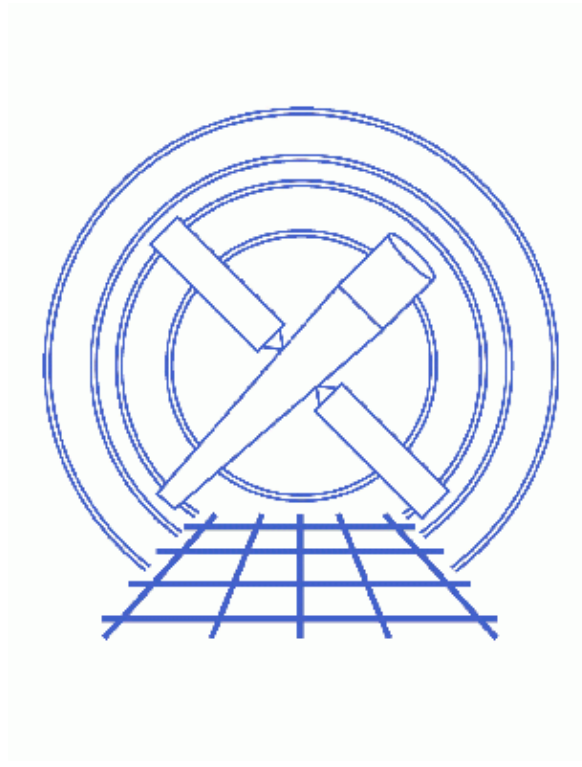


Introduction to Fitting PHA Spectra



Sherpa Threads (CIAO 3.4)

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Introduction to Fitting PHA Spectra

Sherpa Threads

Overview

Last Update: 6 Jan 2007 – example of defining instrument model manually added to [Load the Spectrum & Instrument Responses](#) section

Synopsis:

The basic steps used in fitting spectral data are illustrated in this thread. The data used herein were created by running the [Step-by-Step Guide to Creating ACIS Spectra for Pointlike Sources](#) thread (or, equivalently, the [psextract script](#)).

There are many options and variables that may affect how this process is applied to your data; for a more detailed explanation of the steps, see the following threads:

- [Fitting Spectral Data: PHA Data & Responses and Multi-Component Source Models](#)
- [Fitting Spectral Data: With/Without Independent Background Responses](#)

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

Getting Started

Please follow the "[Sherpa Threads: Getting Started](#)" thread.

Load the Spectrum & Instrument Responses

First, load the spectrum file:

```
sherpa> DATA 3c273.pi
The inferred file type is PHA.  If this is not what you want, please
specify the type explicitly in the data command.
WARNING: statistical errors specified in the PHA file.
        These are currently IGNORED.  To use them, type:
        READ ERRORS "<filename>[cols CHANNEL,STAT_ERR]" fitsbin
Background data are being input from:
  /data/sherpa/pha_intro/3c273_bg.pi
WARNING: statistical errors specified in the PHA file.
        These are currently IGNORED.  To use them, type:
        READ BERRORS "<filename>[cols CHANNEL,STAT_ERR]" fitsbin
RMF is being input from:
  /data/sherpa/pha_intro/3c273.rmf
ARF is being input from:
  /data/sherpa/pha_intro/3c273.arf
sherpa>
```

Introduction to Fitting PHA Spectra – Sherpa

Since the `RESPFILE`, `ANCRFILE`, and `BACKFILE` header keywords were updated in the spectrum file, the response files (`RMF` and `ARF`) and background file are automatically read in as well.

In this case, *Sherpa* automatically defines the instrument model (`RSP`) for source and background data and adds it to the instrument model stack. If *Sherpa* does not automatically read in the response files, define the instrument model manually:

```
sherpa> INSTRUMENT SOURCE 1 = RSP[mydetector]("3c273.rmf", "3c273.arf")
The inferred file type is ARF.  If this is not what you want, please
specify the type explicitly in the data command.

sherpa> INSTRUMENT BACK 1 = mydetector
```

Use `SHOW` to get the status of the *Sherpa* session:

```
sherpa> SHOW
...
-----
Defined analysis model stacks:
-----


instrument source 1 = AutoReadResponse
instrument back 1 = AutoReadResponse

-----
Defined instrument model components:
-----

rspld[AutoReadResponse]
  Param  Type      Value          Min      Max      Units
  ----  -
  1      rmf string: "/data/sherpa/pha_intro/3c273.rmf" (N_E=1090,N_PHA=1024)
  2      arf string: "/data/sherpa/pha_intro/3c273.arf" (N_E=1090)
```

Plot the data:

```
sherpa> LPLOT DATA
```

The data are plotted in energy space – as seen in [Figure 1](#)  – since the instrument model provides the information necessary to compute the predicted counts for each bin.

Filter the Data & Subtract the Background

Looking at the plot, we decide to evaluate the fit on the energy range between 0.1 and 6.0 keV. The CIAO why topic on [Choosing an Energy Filter](#) has more information on this process. To apply this filter to the dataset:

```
sherpa> NOTICE ENERGY 0.1:6.0
```

At this point, we also opt to subtract the background data (see the [Fitting Spectral Data: With/Without Independent Background Responses](#) thread for other options):

```
sherpa> SUBTRACT
```

[Figure 2](#)  shows the resulting plot.

Defining the Source Model

Before fitting the data, it is necessary to define a model that characterizes the source. We use a source model composed of two model components:

- `POWLAW1D` – a one-dimensional power law.
- `XSPHABS` – an XSpec photoelectric absorption model.

After turning off parameter prompting, we define an expression that is the product of these two components:

```
sherpa> PARAMPROMPT OFF
Model parameter prompting is off
sherpa> SOURCE = xsphabs[abs]*powlaw1d[p1]
sherpa> abs.nh=0.07
sherpa> FREEZE abs
```

Based on the data that has been loaded, *Sherpa* estimates the initial value for each parameter. We manually set the value of the hydrogen column density (nH) to the known Galactic value for our source and freeze the parameter; this means that it will not be included in the fit.

The current source model definition may be displayed:

```
sherpa> SHOW SOURCE
Source 1: (abs * p1)
xsphabs[abs] (XSPEC model name: phabs) (integrate: off)
  Param  Type      Value      Min      Max      Units
  -----
  1      nH frozen    7e-02     1e-07    10      10**22 atoms/cm**2
powlaw[p1] (integrate: on)
  Param  Type      Value      Min      Max      Units
  -----
  1      gamma thawed    1          -10     10
  2      ref frozen    1          0.1248  5.9057
  3      ampl thawed  7.9257e-06 7.9257e-08 7.9257e-04
```

By default, integration of model values over each energy bin (delta E) is turned off for `xsphabs` and is turned on for `powlaw1d`. Since we are using a multiplicative source model expression, *integration will be performed* during fitting; see "[ahelp integrate](#)" for more information.

Note that *Sherpa* and *XSPEC* absorption models have to be multiplied by models which have the normalization and amplitude parameters, such as `powlaw1d`. These models cannot be used as single model in the source expression, while the models with the normalization can.

Fitting


Now we are ready to run the fit. We use the default statistics (`CHI GEHRELS`) and optimization method (`Levenberg–Marquardt`):

```
sherpa> FIT
LVMQT: V2.0
LVMQT: initial statistic value = 355.854
LVMQT: final statistic value = 37.9079 at iteration 10
      p1.gamma  2.1585
      p1.ampl   0.000224838
```

The screen output shows the final value of the minimum statistics with the total number of iterations and the final values of the thawed parameters of the power law, namely photon index and amplitude at ~1 keV.

Plotting the fit and residuals:

```
sherpa> LPLOT 2 FIT DELCHI
```

produces [this plot](#) . The errors are plotted as DELCHI, the sigma residuals of the fit [(data - model)/error].

Examining Fit Results

There are several ways to calculate statistics on fit results in *Sherpa*. Here we show two of them: [GOODNESS](#) and [COVARIANCE](#).

Goodness of fit

The [GOODNESS](#) command – which may be shortened to `GOOD` – reports how well specified models were fit to the data, i.e. it gives the final statistic value for the best fit parameters reported above.

```
sherpa> GOODNESS
Goodness: computed with Chi-Squared Gehrels

DataSet 1: 44 data points -- 42 degrees of freedom.
Statistic value           = 37.9079
Probability [Q-value]    = 0.651155
Reduced statistic        = 0.902569
```

It reports the choice of statistic, the number of bins in the fit, the number of degrees of freedom (i.e. the number of bins minus the number of free parameters), and the statistic value. If the chosen statistic is one of the chi-square statistics, as in this example, the reduced statistic (i.e. the statistic value divided by the number of degrees of freedom) and the probability (Q-value) are also reported. The [help file](#) has information on how the Q-value is calculated.

Confidence intervals

The [COVARIANCE](#) command – which may be shortened to `COVAR` – computes covariance matrices and provides an estimate of confidence intervals for the thawed parameters (see also the related command [PROJECTION](#)):

```
sherpa> COVAR

Computed for sherpa.cov.sigma = 1

-----
Parameter Name      Best-Fit Lower Bound   Upper Bound
-----
p1.gamma            2.1585  -0.0827851  +0.0827851
p1.ampl              0.000224838 -1.48256e-05  +1.48256e-05
```

The output is the best-fit parameter value with positive and negative error estimates. The [covariance help file](#) describes the relationship between sigma and the change in statistic value. One sigma corresponds to 68.3% errors.

Script the Session

The commands used in this thread may also be executed via a *Sherpa* script, which we have named [pha_intro.shp](#):

```
DATA 3c273.pi
NOTICE ENERGY 0.1:6.0
SUBTRACT
PARAMPROMPT OFF
SOURCE = xsphabs[abs]*powlaw1d[p1]
abs.nh=0.07
FREEZE abs
FIT
GOODNESS
COVAR
```

There are two ways to load this script:

- With the USE command in an existing session:

```
sherpa> USE pha_intro.shp
```

- When starting a new *Sherpa* session:

```
unix% sherpa pha_intro.shp
```

Note that when the script ends, you are at the *Sherpa* prompt. This allows you to continue the analysis – plot, adjust parameters, fit the data again – if desired.

History

14 Jan 2005 reviewed for CIAO 3.2: no changes

21 Dec 2005 reviewed for CIAO 3.3: no changes

01 Dec 2006 reviewed for CIAO 3.4: no changes

06 Jan 2007 example of defining instrument model manually added to [Load the Spectrum & Instrument Responses section](#)

URL: http://cxc.harvard.edu/sherpa/threads/pha_intro/

Last modified: 6 Jan 2007

Image 1: Plot of source spectrum

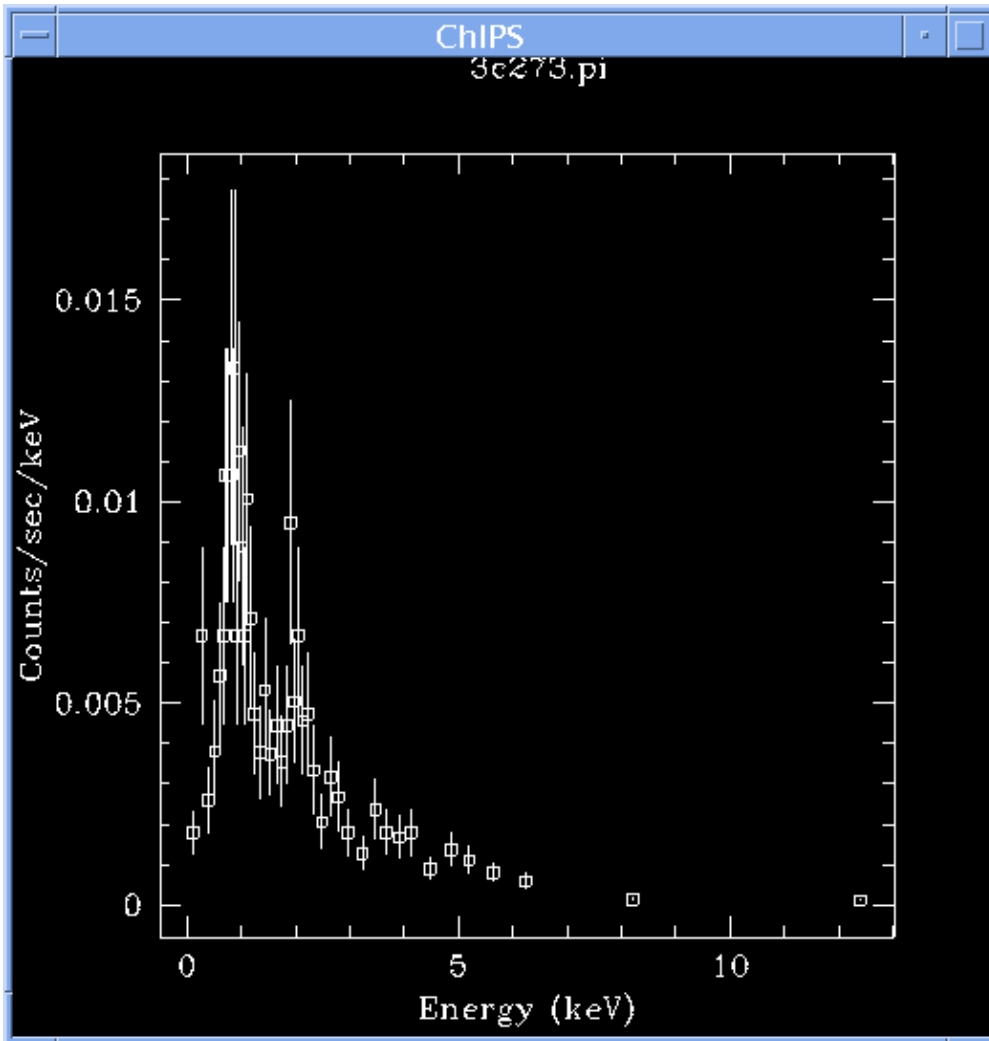


Image 2: Source spectrum, filtered and background-subtracted

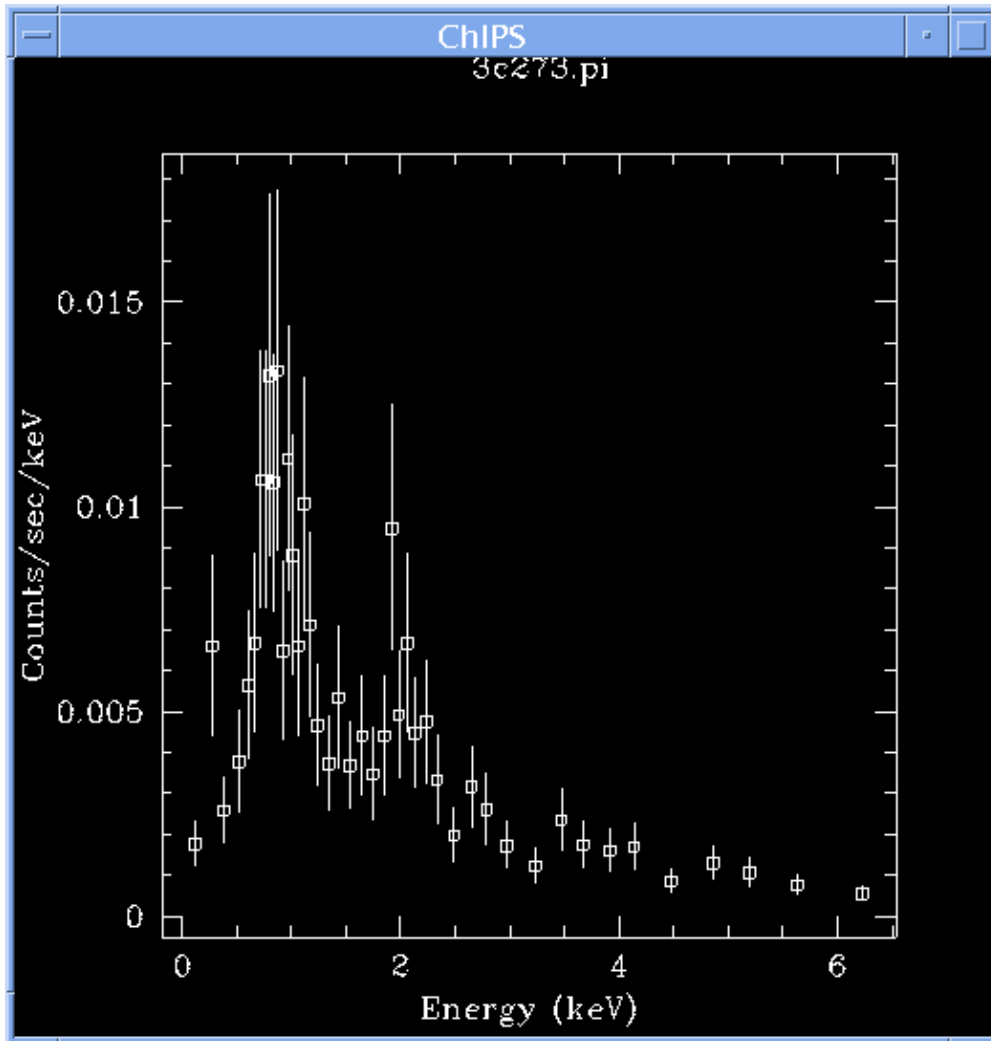


Image 3: Fit and sigma residuals

