

## CIAO 4.5

Improved tools and Sherpa, ability to merge observations, and now featured on YouTube

Antonella Fruscione, for the CIAO Team

Version 4.5 of CIAO and CALDB 4.5.5, the newest versions of the *Chandra* Interactive Analysis of Observations software and the *Chandra* Calibration Database, were released in December 2012. CIAO 4.5 (<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 Tools

- The new `tg_findzo` tool helps users locate the source position for grating data with a piled or blocked zero order.

In general the `tgdetect` tool is used to find the centroid of the zero-order image in a grating event list. If the zero-order source is piled-up, there is the potential for the centroid to be incorrect due to the “hole” created in the data. Also, when observing a bright source, an observer may choose to have the zero-order region blocked via on-board software to avoid telemetry problems. The new tool is useful in determining the correct source position for a grating observation with either a piled or blocked zero order. New spectral data is extracted with the updated source position. `tg_findzo` works by computing the intersection of the data dispersed along one of the grating arms and the readout streak that is associated with bright sources.

- Various updates were added related to creating merged datasets, especially larger mosaics that exceed the standard image sizes. This includes updates to `reproject_events` and `dmmerge` to adjust the limits based on the data and to `dmextract` to keep a consistent definition of BACKSCAL regardless of image size.

- The `modelflux` tool has a new option to calculate the unabsorbed flux. If the user does choose this

new option, then both absorbed and unabsorbed fluxes are calculated and reported to the screen in addition to being written to the `modelflux` parameter file. Users are reminded that the `mkpsf` tool is now retired and either ChaRT (<http://cxc.harvard.edu/chart/>) or MARX (<http://space.mit.edu/cxc/marx-4.5/>) should be used to simulate the *Chandra* point spread function. We are actively working to make these tools easier to use in the global CIAO context.

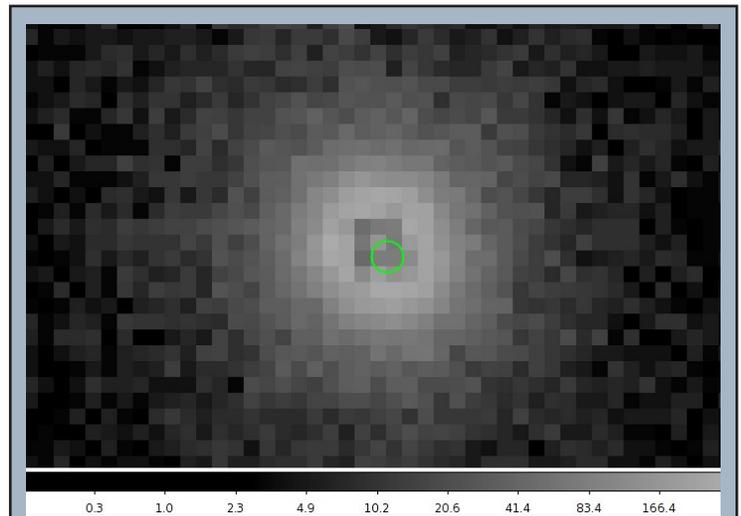
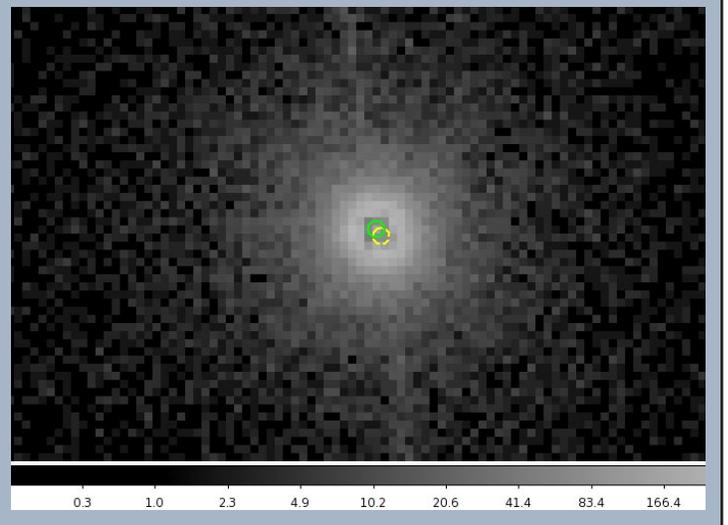


Fig. 1 - The zeroth order location determined by `tgdetect`. The image has been zoomed in and the region radii reduced to show that the zeroth order location is offset from the true center of the source, which will cause wavelength shifts in the extracted spectrum. Using the zeroth order location will cause systematic errors in the wavelengths and may lead to invalid results.

Fig 2. - The zeroth order location determined by `tg_findzo`. The image has been zoomed in and the region radii reduced to show the zeroth order. The solid green circle is the new `tg_findzo` result compared to the incorrect `tgdetect` location (yellow, dashed).



## 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. These 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 4.5, all scripts were retested to ensure that they run smoothly within the new system.

A few weeks before the CIAO release, the new scripts `merge_obs`, `reproject_obs`, and `flux_obs` were released together with much improved version of the `fluximage` script and extensive documentation on how to use them. These scripts (which globally replace the “old” `merge_all` script which is now deprecated) are designed to easily reproject and merge observations, with the option of creating exposure-corrected images of the combined data. `Fluximage` creates exposure-corrected images and exposure maps for ACIS or HRC observation.

## ChIPS

ChIPS (<http://cxc.harvard.edu/chips/>) is the imaging and plotting platform for CIAO which can be used during data analysis — 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.

In the CIAO 4.5 release of ChIPS the major update is the support for adding annotations (labels, lines, regions, and color bars) directly from the ChIPS GUI; other changes include improvements and fixes to both the GUI and a range of commands.

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.

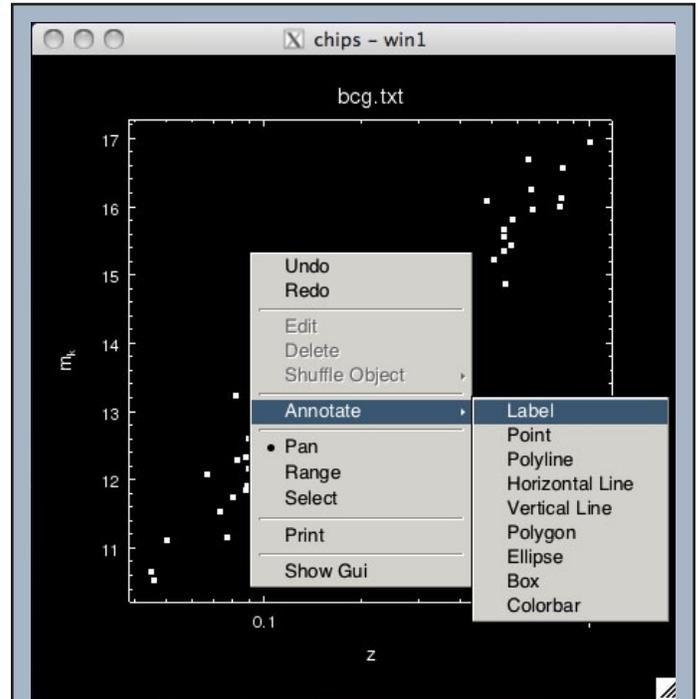
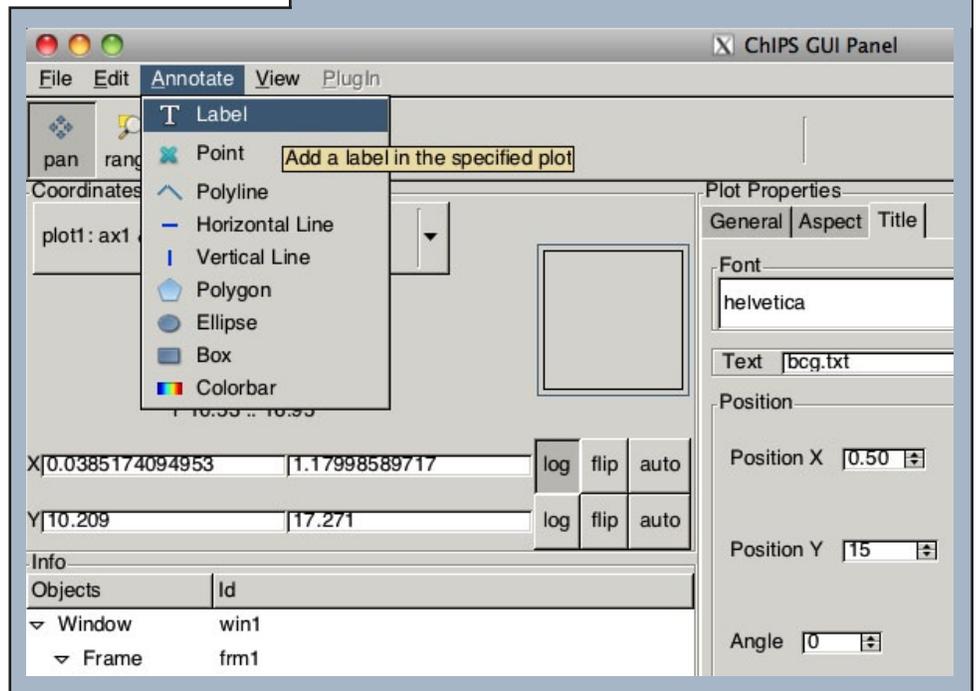


Fig. 3 -The ChIPS GUI has been updated to support adding annotations - namely labels, points, lines, polygons, or color bars - either from the right-mouse-button menu (top) or from the main GUI window, using the Annotate menu (bottom).



## How Did We Combine the Data?

### A) What data is available?

The *Chandra* Footprint Service at <http://cxc.harvard.edu/cda/footprint/> allows you to search for observations that overlap a position. We can use the `find_chandra_obsid` script to perform this search from the command line, including some basic filtering options:

```
% find_chandra_obsid 'eta carinae'  
% find_chandra_obsid 'eta carinae' radius=60  
% find_chandra_obsid 'eta carinae' inst=acisi radi-  
us=60
```

### B) Download the data

Now we have decided on the observations we are interested in, we can download them from the archive:

```
% find_chandra_obsid 'eta carinae' inst=acisi radi-  
us=60 download=all
```

A simple way to list the obsids we have downloaded is to change the detail level:

```
% find_chandra_obsid 'eta carinae' inst=acisi radi-  
us=60 detail=obsid > obsids.lis
```

### C) Reprocess the data

A recent change to the `chandra_repro` script lets us reprocess all the observations with just one call; it will however take some time for this particular example!

```
% chandra_repro indir=@obsids.lis outdir=.
```

### D) Create the combined, exposure-corrected, images

```
% merge_obs “*/repro/*evt2.fits[ccd_id=0:3]” com-  
bined/ bands=broad,csc
```

Note that we use the `ccd_id` filter to get only the near-axis ACIS-I FI chips. This will eventually create the exposure-corrected images `combined/<band>_flux.img`, where `<band>` is one of `soft`, `medium`, `hard` and `broad`.



Fig. 4 - The left image shows the broad (0.5 to 7.0 keV) band data for the neighborhood around Eta Carinae, and the right image shows the exposure map for this data set, calculated assuming a monochromatic source emitting at 2.3 keV. The data consists of 41 ACIS-I observations, downloaded using `find_chandra_obsid`, processed with `chandra_repro`, and aligned and combined using `merge_obs` (the S-array chips were excluded in this analysis). The output image has 1363 x 1537 pixels, with a pixel size of 3.936 arcseconds (8 times the default ACIS pixel scale).

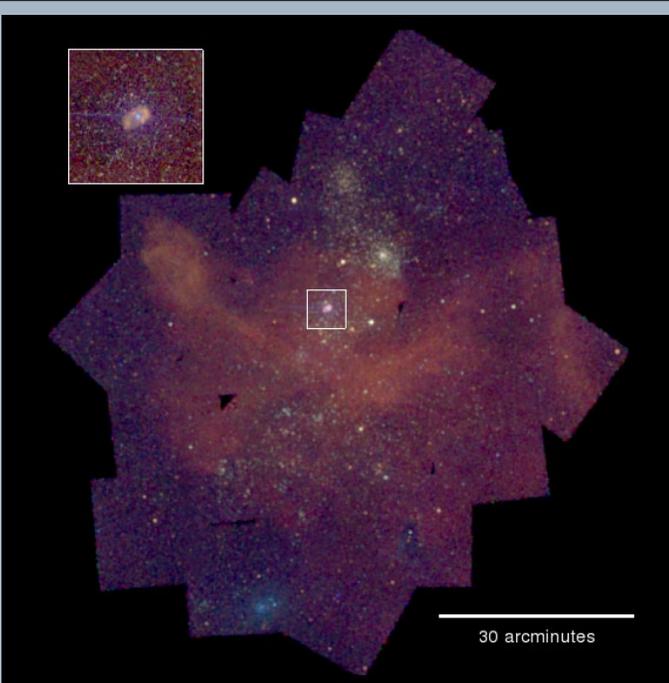


Fig. 5 - A three-color image - visualized with ChIPS - of the Eta Carinae nebula, using the 0.5 to 1.2 keV, 1.2 to 2.0 keV, and 2.0 to 7.0 keV pass bands for the red, green, and blue channels respectively. Each band was divided by its corresponding exposure map (evaluated at 0.92, 1.56, and 3.8 keV) before being combined. The image size and pixel scale is the same as the previous figure, but it has been smoothed by a Gaussian with a sigma of 12 arcseconds, and a log scale applied, to bring out the diffuse emission. The inset shows a zoom in of the Eta Carinae nebula with no smoothing. The almost-horizontal blue line is the read-out streak from the central object.

## 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 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 4.5 release are described in a dedicated webpage at <http://cxc.harvard.edu/sherpa/updates.html> Among several improvements to the software, we highlight two features:

`sample_flux`: this new function has been added to calculate the energy flux with uncertainties due to a Sherpa model. It returns a sample of parameters with a corresponding flux and a flux uncertainty for a model component or a combination of model components. The model components have to be previously defined and used in the fit. The samples are generated from the multi-variate normal distributions with the scales defined by covariance (if at the best fit) or supplied (as “scales”). The flux is calculated for each set of new parameters. The returned flux value is given by a sample’s median with the lower and upper quantiles defined by the confidence level supplied to the function.

Modeling of non X-ray data: a set of optical models (e.g. `absorptionedge`, `emissionlorentz`, etc.) is now available allowing users to model emission and absorption lines in optical spectra. Also XSPEC models such as `xsdiskbb`, or `xsdiskp` work in Sherpa with ASCII-type data and do not require any response files; this makes the models easily useable for optical-UV data.

## CIAO on YouTube

Since interactive or graphical features, like the interaction of CIAO with the `ds9` imager, can be difficult to describe in a static document, we have attempted to capture this experience on a YouTube channel. The “4ciaodemos” channel at <http://www.youtube.com/user/4ciaodemos> features tutorials, demos, and screen-casts of CIAO. It currently contains 13 videos which already have 1060 views and counting. Sit back, relax and watch CIAO in action!

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` Just send e-mail to ‘`majordomo@head.cfa.harvard.edu`’, and put ‘subscribe chandra-users’ (without the quotation marks) in the body of the message.