SHERPA

CIAO's Modeling and Fitting Application

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Modeling and Fitting Software

- **XSPEC** - analysis of 1D X-ray data (imaging + grating)
- **ISIS** and **Pint of Ale** - primarily for analysis of high-resolution (ie grating) X-ray data
- **Sherpa** - generalised multi-dimensional fitting package

All programs use the technique of **forward fitting**: a model is evaluated, compared to the actual data, and then the parameters are changed to improve the match. This is repeated until convergence occurs.
What can you do in Sherpa?

- Standard PHA based analysis.
- Model data in many spectral bands simultaneously, e.g., optical/ X-rays.
- Access ATOMDB and GUIDE/ISIS for grating data analysis.
- Fit radial profiles.
- Simulate 1D data.
- Model 2D image data, e.g., fit surface brightness of the extended source.
- Get normalization of your PSF, while fitting the data with 1D/2D PSF.
- Use the PSF as a convolution kernel in the 2D image analysis (FFT or sliding cell).
- Convolution using the TCD library kernel.
- Use of exposure maps in the image analysis.
- Joint-mode data: spatial-spectral, spatial-timing
- Use scripts based on Sherpa only commands.
- Use S-lang on command line and in S-lang based scripts. S-lang allows you to access directly the internal information about the data, models, statistics.
- Use your own models with User Models and S-lang user models.
What happens in Sherpa?

A set of Models

Combined to create a Source Expression

Model Parameters

Instrument Stack (ARF&RMF for PHA data Exposure Map and/or PSF for an image, NONE for radial profile)

Add on the Background Stack

Predicted Data

Input Data (with Errors)

Compare

Fit Statistics

Optimization
Main SHERPA Components

- Data Input/Output.
- Visualization through ChIPS and ds9
- Model library and model language.
- Statistics and Error Analysis.
- Optimization Methods.
- Access to the internals through S-lang.
Data Input/Output

- General use of data type and dimensionality.
- Supported types of files: ASCII, FITS binary tables and Images, PHA types I & II, IRAF IMH and QPOE files
- Sherpa:
  - groups the data if appropriate;
  - treats integer, float or double precision data;
  - supports data of arbitrary dimensionality
- I/O interface through Data Model and Varmm
- Filtering while reading the data.
- Input data on the command line in two ways.
MODELS

- Three main type of models:
  - Source
  - Background
  - Instrument

- Model library consists of several models (plus XSPEC v.11) which can be used to define a source or background model

- There are different types of instrument models to support both 1D and 2D analysis.

- Instrument models are convolved with Source and Background models before the model predicted data is compared with the observed data.

- Instrument and Background models are NOT required. Source models have to be defined for fitting.
Fit Statistics in Sherpa:

*Sherpa* has a large array of statistics appropriate for analyzing Poisson-distributed (i.e. counts) data.

- **Statistics based on $\chi^2$:**
  - CHI GEHRELS
  - CHI DVAR
  - CHI MVAR
  - CHI PARENT
  - CHI PRIMINI

- **Statistics based on the Poisson likelihood:**
  - CASH
  - BAYES

If the data are not Poisson-distributed (i.e. fluxes), then alternatives include:

- least-squares fitting: setting all variances to one
- providing errors in an input file.
Optimization in Sherpa

**Optimization** => minimizing the statistics ($\chi^2$ or $\log L$) by varying the thawed parameters of the model.

- **Find a local minimum:**
  - LEVENBERG-MARQUARDT
  - POWELL
  - SIMPLEX

- **Attempt to find the global minimum:**
  - GRID
  - GRID-POWELL
  - MONTECARLO
  - MONTE-LM
  - MONTE-POWELL
  - SMULATED ANNEALING

- **Optimize/Reject/Filter:**
  - SIGMA-REJECTION  outliers are filtered from the data.
Confidence Intervals

- Vary a parameter's value, while holding the values of all the parameters to their best-fit values, until the fit statistic increases by some preset amount from its minimum value ($\chi^2 = 1$ for 1).

- Uncertainty

- Projection

- Calculate **Covariance** matrix:

  1. confidence intervals are given by $\sqrt{C_{i,i}}$

  where $C_{j,i} = I^{-1}_{i,j}$

  and $I_{i,j}$ - the information matrix computed at the best-fit point:

$$I_{i,j} = \frac{\partial^2}{\partial p_i \partial p_j}$$

or any other statistics
Visualize Confidence Levels

Data and the Best Fit Model

Well behave parameter space!
Customize Sherpa

Sherpa State Object (e.g. Configuration file) – S-lang variable initialized at the start of the Sherpa session:

```
sherpa> print(sherpa)
plot = sherpa_Plot_State
dataplot = sherpa_Plot_State
fitplot = sherpa_FitPlot_State
resplot = sherpa_Plot_State
multiplot = sherpa_Draw_State
output = sherpa_Output_State
regproj = sherpa_VisParEst_State
regunc = sherpa_VisParEst_State
intproj = sherpa_VisParEst_State
intunc = sherpa_VisParEst_State
proj = sherpa_Proj_State
cov = sherpa_Cov_State
unc = sherpa_Unc_State
con_levs = NULL
modeloverride = 0
multiback = 0
deleteframes = 1
clobber = 0
```

Customize Plotting

```
sherpa> print(sherpa.regproj)
fast = 1
expfac = 3
arange = 1
min = Double_Type[2]
max = Double_Type[2]
log = Integer_Type[2]
nloop = Integer_Type[2]
sigma = Double_Type[3]
```
Customize Sherpa

- **Sherpa Resource File:**
  - A text file with Sherpa/Chips/S-lang commands

- **Access:**
  - Environment variable **SHERPARC**
  - File `.sherparc` in current directory `$PWD$
  - File `.sherparc` in HOME directory `$HOME$

- **Example:**
  ```bash
  unix% more .sherparc
  # Example Sherpa resource file
  message("Starting to process sherparc")
  paramprompt off
  method simplex
  define q () { () = sherpa_eval("quit"); } 
  message("Finished processing .sherparc")
  ```
Learn More on Sherpa Web Page

http://cxc.harvard.edu/sherpa/

Sherpa CIAO 3.1 Highlights

- Sherpa CIAO's preprocessed modeling and fitting facility allows users to analyze complex models and to create custom fits.
- Sherpa's extensive library of function models and statistical algorithms is modular, allowing for greater flexibility.
- The Sherpa package is designed to be user-friendly and efficient, with a focus on ease of use.
- Sherpa threads explain the basic CxO reading data, obtaining models, fitting, and plotting. These threads describe the interface between Sherpa and CIAO, focusing on the use of the Sherpa Web Page.

Sherpa Threads for CIAO

Introduction

These threads explain the basic CxO reading data, obtaining models, fitting, and plotting. These threads describe the interface between Sherpa and CIAO, focusing on the use of the Sherpa Web Page.

Fitting

Sherpa provides extensive facilities for modeling and fitting data. These include both the classical method and the statistical approach to fitting data. These threads describe the use of the Sherpa Web Page.

Plotting

Sherpa provides extensive facilities for plotting data. These include the use of the Sherpa Web Page.

Statistics

Sherpa provides extensive facilities for conducting statistical analyses, including parameter estimation, confidence intervals, and other statistical tests. These threads describe the use of the Sherpa Web Page.

Miscellaneous

These threads provide additional information that can be performed using Sherpa.