CIAO 4.4

Improved tools, a new graphical user interface for plotting and advanced Sherpa functionality

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The newest versions of the *Chandra* Interactive Analysis of Observations software and the *Chandra* Calibration Database (Version 4.4 of CIAO and CALDB 4.4.7), were released in December 2011 (*http://cxc.harvard.edu/ciao*). These include 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 Tools

• `acis_find_afterglow` is a new tool which improves over previous algorithms by identifying shorter afterglows as well as ones with larger gaps between the events comprising them.

A cosmic-ray "afterglow" is produced when a large amount of charge is produced by interaction with a charged particle. Most of the charge is clocked off of the CCD in a single frame. However, a small amount can be captured in charge traps, which release the charge relatively slowly. As a result, a sequence of events can appear in a single pixel over a few to even a few dozen frames, and the events do not necessarily occur in consecutive frames; there can be gaps of several frames with no events for the pixel. In general, the amount of charge released per frame declines with time. However, the trend is not monotonic, especially near the end of an afterglow. More details on afterglows, afterglow-identification algorithms and how to display the afterglow events can be found in the "Why Topic" "Cosmic-Ray Afterglows" at *http://cxc.harvard.edu/ciao/why/afterglow.html*

The tool `acis_find_afterglow` searches for afterglows using a short, sliding time window. If there is a statistically significant excess of events compared to the expected number of background events, then the excess is identified as an afterglow unless the excess seems to be associated with a source that is periodically dithered across the pixel. The algorithm used to estimate the nominal number of background events is designed to avoid contamination by bright sources. Essentially all of the afterglows that have four or more events are identified by `acis_find_afterglow`. The tool `acis_find_afterglow` also searches for hot pixels, using an algorithm that is similar to the afterglow-identification algorithm except that the time window used is the entire duration of an observation. Events associated with afterglows are ignored during the search for hot pixels. The tool `acis_find_afterglow` supersedes the tools `acis_classify_hotpix`, `acis_detect_afterglow`, `acis_find_hotpix`, and `acis_run_hotpix` for all analyses.

• The Mexican-Hat Wavelet source detection tool `wavdetect` now takes an observation-specific PSF map file (created for example with `mkpsfmap`) instead of using *Chandra* PSF table data from the CALDB. Data from other missions (e.g. ROSAT, *XMM-Newton*) can also be supported by providing a psfmap (see "ahelp `wavdetect`" for more details).

• The `addrsp` tool adds together multiple imaging ARFs (auxiliary response files) and RMFs (response matrix files) to create a pair of merged ARF and RMF files weighted by ARFs and exposure. The tool may be run with just ARF files as input to create a merged ARF weighted by exposures. The `addresp` tool may now be used to combine grating ARFs, creating the same output as the `dmarfadd` tool. We have also added support for combining the ARF and RMF into an RSP file instead of making two separate files.

• The `asphist` tool bins the aspect solution of an observation into a 3D histogram of duration vs x and y pointing offset and roll offset. The value in each bin is the time the pointing was within that offset bin during the observation, as modified by the good-time interval (GTI) and dead-time-correction factor (DTF). The updated algorithm uses the full tangent plane offset computations and the correct angle between pointing and North. Both of these changes improve the accuracy of data reprojected to different tangent points and/or combined from multi-obi observations with significantly different pointings.

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 about once a month and concurrently with major CIAO releases. For CIAO 4.4. all scripts were retested to ensure a smooth running within the new system. Some scripts, including specifically `Chandra_repro`, `combine_spectra` and `specextract`, were upgraded to use the new tools and features of CIAO 4.4. For example, `Chandra_repro` is using the new tool `acis_find_afterglow` in place of `acis_run_hotpix` to identify

cosmic ray afterglows and bad pixels in ACIS observations. In `combine_spectra`, users can now specify whether the script should sum or average the PHA exposure times for the header of the combined spectrum and ARF files. In `specextract`, a binning of the sky2tdet WMAP (used as input to the tool `mkwarf`) can now be specified: this is useful for example when making a weighted ARF for a large region.

The script package has been updated after CIAO 4.4 with a new script `splitroi`, for splitting the source and background regions created by the roi ("region of interest") tool, and a new module, `crates_contrib.utils`, with new routines helpful within CRATES (the software package developed by the CXC to provide a high level I/O interface for use by Python). Most likely by the time of printing, further updates to the script package will be available.

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 major updates in the CIAO 4.4 release are the inclusion of a new ChIPS graphical user interface (the ChIPS GUI) and improvements to the PDF support (e.g. to support the alpha and opacity settings of images, regions, and histograms). The ChIPS GUI
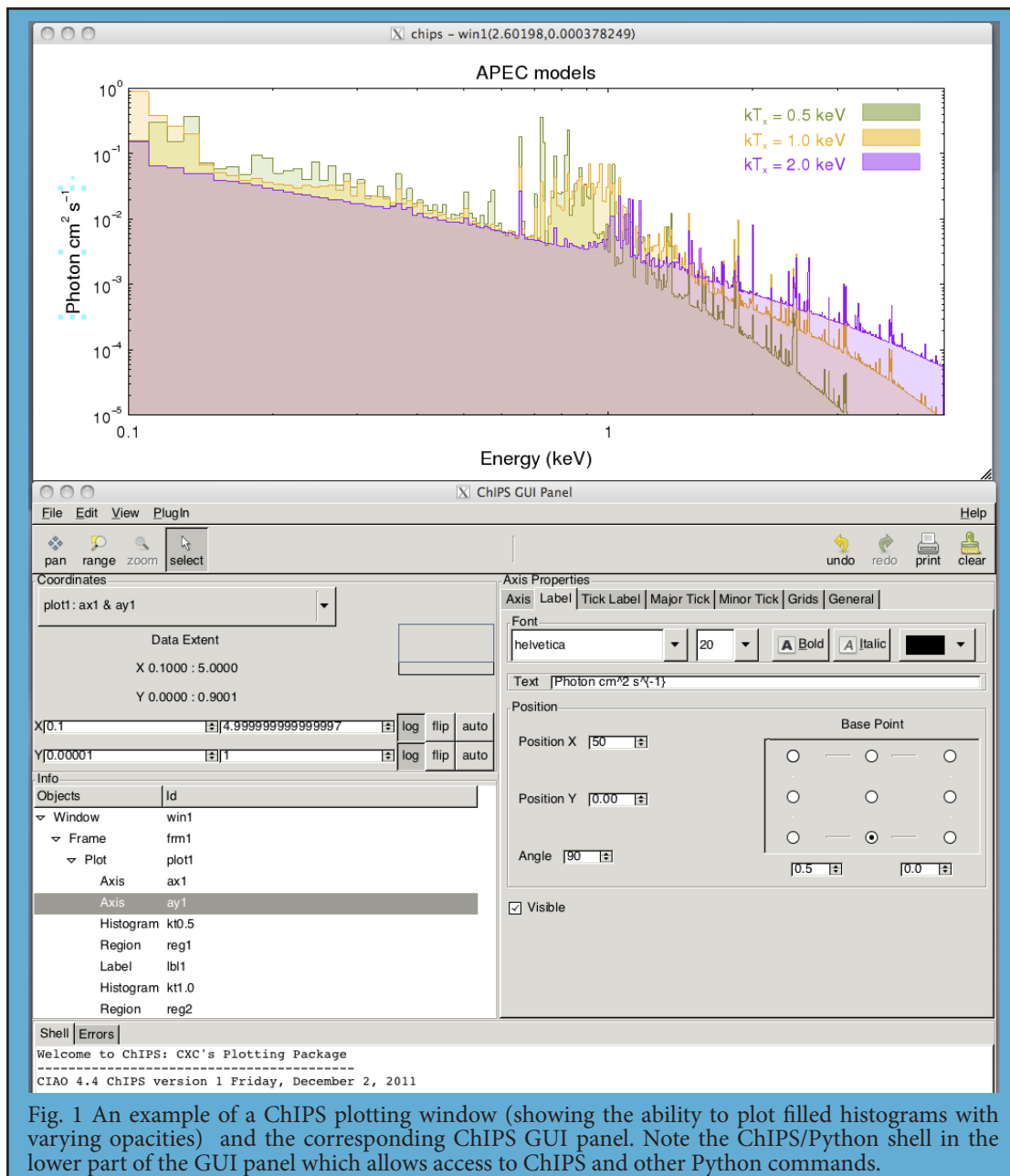

Fig. 1 An example of a ChIPS plotting window (showing the ability to plot filled histograms with varying opacities) and the corresponding ChIPS GUI panel. Note the ChIPS/Python shell in the lower part of the GUI panel which allows access to ChIPS and other Python commands.

(Fig.1) allow users to adjust the layout of their plots and make edits to many of the plot properties. A Python terminal is built into the GUI, allowing access to ChIPS and other Python commands. The GUI is available to any process that creates a ChIPS plot, such as Sherpa and Prism. It can be launched by right-clicking on on an existing ChIPS window and selecting "Show GUI", or by running the `show_gui` command from the ChIPS command line. Currently the GUI allows users to edit the properties of existing visualizations but does not provide the ability to add or create new objects.

A large gallery of ChIPS examples is included in the ChIPS website at *http://cxc.harvard.edu/chips/gallery/* and there are a number of introductory threads to guide beginners.

SHERPA

Sherpa (*http://cxc.harvard.edu/sherpa/*) is the modeling and fitting application within CIAO that 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 is also an importable Python module. Sherpa models, optimization and statistical functions are available via both C++ and Python for software developers wishing to link such functions directly to their own compiled code. Important changes and additions to the Sherpa functionality in the CIAO 4.4 release are described in a dedicated webpage at *http://cxc.harvard.edu/sherpa/updates.html* Among the several improvements to the software, we highlight two advanced features below.

Bayesian Analysis with pyBLoCXS

pyBLoCXS, a sophisticated Markov chain Monte Carlo based algorithm designed to carry out Bayesian Low-Count X-ray Spectral (BLoCXS, van Dyk, et al. 2001) analysis in the Sherpa environment, is available via several new Sherpa functions. The algorithm explores parameter space at a suspected minimum, using a predefined Sherpa model applied to high-energy X-ray spectral data. pyBLoCXS supports the ability to flexibly define priors and allows for variations in the calibration information. It can be used to compute posterior predictive p-values for the likelihood ratio test (Protassov et al. 2002) .

Template Models

Sherpa supports a new template model (an extension of the table model). Sherpa can now read in a collection of templates from a directory full of template files, and can compare a data set to all the templates in that collection. Sherpa finds the template that best matches the data, and reports back the parameter values associated with that template. The gridsearch optimization method will select the best template model by trying all of the templates. This method evaluates the fit statistic for each point in the parameter space grid; the best match is the grid point with the lowest value of the fit statistic. Gridsearch reports back the parameter values associated with this point. The Sherpa template model supports nearest-neighbor and polynomial interpolation.

Users interested in hands-on CIAO training should plan to attend a future CIAO workshop at the *Chandra* X-Ray Center. More information will be posted at *http://cxc.harvard.edu/ciao/workshop/* when available.

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*

To keep up-to-date with CIAO news and developments subscribe to chandra-users@head.cfa.harvard.edu (send e-mail to 'majordomo@head.cfa.harvard.edu', and put 'subscribe chandra-users' (without quotation marks) in the body of the message).

References

Protassov, R., van Dyk, D.A., Connors, A., Kashyap, V.L., Siemiginowska, A. (2002). ApJ 571:545.
van Dyk, D.A., Connors, A., Kashyap, V.L., & Siemiginowska, A. (2001). ApJ 548:224.