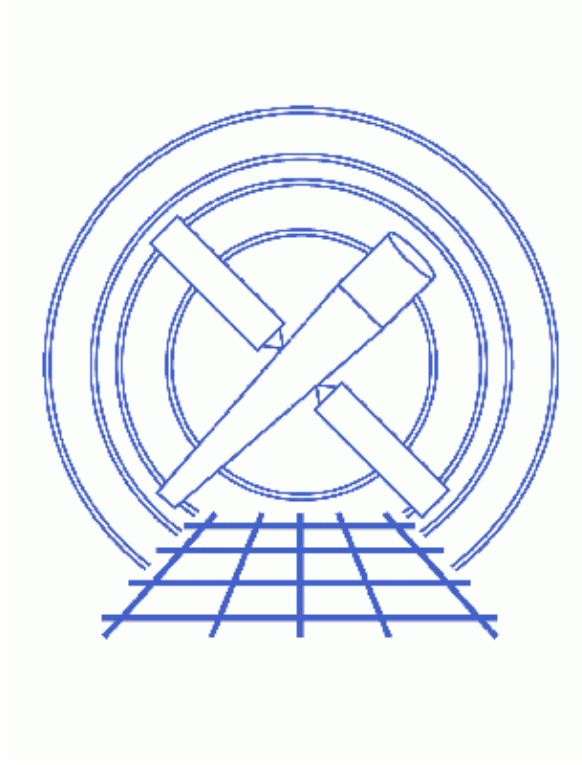


Examining Grating Spectra and Regions: PHA2 files



CIAO 3.4 Science Threads

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Examining Grating Spectra and Regions: PHA2 files

CIAO 3.4 Science Threads

Overview

Last Update: 1 Dec 2006 – updated for CIAO 3.4: ChIPS and Sherpa versions

Synopsis:

An overview of displaying grating data Type II PHA files and the source and background extraction regions.

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.

What is a PHA2 File?

A Type II PHA file is a standard FITS format in which each row contains array columns. The PHA file is a product of standard data processing and is identified by the `pha2.fits` extension; note that the "2" in the filename refers to the fact that it is a level=2 data product, *not* that it is a Type II file. In the case that the user has to manually reprocess an event file (e.g. when applying an updated order sorting table), the PHA2 spectrum file is obtained from the level 2 event file by `tgextract`; see the [Obtain Grating Spectra from HETG/ACIS–S Data](#) for an example of this.

The SPECTRUM block of a PHA2 file has 13 columns of data:

ColNo	Name	Description
1	SPEC_NUM	Spectrum Number
2	TG_M	Diffraction order (m)
3	TG_PART	Spectral component (HEG, MEG, LEG, HESF parts)
4	TG_SRCID	Source ID, output by tgdetect
5	X	X sky coord of source
6	Y	Y sky coord of source
7	CHANNEL[8192]	Vector of spectral bin numbers.
8	COUNTS[8192]	Counts array (a spectrum)
9	STAT_ERR[8192]	Statistical uncertainty (error) on counts column
10	BACKGROUND_UP[8192]	Upper Background count vector.
11	BACKGROUND_DOWN[8192]	Lower Background count vector.
12	BIN_LO[8192]	Bin boundary, left edge
13	BIN_HI[8192]	Bin boundary, right edge

There are two columns that are especially relevant when doing analysis:

- TG_M indicates the order of the spectrum (+/- 1, +/-2, +/- 3)
- TG_PART indicates the spectral component / grating arm (1 = HEG, 2 = MEG, 3 = LEG)

Examining the Files with Prism


Sample ObsIDs used: 459 (HETG/ACIS-S 3C 273); 460 (LETG/HRC-S, 3C 273); 1198 (LETG/ACIS-S, 3C 273); 1800 (LETG/HRC-I, PKS2155-304)


File types needed: evt2; pha2

ACIS-S HETG/LETG Observations

We can use `prism` to examine the PHA2 file for ObsID 459:


```
unix% prism acisf00459N002_pha2.fits &
```

which will give you something like [Figure 1](#) . In this example, there are twelve rows – all the +/- orders for both HEG and MEG – for the observation. The columns CHANNEL, COUNTS, BIN_LO, etc. are all so-called "vector columns"; each contains a vector of elements which, in this example, is 8192 elements long.

An ACIS-S/LETG observation (ObsID 1198) [looks similar in Prism](#)  but only contains 6 rows (+/- orders for the LEG).

Each vector column can be viewed as follows:


```
unix% prism acisf00459N002_pha2.fits &
left-click on column of interest (to select column)
Navigate menu -> Expand Column (to expand column)
```


[Figure 3](#)  shows the (partial) result of the expansion of column BIN_LO.

HRC-S/HRC-I LETG Observations

Examining an HRC-S/LETG observation (ObsID 460) is done in the same way as an ACIS grating observation:

```
unix% prism hrcf00460N002_pha2.fits &
```

but there is an important difference in the results. As seen in the [Prism display](#) , there are only two rows for the LEG observation. HRC-S cannot resolve orders and the COUNTS in the +/- 1 order are in fact the **total counts of all orders combined**. Also, the BIN_LO and BIN_HI columns should be considered for reference only; they actually represent the boundary wavelength of the +/- 1 order alone, while photons from all orders are included in the spectra.

The same holds true for HRC-I/LETG observations, as seen [Figure 5](#)  in the example of ObsID 1800.


Displaying the Spectrum

With Prism

The quickest way to display one of the spectra of a PHA2 file is with *Prism*. For example a user who wants to take a quick look at BIN_LO vs. COUNTS for the order +1 (TG_M=1) of the HEG spectrum (TG_PART=1) should do the following (ObsId 459):

```
unix% prism acisf00459N002_pha2.fits &

middle-click on row #4 (to select spectrum)
left-click on BIN_LO column (to select X-axis column)
left-click on COUNTS column (to select Y-axis column)
Visualization menu -> Interactive plot (to view the plot)
Visualization menu -> Print plot (to print the plot)
```

As clearly visible from the [output in Figure 6](#) , the plot is good for a general overview only (are there enough counts, are there striking features, etc.). At the same time as the plot was created, a *ChIPS* session was launched by *Prism* in an xterm window. This window can be used to customize the plot; see the [Introduction to ChIPS](#) thread for more information on plotting with *ChIPS*.

With ChIPS

In order to display a spectrum with *ChIPS*, we need to separate it out from the PHA2 file (keep in mind that each row of the PHA2 file corresponds to one spectrum):

```
unix% dmtyp2split "acisf00459N002_pha2.fits[#row=4]" acisf00459N002_heg_p1.pha
```

The newly created file, which is the +1 order HEG spectrum for this observation, can be used as input to *ChIPS*:

```
unix% chips

Welcome to ChIPS, version CIAO 3.4
Copyright (C) 1999-2003, Smithsonian Astrophysical Observatory

chips> plot "acisf00459N002_heg_p1.pha[cols bin_lo,counts]"
chips> symbol none
chips> step
chips> xlabel "Wavelength (\AA)"
chips> ylabel Counts
chips> title "ACIS+HEG order=+1"
```

These commands produce the plot shown in [Figure 7](#) .

An alternative way to read and display a PHA2 spectrum is through [S-Lang variables](#). In this case the PHA2 does not need to be split first. To produce the plot above using S-Lang syntax:

```
chips> clear
chips> pha2 = readbintab("acisf00459N002_pha2.fits")
chips> print(pha2)
_filename      = acisf00459N002_pha2.fits
_path          = /data/ciao/threads/
_filter        = NULL
_filetype      = 4
_header        = String_Type[190]
_ncols         = 13
_nrows        = 12
SPEC_NUM       = Short_Type[12]
```

Examining Grating Spectra and Regions: PHA2 files – CIAO 3.4

```
TG_M           = Short_Type[12]
TG_PART        = Short_Type[12]
TG_SRCID       = Short_Type[12]
X              = Float_Type[12]
Y              = Float_Type[12]
CHANNEL        = Short_Type[12,8192]
COUNTS        = Short_Type[12,8192]
STAT_ERR       = Float_Type[12,8192]
BACKGROUND_UP  = Short_Type[12,8192]
BACKGROUND_DOWN = Short_Type[12,8192]
BIN_LO         = Double_Type[12,8192]
BIN_HI         = Double_Type[12,8192]

chips> bin_lo_heg_p1 = pha2.BIN_LO[3,*]
chips> counts_heg_p1 = pha2.COUNTS[3,*]
chips> curve(bin_lo_heg_p1,counts_heg_p1)
0
chips> symbol none
chips> step
chips> xlabel "Wavelength (\AA)"
chips> ylabel Counts
chips> title "ACIS+HEG order=+1"
```

Note that S-Lang follows C conventions by numbering array indexes from 0, rather than 1. Therefore the 4th row (HEG, +1 order) in the PHA2 file is the 3rd row within the pha2 data arrays (hence the syntax "bin_lo_heg_p1 = pha2.BIN_LO[3,*]" and "counts_heg_p1 = pha2.COUNTS[3,*]").

With Sherpa

Sherpa can also be used to plot a PHA2 spectrum. In this case, the spectra do not need to be split first; *Sherpa* reads all the rows and allows you to specify individual ones for plotting or fitting purposes:

```
unix% sherpa

-----
Welcome to Sherpa: CXC's Modeling and Fitting Program
-----
Version: CIAO 3.4

Type AHELP SHERPA for overview.
Type EXIT, QUIT, or BYE to leave the program.


Notes:
  Temporary files for visualization will be written to the directory:
  /tmp
  To change this so that these files are not deleted when you exit Sherpa,
  edit $ASCDS_WORK_PATH in your 'ciao' setup script.

  Abundances set to Anders & Grevesse


sherpa> data acisf00459N002_pha2.fits
The inferred file type is PHA Type II.  If this is not what you want, please
specify the type explicitly in the data command.
Warning: could not find SYS_ERR column
WARNING: statistical errors specified in the PHA file.
  These are currently IGNORED.  To use them, type:
  READ ERRORS "<filename>[cols CHANNEL,STAT_ERR]" fitsbin
WARNING: backgrounds UP and DOWN are being read from this file,
and are being combined into a single background dataset.
WARNING: multiple datasets have been input.
  The next available dataset number is 13.

sherpa> sherpa.dataplot.curvestyle="histo"
sherpa> sherpa.dataplot.symbolstyle="none"
```

```
sherpa> analysis channel
sherpa> lp 2 data 3 data 4
```

Figure 8  shows the plot of the HEG -1 order (row 3, upper drawing area) and +1 order (row 4, lower drawing area) that is created. To change the axes to CHANNEL vs. COUNTS:

```
sherpa> ploty 3 counts
sherpa> ploty 4 counts
sherpa> lp 2 data 3 data 4
```

These commands alter the plots to look like Figure 9 . *ChIPS* commands (within *Sherpa*) can be used at this point to customize the plot.

```
sherpa> exit
Goodbye.
```

Displaying the Extraction Regions

Each pha2 file has a second block, named REGION, which stores the regions used by `tgextract` to extract the source and background spectra. There are three regions associated with each order: source, upper background, and lower background. For an ACIS/HETG observation, this gives 36 regions: 12 spectral components (+/- 3, +/- 2, and +/- 1 for HEG and MEG) times 3 regions apiece (source and two backgrounds).

To look at the columns of a REGION block:

```
unix% dmlist "acisf00459N002_pha2.fits[REGION]" cols
-----
Columns for Table Block REGION
-----
```

ColNo	Name	Unit	Type	Range	
1	SPEC_NUM		Int2	1:32767	Spectrum number
2	ROWID		String[64]		Source or a background
3	SHAPE		String[16]		Shape of region
4	TG_LAM	angstrom	Real4	0: 400.0	Dispersion coordinate
5	TG_D	degrees	Real4	-2.0: 2.0	Cross-dispersion coordinate
6	R[2]	(angstrom , degrees)	Real4(2)	-Inf:+Inf	Radius vector for source
7	ROTANG	degrees	Real4	-360.0: 360.0	Rotation angle for source
8	TG_PART		Int2	0:9	Grating part index
9	TG_SRCID		Int2	1:32767	Source identification
10	TG_M		Int2	-62:62	Diffraction order
11	COMPONENT		Int2	-	Component number

ds9 cannot display these regions as they are written in the pha2 file. In order to view them, we need to rename the (TG_LAM, TG_D) columns to (X, Y) so that ds9 knows how to interpret them. We will also need to create images in (TG_LAM, TG_D) coordinates, on which we can display the regions.

The following `dmcopy` commands create image and region files for the 1st and 3rd orders of the MEG arm:

```
unix% dmcopy \
  "acisf00459N002_evt2.fits[bin tg_lam=0:30:0.08,tg_d=-0.01:0.01:0.00008][tg_m=-1,1,tg_part=1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36]
  459_order1.fits

unix% dmcopy \
  "acisf00459N002_evt2.fits[bin tg_lam=0:15:0.08,tg_d=-0.01:0.01:0.00008][tg_m=-3,3,tg_part=1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36]
  459_order3.fits

unix% dmcopy \
```

Examining Grating Spectra and Regions: PHA2 files – CIAO 3.4

```
"acisf00459N002_pha2.fits[region][tg_m=1,tg_part=2][cols x=tg_lam,y=tg_d,*]" \  
region_order1.fits  
  
unix% dmcoppy \  
"acisf00459N002_pha2.fits[region][tg_m=3,tg_part=2][cols x=tg_lam,y=tg_d,*]" \  
region_order3.fits
```

In creating the images, the filter includes + and – orders to obtain more events in the image. Since the regions are the same for +/- orders, it is only necessary to copy one (the + orders were used here). The image limits are typical for ACIS/HETG observations, but will need to be adjusted for other configurations.

To display the event files with the regions overlaid:

```
unix% ds9 -tile 459_order1.fits -region region_order1.fits -cmap a\  
459_order3.fits -region region_order3.fits -cmap a
```

which produces [Figure 10](#). We can see that all events are contained within at least one extraction region.

History

- 01 Jun 2004 reviewed for CIAO 3.2: no changes
- 06 Dec 2005 updated for CIAO 3.3: version numbers
- 01 Dec 2006 updated for CIAO 3.4: ChIPS and Sherpa versions

URL: <http://cxc.harvard.edu/ciao/threads/examinepha2/>

Last modified: 1 Dec 2006

Image 1: Prism view of ACIS–S HETG dataset

prism-1 : acisf00459N002_pha2.fits

File Edit Navigate Visualization Session Analysis

IMAGE	PRIMARY	NULL
TABLE	SPECTRUM	13 cols, 12 rows
TABLE	REGION	11 cols, 36 rows

```

COMMENT This FITS file may contain long string keyword values
COMMENT continued over multiple keywords. The HEASARC convent
COMMENT character at the end of each substring which is then c
COMMENT on the next keyword which has the name CONTINUE.
DATE 2000-10-31T13:18:03 / Date and time of file creatio
DATE-OBS 2000-01-10T06:47:15 / Date and time of observatio
DATE-END 2000-01-10T18:23:09 / Date and time of observatio
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	-3	1	1	4124.92	4068.34	short[8192]	short[819
2	2	-2	1	1	4124.92	4068.34	short[8192]	short[819
3	3	-1	1	1	4124.92	4068.34	short[8192]	short[819
4	4	1	1	1	4124.92	4068.34	short[8192]	short[819
5	5	2	1	1	4124.92	4068.34	short[8192]	short[819
6	6	3	1	1	4124.92	4068.34	short[8192]	short[819
7	7	-3	2	1	4124.92	4068.34	short[8192]	short[819
8	8	-2	2	1	4124.92	4068.34	short[8192]	short[819
9	9	-1	2	1	4124.92	4068.34	short[8192]	short[819
10	10	1	2	1	4124.92	4068.34	short[8192]	short[819
11	11	2	2	1	4124.92	4068.34	short[8192]	short[819
12	12	3	2	1	4124.92	4068.34	short[8192]	short[819

View Mode: Read/Write Processing : 11 of 12

Fri 14-Sep 14:00:28 Loading file acisf00459N002_pha2.fits

Image 2: Prism view of ACIS–S LETG dataset

prism-1 : acisf01198N002_pha2.fits

File Edit Navigate Visualization Session Analysis

IMAGE PRIMARY NULL	COMMENT This FITS file may contain long string keyword values that are
TABLE SPECTRUM 13 cols, 6 rows	COMMENT continued over multiple keywords. The HEASARC convention uses
TABLE REGION 11 cols, 18 rows	COMMENT character at the end of each substring which is then continued
	COMMENT on the next keyword which has the name CONTINUE.
	DATE 2000-10-31T18:39:28 / Date and time of file creation
	DATE-OBS 2000-01-09T19:18:45 / Date and time of observation start
	DATE-END 2000-01-10T06:47:15 / Date and time of observation stop
	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	S
Units					pixel	pixel		count	
Types	short	short	short	short	float	float	short	short	f
1	1	-3	3	1	4162.24	4084.68	short[8192]	short[8192]	f
2	2	-2	3	1	4162.24	4084.68	short[8192]	short[8192]	f
3	3	-1	3	1	4162.24	4084.68	short[8192]	short[8192]	f
4	4	1	3	1	4162.24	4084.68	short[8192]	short[8192]	f
5	5	2	3	1	4162.24	4084.68	short[8192]	short[8192]	f
6	6	3	3	1	4162.24	4084.68	short[8192]	short[8192]	f

View Mode: Read/Write Processing : 1 of 6

Fri 14- Sep 15:03:06 Loading file acisf01198N002_pha2.fits

Image 3: Expanded view of BIN_LO column

Expanded double array column: BIN_LO							
	Element 1	Element 2	Element 3	Element 4	Element 5	Element 6	Element 7
1	6.992867	6.992034	6.991200	6.990367	6.989533	6.988700	6.987867
2	10.489300	10.488050	10.486800	10.485550	10.484300	10.483050	10.481800
3	20.978601	20.976101	20.973601	20.971101	20.968600	20.966100	20.963600
4	20.978601	20.976101	20.973601	20.971101	20.968600	20.966100	20.963600
5	10.489300	10.488050	10.486800	10.485550	10.484300	10.483050	10.481800
6	6.992867	6.992034	6.991200	6.990367	6.989533	6.988700	6.987867
7	13.985000	13.983333	13.981667	13.980000	13.978333	13.976667	13.975000
8	20.977500	20.975000	20.972500	20.970000	20.967500	20.965000	20.962500
9	41.955000	41.950000	41.945000	41.940000	41.935000	41.930000	41.925000
10	41.955000	41.950000	41.945000	41.940000	41.935000	41.930000	41.925000
11	20.977500	20.975000	20.972500	20.970000	20.967500	20.965000	20.962500
12	13.985000	13.983333	13.981667	13.980000	13.978333	13.976667	13.975000

Processing : 11 of 12

Goto Forward Back

OK Help

Image 4: Prism view of HRC–S LETG dataset

prism-1 : hrcf00460N002_pha2.fits

File Edit Navigate Visualization Session Analysis

IMAGE PRIMARY NULL	COMMENT This FITS file may contain long string keyword values that are continued over multiple keywords. The HEASARC convention uses character at the end of each substring which is then continued on the next keyword which has the name CONTINUE.
TABLE SPECTRUM 13 cols, 2 rows	COMMENT
TABLE REGION 11 cols, 6 rows	DATE 2000-11-01T02:28:25 / Date and time of file creation
	DATE-OBS 2000-01-09T07:47:42 / Date and time of observation start
	DATE-END 2000-01-09T19:18:45 / Date and time of observation stop
	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	32831.1	32640	short[16384]	short[16384]
2	2	1	3	1	32831.1	32640	short[16384]	short[16384]

View Mode: Read/Write Processing : 1 of 2

Fri 14- Sep 15:04:40 Loading file hrcf00460N002_pha2.fits

Image 5: Prism view of HRC-I LETG dataset

prism-1 : hrcf01800N002_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 2001-03-01T15:34:00 / Date and time of file creation
 DATE-OBS 2000-08-10T17:38:15 / Date and time of observation s
 DATE-END 2000-08-10T23:20:27 / 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	11783.5	19085	short[16384]	short[16
2	2	1	3	1	11783.5	19085	short[16384]	short[16

View Mode: Read/Write Processing : 1 of 2

Fri 14- Sep 15:06:06 Loading file hrcf01800N002_pha2.fits

Image 6: View of order +1 spectrum with Prism

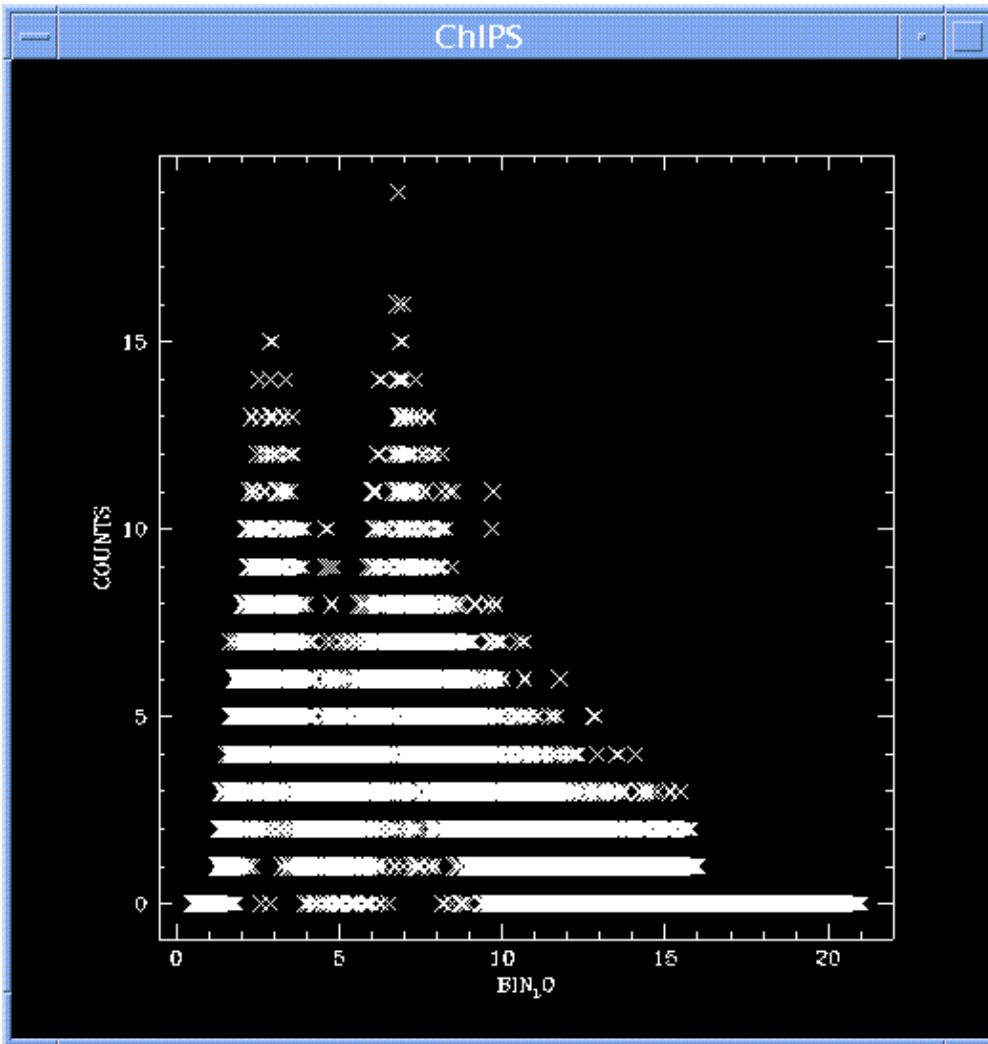


Image 7: View of order +1 spectrum with ChIPS

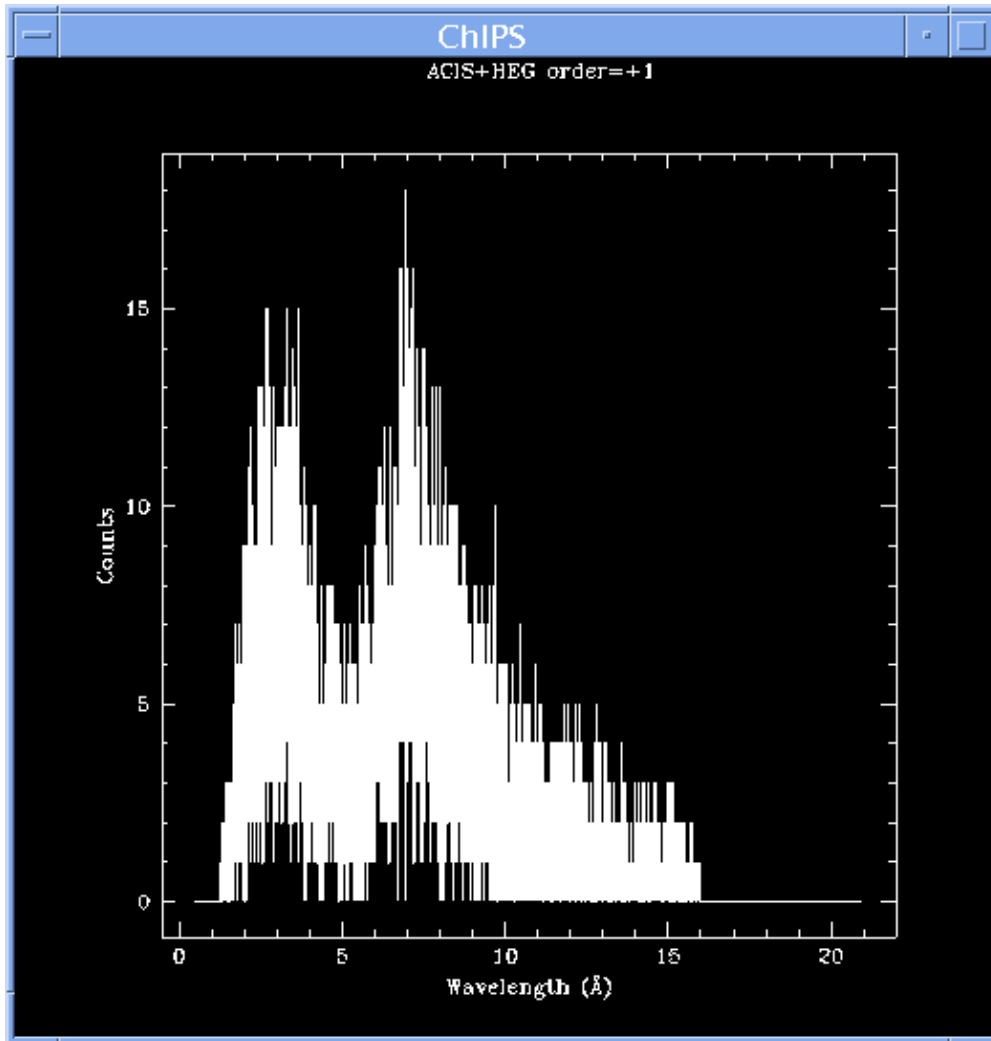


Image 8: View of order ± 1 spectrum with Sherpa: count rate

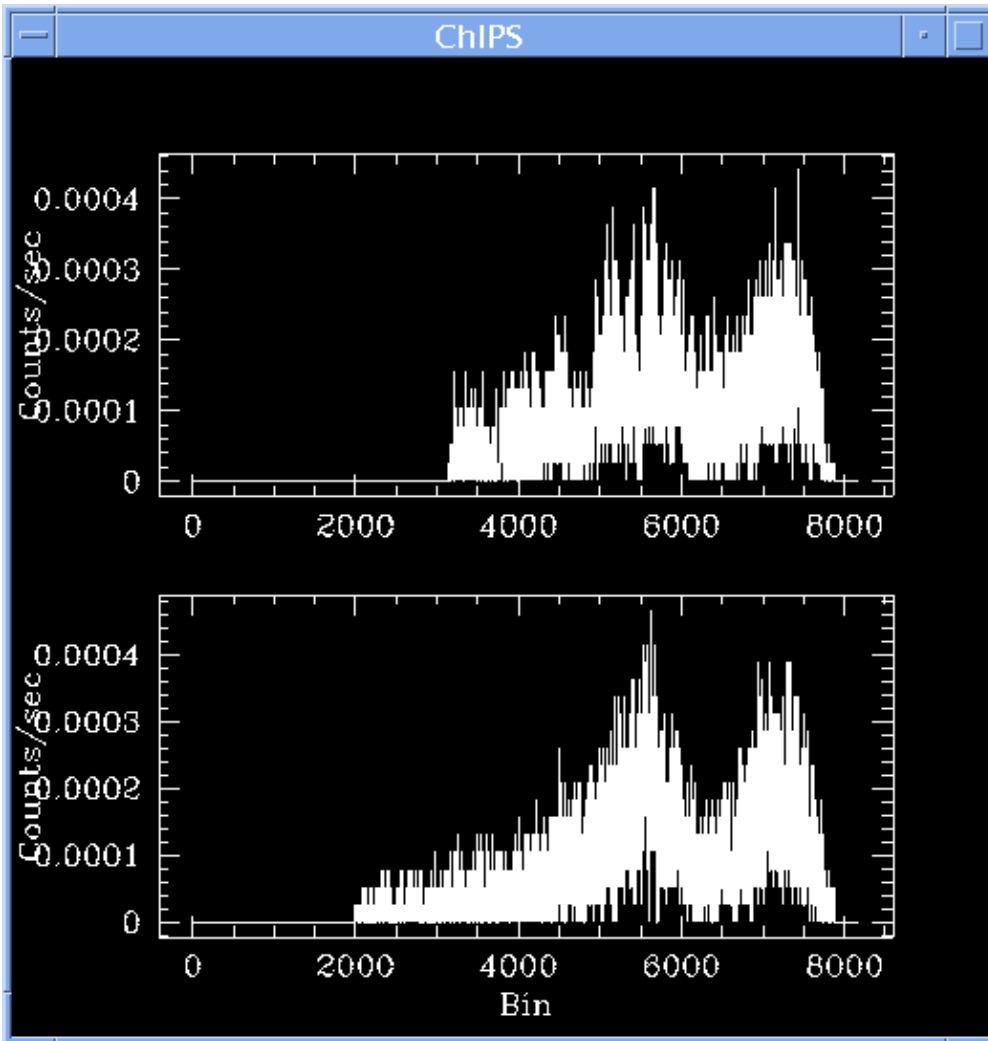


Image 9: View of order ± 1 spectrum with Sherpa: counts

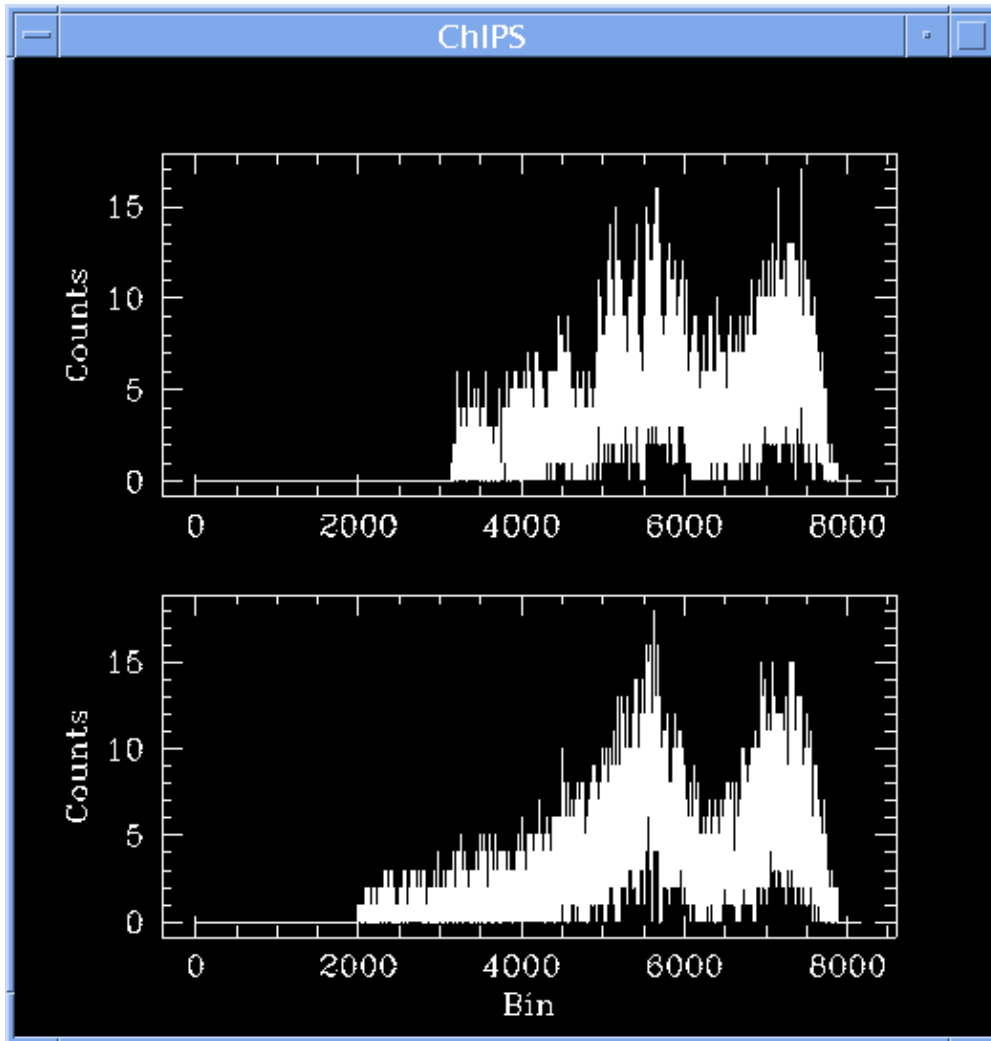


Image 10: Data with source and background regions overlaid

The first order (left) and third (right) order images with extraction regions overlaid.

