1.0            / The OGIP long string conventio
```

```
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 .
HISTORY    Input event file: acis123456789N000_evt0.fits

COMMENT                         / Time information block----------------------
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)
COMMENT                        / MJD   JD - 2400000.5
TIMEZERO=                  0.0 / 0.0 is the cumulative clock correction
TIMEUNIT= 's       '           /
BTIMNULL=                  0.0 / Basic Time offset (s)
BTIMRATE=                 0.25 / Basic Time clock rate (s / VCDUcount)
BTIMDRFT=                  0.0 / Basic Time clock drift (s / VCDUcount^2)
BTIMCORR=                  0.0 / Correction applied to Basic Time rate (s)
TIMEREF = 'LOCAL   '           / No pathlength corrections
TASSIGN = 'SATELLITE'          / Spacecraft clock
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-1.1'       / 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
STARTOBT=                    0 / On-Board MET close to STARTMJF and STARTMNF
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)

COMMENT                        / Observation information block-----------------
OBSERVER= '/       '           / Name of Principal Investigator/Guest Observer
OBS_ID  = 'xxxxxxxxxxxxxxxx'    / Whatever the convention is ...
MISSION = 'AXAF    '           / Mission is AXAF
TELESCOP= 'AXAF    '           / Telescope is AXAF
INSTRUME= 'ACIS    '           / HRC, ACIS, EPHIN, S/C subsystems
DETNAM  = 'ACIS-S  '           / Detector name
GRATING = 'HETG    '           / Grating
OBS_MODE= 'POINTING'           / Pointing, slew, or scan
DATAMODE= 'RAW     '           / 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
```

```
COMMENT                       / Source information block----------------------
OBJECT  = 'TEST    '          / 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'         / for real data, use  OBSERVED
END
```

3.1.3 Region Extension Header

TBS

3.2 Full Header: spectral redistribution file (RMF)

TBS

3.3 Full Header: spectral measurements file

TBS