

CIAO 4.9 and Beyond

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CIAO 4.9 (<http://cxc.cfa.harvard.edu/ciao/index.html>) is the latest installment in the annual releases of the *Chandra* Interactive Analysis of Observations, the software used to analyze *Chandra* data. It was released in December 2016 together with the most recent versions of both the Calibration Database ([CALDB 4.7.3](#)) and [MARX 5.3.2](#), the suite of programs created and maintained by the CXC group at MIT and designed to enable users to simulate the on-orbit performance of the *Chandra* X-ray Observatory.

While CIAO 4.9 is mostly a “maintenance” release (which fixes bugs, supports new compilers and updates some of the required OTS software) it also contains a few changes and improvements worth noticing: not only the support of larger number of operating systems (two for Linux and four for Apple systems), but also the support for Python 3.5 which required updating many parts of code that can now work with either Python 2.7 or Python 3.5.

In *Sherpa*—the modelling and fitting application in CIAO—the most notable improvements were the addition of the *wstat* statistic, an implementation of the Cash statistic where the observed background data is included and does not have to be modelled separately, and the update of the XSPEC models to version 12.9.0d.

[Sherpa 4.9.0](#) is also released on Github as a standalone package for both Python 2.7 and Python 3.5.

Three new “CIAO scripts”—high level programs which have the goal to simplify the analysis steps for the most common cases—[blanksky](#), [blanksky image](#) and [correct_periscope_drift](#) were released two months before CIAO 4.9. The first two deal with the “blank sky” background and create respectively a blank-sky background dataset tailored to a specific observation and the corresponding output image

matched to the user image and its energy filter (see Figure 1)

`Correct_periscope_drift` corrects small (~0.1 arcsec) intra-observation alignment drifts that can be seen in recent, long (>50 ks) observations.

The entire scripts package was updated in the CIAO 4.9 release and to run under Python version 3.5 as well as Python 2.7.

X-ray Data Analysis for the Next Decade

In order to gauge the interest from the community regarding priorities for the future of CIAO and X-ray data analysis in general, a lunchtime panel was held during the *Chandra* Science for the Next Decade workshop. The goal was to hear the thoughts from experts and from the community, regarding the direction the X-ray data analysis (and more specifically—but not exclusively—CIAO) should take for the future.

We invited five colleagues and long-time users of high energy data and software to illustrate their vision and to participate in the discussion initiated by questions from the audience. Koji Mukai from Goddard, Nico Cappelluti from Yale, Ewan O’Sullivan from CfA, Raffaella Margutti from Northwestern, and Joey Nielsen from MIT presented their thoughts on hardware, software and algorithm challenges for the next decade.

The presentation was followed by comments from the audience and comments from users following on-line.

A few points came up repeatedly in the discussion and in particular the desire to use Jupyter Notebook and Python packages such as Astropy, Scipy, and Matplotlib within the CIAO environment, integration with the Anaconda Python environment, and the demand for parallel processing, particularly for some of the core CIAO tools.

Last summer the [Sherpa-Astropy Bridge \(Saba\)](#) package was developed to provide Sherpa functionality within the Astropy modeling fitting package. It was done as part of

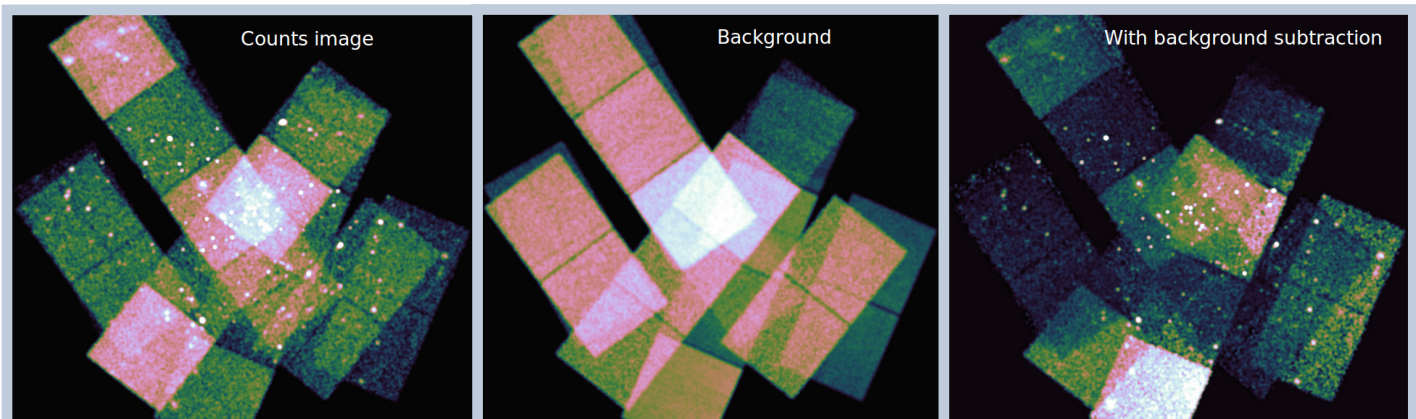


Figure 1: Combined reprojected M101 counts data. For each event file the script finds the CALDB blank sky background for the correct epoch; scales the background exposure time keywords so that scaled particle background-dominated count rates (in the 9-12 keV range) match the data; reprojects to the correct roll angle and adds the correct RA, Dec coordinates. The result is a matched set of background event files which can be used for either image background subtraction (as shown in the figure) or event-based spectral subtraction.



Figure 2: CIAO workshop participants

the Google Summer of Code 2016 under the [OpenAstronomy organization](#) by student Michele Costa and the Sherpa team.

Parallelization for CIAO tool would allow processing many sources at once. It is a complex problem since the tools were designed when parallel processing was neither common nor widespread and would require a more fundamental redesign of the software.

An interesting discussion ensued about science algorithms for the future where it became clear that multi-observation and multi-wavelength is forever more the way of the future. Therefore improvements in multi-wavelength spectral analysis and in multi-resolution analysis (for example simultaneous fitting of high and low resolution data or joint analysis of multi-observatory data) were discussed. Easy generation of the PSF and easier analysis of extended sources and grating data were also suggested as priorities for the future. Continuing the development of advanced statistical tools with accessible interfaces for general users was discussed as an important step forward.

Several of the items discussed by the panelists are already included in existing CIAO development priorities. In the

future we are planning to improve the support to data analysis of extended source via tools like smoothing and temperature map generation plus improved PSF and extended source fitting. We plan to improve the source flux tool to support multiple observations and a multi observation detect tool is being developed for the production of the *Chandra* Source Catalog. We are also working on upgrades to the current interface in Sherpa to allow non-expert use of the Bayesian analysis and MCMC methods.

Community input regarding the future direction of CIAO is welcome and any user with additional thoughts or suggestions can submit their ideas via the [CXC HelpDesk](#).

12th CIAO Workshop

A one and a half day CIAO workshop was held at the CFA in August before the *Chandra* Science for the Next Decade workshop. About twenty students, postdocs and faculty or staff members attended the workshop from around the world. As it is customary in CIAO workshops, the time was split between talks and the hands-on session. Students learned or were updated about the latest advancements in the CIAO data analysis, ds9 for high energy astrophysics (including the DAX extension which allows to run CIAO

tools directly from ds9) and the *Chandra* PSF. The hands-on session is truly the highlight of the workshop since it is a time when students experiment on their own, but with the full and prompt support of the CIAO team. This is not only beneficial for the students, but it is a two-way process since invariably the CIAO team learns how “real” users work with the data, the software and the documentation and the out-

come of the workshop are improvements in documentations and at times, requests for enhancement in the software.

Future CIAO workshops are planned and will be advertised via the CXC social media and *Chandra* announcements. More details will be available on the [CIAO workshops webpage](#) where electronic copies of all the previous presentations are also archived. ■

CIAO WORKSHOP FEEDBACK

Some positive feedback from students:

“Great workshop. I would love to have this more often for people who are new to CIAO so that they can start working on it much faster than just looking through the documentation”

“I thought the workshop was all-around very good.”

“You always learn something new from these workshops even if you have analysed *Chandra* data for many years”

And some room for improvement:

“It would be nice maybe to have more talks about the history of *Chandra* and CIAO in general. It was easy to miss how we get to here and knowing about it will help us appreciate the program more.”