AXAF Science Center

HEAD-CC-3

1998 December 11

AXAF Dispersive Spectroscopy Pipeline Overview

David Huenemoerder

1 Outline

Pipeline data flow - all the steps, inputs, and products to go from event-lists, to diffraction coordinates, to binned spectra, and simple measurements for both HETG and LETG.

Graphical examples - some views of the data, test cases.

Data product descriptions - detailed descriptions of the data products, if you really want to know.

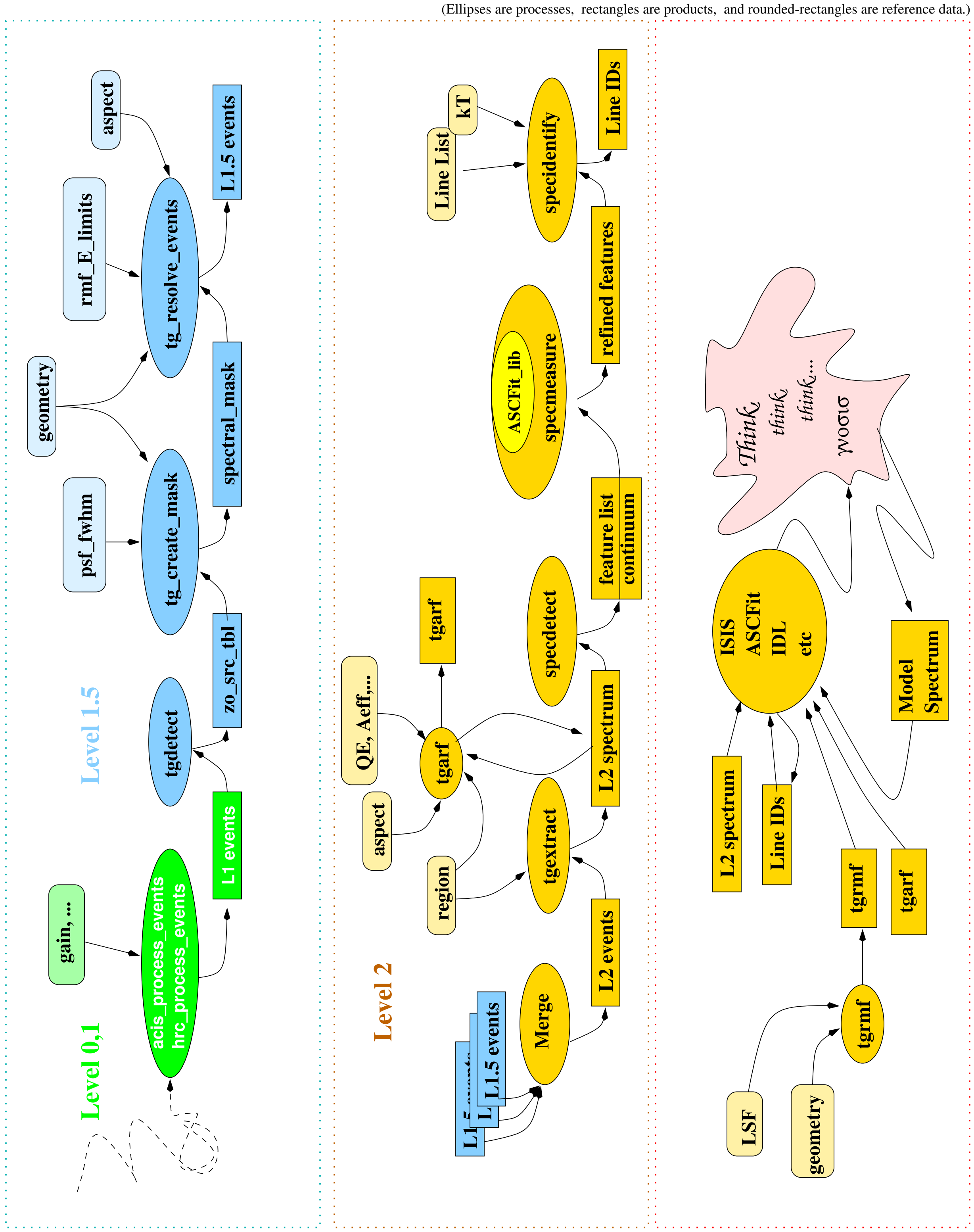
Issues - unfinished, unresolved, ...

Credits - who does what.

Information - some links, for more details.

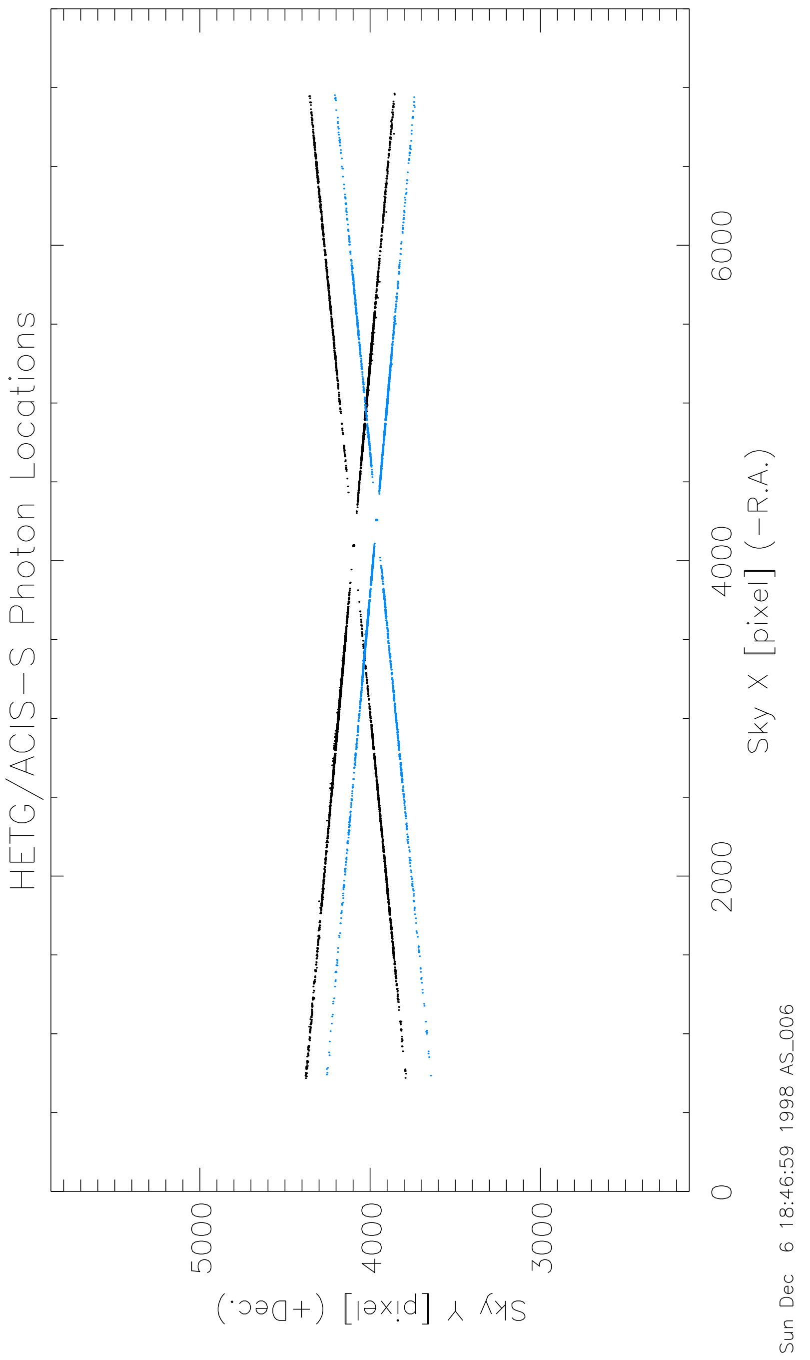
2 Pipeline Data Flow

(Ellipses are processes, rectangles are products, and rounded-rectangles are reference data.)

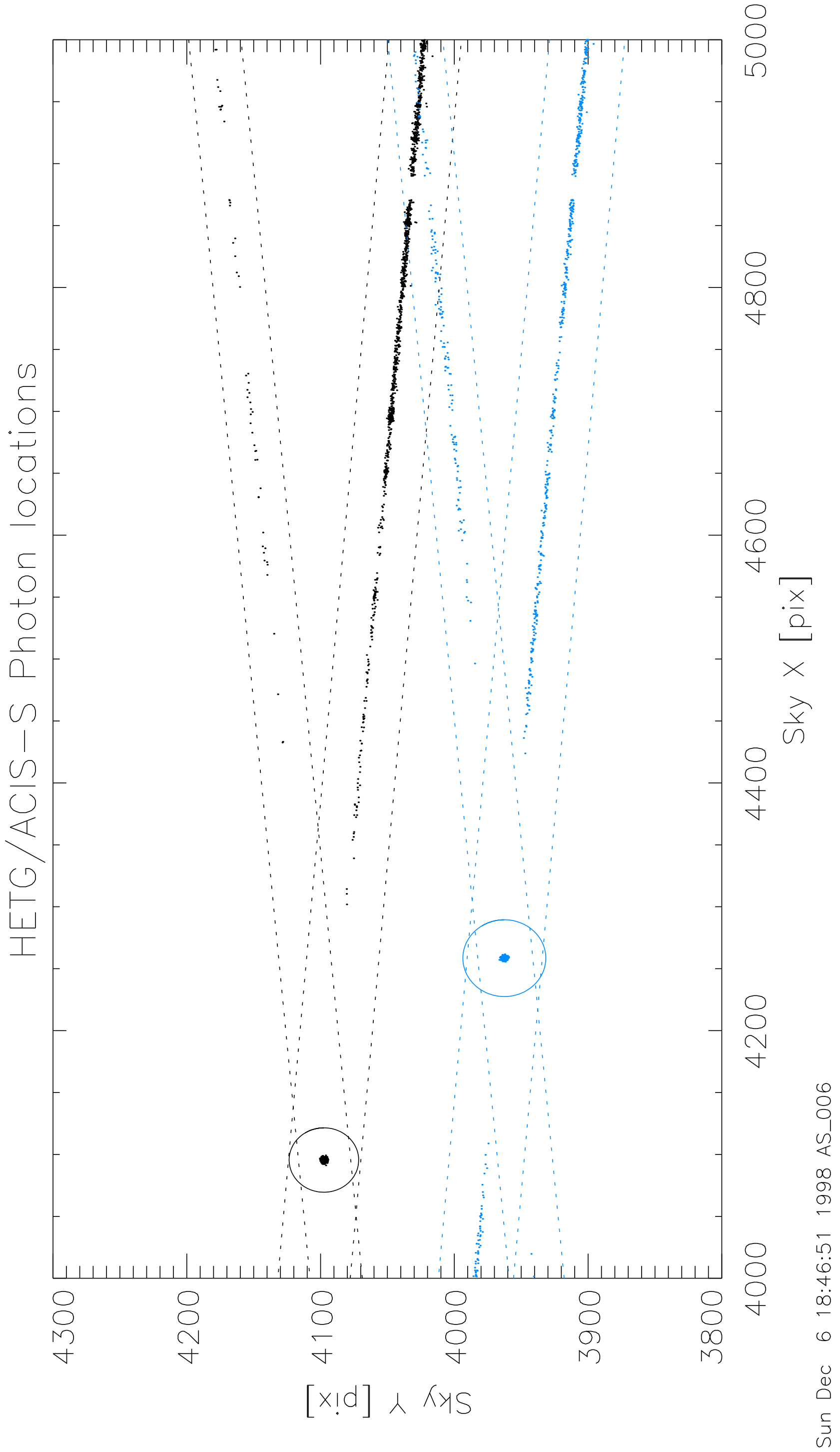


3 Graphical Examples

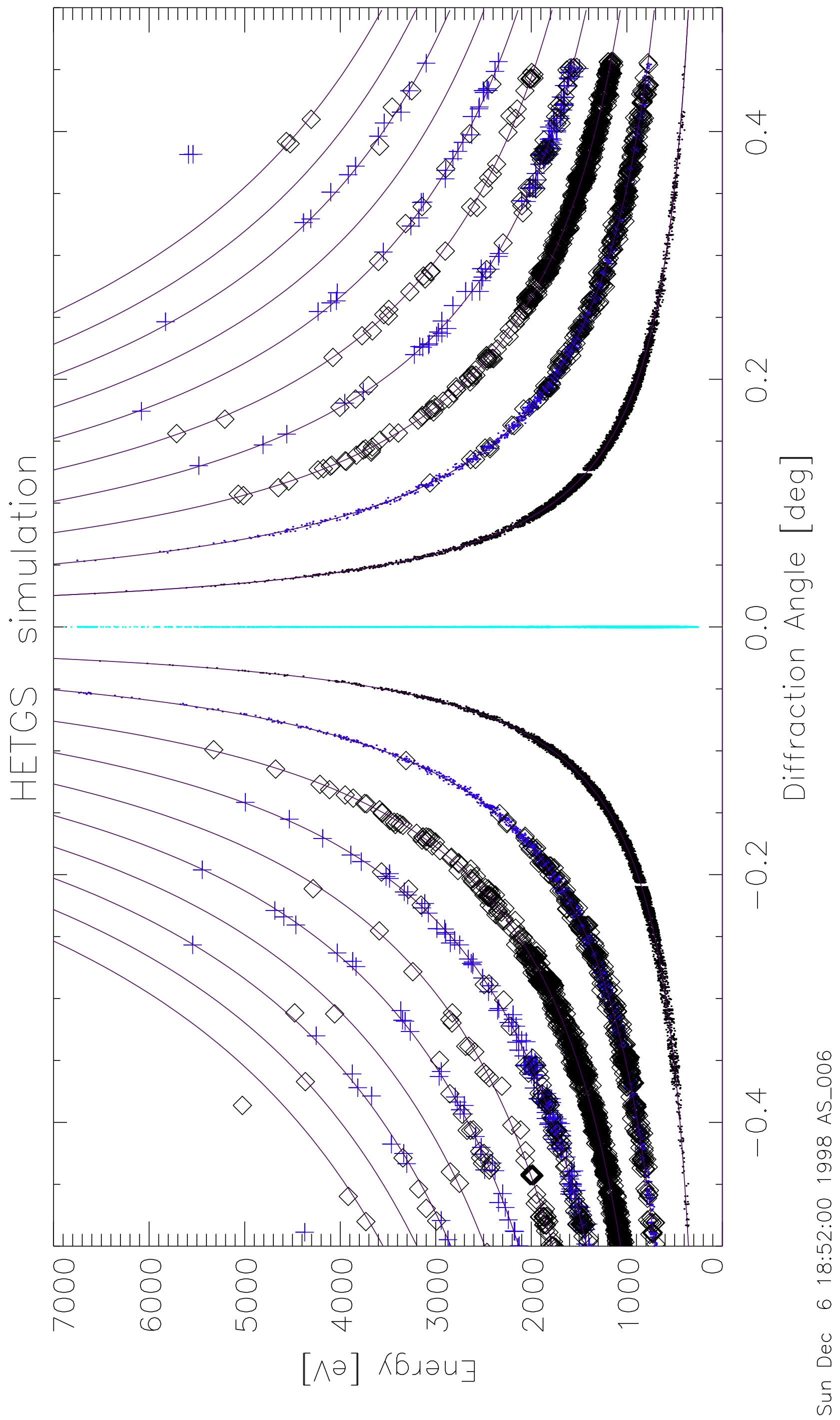
This is a view of photon locations (*not intensity!*) for a simulation with 2 sources separated by 1.7 arcmin. The upper source is the more-northern. The sky coordinates were determined by `acis_process_events` (without dither).



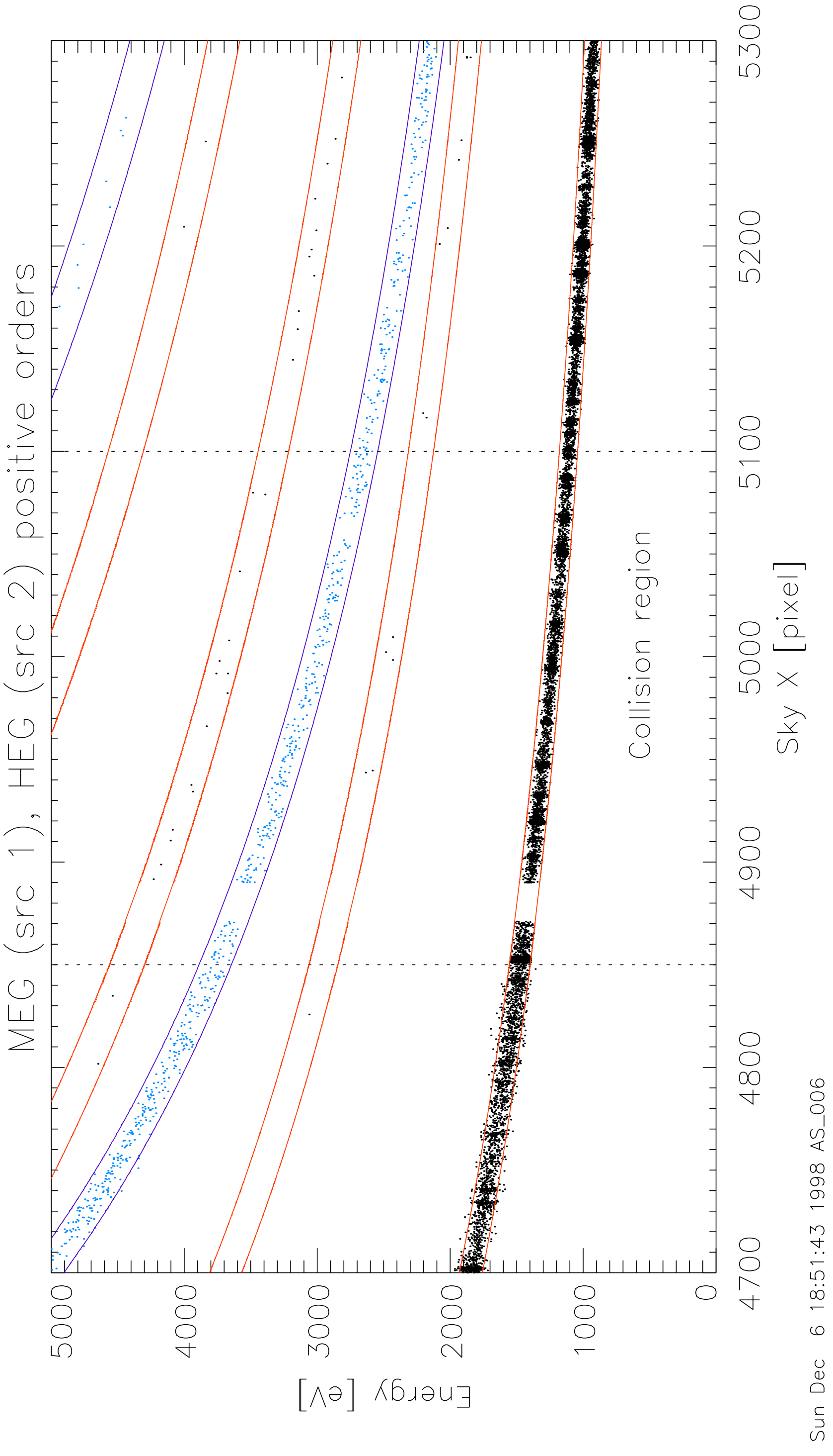
This is a close-up of the zero-order region, showing the default regions, as calculated by **tg_create_mask**. Note the region where the MEG positive orders of the upper source cross the HEG positive orders of the lower source. There is also a chip-gap visible near $x = 4900$.



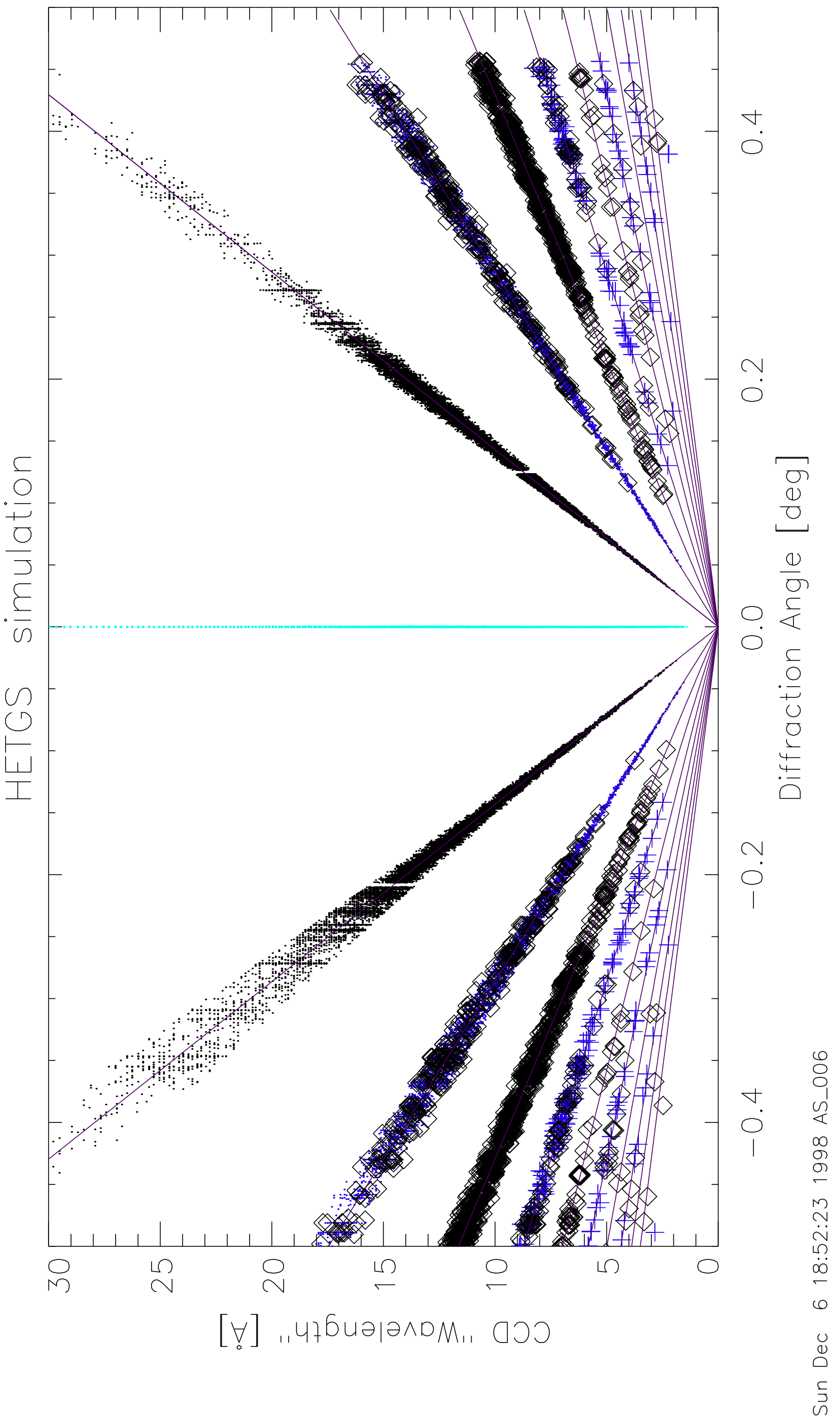
Orders are sorted (for ACIS) by using the CCD redistribution function to determine limits in PI (linearized to energy) expected for each order at each diffraction angle. This is the distribution in diffraction coordinates.



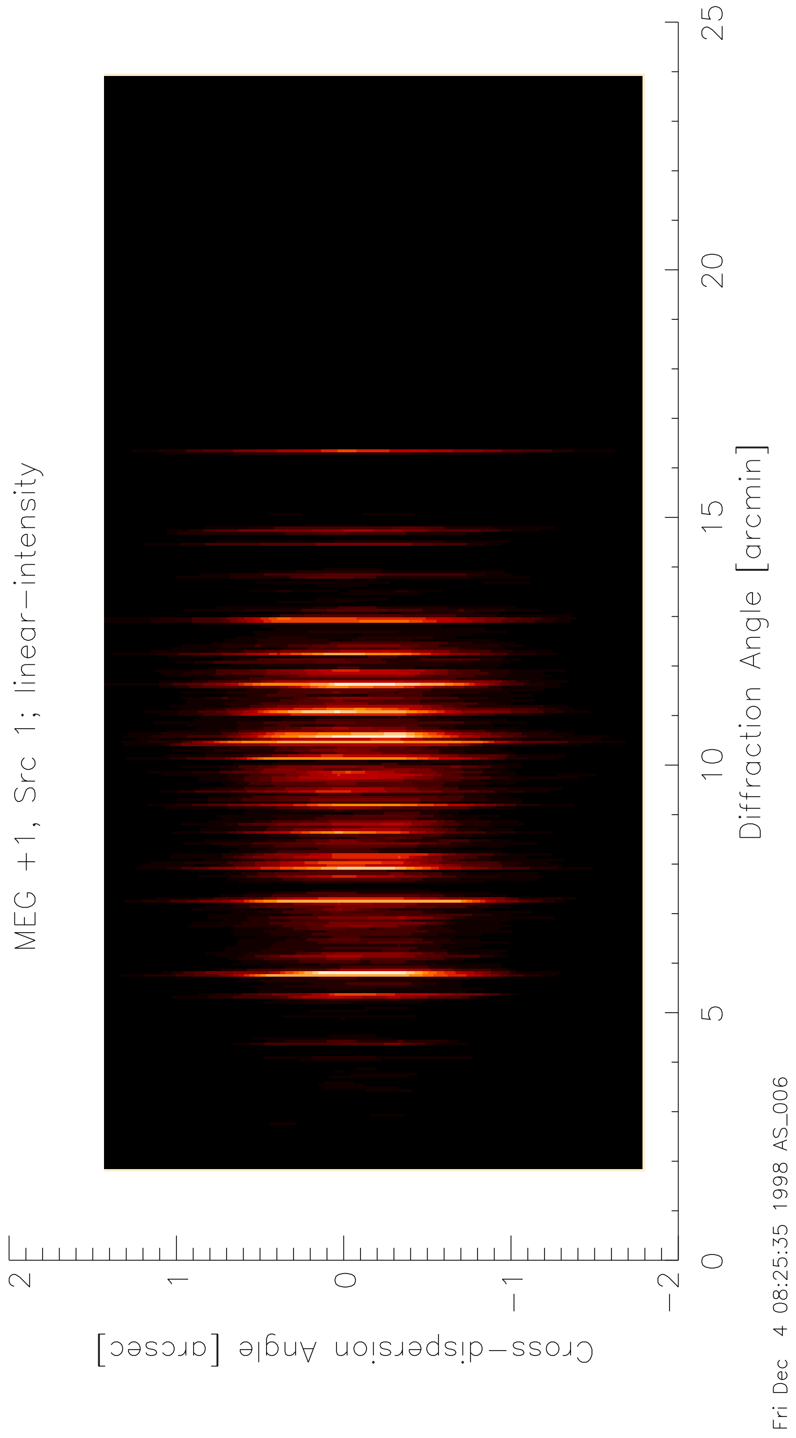
A close-up of the region where one source's MEG order cross the other's HEG is shown here:



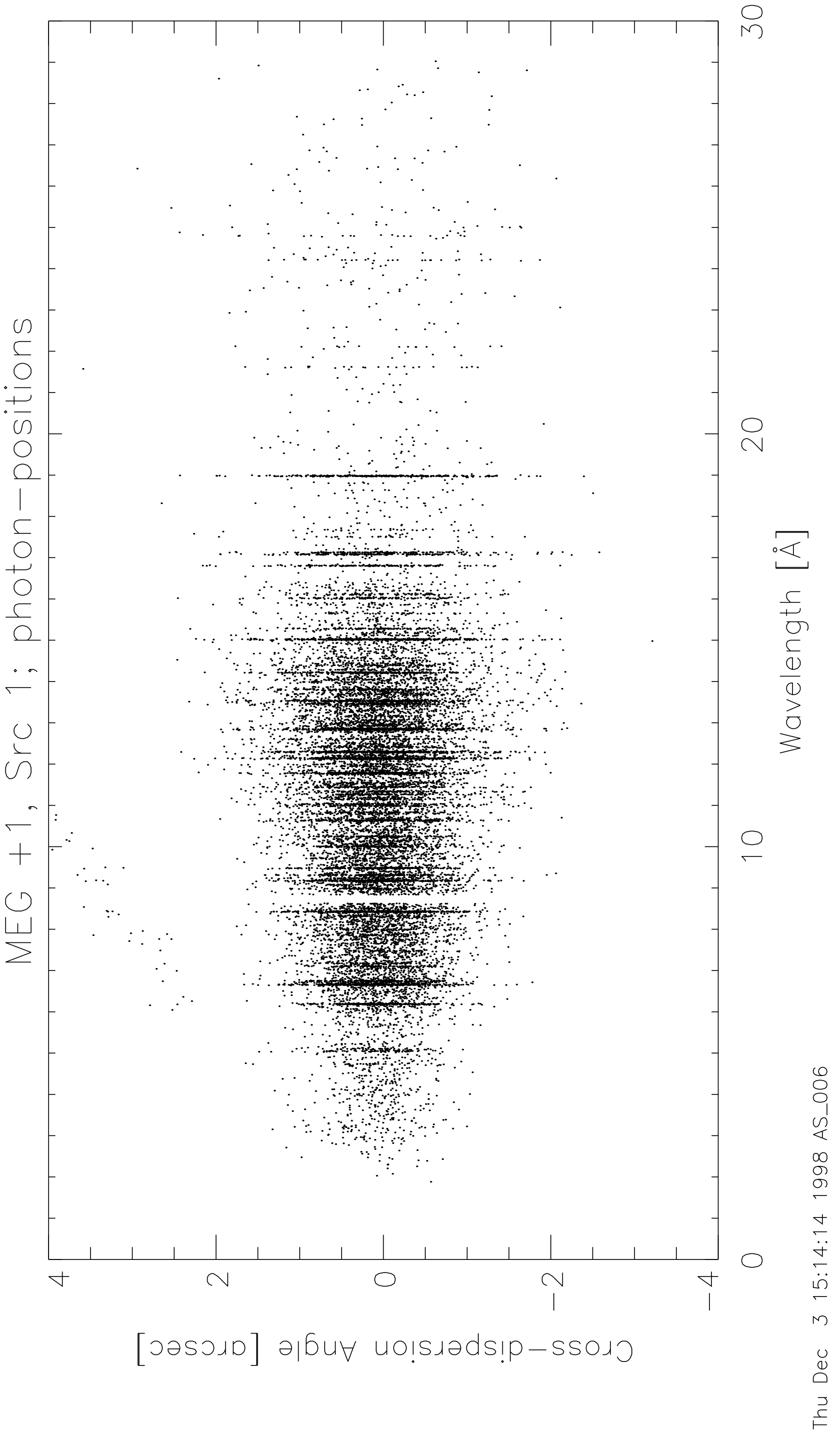
This view is similar to the last, except that the CCD PI values have been converted into a linearized CCD “Wavelength”.



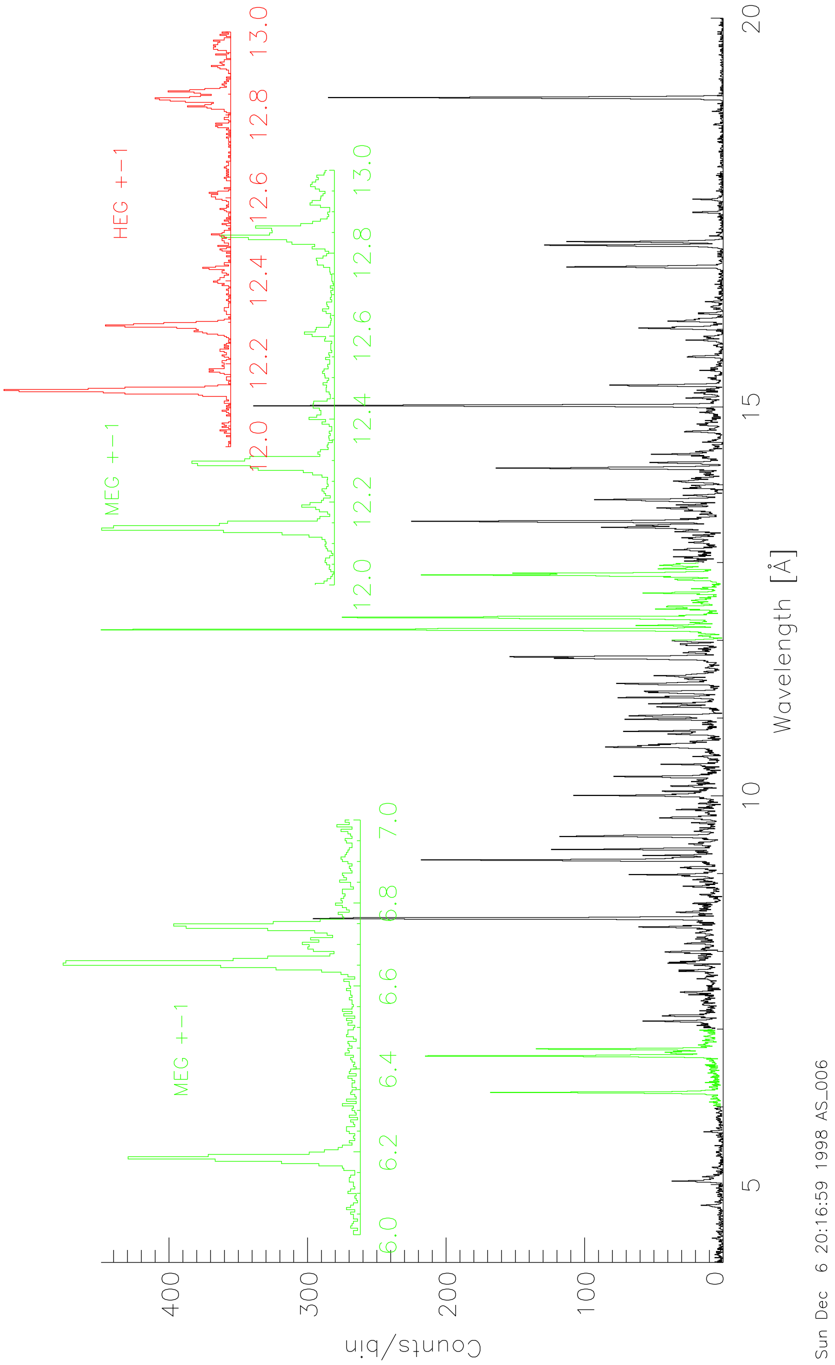
This is an intensity image of the MEG first order for one source, made by binning the angular dispersion and cross-dispersion coordinates (TG_R, TG_D) in the Level 1.5 event file:



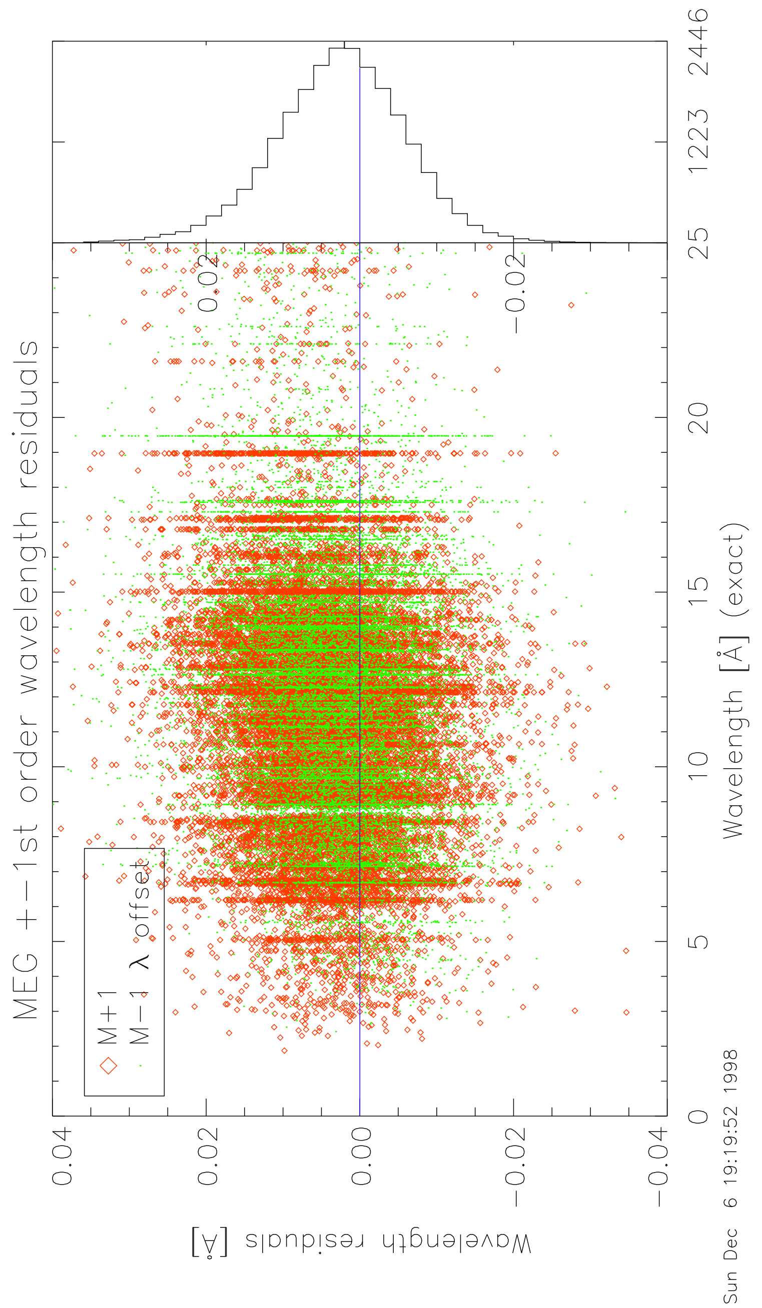
This is a photon-position scatterplot of the same spectrum in wavelength coordinates:



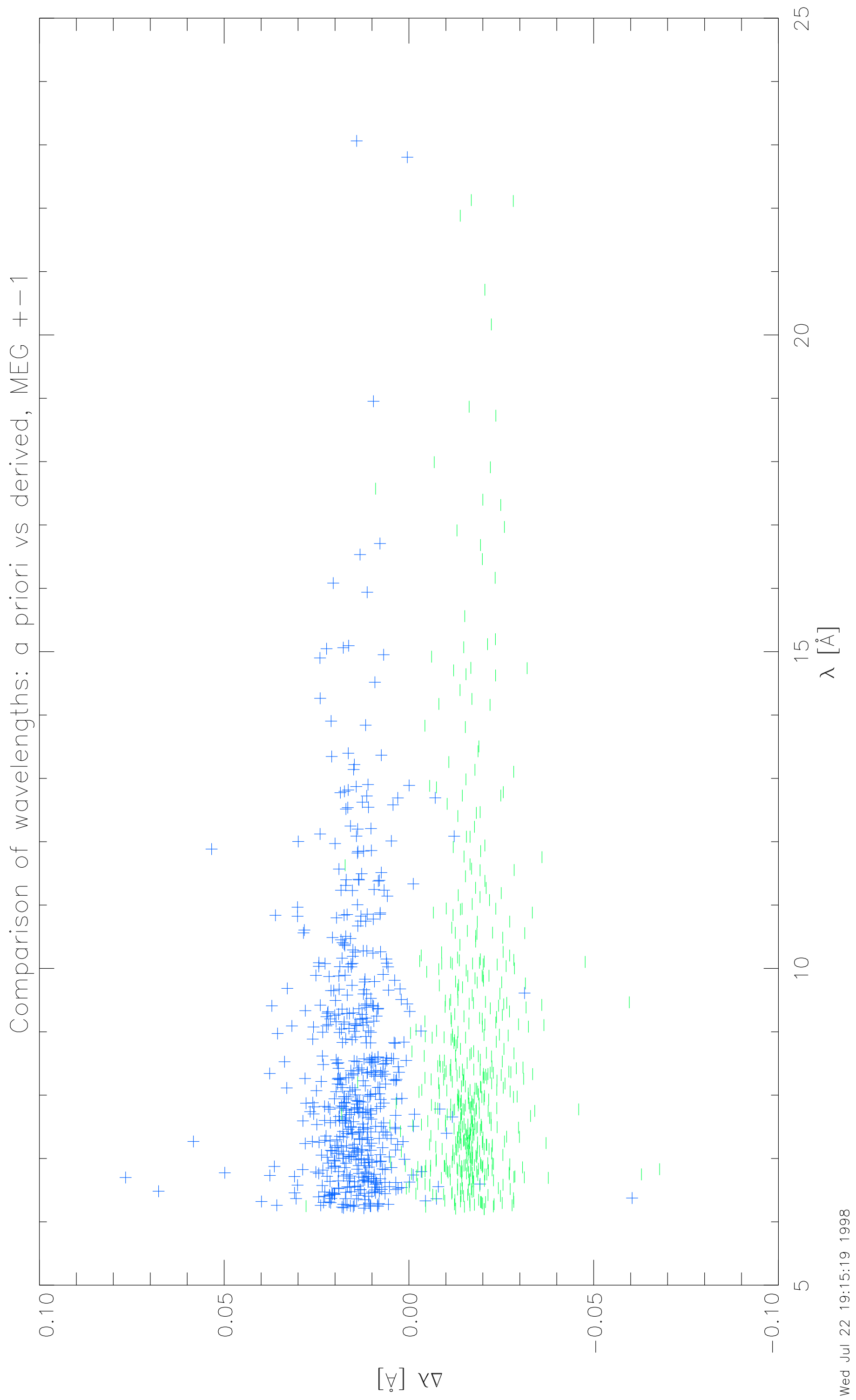
Finally, we bin the spectrum into a "Type II PHA" file, in which each row holds a spectrum for a specific order, source, and grating. Background spectra are also binned. Here is the combined first-order MEG spectrum, with insets showing expanded views of 2 one-Angstrom regions, and the corresponding HEG counts spectrum for one region. ("Type I PHA" output is also an option.)



How do we know the results are correct? Test, test, test, test, test, …. For example, we know wavelengths *a priori* in `marx`, so we can compare to the derived value. The figure shows the residuals ($\lambda - \lambda_{\mathrm{true}}$) for MEG +1 (diamonds) and −1 (dots). …and we notice an offset by about 1/2 pixel, and maybe a slope.



The previous is much improved over the July, 1998 case here. The large difference between plus and minus orders was due to a zero-order mis-placement.



4 Data Products

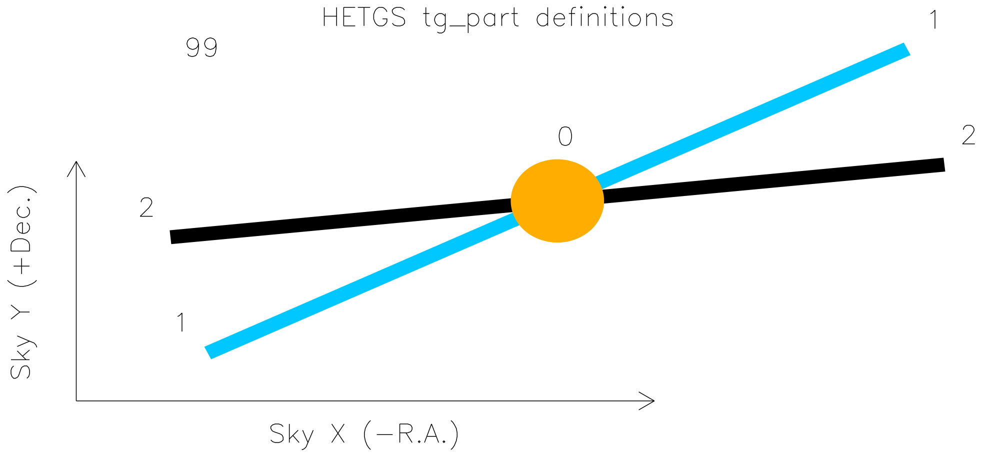
4.1 Level 1.5

"Level 1.5" processing refers to the determination of zero-order centroids, definition of spectral regions, and computation of diffraction coordinates. The resulting products are a source table, an augmented event-list, and a region, with the event-list being the fundamental product.

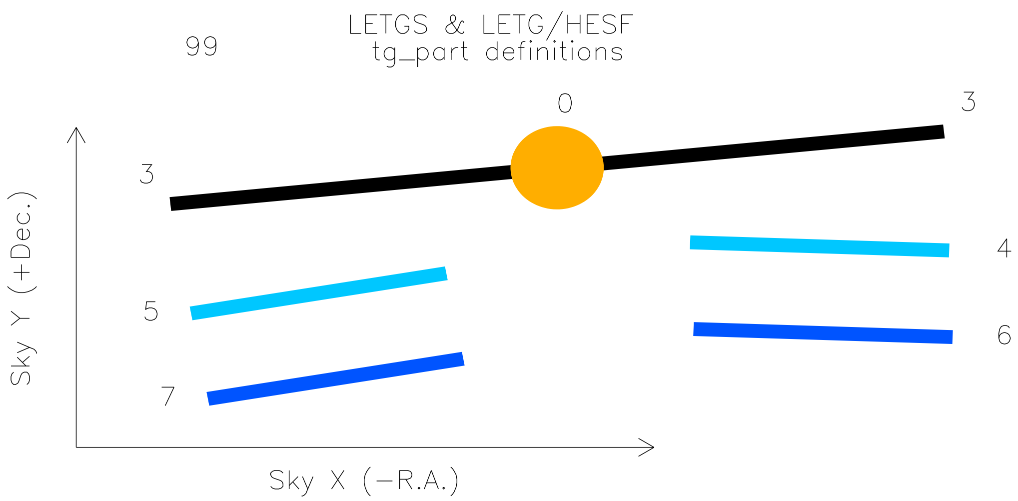
The region is used to classify the "Level 1" events according to the part of the spectrum. Then the events' detector positions of diffracted photons are transformed to diffraction coordinates using the zero-order centroid as the origin, after transforming it from sky coordinates to instantaneous detector coordinates using the aspect solution. The attributes of each photon thus determined are appended to the event-list as new columns:

TTYPE	TUNIT	TFORM	Comment
TG_R	deg	1D | 1E	diffraction angle; default form is 1D.
TG_D	deg	1D | 1E	cross-dispersion angle; default form is 1D.
TG_MLAM	angstrom	1D | 1E	$m \times \lambda$ Default form is 1D.
TG_M		1I	order (m)
TG_LAM	angstrom	1D | 1E	wavelength (λ) Default form is 1D.
TG_PART		1I	component (HEG, MEG, LEG, ...)
TG_SMAP		1I	source map, for matching ambiguous photons to zero-orders
TG_SRCID		1I	source ID
GDPX	pixel	1J	grating diffraction pixel, dispersion direction (optional)
GDPY	pixel	1J	grating diffraction pixel, cross-dispersion (optional)

The part definitions are shown in these schematics of the different regions. For multiple sources, each source will have a set of parts defined.



For LETG with HRC-S, the HESF parts are only present if a source is incident on the flat (either by being off-axis, or by intentional placement of the detector).



4.2 Level 2

Level 2 is primarily defined by derivation of "secondary" products, particularly those which yield physical information upon inspection — such as an image, or a spectrum, or a light-curve. Level 2 also refers to measurement products, such as fluxes. Hence, instrumental responses are also Level 2.

After event-lists are merged over any multiple observation intervals, photons are binned into 1-dimensional spectra *vs.* source-ID, part, and order. The output format is a Type II "PHA" file, with slight modifications to include AXAF grating-related information. (The file format is, in fact, compatible with XSPEC.) The structure is defined, in part, as follows:

TTYPE	TUNIT	TFORM	Comments
SPEC_NUM		1I	Required. Spectrum number.
ROWID		64A	Optional; Arbitrary string identifier
TG_M		1I	Required; diffraction order (m)
TG_PART		1I	Required; Spectral component (HEG, MEG, LEG, ...)
TG_SRCID		1I	Required; source ID. If constant (files split by source), then this becomes a header keyword: `TG_SRCID = ` n
CHANNEL		16384I	Required; Vector of spectral "channel" numbers.
COUNTS	counts	16384I	Required; Counts array (a spectrum).
STAT_ERR	counts	16384E	Optional; statistical uncertainty ("error") on count column.
BINLO	angstrom degrees mm keV pixel	16384D 16384D 16384D 16384D 16384I	Required; Bin boundary, low coordinate.
BINHI	angstrom degrees mm keV pixel	16384D 16384D 16384D 16384D 16384I	Required; Bin boundary, high coordinate
FLUX	photons /s /cm**2 / angstrom	16384E	Optional; Flux; ergs or photons per angstrom.
FLUX_ERR	(same as FLUX)	16384E	Optional. Uncertainty on flux.

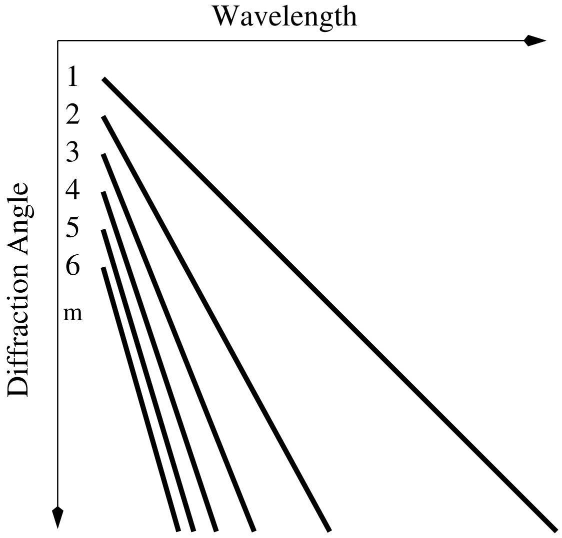
4.2.1 The Effective Area ("ARF")

We need an effective area for each source, spectral part, and order. This also depends upon the aspect history, since parts of the spectrum fall in gaps, or on detector regions of different sensitivity. We have defined a "Type II ARF", in analogy with the Type II PHA file (ARF = Auxiliary Response Function), and uses the same spectral labeling columns as the PHA file:

TTYPE	TUNIT	TFORM	Comments
SPEC_NUM		1I	Required. Response index.
ROWID		64A	Optional; Arbitrary string identifier
TG_M		1I	Required; diffraction order (m)
TG_PART		1I	Required; Spectral component (HEG, MEG, LEG, ...)
TG_SRCID		1I	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	Required; Vector of spectral "channel" numbers.
SPECRESP	cm**2	16384I	Required; The spectral response array.
STAT_ERR	cm**2	16384I	Optional; statistical uncertainty ("error") on the response array.
BINLO	angstrom	16384E	Required; Bin boundary, low coordinate.
BINHI	angstrom	16384E	Required; Bin boundary, high coordinate

4.2.2 Grating Redistrubution Function

An "RMF" (Redistribution Matrix Function) will be defined for HETG and LETG. This is in the same form as the OGIP, except that it redistributes from wavelength (or energy) into position, and so encodes the Line Spread Function (LSF). We may add a column to hold the diffraction order which goes with each group. (Or we may find it more useful to call a function to return the profile for the desired energy, order, off-axis-angle, . . .).



4.3 Other Products

There are other supporting products, which will only be listed here, without details:

source table - positions of zero-order centroids in sky coords, used by `tg_create_mask`.

sky region - for filtering photons during `tg_resolve_events` (both ASCII and FITS versions).

binning region - for filtering photons in diffraction coordinates for binning into 1D spectra.

spectral features - detected peaks table.

measured features - fits to detected peaks.

identified features - table of matches of measured features to line-list.

5 Some Issues

In no particular order some items remaining to be implemented or specified are:

1. continuous-clocking mode processing specs and calibration
2. HESF mask implementation
3. zero-order blocking, and coordinate system reference
4. RMF usage; too big? function better?
5. HRC filter shadows and calibration
6. 2D analysis, optimal extraction
7. LETG recursion for order-resolution
8. 3D response ($R(\lambda, \beta, \mathrm{PHA})$) analysis
9. Extended source analysis
10. Variable source analysis

6 Credits

Some of those more directly involved with the grating processing are:

- Software specification:
  - David Huenemoerder: pipeline event processing tools, binning tools
  - John Houck: pipeline line tools.
  - Michael Wise, David Davis: RMF, PSF tools
  - John Davis: ARF Tools
  - Dan Dewey, Herman Marshall, Jeremy Drake: Calibration consultants.
- Software coding:
  - Anastasia Alexov: pipeline tools, line tools
  - Warren McLaughlin: pipeline tools
  - Helen He: RMF tools
  - Kenny Glotfelty: PSF tools.
  - John Davis: ARF tools

7 More Information

For more information, check the following:

1. Detailed specification of data products are in "Interface Control Documents". Some relevant to gratings can be found at
   `http://space.mit.edu/ASC/docs/docs.html`
2. A "How-To" guide to using the ASCDS tools:
   `http://space.mit.edu/ASC/analysis/TG_HowTo/TG_HowTo.html`
3. A gallery of planned HETG observations:
   `http://space.mit.edu/ASC/science/science.html`
4. Norberts's AXAF Science Page:
   `http://space.mit.edu/%7Enss/axaf.html`
5. An overview of grating processing (somewhat dated, and yet to be updated):
   `http://space.mit.edu/ASC/analysis/L1.5_overview/L15.html`
6. This document, and hypertext version: TBD. Look for it in:
   `http://space.mit.edu/ASC/analysis/analysis.html`