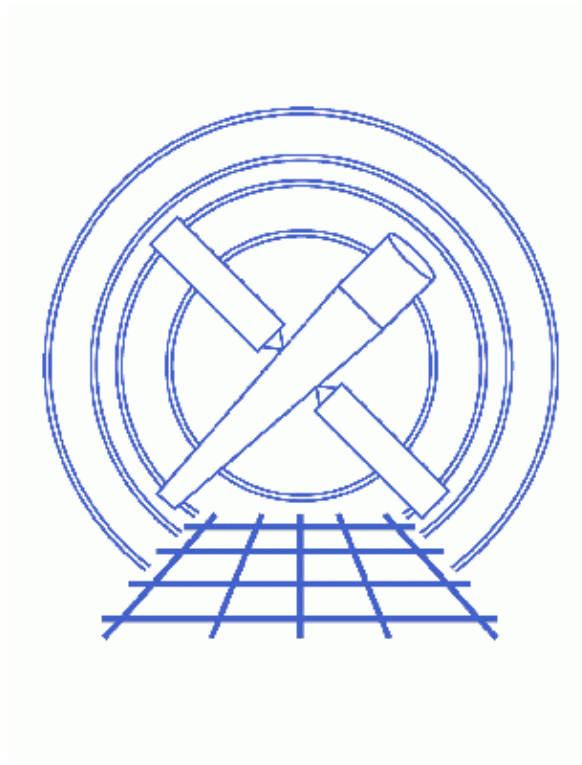


Compute LETG/HRC-S Grating ARFs



CIAO 3.4 Science Threads

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Compute LETG/HRC–S Grating ARFs

CIAO 3.4 Science Threads

Overview

Last Update: 1 May 2007 – updated for CALDB 3.4.0: new HRC–S QE file

Synopsis:

`mkgarf` creates a grating ARF for a particular order of an observation. The tool operates on a single detector element (i.e. one HRC plate) and grating order at a time. Therefore, it is necessary to generate all the individual component gARFs and then combine them with `dmarfadd` to create a grating ARF that covers the region of interest for that order.

Purpose:

To create grating ARFs for several orders of an LETG/HRC–S observation.

Read this thread if:

you are working with an LETG/HRC–S observation and intend to model and fit the spectra in *Sherpa*.

Calibration Updates:

- **CALDB v3.4.0** (16 May 2007): HRC–S QE version 9 (hrctD1999–07–22qeN0009.fits) has been added to the CALDB. The LETGS calibration team has released refinements to the HRC–S QE in the region of the Oxygen K–edge which resolve certain instrumental structures at that point, enabling more accurate characterization of source spectra.
- **CALDB v3.0.1** (10 Feb 2005): HRC–S QE version 7 (hrctD1999–07–22qeN0007.fits) and QEU version 4 (hrctD1999–07–22qeN0004.fits) are available. The HRC–S QE and QEU why topic outlines the details.

Related Links:

- Analysis Guide for Chandra High Resolution Spectroscopy: an in–depth discussion of grating analysis.

Proceed to the HTML or hardcopy (PDF: A4 / letter) version of the thread.

Background Information

`mkgarf` incorporates the telescope dither explicitly and averages over the response of the detector region which is exposed to a point in the sky. Hence, plate gaps and other detector non–uniformities, as well as the mirror vignetting function, are included. Arbitrary dither, off–axis response, or off–nominal source positions

are not accounted for in the pre-computed effective area files.

The tool computes the efficiency for a full aperture in the cross-dispersion direction. The effect of the finite region width is calculated by `mkgrmf`, since the line-spread-function is physically coupled to the extraction width. This aperture efficiency factor is accounted for in analysis when using an ARF and RMF jointly to model the instrument. *Sherpa*, ISIS, and XSPEC will include this factor automatically when using both the ARF and RMF. ISIS also provides a `factor_rsp` function with which this energy-dependent term can be extracted, if it is explicitly needed.

Get Started

Sample ObsID used: 460 (LETG/HRC–S, 3C 273)

File types needed: evt2; pha2; asol1; bpix1; dtf1


It is assumed that you have created gRMFs for your observation by running the [Create Grating RMFs for HRC–S Observations thread](#).

If you created a new bad pixel file by running the [Creating a New Observation-Specific HRC Bad Pixel File thread](#), make sure that you have [set up ardlb](#) to use the same bad pixel file.

Can't I use `fullgarf` anymore?

A previous version of this thread simply used the `fullgarf` script to generate the gARFs. While the script correctly creates ± 1 gARFS, the functionality does not yet exist to create higher orders. Until `fullgarf` is enhanced to handle those higher orders, it is recommended that users generate the gARFS "manually" by following this thread.

Determine the orders to model

Because of the low energy resolution in the HRC–S, [the PHA2 file contains two rows \(negative and positive\)](#)  containing all the spectral orders. While it is not possible to separate the overlapping orders, CIAO can make response files (gRMFs and gARFs) for higher orders, allowing you to model and fit them.

We choose to focus on the first three positive and negative orders of the spectra. The [Creating Higher-order Responses for HRC–S/LETG Spectra thread](#) provides some advice on determining the number of orders to model.

HRC–S plates and LETG orders

There are three plates in the HRC detector: S1, S2, and S3. When the LETG grating is used, the orders are distributed as follows:

- positive orders: S1 and S2
- negative orders: S2 and S3

Further details on this are available from [Table 9.3](#) in the [The Proposer's Observatory Guide](#).

If you are only interested in the positive orders, for instance, it is unnecessary to create gARFs for the S3 plate; the files generated will contain no data. The "ARF was computed to be zero at all energies" Warning section contains some related information.

Compute the Aspect Histograms (asphist)

The aspect solution files are used to create a binned histogram detailing the aspect history of the observation. An aspect histogram must be created for each plate of the detector you are going to use.

To create a histogram for each of the three plates – S1 (chip_id=1), S2 (chip_id=2), and S3 (chip_id=3) – the tool is run three times:

```
unix% punlearn asphist
unix% pset asphist infile=pcadf063792009N003_asol1.fits
unix% pset asphist dtffile=hrcf00460_000N004_dtf1.fits

unix% foreach f ( 1 2 3 )
foreach? asphist evtfile="hrcf00460N004_evt2.fits[chip_id=$f]" \
          outfile=460_asphist_s{$f}.fits mode=h
foreach? end

# asphist (CIAO 3.4): WARNING: skipping 41 livetime correction records (from time: 63792195.7362
...

unix% ls -l *asphist*
460_asphist_s1.fits
460_asphist_s2.fits
460_asphist_s3.fits
```

In many cases there will be more than one asol1.fits file for an observation. **All** the files must be input to the infile parameter, either as a list or as a stack (see ahelp stack for more information).

Many "skipping N livetime correction records" may be printed to the screen. These warnings are common and *do not* indicate a problem.

Get Source Position (dmlist)

The source position is required as one of the inputs to mkgarf. This information can be easily obtained from the PHA2 file with dmlist:

```
unix% dmlist hrcf00460N004_pha2.fits"[cols x,y]" opt=data

-----
Data for Table Block SPECTRUM
-----
```

ROW	X	Y
1	32842.6250	32638.082031250
2	32842.6250	32638.082031250

The source is located at (32842.6250, 32638.082031250).

Run mkgarf

Now we have all the information needed to run `mkgarf`. The tool needs to be run *once per plate for each order*; each order falls on two of the plates. Since we are interested in three positive and three negative orders, we need to run the tool *twelve times*:

- S1: +1, +2, +3
- S2: -1, -2, -3, +1, +2, +3
- S3: -1, -2, -3

Again, refer to the [HRC-S plates and LETG orders section](#) if you need assistance determining how many times to run `mkgarf`. Remember that if you run it for the "wrong" plate, the tool will just issue a warning and create an empty file.

1. HRC-S1

First, we make a gARF for each order on plate S1. To simplify the steps, we loop through the three orders, using a variable to change the necessary parameters between runs. Setting the `mode` parameter to "h" tells the tool not to prompt for values.

Be sure that the S1 aspect histogram is used in the `asphistfile` parameter and that `detsubsys=HRC-S1`.

```
unix% punlearn mkgarf
unix% pset mkgarf asphistfile="460_asphist_s1.fits[ASPHIST]"
unix% pset mkgarf detsubsys=HRC-S1
unix% pset mkgarf grating_arm=LEG
unix% pset mkgarf sourcepixelx=32842.6250 sourcepixely=32638.082031250

unix% foreach f ( 1 2 3 )
foreach? mkgarf outfile=garf_460_S1_LEG_{f}.fits order=$f \
          engrid="grid(460_leg_$.grmf[cols ENERG_LO,ENERG_HI])" \
          mode=h
foreach? end
```

2. HRC-S2

The process is repeated for the S2 plate. **Do not** issue "`punlearn`" before running the tool again, as only a few parameters need to change. Note that the loop needs to cover the positive and negative orders, as they all fall on S2.

```
unix% pset mkgarf asphistfile="460_asphist_s2.fits[ASPHIST]"
unix% pset mkgarf detsubsys=HRC-S2

unix% foreach f ( -1 -2 -3 1 2 3 )
foreach? mkgarf outfile=garf_460_S2_LEG_{f}.fits order=$f \
          engrid="grid(460_leg_$.grmf[cols ENERG_LO,ENERG_HI])" \
          mode=h
foreach? end
```

3. HRC-S3

And, finally, gARFS for S3 are created.

```
unix% pset mkgarf asphistfile="460_asphist_s3.fits[ASPHIST]"
```

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```
unix% pset mkgarf detsubsys=HRC-S3

unix% foreach f ( -1 -2 -3 )
foreach? mkgarf outfile=garf_460_S3_LEG_{$f}.fits order=$f \
          engrid="grid(460_leg_{$f}.grmf[cols ENERG_LO,ENERG_HI])" \
          mode=h
foreach? end
```

The history of each file, stored in the header, contains the complete `mkgarf` command used to create that gARF:

```
unix% dmhistory garf_460_S2_LEG_3.fits mkgarf
mkgarf asphistfile="460_asphist_s2.fits[ASP HIST]"
outfile="garf_460_S2_LEG_3.fits" order="3" sourcepixelx="32842.625"
sourcepixely="32638.08203125" engrid="grid(460_leg_3.grmf[cols
ENERG_LO,ENERG_HI])" obsfile="460_asphist_s2.fits[ASP HIST]"
osipfile="NONE" maskfile="NONE" mirror="hrma" detsubsys="HRC-S2"
grating_arm="LEG" ardliparfile="ardlib.par" geompar="geom"
verbose="0" clobber="no"
```

Combine the gARFs (dmarfadd)

`dmarfadd` is used to combine the individual gARFs for each order into a single response file. The tool is run six times, once for each order:

```
unix% punlearn dmarfadd
unix% dmarfadd infile="garf_460_S2_LEG_-1.fits,garf_460_S3_LEG_-1.fits" \
  outfile=460_LEG_-1.garf

unix% dmarfadd infile="garf_460_S2_LEG_-2.fits,garf_460_S3_LEG_-2.fits" \
  outfile=460_LEG_-2.garf

unix% dmarfadd infile="garf_460_S2_LEG_-3.fits,garf_460_S3_LEG_-3.fits" \
  outfile=460_LEG_-3.garf

unix% dmarfadd infile="garf_460_S1_LEG_1.fits,garf_460_S2_LEG_1.fits" \
  outfile=460_LEG_1.garf

unix% dmarfadd infile="garf_460_S1_LEG_2.fits,garf_460_S2_LEG_2.fits" \
  outfile=460_LEG_2.garf

unix% dmarfadd infile="garf_460_S1_LEG_3.fits,garf_460_S2_LEG_3.fits" \
  outfile=460_LEG_3.garf
```

The "ARF was computed to be zero at all energies" Warning

When running `mkgarf`, a warning of this form may be printed:

```
*** WARNING: The ARF was computed to be zero at all the specified energies.
              This is probably due to an incorrect source position
```

There are a few possible situations that are causing this:

1. An incorrect source position was input to the `sourcepixelx` and `sourcepixely` parameters. Confirm that the source position is correct, and re-run the tool if it's not.
2. You are attempting to create a gARF for an order that does not fall on that plate, e.g. a positive order on HRC-S3. Refer to the HRC-S plates and LETG orders section for more information.

If neither of these seems to fix the problem, contact the [Helpdesk](#) for assistance.

Note on the Effective Area

The grating ARFs as generated by `mkgarf` are appropriate for events falling within the full 2pi steradian solid angle behind the grating. They do not include a correction for the fraction of these events that fall outside the "bowtie" extraction region whence the first-order spectra are selected from the L2 event file (`tgextract`). This fraction is of order 10%, and a correction for this is included in the RMF generated by `mkgrmf`, specifically in the LSFARM calibration file.

Use of ARF and RMF files combined, e.g. within *Sherpa*, XSPEC, or ISIS, will result in the correct effective area being applied. Should they be required for analysis of LETG+HRC-S observations using methods or software that cannot easily combine RMF and ARF files, pre-generated on-axis LETG+HRC-S ARF files that include the bow-tie "extraction efficiency" are available on the [LETG instrument team web page](#).

Summary

The thread is now complete. The grating ARFs for this dataset are:

460_LEG_-1.garf	460_LEG_1.garf
460_LEG_-2.garf	460_LEG_2.garf
460_LEG_-3.garf	460_LEG_3.garf

If you have not yet grouped your spectra, refer to the [Grouping a Grating Spectrum thread](#). Otherwise proceed to the [Sherpa Fitting Multiple Orders of HRC-S/LETG Data thread](#) for information on how to model and fit the data.

History

- 20 Dec 2004 updated for CIAO 3.2: canned gARFs are no longer available in the CALDB, users *must* run this thread, removed "Choosing an RMF" section
- 10 Feb 2005 new *Calibration Updates* entry for CALDB 3.0.1
- 08 Apr 2005 rewritten to no longer use the `fullgarf` script; added information on modeling higher orders
- 06 Dec 2005 updated for CIAO 3.3: new `asphist` tool syntax (the GTI filter is associated with the event file instead of the aspect solution file)
- 01 Dec 2006 updated for CIAO 3.4: CIAO version in warning
- 01 May 2007 updated for CALDB 3.4.0: new HRC-S QE file

Image 1: PHA2 file displayed in prism

prism-1 : hrcf00460N003_pha2.fits

File Edit Navigate Visualization Session Analysis

IMAGE	PRIMARY	NULL
TABLE	SPECTRUM	13 cols, 2 rows
TABLE	REGION	11 cols, 6 rows

```

COMMENT This FITS file may contain long string keyword values t
COMMENT continued over multiple keywords. The HEASARC conventi
COMMENT character at the end of each substring which is then co
COMMENT on the next keyword which has the name CONTINUE.
DATE      2001-05-08T12:11:44 / Date and time of file creation
DATE-OBS  2000-01-09T07:47:42 / Date and time of observation s
DATE-END  2000-01-09T19:18:45 / Date and time of observation s
TIMESYS   TT / Time system
MJDREF    50814.0 / MJD zero point for times
TIMEZERO  0 / Clock correction
    
```

	SPEC_NUM	TG_M	TG_PART	TG_SRCID	X	Y	CHANNEL	COUNTS
Units					pixel	pixel		count
Types	short	short	short	short	float	float	short	short
1	1	-1	3	1	32843.2	32637.4	short[16384]	short[16
2	2	1	3	1	32843.2	32637.4	short[16384]	short[16

View Mode: Read/Write Processing : 1 of 2 Goto Forward

Fri 05 - Oct 12:35:31 Loading file hrcf00460N003_pha2.fits

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