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	1.0	all	Update for review
hline 8 July 98	1.1	all	Update for release; ARF deleted from Type II PHA file. Type II PHA header refined. Added spectral measurement products.

Unresolved Issues

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

1. 980713: Need ASC FITS guidelines for header keyword file-name references (e.g., to GTI file used for ARF generation).
2. 980709: Summary products deferred to USG (postscript, gif, html, TBD).
3. 980709: Output file names for measurement product pipeline applications (if any).
4. 980709: Content keywords identifying the various FITS extensions for measurement products.
5. 980709: Applicable document references for measurement products.

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.

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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 2).

1.1 Purpose

TG (generically referring to HETG and LETG Transmission Grating instruments) Level 2 processing, described in Applicable Document 2, consists of processing TG Level 1.5 event files and ancillary products (which are described in Applicable Document 7 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 2 and the "ASC Data System Software Design," Applicable Document 3) 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 Coordinate Systems
   `http://hea-www.harvard.edu/~jcm/asc/coords`
2. ASC AMO-2400 (SE03)
   ASC Data System Requirements (ASC.302.93.0008)
3. ASC AMO-2401 (DS01)
   ASC Data System Software Design (ASC.500.93.0006)
4. ASC FITS File Designers' Guide
   `http://hea-www.harvard.edu/~arots/asc/fits/ascfits.ps`
5. HRC Data Products Guide:
   Level 1 to ASC Archive Interface Control Document
   `http://hea-www.harvard.edu/asclocal/sds/ICD/l1icd.ps.gz`
6. ACIS Data Products Guide:
   Level 1 to ASC Archive Interface Control Document
   `http://space.mit.edu/ASC/docs/acis_l1.ps.gz`
7. Grating Data Products:
   Level 1.5 to ASC Archive Interface Control Document
   `http://space.mit.edu/ASC/docs/ICD_L1.5.ps.gz`

8. FITS File Names for the AXAF Archive:
   `http://hea-www.harvard.edu/~arots/asc/archive/files.html`
9. FITS REGION Binary Table Design (ASC-FITS-REGION-1.0)
   `http://hea-www.harvard.edu/~arots/asc/fits/region.ps`
10. 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 Data Content Summary

TG data sets generated by the Level 2 processing pipeline shall consist of data files conforming to the FITS format coforming to conventions described in the "ASC FITS File Designers' Guied" (Applicable Document 4, and references therein). These files contain header keyword entries and binary table (BINTABLE) extensions. Following rules outlined in Applicable Document 4, 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.

1.5 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.

1.6 Pertinent Relationships with Other Interfaces

Changes to the definition of Level 1.5 data products, as described in Applicable Document 7 may affect the Level 2 data products described in the current document.

1.7 Assumptions and Constraints

1.7.1 Missing or Undefined Data

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 table headers; it is implicit in the FITS standard.

1.7.2 Time Dependent Data

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. The products depend upon possibly time-dependent calibration data for coordinate transformations and region definitions.

1.7.3 Observation Intervals

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.

1.7.4 Un-specified FITS Bintable 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.

1.8 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 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 8):

<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.

Measurements files TBD by J.Houck

*_pha2.fits	Binned spectra, Level 2, contents are "Type II 'PHA' "	required
*_arf.fits	spectral responses	Required.
*_rmf.fits	Spectral redistribution file	Required
*_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 (TBS by USG)
*_sum.html	Hypertext summary	(TBR by USG)
*_TBD.gif	GIF summary images	(TBR by USG)

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

3 Overview of Files

The "ASC FITS Designers' Guide" (Applicable Document 4) 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 5 and 6). Level 1.5-added content is described in the Level 1.5 ICD (Applicable Document 7).

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 10. 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), which is equivalent to the exposure map divided by time ([cm^2] vs energy). It is a source-specific functio for AXAF grating observations. Since a finer grid than the counts spectrum is generally desired, it will be provided as a separate file, instead of including the information as another 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 [$\mathrm{photons\,cm}^{-2}\,\mathrm{s}^{-1}\,\text{Å}^{-1}$]. 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-dispersion direction; see Applicable Documents 1 and 7). 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 9) 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:

TBD by USG: summary products

- 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.

4 Spectral Histogram Files (*_pha2.fits)

Data Product Summary

ASC Data Product	Binned Spectrum
Instrument(s)	HETG, LETG
Level	2
Scientist/SDS	D. Huenemoerder
Filetype	PHA II
Created by tool	tgextract
Used by tool(s)	various
Sample file	TBS

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. It is permitted to store binned spectra from multiple sources in one Type II file. However, for archival use it is advantageous to split files by source when this can be done uniquely. Hence, pipeline binned spectral products will be per source.[1]

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.

[1] It must be kept in mind that if there are multiple sources in HETG observations the orders from different sources cross and photons in those regions may not be unambiguously resolved. If the region is scientifically important, the spectra must be analyzed jointly starting with the Level 1.5 event-list.

4.1 HDU Components

The following table (Table 4.1) describes the file structure by Header-Data Unit number, type, extension name, content, and HDU classes. An asterisk (*) denotes the principal HDU. The structure of the HDUs, as specified by the ASC FITS Guide

HDU	Type	EXTNAME	CONTENT	HDUCLASS	Description
1	NULL	N/A	N/A	N/A	
2 (*)	BINTABLE	SPECTRUM	SPECTRUM	ASC SPECTRUM TOTAL COUNTS TYPE:II TG	Binned spectra, vs order vs source, grid, and ancillary information.
3	BINTABLE	REGION	REGION	ASC REGION TG	Spectral-spatial region over which the spectrum was binned.

Table 2: *The Header-Data Unit structure of the binned spectrum FITS file.*

(Document 4), is

- Null Primary HDU:
  - image mandatory
  - null configuration control
  - short timing
  - short observation
- Principal table HDU:
  - bintable mandatory
  - table coordinates
  - full configuration control
  - full observation
  - full timing
- Auxiliary table HDU:
  - bintable mandatory
  - table coordinates
  - short configuration control
  - short timing
  - short observation

4.2 Column Specifications

The contents of the FITS columns of the binned spectrum extension are given in the following tables (Table 3). These generally conform to the “OGIP Type II PHA” definition (See Document 10), with some additions appropriate for AXAF grating spectra. Some columns are optional, but are listed for complete compatibility with the OGIP standard; those that probably won't be used are in a separate table (Table 4). Columns which are constant may be promoted to header keywords. Some are mutually exclusive; for example, if a `BACKGROUND` array column is present, then `BACKFILE` does not need to be specified. These various conditions will be explained below. The primary point of following the OGIP Type II specification is to maintain compatibility with XSPEC.

The length of the vector columns (specified by `TFORM`n, such as for "COUNTS" 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. Custom analysis may produce files only containing a few bins around lines of interest, or even arrays discontinuous in wavelength to hold several regions of interest.

The pipelines will bin the events into counts *vs.* wavelength, and fluxes into the natural units of photons $\mathrm{cm}^{-2}\,\mathrm{s}^{-1}\,\text{Å}^{-}1$ *vs.* Å, and so these are the units and coordinates specified in the column descriptions. However, custom analysis may convert wavelengths to energy units in the Level 1.5 event list, and then bin into counts *vs.* energy. Likewise, analysis could produce flux in units of ergs instead of photons. These are all permitted in a spectrum file, as long as consistency is maintained within the grid columns (BINLO, BINHI) and units column.

TTYPE	TUNIT	TFORM	TLMIN	TLMAX	TDBIN	TNULL	Comments
SPEC_NUM		1I	1	16384	1	0	Required. Spectrum number.
ROWID		64A	N/A	N/A	N/A	NONE	Optional; Arbitrary string identifier
TG_M		1I	−62	62	N/A	99	Required; diffraction order (m)
TG_PART		1I	0	99	N/A	N/A	Required; Spectral component (HEG, MEG, LEG, ...)
TG_SRCID		1I	1	TBD	N/A	0	Required; source ID. If constant (files split by source), then this becomes a header keyword: `TG_SRCID =` n
ANCRFILE		64A	N/A	N/A	N/A	NONE	Required; Ancillary response file name (ARF).
RESPFILE		64A	N/A	N/A	N/A	NONE	Required. Redistribution file name (RMF).
BACKFILE		64A	N/A	N/A	N/A	NONE	Optional; background file.
CHANNEL		16384I	1	16384	1	0	Required; Vector of spectral "channel" numbers.
COUNTS	counts	16384I	0	16384	1	TBD	Required; Counts array (a spectrum).
STAT_ERR	counts	16384I	0	16384	1	TBD	Optional; statistical uncertainty ("error") on count column.
QUALITY		16384I	0	16384	N/A	TBD	Optional; Quality flag.
GROUPING		16384I	-1	1	N/A	TBD	Optional. Grouping vector.
BACKGROUND	counts	16384E	0.0	TBD	1	NaN	Optional; background count vector.
BINLO	angstrom	16384E	0.0	400.0	1.0E-04 (TBR)	NaN	Required; Bin boundary, low coordinate.
BINHI	angstrom	16384E	0.0	400.0	1.0E-04 (TBR)	NaN	Required; Bin boundary, high coordinate
FLUX	photons /s /cm**2 / angstrom	16384E	0.0	TBD	TBD	NaN	Optional; Flux; ergs or photons per angstrom.
FLUX_ERR	(same as FLUX)	16384E	0.0	TBD	TBD	NaN	Optional. Uncertainty on flux.

Table 3: *Required and Recommended 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).*

TTYPE	TUNIT	TFORM	TLMIN	TLMAX	TDBIN	TNULL	Comments
BACKSCAL		1E	TBD	TBD	N/A	NaN	Optional. Background scale factor.
CORRFILE		64A	N/A	N/A	N/A	none	Optional. "Correction" file.
CORRSCAL		1E	TBD	TBD	N/A	NaN	Optional. "Correction" scale factor.
SYS_ERR	counts	16384E	0.0	TBD	1	NaN	Optional; Systematic uncertainty on count vector column.
AREASCL		1E	0.0	N/A	N/A	NaN	Optional; Area scaling factor, if ANCRFILE needs a correction. If not present as a column, then the header will have `AREASCL=1.0`

Table 4: *Spectrum FITS probably-unused 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). These are the columns defined by the OGIP Type II specification, but which are unlikely to be needed for AXAF grating spectra.*

Additional descriptions of table columns:

SPEC_NUM Required. Spectrum number.

ROWID Optional; Arbitrary string identifier

TG_M Required; diffraction order (m)

TG_PART Required; Spectral component (HEG, MEG, LEG, ...)

TG_SRCID Required; source ID. If the Level 1.5 file has been split by source, then this will be a constant for the Level 2 file, and it will become a header keyword (`TG_SRCID` $= n$).

ANCRFILE Required; Ancillary response file name (ARF). This is the output of the exposure map calculation. The file referred to will be an analog of this file in that each row here will have a corresponding row in the spectral response file.

RESPFILE Required. Redistribution file name (RMF). This is a redistribution from wavelength to position, and may contain one or more orders, and be valid for one or more sources.

BACKFILE Optional; background file. Mutually exclusive with the BACKGROUND column.

CHANNEL Required; Vector of spectral "channel" numbers.

COUNTS Required; Counts array (a spectrum).

STAT_ERR Optional; statistical uncertainty ("error") on count column. If the keyword POISSERR exists and has the value `T`, then this column need not be present. (Note that this condition applies to all rows.)

QUALITY Optional; Quality flag. The interpretation is as follows:

0: Good;

1: bad – never use;

2: dubious, recommend ignoring;

5: user-specified as bad;

Other values: spare.

If all values are 0, then this should be promoted to a header keyword (`QUALITY=0`) and the column deleted (note: this must be true for *all* rows).

GROUPING Optional. Grouping vector. If the data are un-grouped, then a header keyword is set (`GROUPING = 0`) and the column is not present. Otherwise, the interpretation is:

+1: channel starts a new group;

−1: channel is part of a continuing group;

0: grouping is undefined.

(Note that if *any* row is grouped, then all rows must have the grouping vector present.)

BACKGROUND Optional; background count vector. Mutually exclusive with the BACKFILE column.

BINLO Required; Bin boundary, low coordinate. By default, the bin units are Ångstroms. Custom analysis may produce other units.

BINHI Required; Bin boundary, high coordinate. Default units are Ångstroms. Custom analysis may produce other units, but the units of BINHI and BINLO must be the same.

FLUX Optional; Flux; Default units are photons $\mathrm{cm}^{-2}\,\mathrm{s}^{-1}\,\text{Å}^{-1}$, but custom analysis may specify other units. Flux is determined by dividing the count-rate by the effective area.

FLUX_ERR Optional. Uncertainty on flux. Only present if the FLUX column is defined.

BACKSCAL Optional; background scale factor

CORRFILE Optional; "correction" file

CORRSCAL Optional; "Correction" scale factor

SYS_ERR Optional; Systematic uncertainty on count vector column. If present, these values may get added in quadrature to the statistical errors by processing software (such as XSPEC).

AREASCL This is an optional area-scaling factor. It is most likely a constant and equal to 1.0, and so should be a header keyword (if present at all). It is only for XSPEC compatibility.

4.3 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.

4.4 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 5.

```
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 5: *Special Keywords describing calibration files.*

TBD: Need reference ICD for order sorting table.

4.5 Grating Spectral Region Definitions

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, in which the zero-order is at the origin.

The generic definition of an ASC FITS region is given in the "FITS REGION Binary Table Design" (Applicable Document 9). 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. A schematic of the HETG, LETG, and HESF regions in sky coordinates is shown in Figure 4.5. The interpretation of the `COMPONENT` value is shown in

TTYPE	TUNIT	TFORM	TLMIN	TLMAX	Comment
`SHAPE`	-	16A	-	-	Shape of region: may be `CIRCLE`, `RECTANGLE`, `ROTBOX`, or `BOX`.
`TG_LAM`	angstrom	$2E$	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`, but `tg_lam` is the default.
`TG_D`	deg	$2E$	-2.	2.	Cross-dispersion coordinate vector for `SHAPE`.
`R`	N/A	$2E$	0	2	radius vector for `SHAPE`. The interpretation of coordinates and units depends upon the `SHAPE`.
`ROTANG`	deg	$2E$	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).
`TG_SRCID`	-	I	1	TBD	Source identification number. If constant (files split by source), then this becomes a header keyword: `TG_SRCID` $= n$.
`TG_M`	-	I	1	62	Optional diffraction order. Different orders could be extracted from different regions.

Table 6: *FITS grating region file binary table contents.*

Table 7. The interpretation of the coordinate vectors for grating region shapes, as given in the FITS region specification (Applicable Document 9) is:

`CIRCLE:` First element of X (`tg_lam`), Y (`tg_d`), 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 rectan-

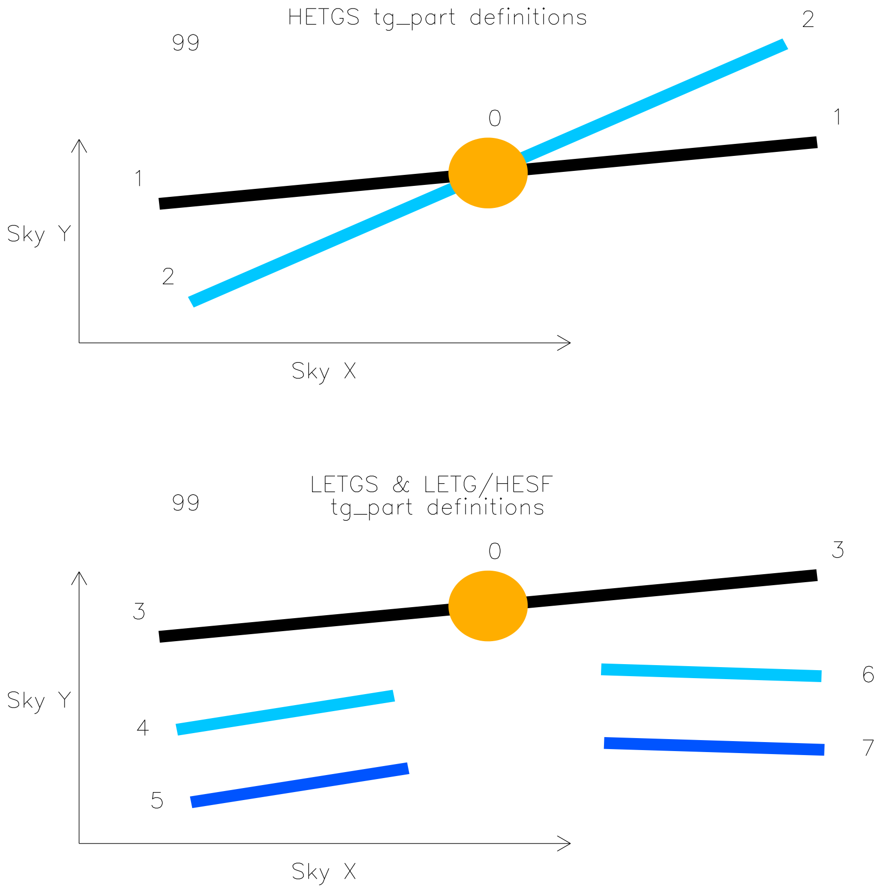

Figure 1: *This is a schematic representation of the grating region showing the different parts of the spectrum. On the top is the HETG specification, and on the bottom, LETG. For the LETG, the parts, 4–7 are optional, only being required if the HESF is in the beam. Scales are arbitrary. There has been 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.*

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 7: *Region table component interpretation. Grating is either HETG or LETG. By default, all diffracted components present are binned.*

gle 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. (Note that the length of the R vector of 2 elements has set the other quantities to 2 elements, even though only the first is used for `CIRCLE` and `ROTBOX`.)

The diffraction coordinates must be tied to the region generic "X" and "Y" tokens so that the `SHAPE` and `R` columns can be properly interpreted. The mechanism for this is via "Data Model" keywords:

```
MFORMn  = 'TG_LAM, TG_D'       / wavelength vs cross-disp angle
MTYPEn  = 'wav-pos '           / Wavelength-vs-position coords
```

where n is the n^{th} coordinate pair (and here would be 1, since there are no others). These keywords specify that `TG_LAM` is to be treated as X and `TG_D` is to be treated as Y, according to the region file specification. There are other coordinates which could be used for the dispersion, such as `TG_R` and `TG_MLAM`. As an example with the former, the header coordinate keywords would become:

MTYPE TBD.

```
MFORMn  = 'TG_R, TG_D'       / wavelength vs cross-disp angle
MTYPEn  = 'pos '           / Wavelength-vs-position coords
```

4.6 Volume, Size, and Frequency Estimates

TBS.

5 Spectral Measurements Files

The quick-look tools are intended to provide the user with a quick introduction to potentially complex, high-resolution X-ray spectra (see section **??**). They perform automated detection of strong spectral features, automated fitting of profile functions to detected features, and automated search of a line database to provide candidate identifications for the detected features. Note that the output from these tools is *not suitable for precise quantitative comparison to physical models*, nor was it intended to be. Quantitative analysis of high resolution X-ray spectra requires human guidance (see section **??**) and is intended to be done using interactive software such as the ASC Data Visualizer (see Applicable Document (TBD)).

5.1 Detailed Interface Specifications

The primary input file is a binned spectrum (histogram) file based on the OGIP Type II PHA spectrum file as described in section **??**. The primary reference data is the spectral line database as described in TBR. The grating line spread function may also be referenced in a future release; at this writing, it is not used. The output file formats are defined in detail in the following sections.

Need document name for spectral line databse ICD

5.1.1 Labeling and Identification

The output files generated by the TG Level 2 quick-look tools shall be assigned external names at the discretion of the user.

File names used for Level 2 pipeline application (if any, TBR) are TBD.

5.1.2 Substructure Definition and Format

The "ASC FITS Designers' Guide" (Applicable Document 4) defines and lists 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 Document 6).

5.1.3 Output File Types

Because input binned spectrum files may contain multiple spectra (histograms), the output format for these tools provides support for the processing of multiple spectra. When multiple spectra are processed, the associated output tables are collected in separate FITS extensions, with one (or sometimes two) extension(s) per input spectrum. The following types of output are produced:

Detect: contains a list of detected emission lines generated by `line_detect_features` along with an (optional) estimate of the global continuum shape in the input spectrum. If present, the estimated continuum histogram is placed in a separate FITS extension.

Fit: contains a list of best-fit parameters generated by `line_measure_features`. These parameters usually represent the line profile and the (optional) associated local continuum shape.

Identification: contains line identifications generated by `line_identify_features`. For each observed line, the tool extracts a list of lines from the spectral line database which 1) lie within some user-defined tolerance of the rest wavelength of the detected peak and which are 2) predicted to be relatively strong at the user-specified collisional ionization equilibrium temperature.

At this writing, the quick-look tools process only emission lines and continuum. Nevertheless, where possible, we often use the term “spectral feature” rather than “emission line” to allow for future upgrades which may include processing of absorption lines, absorption edges, recombination features and blends. In many cases, it is not convenient to retain this level of generality in the discussion of file format details; in those cases we specialize our terminology to that of emission lines. We have tried to make the discussion as clear as possible and to apply appropriate levels of generality. Nevertheless, please be aware of this conflict in terminology and try to interpret this document appropriately.

5.2 Detect:

Data Product Summary

ASC Data Product	Detected Features
Instrument(s)	HETG, LETG
Level	2
Scientist/SDS	J. Houck
Filetype	FITS bintable
Created by tool	`line_detect_features`
Used by tool(s)	various
Sample file	TBS

`line_detect_features` scans each input spectrum and generates a list of emission lines and an optional estimate of the global continuum shape. For details on the input parameters and the algorithms used, see the `line_detect_features` manual page. For a single input spectrum, the detect output may occupy one or two FITS extensions. The first extension contains the list of detected emission lines and the (optional) second extension contains the estimated global continuum.

5.2.1 Detect HDU Components

The following table (Table 5.2.1) describes the file structure by Header-Data Unit number, type, extension name, content, and HDU classes. An asterisk (*) denotes the principal HDU. The structure of the HDUs, as specified by the ASC FITS Guide

HDU	Type	EXTNAME	CONTENT	HDUCLASS	Description
1	NULL	N/A	N/A	N/A	
2 (*)	BINTABLE	LINELIST	LINELIST	ASC LINELIST	List of emission lines detected in an input spectrum.
3	BINTABLE	SPECTRUM	SPECTRUM	ASC SPECTRUM	Continuum function used in line detection.

Table 8: *The Header-Data Unit structure of the* `line_detect_features` *output FITS file.*

(Document 4), is

- Null Primary HDU:
  - image mandatory
  - null configuration control
  - short timing
  - short observation
- Principal table HDU:
  - bintable mandatory
  - table coordinates
  - full configuration control
  - full observation
  - full timing
- Auxiliary table HDU:
  - bintable mandatory
  - table coordinates
  - full configuration control
  - full observation
  - full timing

5.2.2 Keywords Describing Processing History

The following keywords are used to record the parameter settings in effect when the `line_detect_features` output was generated. These settings determine the detection thresholds and (optional) continuum estimation algorithm.

```
HISTFILE='foo_pha2.fits'            /Input binned spectrum (histogram) file
SPECNUM=                          1 /Which spectrum
CONTFILE='NONE'                     /Input continuum histogram file
EMTHRESH=                       4.0 /Emission line detect threshold (sigma)
ABTHRESH=                       0.0 /Absorption line detect threshold (sigma)
CONTMETH='MEDIAN'                   /Continuum calculation method
WINDOWSZ=                        50 /Size of running window (# bins)
ENDMETHD='DEFAULT'                  /Continuum end segment treatment
LENDVALU=                       0.0 /Short wavelength end continuum value
HENDVALU=                       0.0 /Long wavelength end continuum value
LOCUT=                          0.2 /Low end of median filter
HICUT=                          0.8 /High end of median filter
```

Table 9: Keywords describing `line_detect_features` line table extension.

5.2.3 Line Table Column Specifications

The line table contains a list of detected emission lines, giving an estimated center position, amplitude and FWHM for each along with an estimate of the continuum level and continuum slope at the position of each line.

TTYPE	TUNIT	TFORM	TLMIN	TLMAX	TDBIN	TNULL	Comment
INDEX		1I	1.0	16384	1	0	Feature number
POSITION	angstrom or keV	1E	TBD	TBD	N/A	NaN	Feature position. Line center for emission and absorption lines, edge position for absorption edges.
FWHM	angstrom or keV	1E	TBD	TBD	N/A	NaN	Line full width and half maximum above (emission) or below (absorption) continuum
AMPLITUDE	(same as input spectrum)	1E	TBD	TBD	N/A	NaN	Max height of peak above continuum (emission) or max depth below continuum (absorption).
CONTINUUM	(same as input spectrum)	1E	TBD	TBD	N/A	NaN	Estimated continuum level at tabulated position.
CONTSLOPE	(input spectrum unit) / [angstrom or keV]	1E	TBD	TBD	N/A	NaN	Slope of estimated continuum at tabulated position.

Table 10: Contents of the `line_detect_features` line table extension (one entry per detected feature). "N/A" means "Not Applicable". "*NaN*" is the IEEE standard for "Not A Number".

5.2.4 Keywords Describing Processing History

Except for the CONTENT keyword, all history keywords used in the line table HDU should be repeated in the continuum table HDU. The following additional keywords may also appear in the continuum table HDU.

5.2.5 Continuum Table Column Specifications

The continuum table contains the continuum spectrum which was used by the detect algorithm along with a copy of the continuum subtracted spectrum. The histogram bins are the same as those in the input spectrum.

TTYPE	TUNIT	TFORM	TLMIN	TLMAX	TDBIN	TNULL	Comment
INDEX		1I	1.0	16384	1	0	Bin index
BINLO	angstrom or keV	1E	0.0	400.0	TBR	NaN	Bin boundary, low coordinate
BINHI	angstrom or keV	1E	0.0	400.0	TBR	NaN	Bin boundary, high coordinate
CONTINUUM	(same as input spectrum)	1E	TBR	TBR	TBR	NaN	Continuum level
NET	(same as input spectrum)	1E	TBR	TBR	TBR	NaN	Continuum subtracted spectrum

Table 11: Contents of `line_detect_features` continuum table extension. "N/A" means "Not Applicable". "NaN" is the IEEE standard for "Not A Number".

5.3 Fit:

Data Product Summary

ASC Data Product	Fit Parameters
Instrument(s)	HETG, LETG
Level	2
Scientist/SDS	J. Houck
Filetype	FITS bintable
Created by tool	`line_measure_features`
Used by tool(s)	various
Sample file	TBS

`line_measure_features` processes an input spectrum using the output from `line_detect_features` to generate a list of best fit parameters and associated confidence limits. A single set of parameters is listed for each detected feature. The output file will use the FITS Embedded Function format definition with additional special keywords defined below and with additional columns to hold confidence limits and best-fit statistics for each fit parameter.

5.3.1 Fit HDU Components

The following table (Table 5.3.1) describes the file structure by Header-Data Unit number, type, extension name, content, and HDU classes. An asterisk (*) denotes the principal HDU. The structure of the HDUs, as specified by the ASC FITS Guide

HDU	Type	EXTNAME	CONTENT	HDUCLASS	Description
1	NULL	N/A	N/A	N/A	
2 (*)	BINTABLE	PARAMETERS	FUNCTION	ASC FUNCTION PARAMETERS SPECTRUM	List of fit parameters for features detected in an input spectrum.

Table 12: *The Header-Data Unit structure of the* `line_measure_features` *output FITS file.*

(Document 4), is

- Null Primary HDU:
  - image mandatory
  - null configuration control
  - short timing
  - short observation
- Principal table HDU:
  - bintable mandatory
  - table coordinates
  - full configuration control
  - full observation
  - full timing

5.3.2 Keywords Describing Processing History

The `line_measure_features` parameter file values used to generate the model fits are recorded in the following keywords.

```
HISTFILE='foo_pha2.fits'          /Input binned spectrum (histogram) file
SPECNUM=                        1 /Which spectrum
DTCTFILE='foo_det2.fits'          /Input detect file
FITREG =                      2.0 /fit region: line_ctr +/- fit_reg * fwhm_max
FITMETH='simplex'                 /ASCfit method
FITSTAT='chi parent'              /ASCfit statistic
FITCONF=                     68.3 /Confidence level
```

Table 13: Keywords describing the `line_measure_features` parameter table extension.

5.4 Identification:

Data Product Summary

ASC Data Product	Feature Identifications
Instrument(s)	HETG, LETG
Level	2
Scientist/SDS	J. Houck
Filetype	FITS bintable
Created by tool	`line_identify_features`
Used by tool(s)	various
Sample file	TBS

Given a list of detected spectral features from `line_detect_features` with positions and amplitudes refined by `line_measure_features`, `line_identify_features` matches detected features with features in the spectral database. Matching features may be filtered using a number of criteria which are described in the tool manual page. Several candidate identifications may be associated with each detected feature.

5.4.1 Identify HDU Components

The following table (Table 5.4.1) describes the file structure by Header-Data Unit number, type, extension name, content, and HDU classes. An asterisk (*) denotes the principal HDU. The structure of the HDUs, as specified by the ASC FITS Guide

HDU	Type	EXTNAME	CONTENT	HDUCLASS	Description
1	NULL	N/A	N/A	N/A	
2 (*)	BINTABLE	PARAMETERS	TBD	ASC PARAMETERS LINELIST	List of line identifications

Table 14: *The Header-Data Unit structure of the* `line_identify_features` *output FITS file.*

(Document 4), is

- Null Primary HDU:
  - image mandatory
  - null configuration control
  - short timing
  - short observation
- Principal table HDU:
  - bintable mandatory
  - table coordinates
  - full configuration control
  - full observation
  - full timing

5.4.2 Keywords Describing Processing History

The `line_identify_features` parameters used to control the line identification algorithm are recorded in the following keywords. These parameters are used mainly as filters to simplify the task of identification and to reduce the volume of data returned from the spectral database.

```
DTCTFILE='foo_det2.fits'            /Input list of detected spectral features
SPECNUM=                          1 /Which spectrum
LINELIST='db_line.fits'             /Spectral line database
DOPPUNIT='redshift'                 /Source Doppler shift units
DOPPSHFT=                       0.6 /Source Doppler shift
LINETOL =                       0.0 /Fractional position error tolerance
TEMPUNIT='keV'                      /Source temperature unit
TEMPTURE=                       5.0 /Source temperature
DENSITY =                    1.0e-3 /Source ion number density [cm^-3]
FILTER  ='Mg, Si, S, ~Fe'           /Line list filter string
```

Table 15: Keywords describing `line_identify_features` line table extension.

5.4.3 Identification Table Column Specifications

For each observed feature, this table contains a list of items in the spectral database which fit the search criteria. Each item is listed by name (element, ion and transition specification) along with a predicted strength (if available).

For each list of matching lines, a *representative maximum* list length of 16384 is given in the table. We anticipate that most reasonable searches will return far fewer candidate identifications! However, alternate uses of this format could make use of lists which are longer or shorter.

TTYPE	TUNIT	TFORM	TLMIN	TLMAX	TDBIN	TNULL	Comment
INDEX		1I	1	16384	1	0	Observed peak index
POSOBS	angstrom or keV	1E	0.0	400.0	N/A	NaN	Observed peak position
POSREST	angstrom or keV	1E	0.0	400.0	N/A	NaN	Observed peak rest position
NMATCHES		1I	0	16384	N/A	0	Number of matching lines in the database
MINDEX		16384I	0	16384	N/A	0	db line index
MPOS	angstrom or keV	16384E	0.0	400.0	N/A	NaN	db line position
MSTR	TBS	16384E	TBR	TBR	N/A	NaN	db line strength
MDBID		16384I	1	16384	N/A	0	db line id number
MELEM		16384A	N/A	N/A	N/A	‘’	db element label
MIONCHG		16384I	1	100	N/A	999	db ion charge label
MLABEL		16384A	N/A	N/A	N/A	‘’	db line transition label

Table 16: Contents of `line_identify_features` line table extension. “N/A” means “Not Applicable”. “NaN” is the IEEE standard for “Not A Number”.

5.5 Volume, Size, and Frequency Estimates

TBS

5.6 Example Files

TBS

6 Ancillary Response Files (*_arf.fits)

Data Product Summary

ASC Data Product	Grating Spectral Response ("ARF")
Instrument(s)	HETG, LETG
Level	2
Scientist/SDS	D. Huenemoerder
Filetype	ARF Type II
Created by tool	tgarfcalc
Used by tool(s)	various
Sample file	TBS

The Ancillary Response File (ARF) is the effective area function, or spectral response. For AXAF grating data, however, we have many responses: one for each order. In addition, the zero-order placement and the aspect dither conspire with the detector geometry to place gaps and edges at different parts of the spectrum for different lengths of time. Hence, the ARF is really an "exposure map". The file-structure will be very similar to the binned spectrum and carry much of the same information: we define a "Type II ARF" to match the Type II PHA file. A major difference is that the wavelength grid may be finer than the binned spectrum's grid.

6.1 HDU Components

The following table (Table 6.1) describes the file structure by Header-Data Unit number, type, extension name, content, and HDU classes. An asterisk (*) denotes the principal HDU.

HDU	Type	EXTNAME	CONTENT	HDUCLASS	Description
1	NULL	N/A	N/A	N/A	
2 (*)	BINTABLE	RESPONSE	SPECRESP	ASC RESPONSE SPECRESP TYPE:II TG	Spectral response (ARF), vs order vs source, grid, and ancillary information.
3	BINTABLE	REGION	REGION	ASC REGION TG	Spectral-spatial region over which the spectral response was averaged.

Table 17: *The Header-Data Unit structure of the spectral respose FITS file.*

The structure of the HDUs, as specified by the ASC FITS Guide (Document 4), is

- Null Primary HDU:
  - image mandatory
  - null configuration control
  - short timing
  - short observation
- Principal table HDU:

  - bintable mandatory
  - table coordinates
  - full configuration control
  - full observation
  - full timing

- Auxiliary table HDU:
  - bintable mandatory
  - table coordinates
  - short configuration control
  - short timing
  - short observation

6.2 Column Specifications

The contents of the FITS columns of the spectral respose extension are given in the following tables (Table 18). These generally are a subset of the binned spectrum columns.

The length of the vector columns (specified by `TFORM`*n*, such as for "BINLO" or "SPECRESP") 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 for the data. Custom analysis may produce files only containing a few bins around lines of interest, or even arrays discontinuous in wavelength to hold several regions of interest. The respose should in general have smaller bins than the data.

The spectral response will be by default calculated in units of [$\mathrm{cm}^2\,\mathrm{counts\,photon}^{-1}$] *vs.* [Å] (note that [$\mathrm{counts\,photon}^{-1}$] is a unitless quantity). Custom analysis may convert wavelengths to energy units, or analysis could produce flux in units of ergs instead of photons, and a response in commensurate units. These are all permitted in a valid response file as long as consistency is maintained within the grid columns (BINLO, BINHI) and units column.

6.3 Special Header Keywords

Knowledge of the generating parameters for the spectral response are crucial to its application to a counts spectrum. The response is determined by the calibration data, by the zero-order position, by the good-time-intervals and aspect history, and by filtering conditions. When Level 1.5 events are resolved to orders and binned, both spatial and PHA regions are clipped, and both affect the effective area. All these must be accounted for in generating the response and stored in header keywords. These keywords (*cf.* Table 5 on page 13) are:

ACISDPIF: This is the name of the file used to define the PI-clipping region used in order-resolution for ACIS front-illuminated (FI) observations. The table gives the upper and lower bounds on PI vs energy for some fractionally enclosed probability. (Use of one table for FI assumes that all FI CCD's have the same PI response.)

TTYPE	TUNIT	TFORM	TLMIN	TLMAX	TDBIN	TNULL	Comments
RESP_NUM		1I	1	16384	1	0	Required. Response index.
ROWID		64A	N/A	N/A	N/A	NONE	Optional; Arbitrary string identifier
TG_M		1I	−62	62	N/A	99	Required; diffraction order (m)
TG_PART		1I	0	99	N/A	N/A	Required; Spectral component (HEG, MEG, LEG, ...)
TG_SRCID		1I	1	TBD	N/A	0	Required; source ID of source in spectrum file to which this response applies. If constant (file split on source), then this is promoted to a keyword. If null-valued, then the response is for a region for which no source spectrum has been extracted.
CHANNEL		16384I	1	16384	1	0	Required; Vector of spectral "channel" numbers.
SPECRESP	cm**2	16384I	0	16384	1	TBD	Required; The spectral response array.
STAT_ERR	cm**2	16384I	0	16384	1	TBD	Optional; statistical uncertainty ("error") on the response array.
BINLO	angstrom	16384E	0.0	400.0	1.0E-04 (TBR)	NaN	Required; Bin boundary, low coordinate.
BINHI	angstrom	16384E	0.0	400.0	1.0E-04 (TBR)	NaN	Required; Bin boundary, high coordinate

Table 18: *FITS spectral respose data file binary table contents for extension "SPECRESP" (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).*

ACISDPIB: This is the name of the file used to define the PI-clipping region used in order-resolution for ACIS back-illuminated (BI) observations. The table gives the upper and lower bounds on PI vs energy for some fractionally enclosed probability. (Use of one table for FI assumes that all FI CCD's have the same PI response.)

ASP_FILE Filename of aspect solution (or offsets) file used to generate the response.

GTI_FILE: Reference to the file used for Good Time Intervals.

6.4 Region Extension

Generally, the response is averaged over the same region for which a particular spectrum has been binned. In this case, the region extension will match that in the binned spectrum file. It is possible, however, to create the response for an assumed position, independent of any observed source. In this case, the TG_SRCID will have a null value, and we need to specify the (virtual) zero-order reference point. Other crucial piece of reference information are the aspect solution and time-filter applied. We give these with the header keywords:

```
RA_ZO   = xxx.xxxxx    / Assumed zero-order right-ascenion (degrees)
DEC_ZO  = syy.yyyyy    / Assumed zero-order declination (degrees)
ASP_FILE= 'filename'   / Aspect solution (or offsets) filename
GTI_FILE= 'filename'   / Aspect solution (or offsets) filename
```

The region extension is otherwise as given in Section 4.5.

6.5 Volume, Size, and Frequency Estimates

TBD.

6.6 Example Files

TBS.

7 Redistribution Matrix File

TBS

8 Summary Information Files

TBS by USG

A Example Header: Spectral Histogram

TBS.