CIAO4.3: pushing the Chandra spatial resolution to its limits

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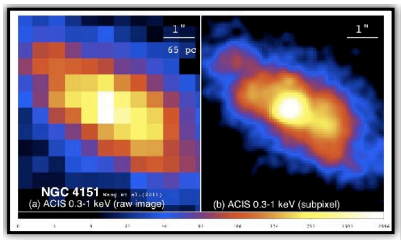
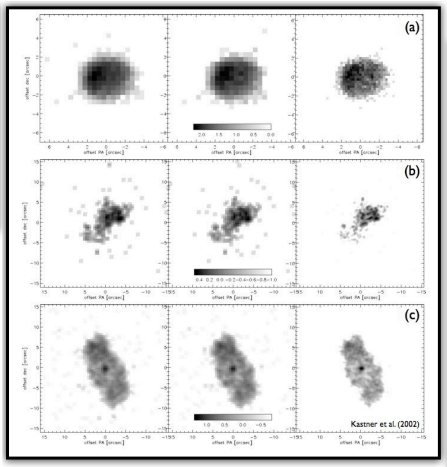
What is new? Highlights!



A comparison between ACIS images of the inner 3"-radius circum-nuclear region in the Seyfert 1 galaxy NGC 4151 before and after subpixel repositioning.

(a) Raw 0.3-1 keV ACIS image; (b) Same image after EDSER algorithm (Li et al. 2004) and subpixel binning (1/8 native pixel), demonstrating the improved resolution. Note the 1 arcsec scale. From **Junfeng Wang, et al. 2011, ApJ, 728, 1.**



Three examples of optimized image resolution by subpixel repositioning of individual X-ray events.

X-ray images of planetary nebulae BD +30°3639 (panel a), NGC 7027 (panel b) and NGC 6543 (panel c). The left panels X-ray images are obtained by binning events before removing position randomization and applying subpixel event position corrections ("original" image). The center panels are images obtained by binning events after removing event position randomization ("unrandomized" image). The right panels are images obtained by binning events after removing randomization and applying subpixel event position corrections ("event relocated" image). The comparisons between "original," "unrandomized," and "event relocated" images illustrate the superior spatial resolution afforded by subpixel event repositioning. From **Kastner et al. 2002, ApJ, 581, 1225.**

Subpixel Event Repositioning

The already unprecedented spatial resolution of Chandra X-ray imaging with the Advanced CCD Imaging Spectrometer (ACIS) can be improved through subpixel event repositioning techniques

For sources near the optical axis of the telescope, the size of the point spread function is smaller than the size of the ACIS pixels. (0.49"). Li et al. (2004, ApJ, 610, 1204) describe various sub-pixel event-repositioning algorithms that can be used to improve the image quality of ACIS data for such sources.

Their algorithm EDSER (Energy-Dependent Subpixel Event Repositioning) was incorporated into the tool acis_process_events in CIAO 4.3, making it possible to reprocess any dataset to apply the subpixel algorithm. EDSER can be applied to all Chandra observing modes - except for continuous-clocking mode - and to data on both front-illuminated and back-illuminated CCDs. The EDSER algorithm will also become the default in standard data processing (SDP) in version DS 8.4 (scheduled for summer 2011).

Before the use of EDSER, the coordinates of ACIS events were randomized by +/- 0.5 pixel to avoid possible aliasing affects associated with the CCD pixel grids. Information on that correction is available in the pixels randomization "why" topic.

Note that most users will not notice a difference in the data with the EDSER subpixel resolution applied. The exception is users working with high-resolution (< 1 arcsec) data on-axis. The figures above show examples of optimized image resolution by subpixel repositioning of individual X-ray events.

CAVEATS

The CXC believes that the sub-pixel event-resolution algorithm does improve the ability to separate small scale structure, but we have not yet calibrated ACIS on sub-pixel scales, so obviously the potential for artifacts exists. As reported last year to the Chandra Users' Committee we have a plan to enhance our simulation tools to represent the EDSER-enhanced PSF. This is a significant calibration, modeling, and development effort since we need to model the grade distribution and have a much more detailed internal model of the instrument. Refer to the Chandra Ray Trace caveats document for some other limitations on the PSF modeling tools.

In principle, sub-pixel analysis should not affect the HRMA ray tracing. However, at the sub-arcsecond scale, HRMA calibration is still on-going (see e.g. the document "Probing higher resolution: an asymmetry in the Chandra PSF"). Therefore, there may be uncalibrated mirror-related effects at the subarcsecond scale in addition to the unmodelled ACIS detector pixel effects.

ARF Correction

Via the tool arfcorr it is now possible to correct an Ancillary Response Function (ARF) for the finite extraction region, while sky2det is an improved weighting algorithm to account for spatial variations in the ARF.

arfcorr calculates the approximate fraction of the point spread function (PSF) enclosed by a region then the tool applies an energy-dependent correction to the ARF file.

sky2det creates a weighted map (WMAP) used by mkwarf: it properly weights the ARF based on how much of the source flux fell onto the bad pixels, columns, or a node boundary and which bad pixels are actually exposed. Without accounting for these effects, the ARF is significantly over-estimated.

User Friendly CIAO Scripts

- The CIAO contributed scripts package contains analysis scripts and modules written in Python by scientists at the CXC to automate repetitive tasks and extend the functionality of the CIAO software package.
- It is installed seamlessly within the CIAO structure and is considered a required part of the installation
- New scripts or updates are released more often than CIAO, generally once a month.

MOST NOTABLE SCRIPTS

download_chandra_obsid: a script to provide easy and quick access command-line downloads of public Chandra data

chandra_repro: a reprocessing script which automates the recommended data processing steps presented in the CIAO analysis threads and may be used to quickly reprocess ACIS and HRC imaging data.

specextract: an improved python-version of the old tool by the same name, which now lets the user create source and background PHA or PI spectra and their associated unweighted or weighted ARF and RMF files for point and extended sources.

combine_spectra: a script which sums multiple imaging source PHA spectra, and optionally, associated background PHA spectra and source and background ARF and RMF instrument responses; the scripts utilizes the new tool addresp which adds multiple RMFs, weighted by ARFs and exposures and adds multiple ARFs, weighted by exposures.

make_psf_asymmetry_region: a script which creates a region file indicating the location of the PSF asymmetry found in HRC and ACIS data as described in in document "Probing higher resolution: an asymmetry in the Chandra PSF".

FORTHCOMING in 2011

fluximage: a script to easily create an exposure corrected ("fluxed") image in specific energy bands

merge-all: a complete Python rewrite and improvement of the "merge_all" script to combine any number of observations and create corresponding exposure maps and exposure-corrected images.

Sherpa enhancements

- Model expressions can now be defined so that response matrices, or PSFs, are only applied to some models in a model expression. An example of this kind is a model expression where a spectral model is defined in energy space, and folded through a response matrix; then, a background model defined in counts, which is not folded through the response, is added to the model expression.

  The new functions set_full_model() and set_bkg_full_model() allow users to explicitly define instrument responses and convolutions that are applied to specified model components. PSF and table models may be used in model expressions defined with these functions.
- Several computationally intensive functions, such as projection and conf, are parallelized in the to make use of multi-core systems (i.e., laptops or desktops with 2 or 4 cores). A new option, "numcores" has been added to several functions to specify the number of cores to use in parallelization.
- Sherpa models now have a "cache" attribute for users to control behavior. The default value for "cache" is a non-zero value indicating that caching will be turned on only if all parameters in the model are frozen. Indicating zero will turn off caching even if all model parameters are frozen.

  Model caching is now available for XSPEC and 1D analytic models; caching is turned on by default. 2D Sherpa analytical models are not cached by default due to the potential impact on memory usage. Compared to fit results in previous releases, there should be no change to any calculated value. The only difference that may be seen is in reduced program execution time.
- Additive and multiplicative XSPEC-style table models are now supported by the Sherpa table model using load_table_model,

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