CIAO in 2013

The 4.6 release, brand new analysis scripts, a workshop, and some tips and tricks.

Antonella Fruscione, for the CIAO Team

Version 4.6 of CIAO and CALDB 4.5.9, the newest versions of the *Chandra* Interactive Analysis of Observations software and the *Chandra* Calibration Database, were released in November/December 2013. A small patch to the Sherpa package, CIAO 4.6.1, was later released in February 2014.

CIAO 4.6 (http://cxc.harvard.edu/ciao) includes numerous enhancements and bug fixes with respect to previous CIAO versions, all listed in detail in the software release notes. We will describe here some of the most notable changes and improvements. CIAO 4.6 is available for several 32 and 64 bit platforms including Linux CentOS 5 & 6 and Fedora Core 11, and Mac OSX 10.6.8 (Snow Leopard), 10.7 (Lion), 10.8 (Mountain Lion) and the latest 10.9 (Mavericks).

CIAO Tools

Two new tools have been added to help automate the detection of the 0th order location in grating observations: `tg_choose_method` and `tgdetect2`. The zeroth order of a *Chandra* grating observation defines the origin of the dispersed spectrum's wavelength scale. Hence, accurate determination of the zeroth order centroid is a fundamental step in the processing of grating data. The ACIS detector, however, can become saturated by bright sources. The brighter the source, the greater the distortion of the zeroth order due to rejection of core events, eventually leading to a "cratered" central region with few or no events. To mitigate telemetry saturation for observations of extremely bright sources, ACIS itself is sometimes configured to exclude the zeroth order from telemetry. In these distorted or blocked zeroth order cases the tgdetect tool fails to give an accurate result and the `tg_findzo` tool needs to be used instead. The new `tgdetect2` tool bundles three programs, `tg_choose_method`, `tg_findzo`, and `tgdetect`, into one so that the most appropriate method is chosen and used for the 0th order determination.

The suite of hotpixel tools, `acis_run_hotpix`, `acis_find_hotpix`, and `acis_classify_hotpix`, has been withdrawn from CIAO. The `acis_find_afterglow` tool is now considered the best tool available to identify cosmic ray afterglows without losing a large fraction of events from bright sources.

The ACIS parameter-block filename parameter, `pbkfile`, in `mkarf`, `mkgarf`, `mkwarf`, `eff2evt`, and `mean_energy_map` is no longer used. The information from this file, used in those tools, is now encoded in all the data products in the *Chandra* archive, which have been processed with the Standard Data Processing pipeline ASCDSVER 8.4.2 and later. It is also properly encoded in data that have been reprocessed with the `chandra_repro` script. So, there is one less input file that users need to carry around: the `acis*pbk*.fits` file is no longer needed for analysis.

Users with older data who choose not to reprocess their data, can use the new `r4_header_update` script to update the header; this will be done automatically if `chandra_repro` is run.

Sherpa

Sherpa (http://cxc.harvard.edu/sherpa/) is the modeling and fitting application within CIAO and can be used for analysis of images, spectra and time series from many telescopes, including optical telescopes such as *Hubble*. Sherpa is flexible, modular and extensible. It has an IPython user interface and it is also an importable Python module. Sherpa models, optimization, and statistical functions are available via both Python and C++ for software developers wishing to link such functions directly to their own code. Important changes and additions to the Sherpa functionality in the CIAO 4.6 release and 4.6.1 patch are described in a dedicated webpage at http://cxc.harvard.edu/sherpa/updates.html.

The most notable improvement in the CIAO 4.6 Sherpa release concerns template models (http://cxc.harvard.edu/sherpa/threads/template_model/). The Sherpa template model is available for comparing a source data spectrum against a set of user-provided template models, in order to find the single template model which best matches the source data. Generally a special grid-search fit optimization method, `gridsearch`, is used to fit a template model to a data set in Sherpa—however CIAO 4.6 adds the ability to use templates with fitting methods other than `gridsearch`. Starting with a directory of template model files conforming to a specific format, and a single index file listing the file contents of that directory, the models are loaded into the Sherpa session using the `load_template_model`

function, an extension of `load_table_model`. After fitting the template model to the source data using the fit optimization method, the parameters of the best-match template model are returned. Fit results may be examined in the usual way with the appropriate plotting commands. The Sherpa template model supports linear, nearest-neighbor, and polynomial interpolation. Interpolation is used by the template model to match the data grid to the model grid, which must match before the fit statistics can be calculated for fitting.

CIAO 4.6 introduces the ability to interpolate between templates loaded with the `load_template_model` function, so that intermediate parameter values may be found during a fit. It also adds the ability to use templates with fitting methods other than gridsearch and to combine templates with other Sherpa models, and fit on all parameters (from both the template and the continuous models).

ChIPS

ChIPS (http://cxc.harvard.edu/chips/) is the imaging and plotting platform for CIAO which can be used during data analysis—e.g. to plot a lightcurve or a spectrum—and to create publication-quality figures. ChIPS is designed for use in a variety of modes: as a user-interactive application and in batch mode. ChIPS is an importable module for the Python scripting language and is available as a C/C++ library for software developers.

The CIAO 4.6 release of ChIPS does not include any major new functionality but several minor enhancements and bug fixes. A large gallery of ChIPS examples is available on the ChIPS website at http://cxc.harvard.edu/chips/gallery/ and there are a number of introductory threads to guide beginners.

CIAO Scripts

The CIAO contributed scripts package (http://cxc.harvard.edu/ciao/download/scripts/) is considered a required part of the software installation and contains analysis scripts and modules written by scientists at the CXC. The contributed scripts and modules automate repetitive tasks and extend the functionality of the CIAO software package by filling specific analysis needs. The package is updated every few months or as needed, and also concurrently with major CIAO releases. During 2013 there were 4 script package releases bringing in some major new functionality and important enhancements, all listed at http://cxc.harvard.edu/ciao/download/scripts/history.html. A few important scripts are highlighted below.

`srcflux`: given an event file and a location, this script calculates the net count rates and fluxes, including uncertainties, using three different methods. The count rate is calculated using the `aprates` tool, and so can be used to estimate upper limits as well as detections, and—for point sources—to account for the PSF contribution to both the source and background regions. The flux is estimated in three ways:

- a model-independent estimate, using the `eff2evt` tool
- a model-dependent estimate, using the `modelflux` tool to calculate the conversion factor for a given spectral model (for this stage ARFs and RMFs will be created for each source).
- in photon units by using the `fluximage` tool to create exposure map and exposure corrected image.

The analysis thread "Calculate Source Count Rates and Fluxes" (http://cxc.harvard.edu/ciao/threads/fluxes/) has examples on how to use this new script as well as tips in case of problems.

Example output from `srcflux` operating on an event file.

```
unix% srcflux acisf13459_repro_evt2.fits "0:55:51.013 +26:22:43.95" myout
[...]
Summary of source fluxes

Position                          0.5-7.0 keV
                                  Value     90% Conf Interval
0 55 51.01 +26 22 43.9  Rate      0.00191c/s (0.00168,0.00214)
                        Flux      2.27E-14 erg/cm2/s (2E-14,2.55E-14)
                        Mod.Flux  2.43E-14 erg/cm2/s (2.14E-14,2.73E-14)
```

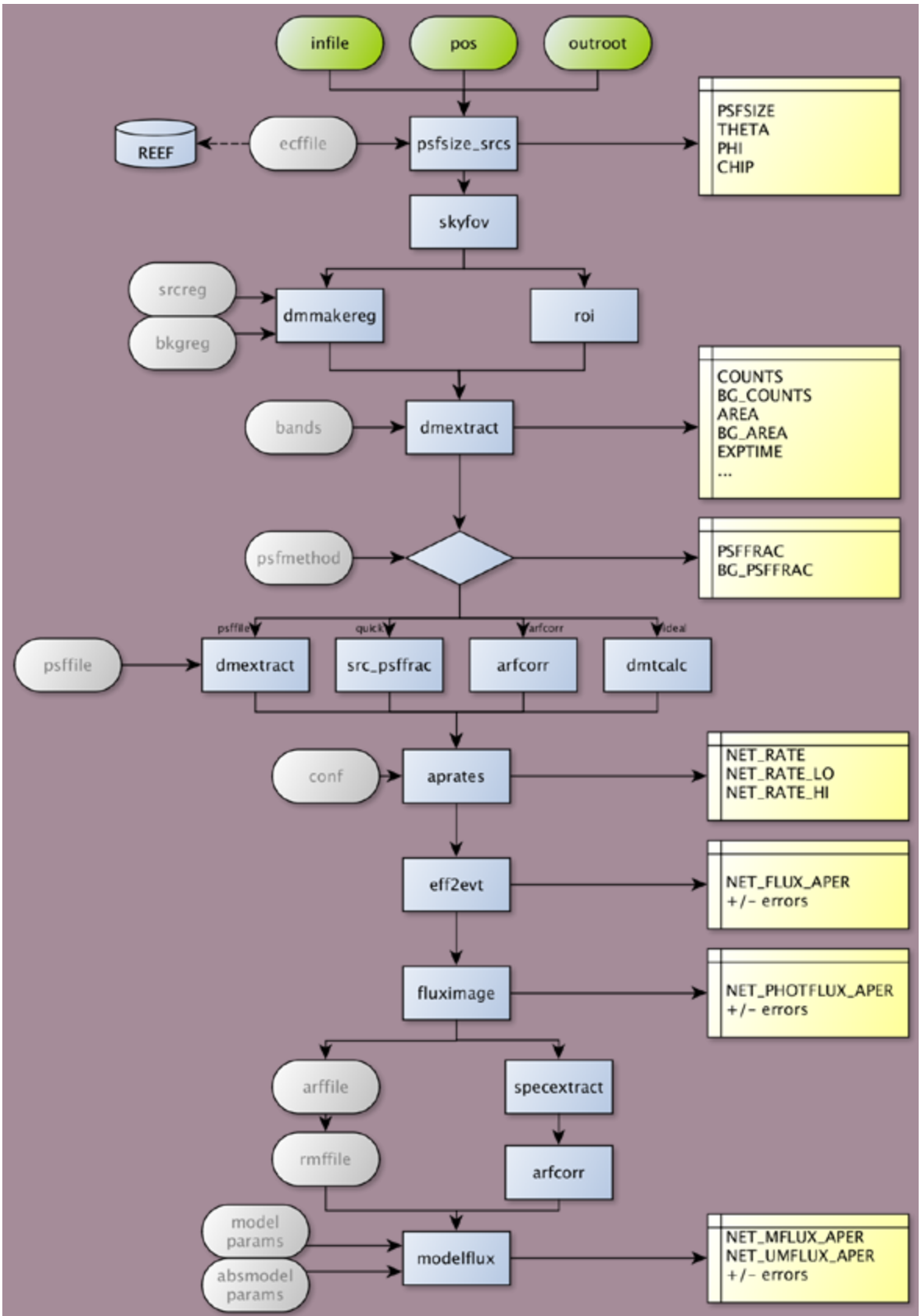

Fig. 1 — As schematically illustrated in this flowchart, `srcflux` *combines many existing CIAO tools and scripts and encodes the logic described in the CIAO threads to return count rates and fluxes with all appropriate corrections.*

The following search will retrieve all the default source properties for all the sources detected in ObsID 635 (RhoOph). The output columns are saved in a Tab Separated Value (TSV) file and includes properties such as position, fluxes, extent, and measures of variability. Additionally, the spectrum (pha) files and the associated response files (ARF and RMF) for each source will optionally be downloaded (only the first source is downloaded in this example).

```
unix% obsid_search_csc 635 outfile=rhooph.tsv verb=0 filetype=pha,rmf,arf download=ask
Download data for CXO J162602.2-242348 in 00635_000 [y,n,a,q]: y
Download data for CXO J162603.1-242336 in 00635_000 [y,n,a,q]: q
Skipping remaining sources
```

```
unix%  ls -1 635/CXOJ162602.2-242348/
acisf00635_000N001_r0067_arf3.fits.gz
acisf00635_000N001_r0067_pha3.fits.gz
acisf00635_000N001_r0067_rmf3.fits.gz
```

The spectrum file that is retrieved can be loaded directly into Sherpa for analysis. The background spectrum is automatically recognized as being located in the second extension of the PHA file. The response files are also automatically recognized.

```
unix% sherpa
-------------------------------------------------
Welcome to Sherpa: CXC's Modeling and Fitting Package
-------------------------------------------------
CIAO 4.6 Sherpa version 1 Monday, December 2, 2013
```

```
sherpa-1> load_data("635/CXOJ162602.2-242348/acisf00635_000N001_r0067_pha3.fits.gz")
read ARF file 635/CXOJ162602.2-242348/acisf00635_000N001_r0067_arf3.fits
read RMF file 635/CXOJ162602.2-242348/acisf00635_000N001_r0067_rmf3.fits
read background file 635/CXOJ162602.2-242348/acisf00635_000N001_r0067_pha3.fits
sherpa-2> plot_data()
```

The source properties are stored in the TSV output file, rhooph.tsv. Thanks to the DM's ASCII kernel, this file can be read into all CIAO applications. Users simply need to specify the specific ASCII format, [opt kernel=text/tsv], due to its unique header structure. Shown here is how to simply plot two columns using ChIPS.

```
unix% chips
---------------------------------------
Welcome to ChIPS: CXC's Plotting Package
---------------------------------------
CIAO 4.6 ChIPS version 1 Monday, December 2, 2013
chips-1> make_figure("rhooph.tsv[opt kernel=text/tsv][cols cnts_aper_b,flux_significance_b]")
chips-2> show_gui() →to customize the plot
```

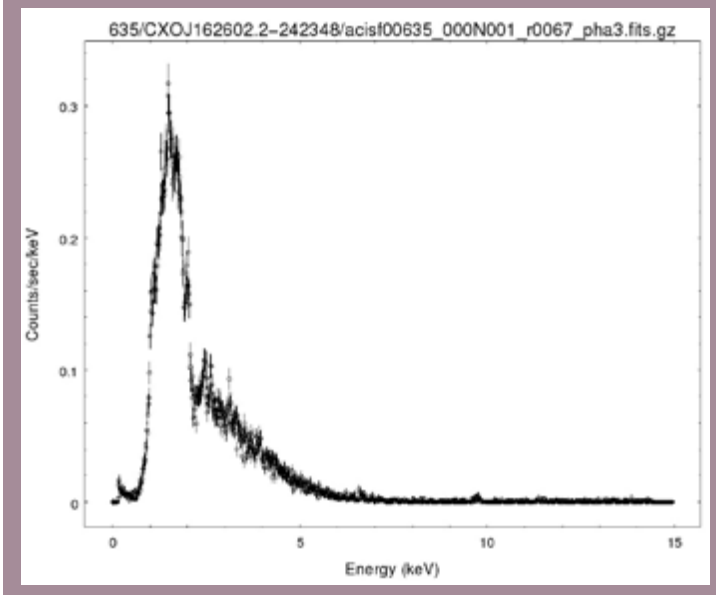

Fig. 2 — Sherpa example output

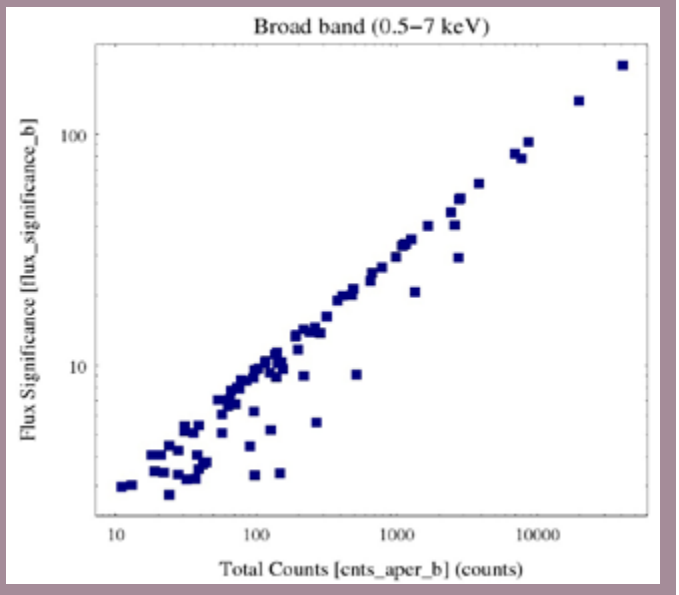

Fig. 3 — ChIPS example output

`search_csc` and `obsid_search_csc`: these scripts allow full command line access to the *Chandra* Source Catalog (CSC), with simple search capabilities. Searches can be accomplished by position or by obsid with access to all the Master and all the Observations properties.

Both scripts can retrieve arbitrary sets of columns from the CSC and save the results as a tab-delimited ASCII file that can be used directly with other CIAO applications. Additionally, the per source and per observation data products—including event files; images; spectra; lightcurves; and their associated response files (PSF, RMF, ARF, exposure maps) may be retrieved.

The thread *Simple Command Line Access to the Chandra Source Catalog* (http://cxc.harvard.edu/ciao/threads/csccli/) illustrates the usage of these new scripts.

`tgmask2reg` and `reg2tgmask`: these scripts allow the use of DS9 to define custom extraction regions for HRC grating observations to be used with the `tgextract2` tool which provides support for variable-shaped background regions (see the thread "*Applying Customized Background Regions to LETG/HRC-S Observations"* at http://cxc.cfa.harvard.edu/ciao/threads/tgextract2/)

`mktgresp`: this script creates ARF and RMF for each spectral order and grating arm in a Type II PHA file. It runs the `mkgrmf` tool and the `full-garf` script with the appropriate inputs using the energy and channel grids. For ACIS data, the default PHA files has 12 spectra for HETG: ± 3 orders for each MEG and HEG, and 6 for LETG: ± 3 orders. Since HRC lacks energy resolution, the spectra cannot be order separated so there are only 2 spectra: ± 1 which represents the contribution from all orders. A corresponding number of responses files are created by `mktgresp`.

`dax` (ds9 analysis extensions): a number of common CIAO tasks are available from the ds9 Analysis menu. This menu addition allows users to get source counts, smooth an image, and create a histogram—among many other things—from the ds9 program in CIAO. A number of new tasks are available in CIAO 4.6 `dax`: a Sherpa menu to automatically fit some simple 1D and 2D models, aperture photometry, period fold, convex hull, PSF size and fraction, distance transform and image moments. Several YouTube demos (http://www.youtube.com/playlist?list=PLE60ED562991C612E) illustrate the use of `dax` in ds9.

`psfsize_srcs` and `src_psffrac`: these scripts (a) compute the size of a circle that encloses the specified fraction of the PSF at the specified energy for each of the input positions or (b) compute an approximate value of the fraction of the PSF in circular regions at the specified monochromatic energy.

`list_datasetid`: this script provides the LaTeX identifier macro used to describe observations in papers written for AAS managed publications. The CXC encourages users to make use of dataset identifiers when publishing in AAS managed publications. This allows the publisher, through agreement with the *Chandra* Data Archive as well as other archives, to provide links to the actual datasets within their document. This makes it easier for readers to locate the data being reported on in the manuscript.

Fig. 2 — The 9th Chandra/CIAO workshop

9th CIAO Workshop

The 9th *Chandra*/CIAO workshop was held on April 23 and 24, 2013 at the Harvard-Smithsonian Center for Astrophysics in Cambridge, MA. It was 2 days of hands-on work with one introductory talk on CIAO and the recent advancements in CIAO scripts. Sample analysis exercises were provided for students, who were also encouraged to bring their own data if they had any: some students arrived with specific problems or questions in hand, while others were beginners just getting started with CIAO for the first time.

From the feedback we received, the workshop was productive for attendees and was certainly very useful for us for improving our existing on-line documentation.

Tips, Tricks, and Techniques

Most of the CIAO analysis threads (http://cxc.harvard.edu/ciao/threads/all.html) are focused on a particular science goal or objective: instrument, grating, point source vs. extended, etc. They present the best path to reduce the data for those specific goals. However, there are many kinds of analysis techniques that apply to general data reduction that can be performed with CIAO—on *Chandra* data or other missions.

The threads presented in this new section of the CIAO threads "Tips, Tricks and Techniques"—TTT (http://cxc.harvard.edu/ciao/threads/ttt.html) will focus on *how* to accomplish a particular task and the options available. *When* one should use these techniques, and *why* one might want to do such a thing is up to the user. The emphasis is to highlight the functionality available. We are expecting that users will find uses for CIAO that the CXC might not have anticipated.

More information and updates on CIAO can always be found at http://cxc.harvard.edu/ciao/ or subscribe to the CIAO News RSS feed at http://cxc.harvard.edu/ciao/feed.xml The latest tutorials, demos, and screen-casts of CIAO are available onthe "4ciaodemos" channel at http://www.youtube.com/user/4ciaodemos

To keep up-to-date with CIAO news and developments subscribe to the *Chandra* Electronic Announcements at http://cxc.harvard.edu/announcements/.