Chandra X-ray Center

Science Data Systems

Jonathan McDowell

Chandra X-ray Center

Team: McDowell, Fruscione (1/2), Siemiginowska, Burke
(SAO scientists: CIAO, Sherpa, Docs, HRC, Catalog, User support)
Glotfelty, Lee, Joye [C Cranmer has now left for grad school]
(SAO computer specialists: Docs, User support, scripts, DS9)
Huenemoerder, Guenther, Principe, Nynka
(MIT scientists: Gratings, ACIS, PSF, V&V, Catalog, Marx, Sherpa, User support)

Overview:

Ensure the science community can turn data products into science papers:

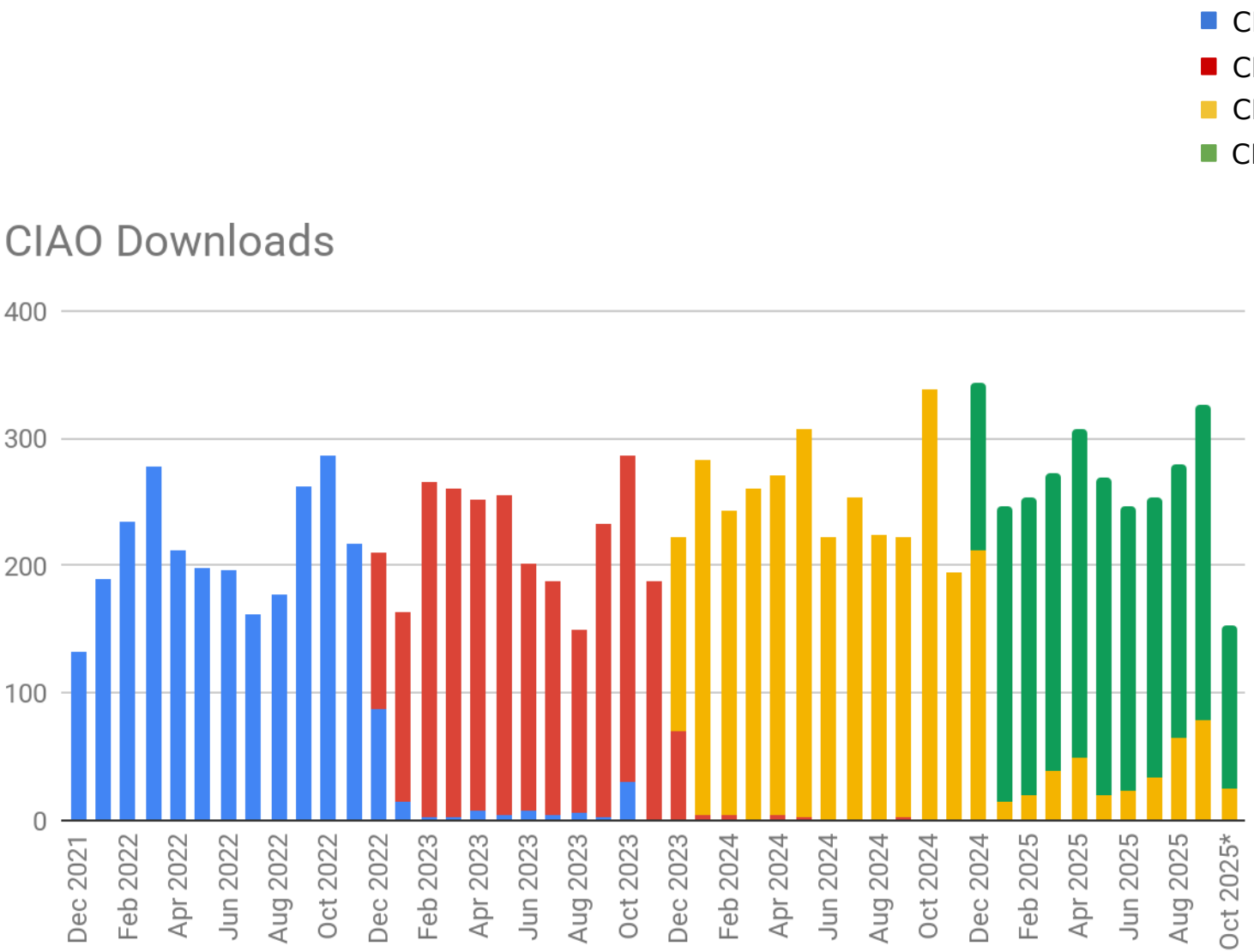
Define, test and support CIAO - the Chandra user data analysis package
User support for data analysis
Maintain and improve science algorithms, data products
Simplify and codify evolving best practices for analysis (scripts, threads)

Chandra X-ray Center

Community Support:

Downloads,
Documentation,
Helpdesk

Chandra X-ray Center



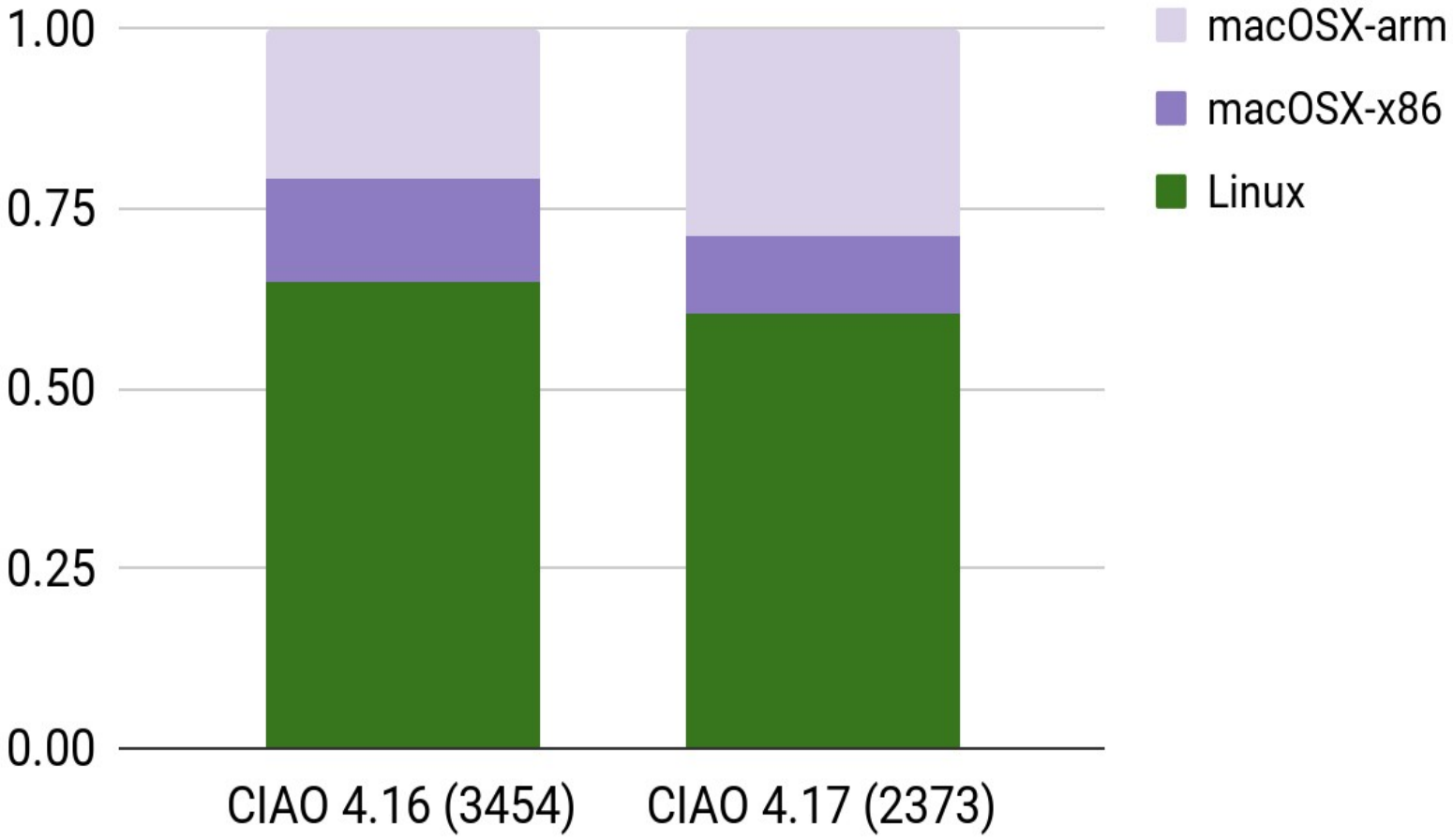
Chandra X-ray Center

Downloads (lifetime)

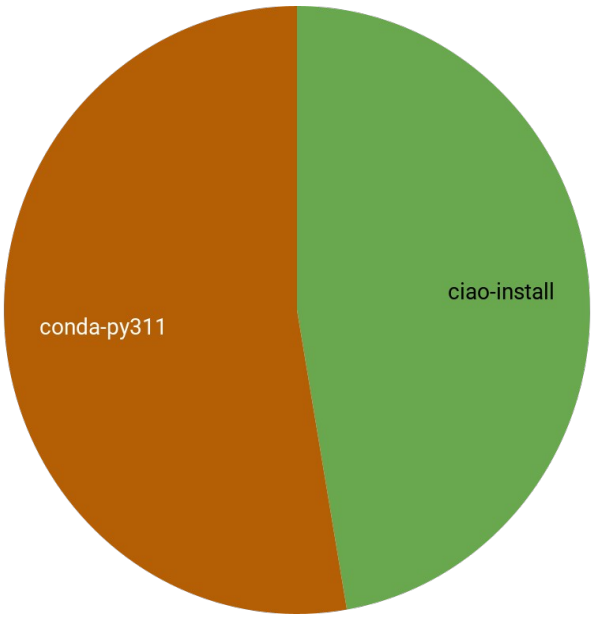
OS	CIAO 4.15	CIAO 4.16	CIAO 4.17
Linux	1550	2236	1432
macOSX-x86	1016	494	258
macOSX-arm		724	683
	2566	3454	2373
Source	6	46	40
Total	2572	3500	2413

Chandra X-ray Center

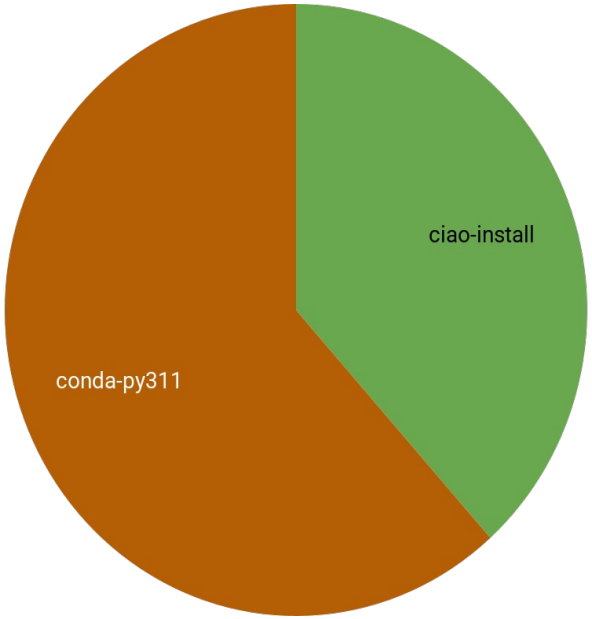
Download by OS



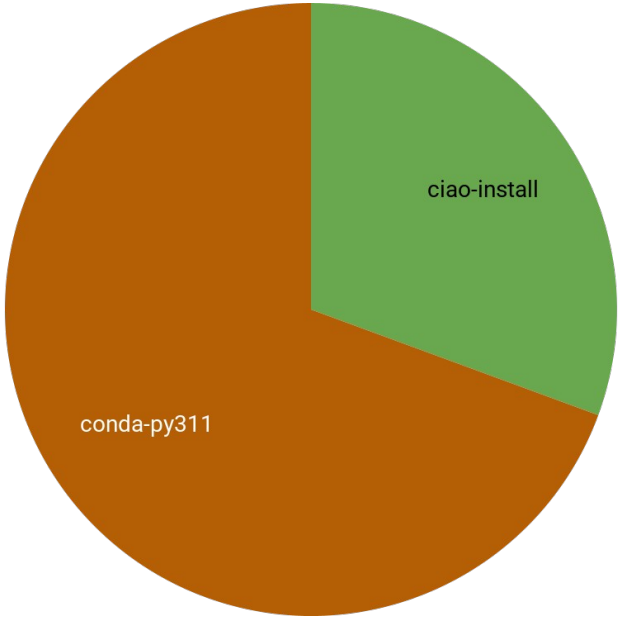
CIAO 4.17 Installation Options



Linux



macOS-intel



macOS-arm

ciao-4.17 is only available with Python 3.11.
ciao-install on macOS broke with Sequoia 15.4. Users forced to use conda.

Chandra X-ray Center

Documentation

Docs

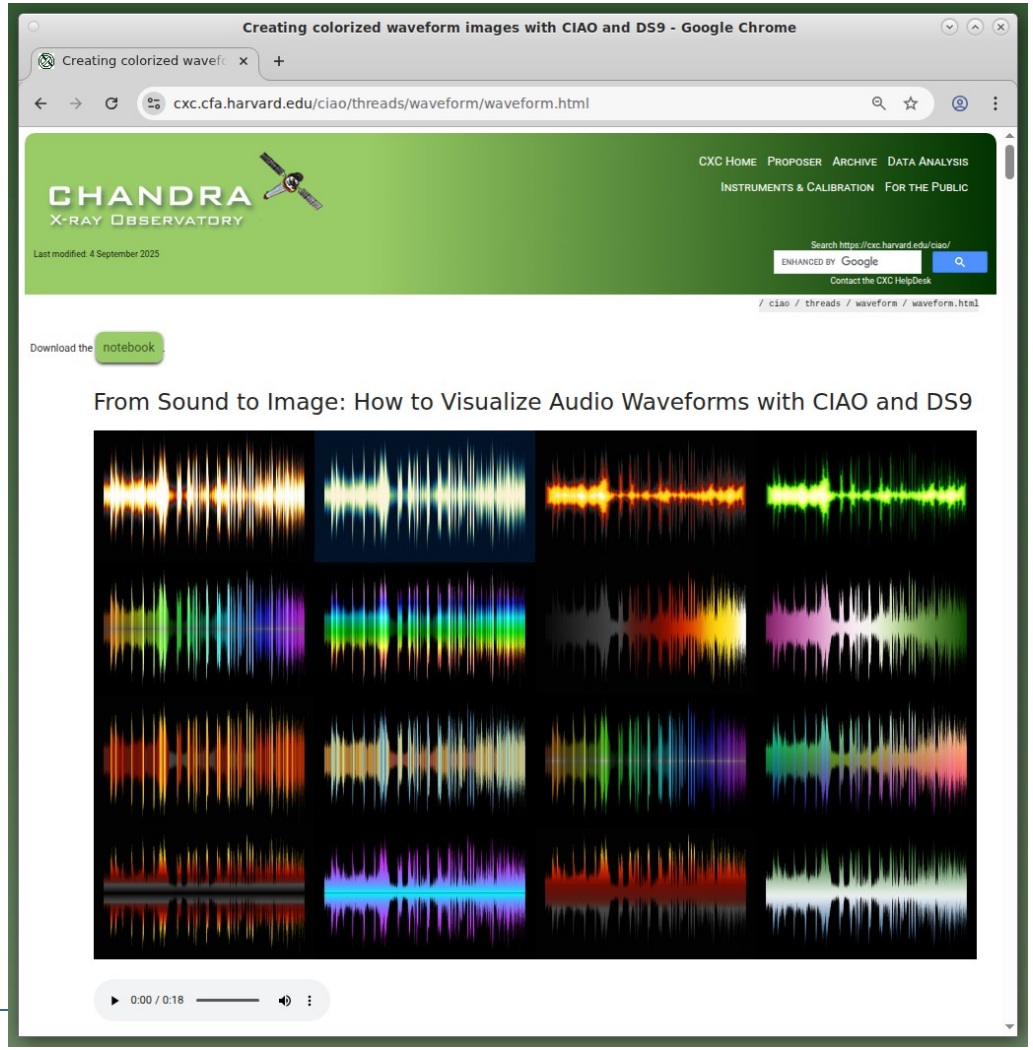
- Routine roll-out of CIAO 4.17 site; CIAO 4.15 site retired.
- Initial release of Merge Central
- **New** thread:
  Extracting Spectra and Responses for ACIS Observations that Undergo Large Focal-plane Temperature Swings

- Final Repro-5 obsids (early datasets) have been processed and threads updated.
- Updated source build instructions to including work around for building optimized code.
- **New** Why topic: **Overview of HRC Secondary Science Corruption** to accompany new patch_hrc_ssc script. Updated createL2 thread to show where to optionally include.
- **New** Why topic: **Why? Radial Profile Aperture Corrections** to accompany new mkrprm script.
- Updated **Correcting Absolute Astrometry** thread to include use of **new** fine_astro script.

Thread: Visualize Audio Waveforms

This new "thread" shows several different ways to create different artistic effects using different image processing techniques available in CIAO.

These techniques are applied to an image of the audio waveform from the STS-93 countdown and launch.



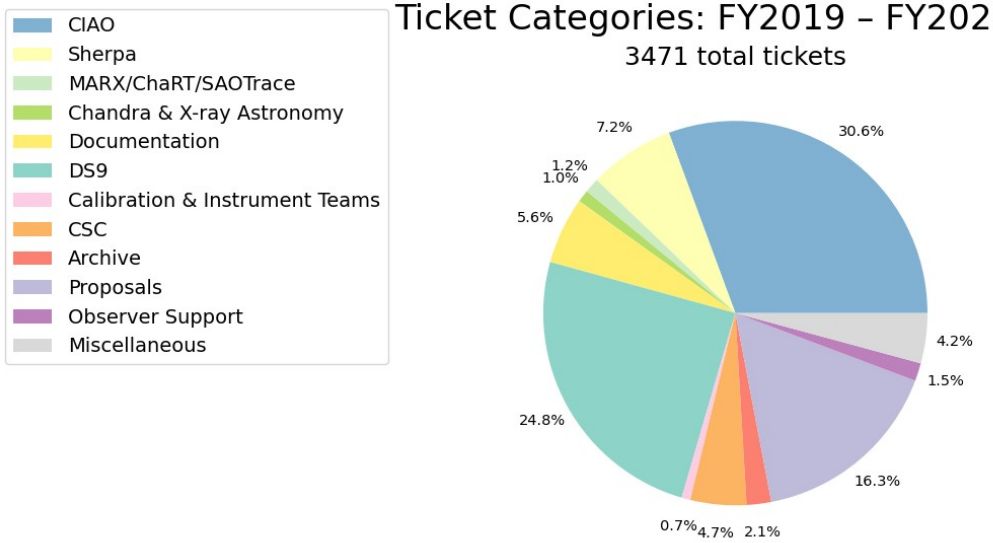
Chandra X-ray Center

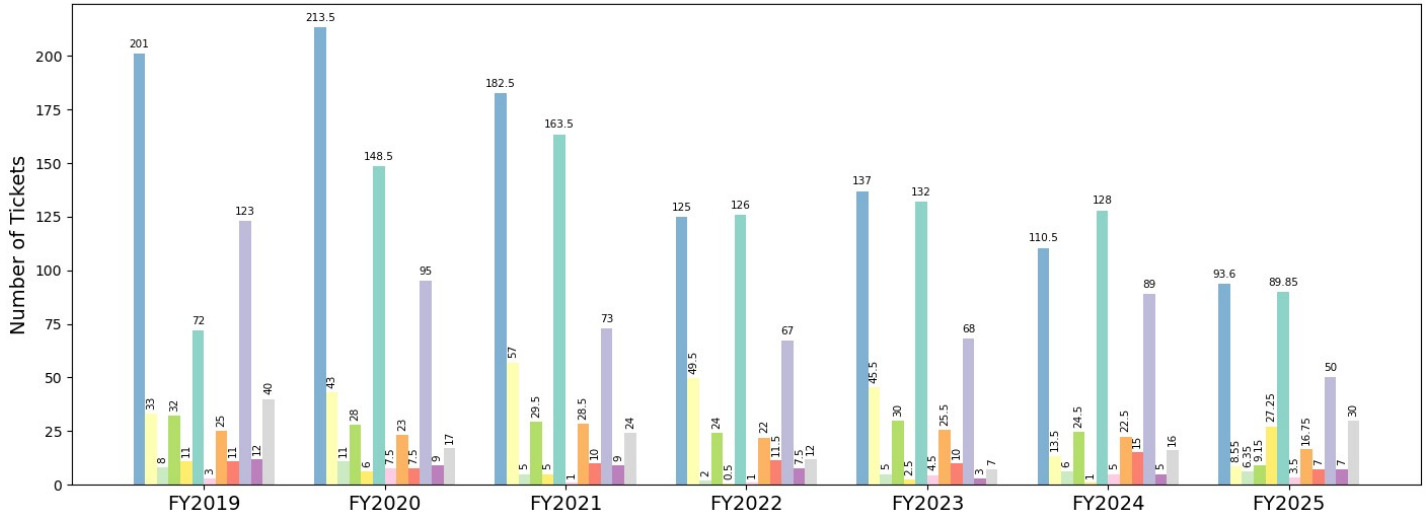
Helpdesk

Chandra X-ray Center

Ticket Categories: FY2019 – FY2025

3471 total tickets





Helpdesk Stats

	2023-10-15 to 2024-10-15	2024-10-15 to 2025-10-15
Time period [months]	12	12
Number of TIckets	210	188
Median time to 1st contact [hrs]	3.87	2.86
Median time to close [hrs]	20.54	11.18
Maximum time to close [hrs]	786.6	747.6

Longest ticket (also the most iterations) was a ticket trying to get flux estimate for a source imaged with HRC-S w/o gratings.

Many system setup issues after initial diagnosis.

Ultimately the problem is that the HRC-S RMF in the CALDB is invalid(*) which triggers a bug in the addresp tool which results in an error.

(*)Inconsistent first channel definition: 0 vs 1. Also data looks to use old HRC PI definition (256 channels rather than 1024 channels now in use.)

Chandra X-ray Center

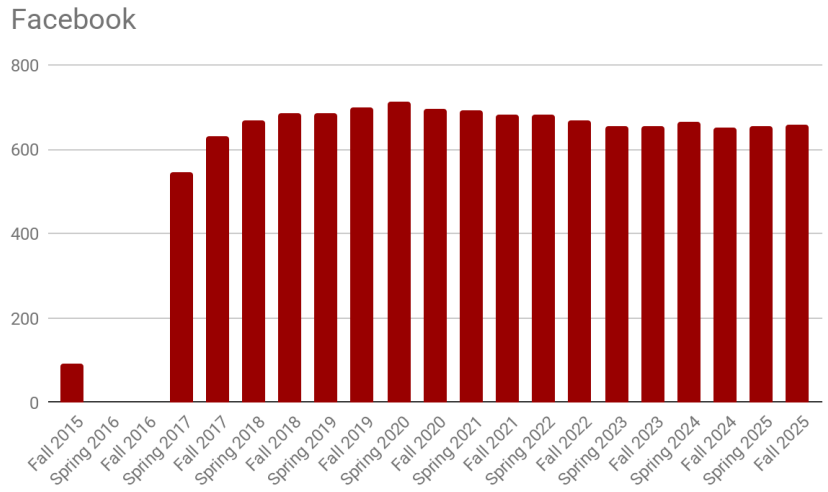
Bugs from Helpdesk

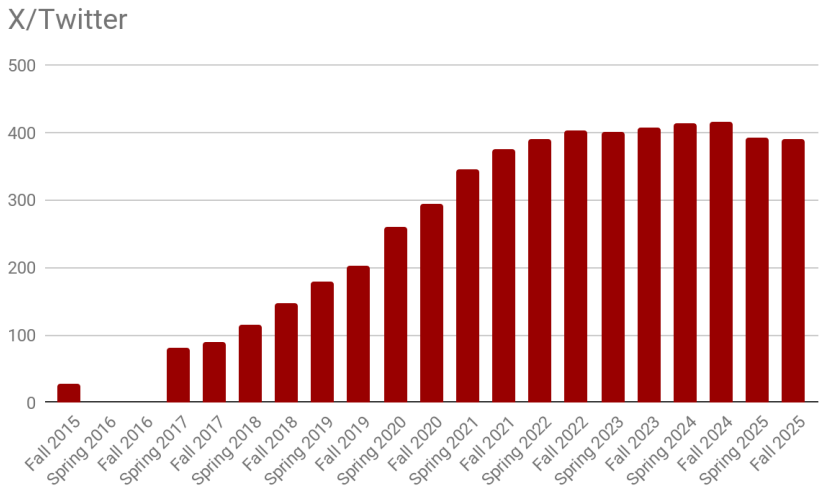
- Bugs in addresp and rmfimg tools when the input RMF file starts with channel=0 rather than channel=1.
- OBSVIS smoke test failure due to CfA web server configuration change and ds9 incompatibility with SSL 1.3.
- ciao-install stopped working with macOS Sequoia 15.4 update. Users forced to use conda. Users upgrading to 15.4 are required to re-install using conda.
- CSC scripts retrieving random numbers of files due to archive backend server configuration.
- srcflux error when using long region expressions.
- Bug unable to read ds9 region files using ICRS coordinates (FK5 is fine).

Chandra X-ray Center

Community

Social Media





Facebook	657 (+2)
X	389 (-4)

Chandra X-ray Center

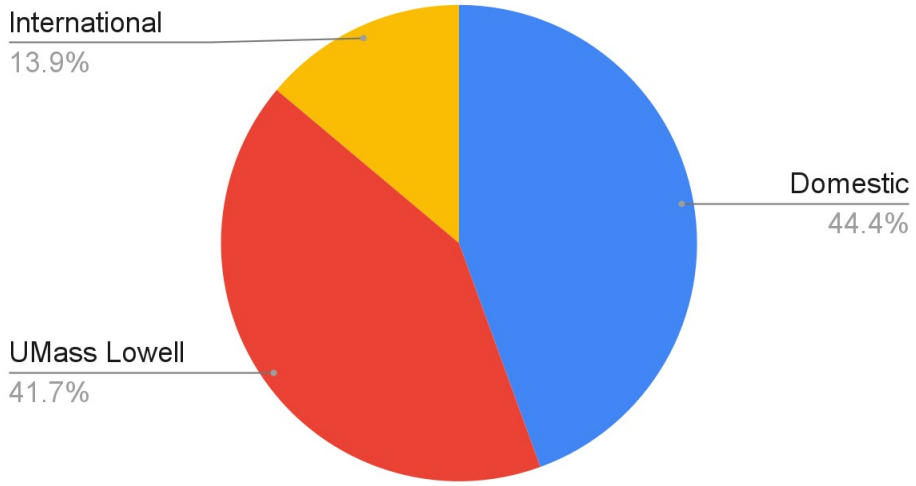
Community

- Chandra CIAO Workshop 19-23 May 2025, held at U Mass Lowell
- 6K funding from CfA, 30K from Helsing-Simons foundation
- 30 Students including 3 CXC developers

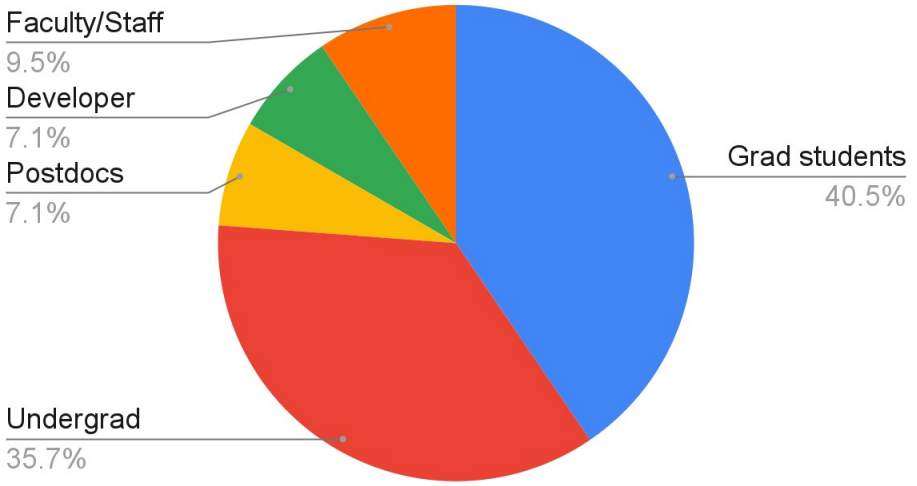
Workshop Cohort Summary

Chandra X-ray Center

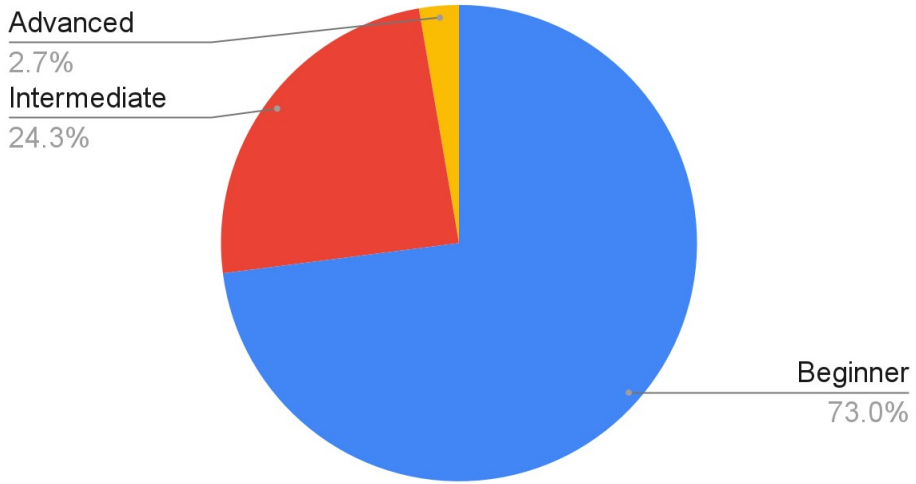
Affiliation



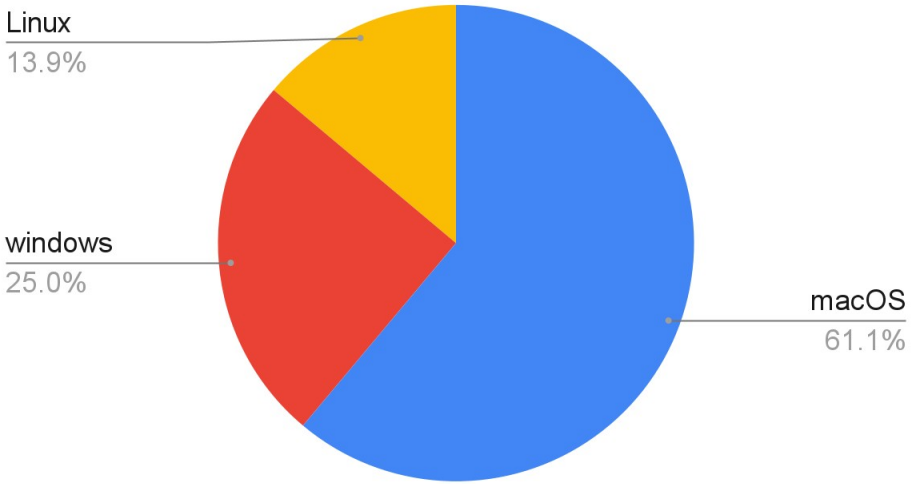
Position



Experience

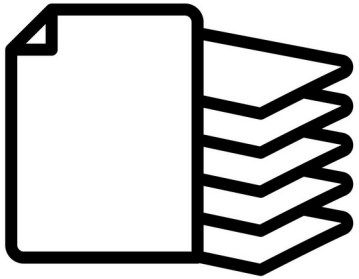


Operating System



Program Summary

2 live demos



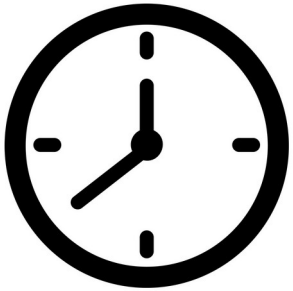
875+ slides

5 days

25 Presentations

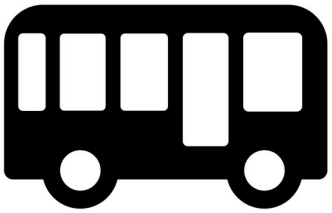
17 presenters

Daily Kahoot! quizzes with 75+ questions



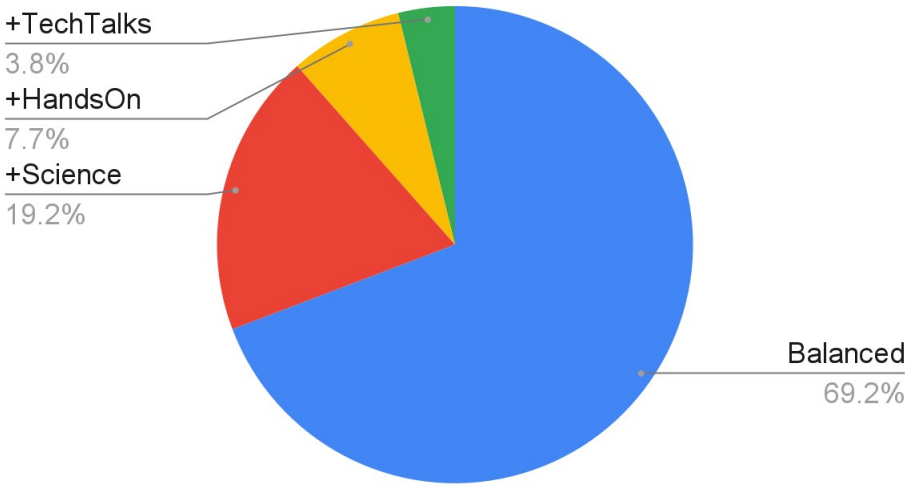
975+ minutes of instruction

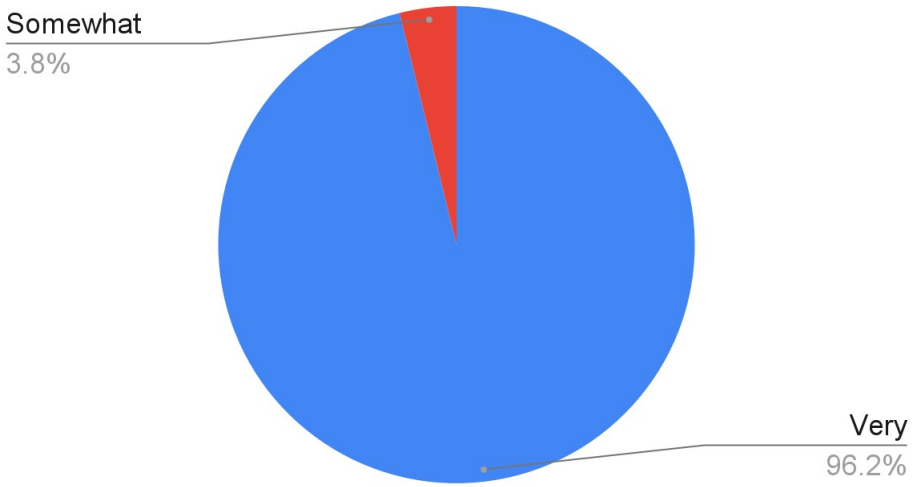
2 off-site excursions

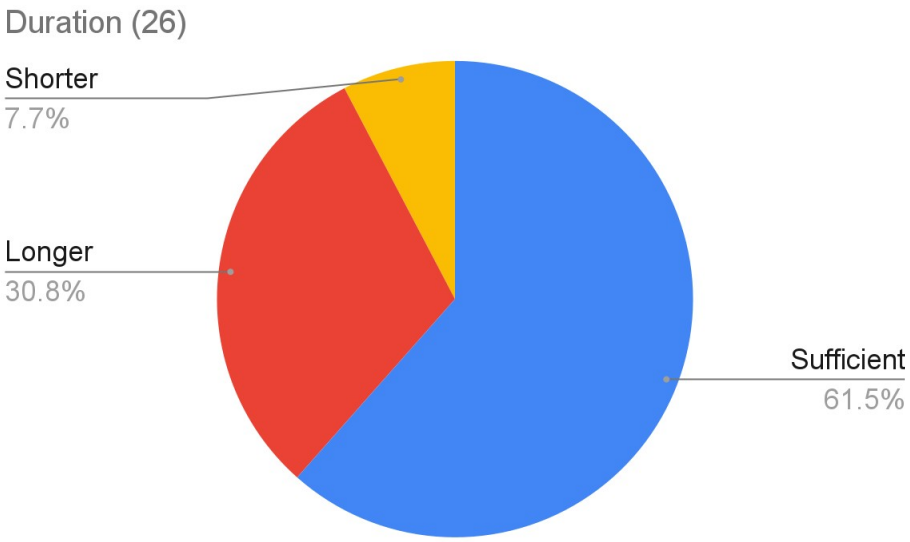


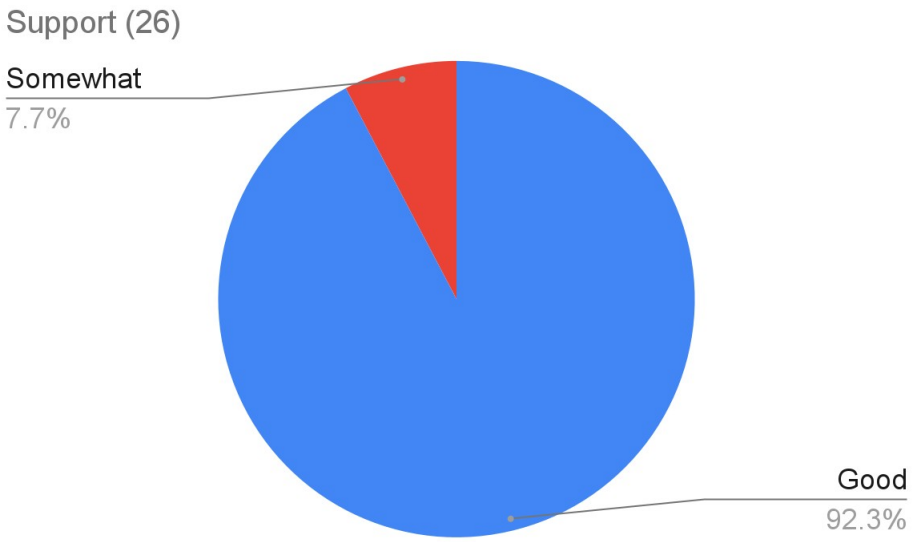
10+ hours of hands-on sessions

Satisfaction Survey



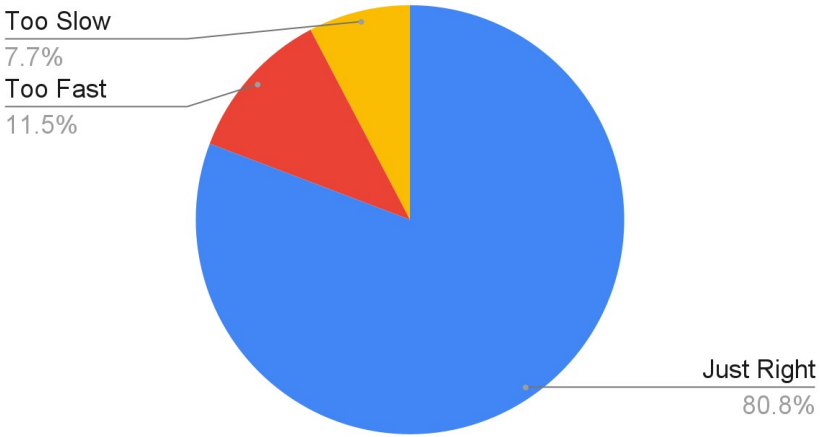




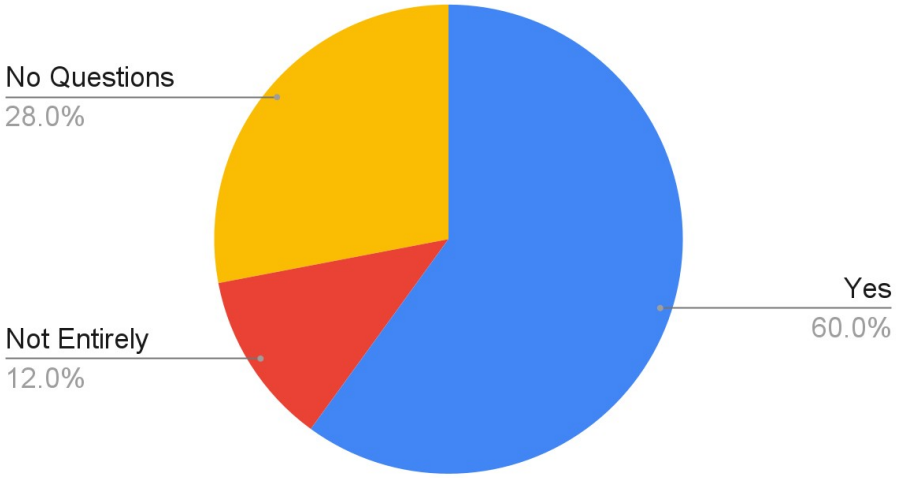


Satisfaction Survey, continued

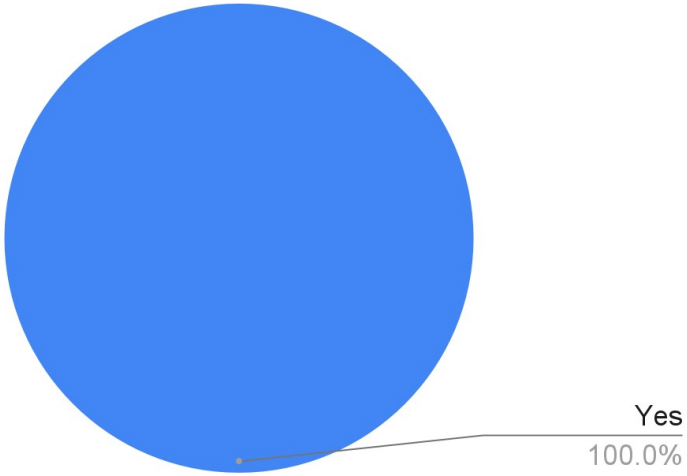
Pace (26)



Questions Answered (25)



Recommend to Others (26)



Chandra X-ray Center

Quotes

Food was excellent, loved the vegetarian options

Thank you so much for hosting us and for so kindly funding it entirely for us. You removed a lot of access barriers

Kahoot was a blast. The people were great. I love that I learned a couple more ds9 tips.

The venue and restaurant were great!

This workshop had been immensely beneficial for my research career.

The housing was amazing

Thank you for a truly valuable and well-organized workshop

I had an incredible time. I knew I would enjoy it and learn, but this far, far, far exceeded my expectations in every way.

I loved the Jupyter notebook we were given as a hands-on exercise

Not only did I learn the fundamentals of Chandra data analysis, but I also gained valuable insights into various new topics related to high-energy astrophysics.

I really enjoyed this worksop, big thanks to all the organisers

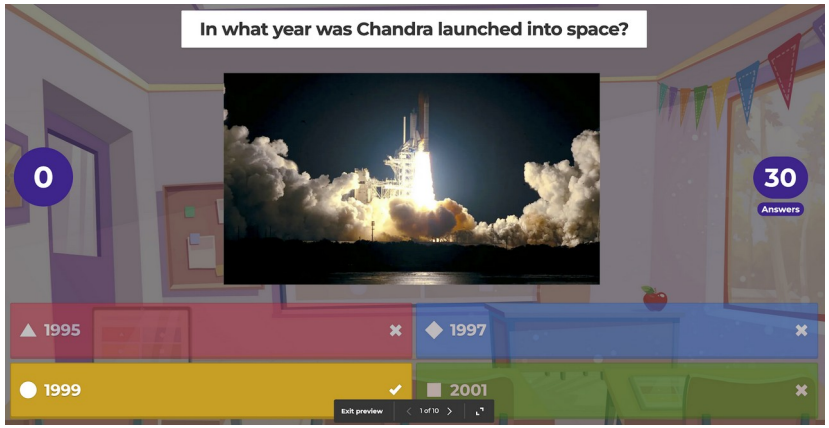
I hope to see more CIAO support for sciserver

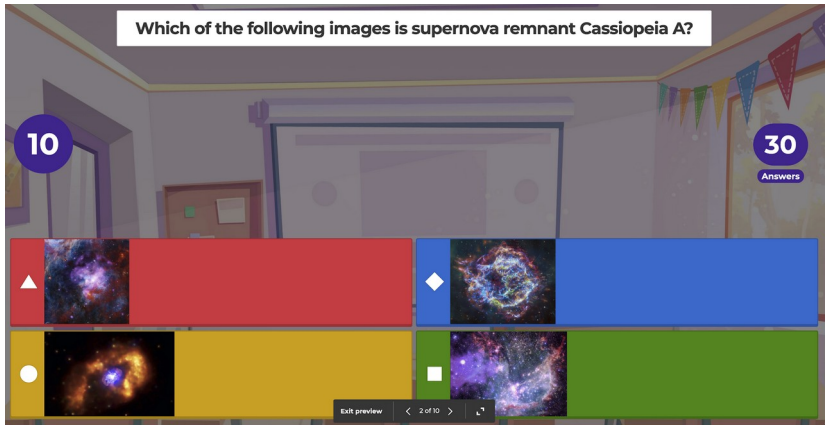
Chandra X-ray Center

N.b. What's a *Kahoot!*™?

Game-based, online, learning platform commonly used in contemporary classrooms.
Participants just need access to a web browser; supports use on smartphones & tablets.

There are a variety of possible questions formats, including True/False and images as answers.





Recently used to drive engagement at conferences and as a means to talk about *Chandra* to a wider audience when contextualizing and explaining answers.

Questions are interactive and points are awarded for correct answers based on speed—if you have to think about it, you might only get 500 points, while a quick answer can see you getting near 1000 points.

Chandra X-ray Center

NASA Hubble Fellows Program (NFHP)

A. Siemiginowska provided support for the NFHP.

- Organized panels, assigned reviewers, resolved conflicts, etc.
- Led offer process, communicated with candidates and institutions
- Prepared NASA press release, reviewed bios of fellows
- Interfaced with HQ to review future process, prepare 2026 AO
- Began work on panel chair selection for 2026
- Served as point of communications for Einstein fellows (budget, reports)

Chandra X-ray Center

CIAO 4.17/4.18 and Scripts Overview

Chandra X-ray Center

CIAO 4.17 - December 17, 2024

Highlights

- Now only supporting 1 version of Python = 3.11.
- New collect_chandra_dois script helps users collect identifiers for custom Chandra Dataset Object Identifiers (dois).
- Fix for long standing bug in dmcopy when using opt=all with gratings datasets which have been time filters (GTIs were getting messed up).
- Updated csmooth, aconvolve, and other tools to perform convolutions with double precision which improves accuracy for high dynamic range images.
- The datamodel library now recognizes the standard DEADC deadtime keyword used by missions like NuSTAR.
- Sherpa updates include
  - Enhancements with fitting models with linked parameters
  - Improvements for fitting 1D data with asymmetric errors
  - Enhancements and fixes to the plotting code

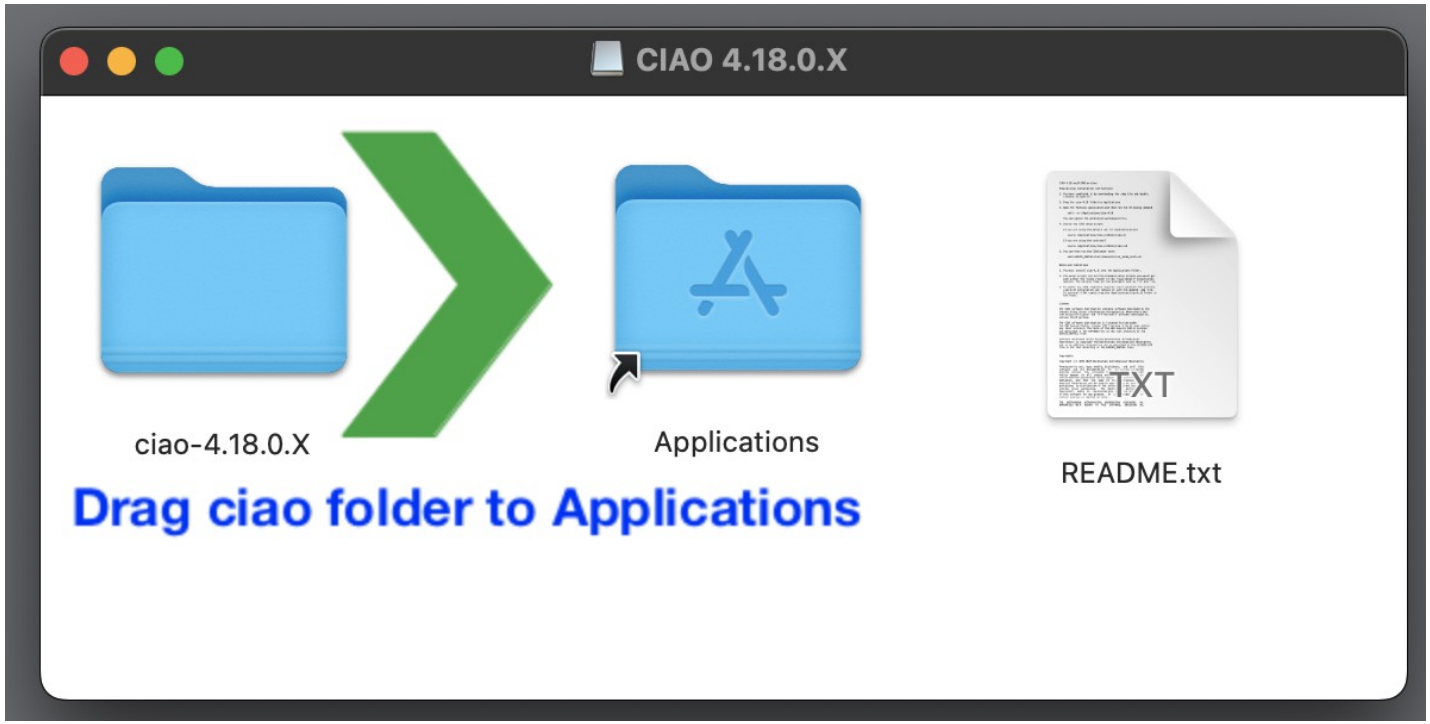
Chandra X-ray Center

CIAO 4.18 Planning

1. Update to Python 3.12 and NumPy 2.3
2. Support for FITS "K" type (8-byte integer, long long).
   a. 4.18 will include tools that manipulate tabular data, future releases will include support for images.
3. Maintenance
   a. Support newer compilers with updated C/C++ standards
   b. Additional OTS updates including CFTISIO and SAOImageDS9.
4. Sundry bug fixes including
   a. glvary fix bug when tool internally filters events (eg due to GTIs) which corrupts probabilities and variability index.
   b. wavdetect & celldetect fix problem when PSFMAP is in physical units.
   c. a_p_e bug in CTI correction when event time equals MTL time.
   d. glvary fix problem using "-" to specify STDOUT
   e. wcs_update/wcs_match fix to allow wcsfile to include DM filter syntax.
   f. dmextract fix to errant "HISTOGRAM" files when an error occurs.

CIAO 4.18, macOS DMG file

Based on work to assist a helpdesk user we will be offering macOS users a disk image of CIAO 4.18, aka a DMG file, that will include CIAO and the main CALDB files. Just drag the CIAO folder to Applications, and then run the `xattr` command.



Chandra X-ray Center

Contributed Scripts

4.17.0 - 17 December 2024

- **New** fine_astro script helps to automate the typical steps to apply a fine astrometric registration to Chandra datasets.
- **New** patch_hrc_ssc script can be used to detect HRC secondary science corruption events that cause an artificial drop in the dead time factors. If detected the script replaces corrupt DTF values with the mean value during good time intervals.
- **New** mkrprm script computes an approximate aperture correction for radial profiles.
  - The **new** sherpa_contrib.matrix_model can be used to include this aperture correction when fitting the radial profile in sherpa.
- convert_xspec_user_model has been updated for sherpa 4.17 and updated to use meson-python build backend.

Contributed Scripts – continued

4.17.1 - April 2025

- download_obsid_caldb: fix to retrieve all temperature dependent P2_RESP calibration files.
- specextract: update to warnings and trigger criteria for warm ACIS observations and calibration validity.
- chandra_repro: Modified file identification logic to support the case where the same filename exists both compressed (.gz) and uncompressed.
- dax: added srcextent task and fixed bug in HETG interactive grating wavelength tool.
- merge_obs: Fix for problem when combining large number of observations with PSFMAPs.
- find_chandra_obsid: Fix issue when no matches are found.

Chandra X-ray Center

Contributed Scripts – continued

4.17.2 - September 2025

- specextract - update to deal with trying to use quotes, ", for arcsec.
- srcflux - improved handling for very long region expressions
- chandra_repro - improved error handling when no sources are detected in gratings datasets.
- dax - the interactive gratings coordinates tool will now work in all frames and now includes the wavelength.
- search_csc and obsid_search_csc - are now using HTTPS to access the CSC services and also ensuring connections to services are closed.
- coords.chandra module - improved docs and added helper routine to retrieve required keyword values.
- Updates to support Numpy 2 & Python 3.12 (back compatible with 3.11)

~/Chandra/DELS_J091054.53-041406.8/fine_astro

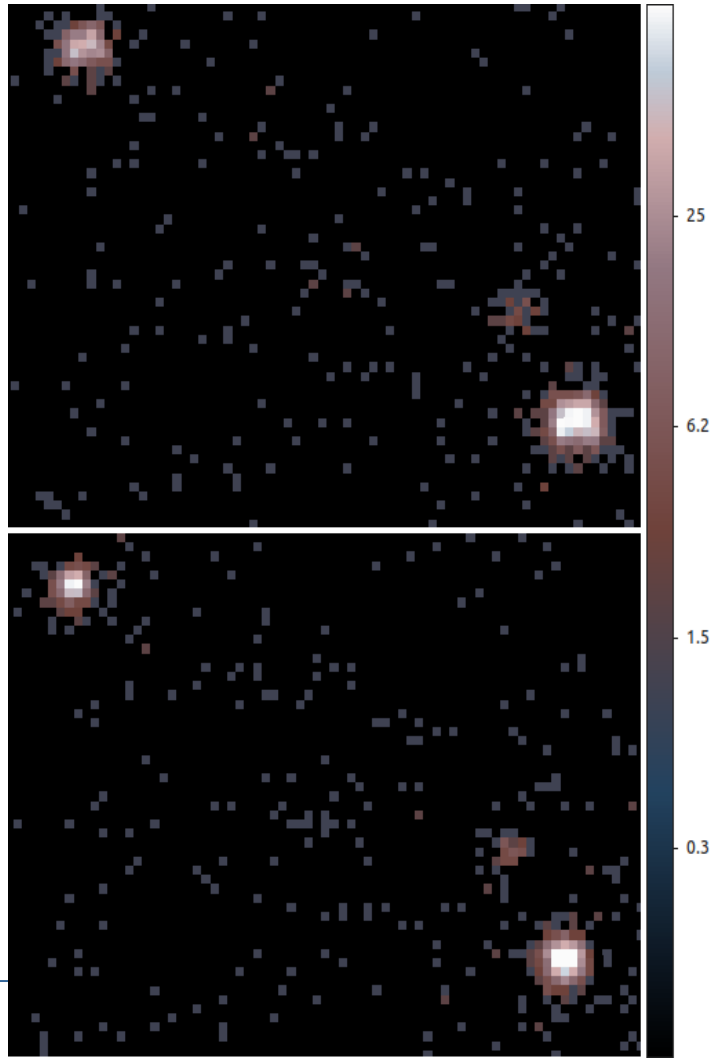
```
% find_chandra_obsid "DELS J091054.53-041406.8" detail=obsid > obi.lis
% download_chandra_obsid @obi.lis
% chandra_repro @obi.lis
% fine_astro @obi.lis fine_astro/out stop=mergeobs
%
```

fine_astro

Top: CIAO commands to identify, download, recalibrate, and apply fine astrometric corrections to **45** observations of DELS J091054.53-041406.8.

Right-Top: Combination of 45 observations before astrometric correction is applied. Note the extent in the horizontal (East|West) direction. This is due to the astrometric offsets between various observations. Data are in the 0.5 to 7.0keV energy range.

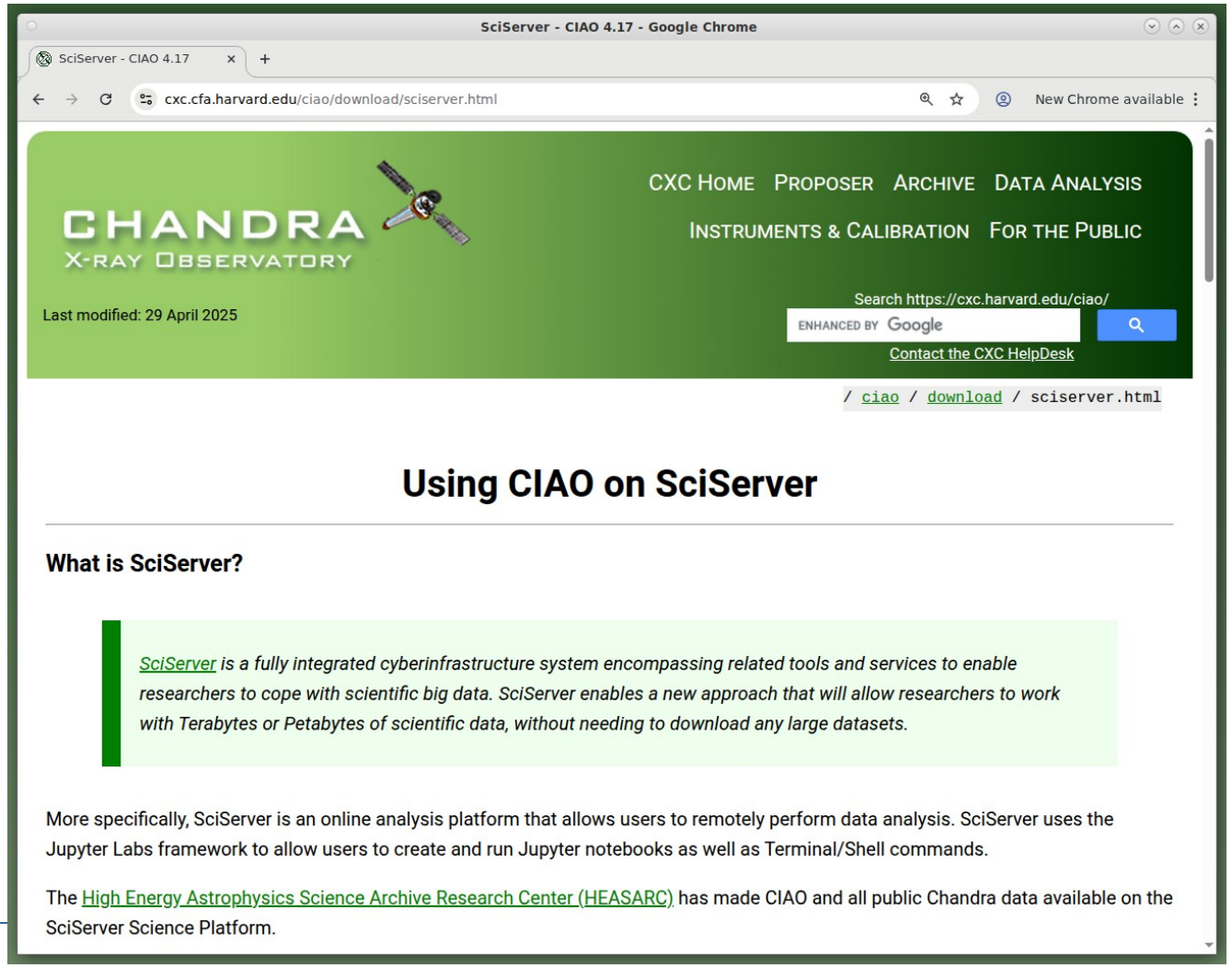
Right-Bottom: Same image as Left-Top but after the fine astrometric correction has been applied. The extent has been reduced after the offsets between the observations has been applied. The new script automates the various steps from creating images, exposure maps, and PSF maps; detecting sources, performing cross matches, and applying offsets to the event file and aspect solution files along with the meta-data updates.



CIAO on SciServer

Based on large number of Windows users attending the Workshop we provided a high level summary of how to use CIAO on the SciServer containers provided by HEASARC.

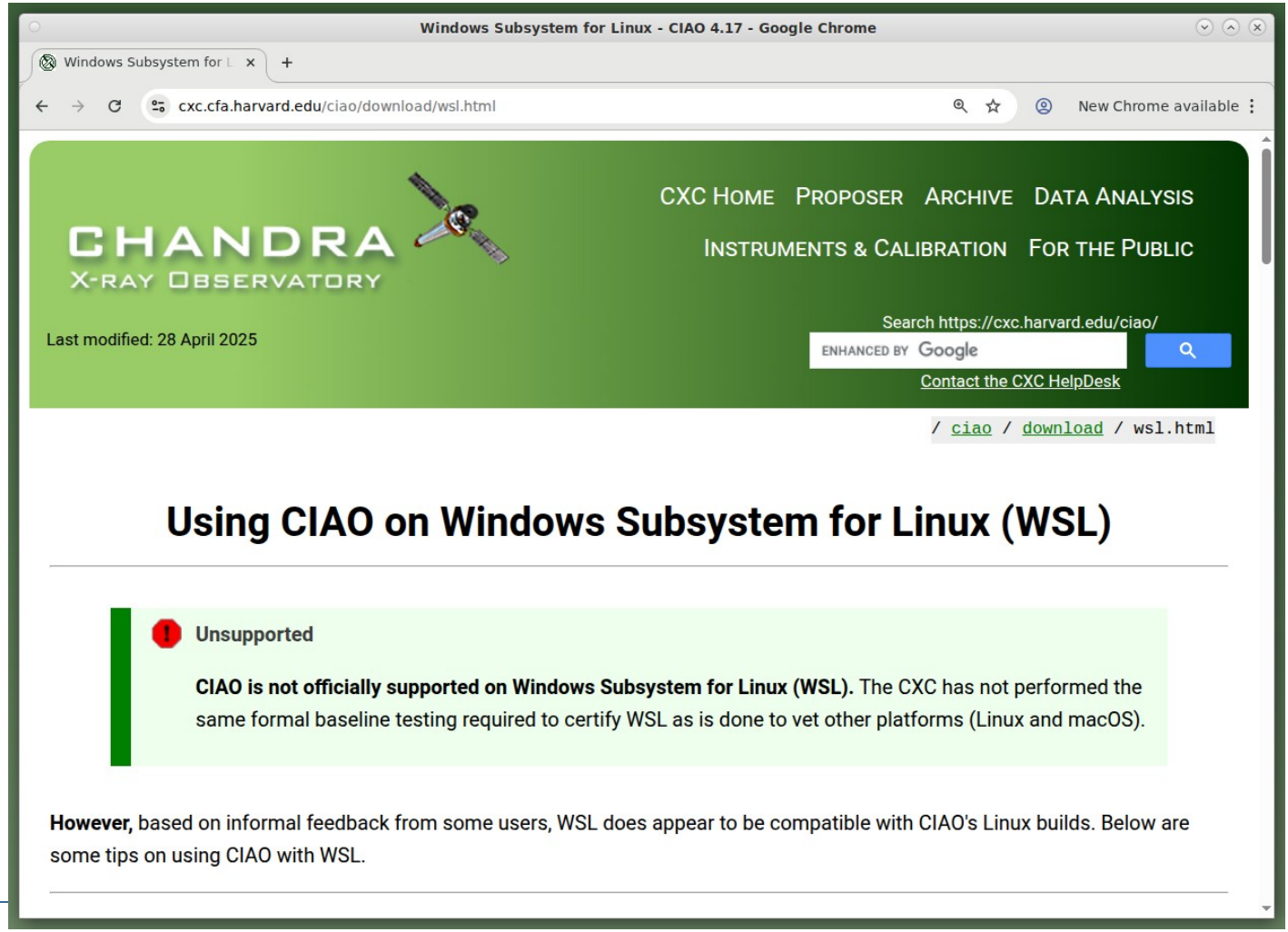
This was a popular choice by the students.



CIAO with Windows Subsystem for Linux (WSL)

CIAO is not officially supported on WSL; however, we know from helpdesk and workshops that users are using it.

We have done **some** more formal testing and provided tips on using WSL.



CIAO container

As an option of last resort, we built a CIAO container that can be used to run CIAO – including DS9, matplotlib, and jupyter notebooks with the CALDB downloaded separately (eg using download_obsid_caldb script).

It was not used during workshop but good exercise for post mission planning activities.

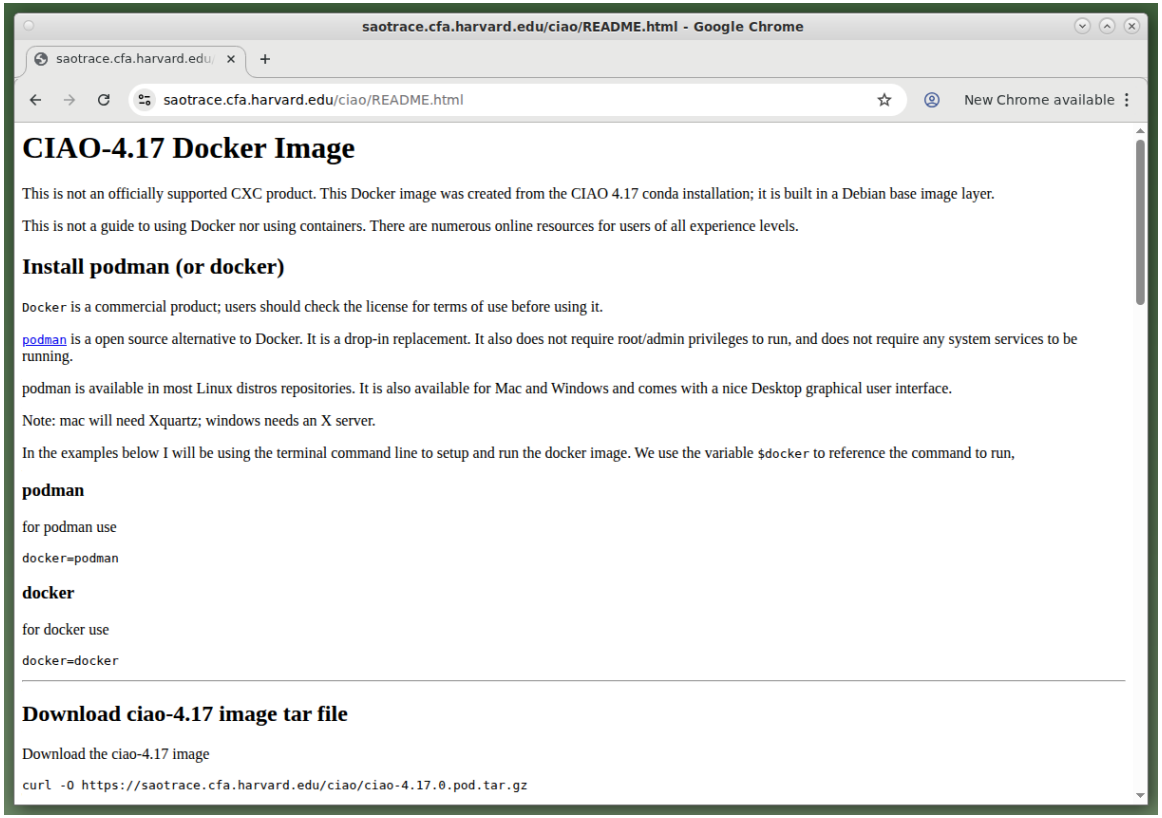
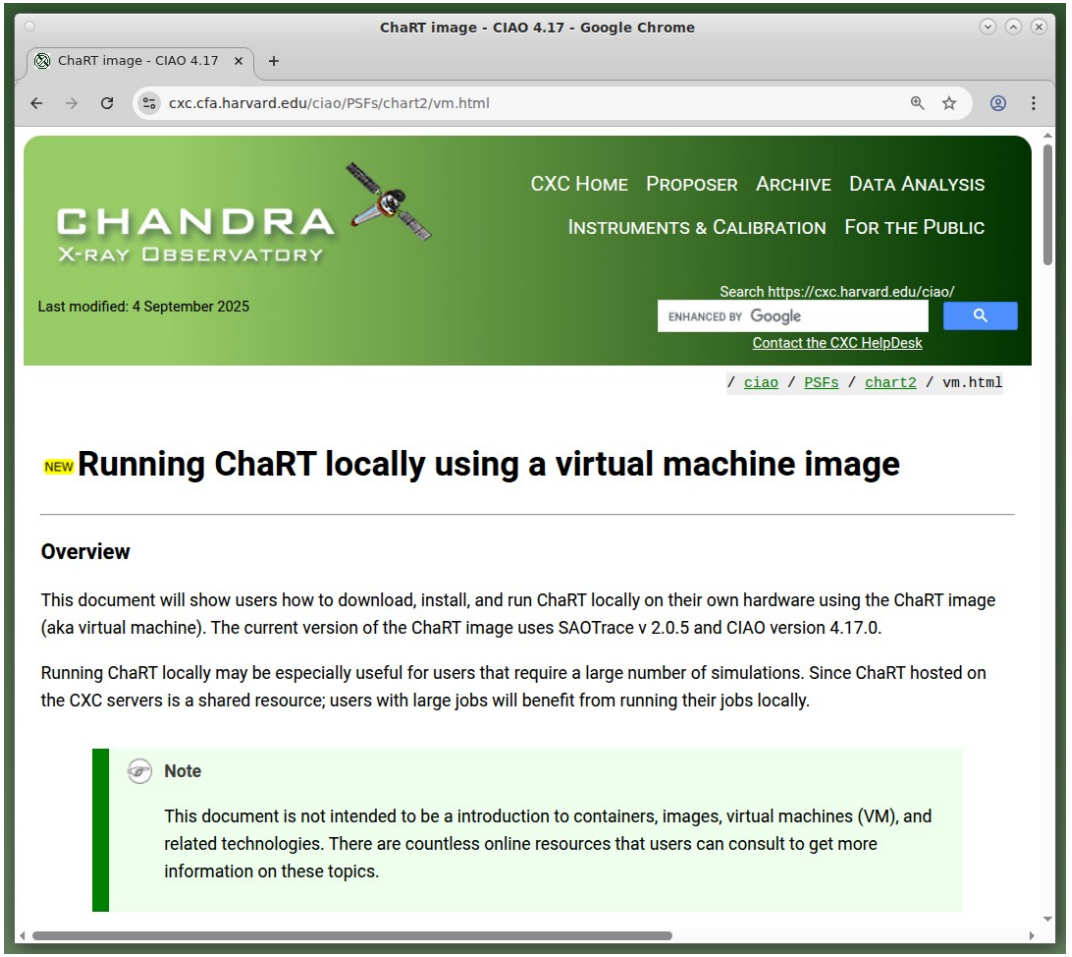


ChaRT container

Similarly, we have also provided a container that runs the ChaRT web services so that users can simulate PSFs locally.



Long Term Contingency Planning

Chandra X-ray Center

CXC is defining a CIAO 'legacy' package
What will the community need after the CXC era?
At NASA direction, CXC considered 3mo, 6mo and 1y closeout scenarios.

Following up from Pepi's list, SDS proposes:

- Full relocatable copy of CIAO website and CALDB website
- CIAO regression test scripts
- Sherpa standalone code
- Sherpa website
- MARX code and docs
- DS9 source package and documentations
- DS9 test files and scripts
- Archived CIAO and MIT HETG memos
- TGCAT archive copy

CUC suggestions are requested.

Chandra X-ray Center

Sherpa

Chandra X-ray Center

Sherpa development 2025

Releases

- 4.17 December 17 2024 - in CIAO - includes 2024 Sherpa development
- 4.17.1 May 13 2025 - standalone Python release
- 4.18.0 October 7 2025 to be included in CIAO 4.18 release

Highlights

- Enhancements
  - Allow models to contain “unary functions” such as `np.log(mdl)`
  - Allow use of optional SciPy and optimagic optimisers
  - Allow multiple datasets to be plotted in a single call
  - Support the optional ArviZ package for Bayesian analysis
  - Add a version of CStat to better handle models that can produce negative values (“`cstatnegativepenalty`”)
  - Improvements to handling free parameters that are linked to models not directly included in the source expression.

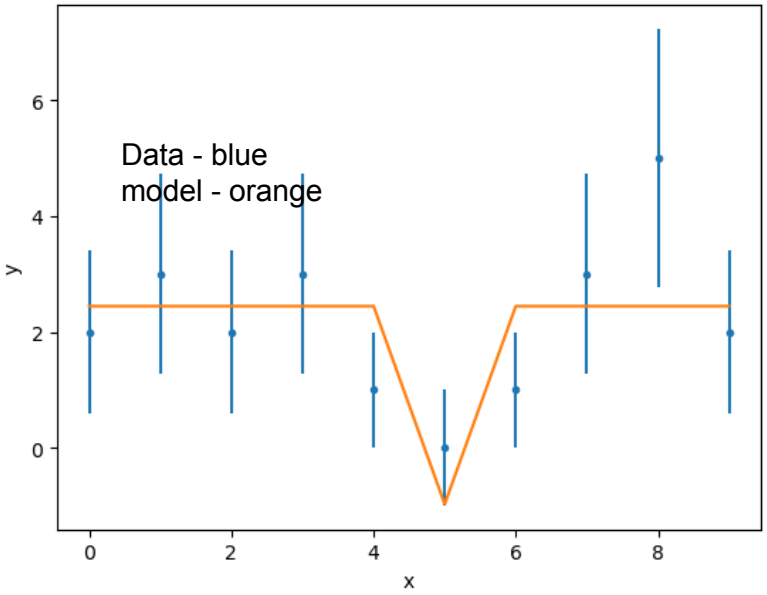
Chandra X-ray Center

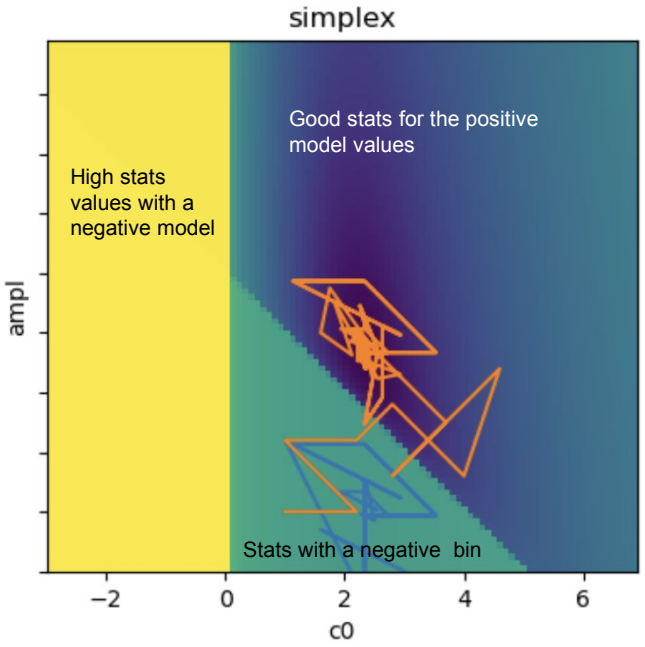
Sherpa development 2025

Highlights (continued)

- Infrastructure changes
  - Fix tests due to NumPy 2 changes in displaying numbers
  - Support updates to code used to build and test Sherpa
  - Supported versions of Python are 3.10 to 3.13
  - Supported versions of XSPEC are 12.13.0 to 12.15.0d
  - Continued adding typing statements to simplify code maintenance
- Documentation changes
  - Improved the optimisation documentation.
- Bug fixes
  - Fixed an issue with model caching
  - Updated `fake_pha` to handle missions with channels which start at 0
  - Improve the output of `save_all` when using PHA2 data
  - Improve the output of routines that sample parameters (`get_draws` and `eqwidth`)

Sherpa cstatnegativepenalty: fitting example





Right panel shows the visualization of the simplex optimization path in the parameter space (2 parameters) when fitting the data in the left panel:

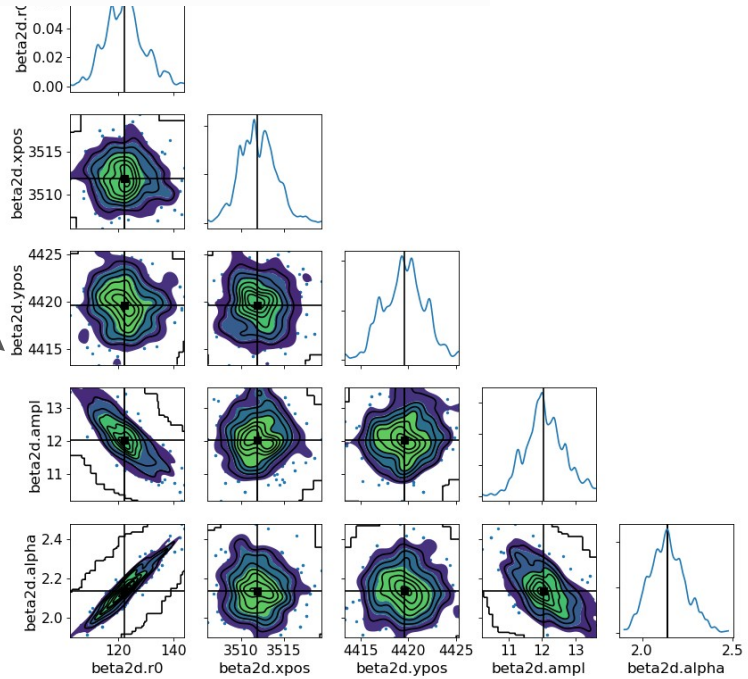
cstat - blue line - does not converge - truncated negative model values
cstatnegativepenalty - orange - negative penalty - when model values are negative nudges in right direction and converges)

Sherpa: Interface to Arviz

Sherpa MCMC

```
>>> import arviz as az
>>> from sherpa.sim import mcmc_to_arviz
>>> dataset = mcmc_to_arviz(mcmc=mcmc, fit=f, list_of_draws=[draws])
>>> _ = az.plot_pair(dataset, kind=["scatter", "kde"], kde_kwargs={"fill_last": False},
...     marginals=True, point_estimate="median", figsize=(12, 12))
```

Makes this plot with no extra work on Sherpa



Sherpa: external optimizers from other packages in Sherpa

Chandra X-ray Center

Sherpa built-in optimizers

```
from sherpa.astro import ui
ui.set_method('levmar')
```

- The sherpa.optmethods module
  - OptMethod
  - LevMar
  - NelderMead
  - MonCar
  - GridSearch

If *SciPy* package is installed:

```
from sherpa.astro import ui
ui.set_method('scipy_basinhopping')
```

- Adds 5 global optimizers (e.g. DualAnnealing)
- 15 local optimizers

If *optimagic* and its dependencies are installed:

- > 60 optimizers with more added with each optimagic release
- Incl. established libraries such as iminuit, but also experimental algorithms.

- Gives users options for a variety of fitting problems.
- Furthers Sherpa's mission as a general fitting package for any type of problem.

Sherpa Impact on Astronomy Research

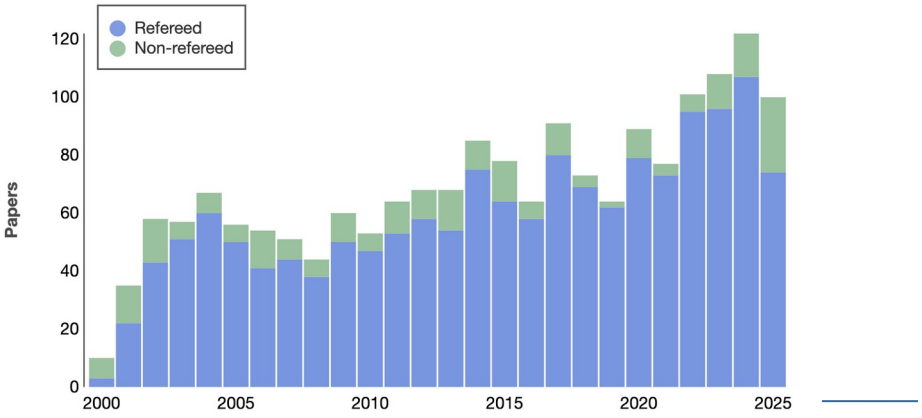
1797 publications in ApJ, AJ, MNRAS, A&A and others use Sherpa (since 2001 and including astro-ph abstracts)
https://ui.adsabs.harvard.edu/public-libraries/X6orMXwpRtSPy8x1uiiRMg

500 citations to Freeman et al 2001 SPIE paper
103 citations to Doe et al 2007 ADASS paper on Python implementation
81 citations to zenodo releases: DOI: 10.5281/zenodo.593753
7 PhD theses listed in ADS that used Sherpa

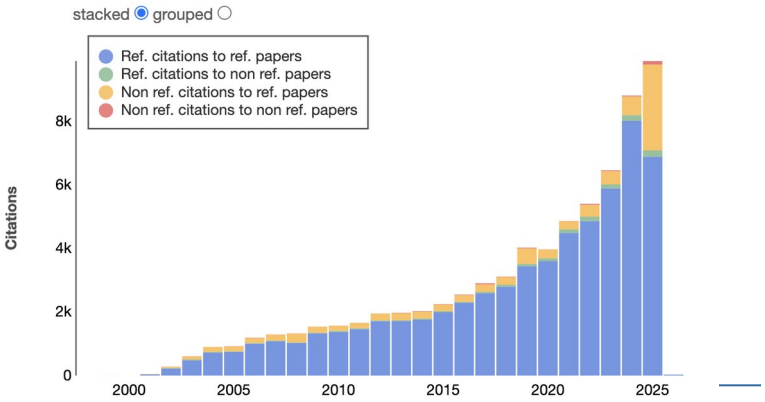
101 research papers published in 2025

IMPACT 2001-2025 Statistics from ADS

Sherpa used in research



Cited Papers which used Sherpa



Chandra X-ray Center

Instruments/ Gratings

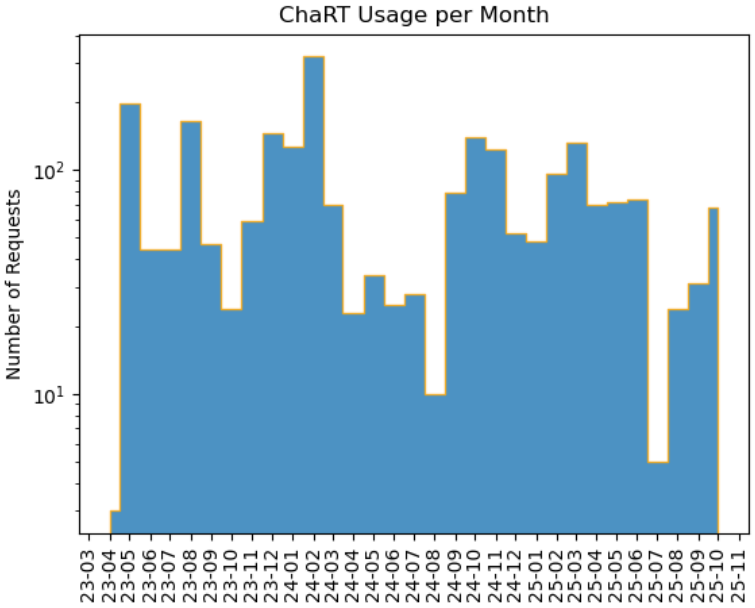
HRC: We are working on a script to fix the HRC secondary science corruption (SSC) --- basic algorithm looks OK as per HRC team review.
Next step is to make it look like a tool in our contrib area, and have it for application during V&V, and eventually in the pipeline.
(SSC makes it look like there are big data dropouts, but the data are there and one just needs to identify the times and update the GTI info)

High-T observations (mostly with gratings): modified the V&V statement (reviewed decision tree from Cal).

Chandra X-ray Center

PSF

ChaRT



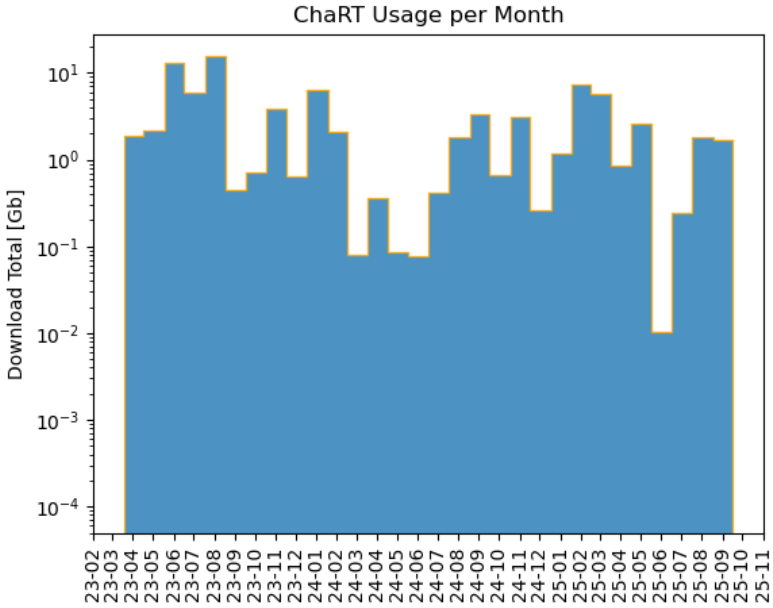


ChaRT updated to CIAO 4.17. Routine OS updates.

Chandra X-ray Center

Visualization

DS9 v 8.7b2 released Oct 2025
This will be the version included in CIAO 4.18 (Dec 2025)
Includes autosave option, bug fixes

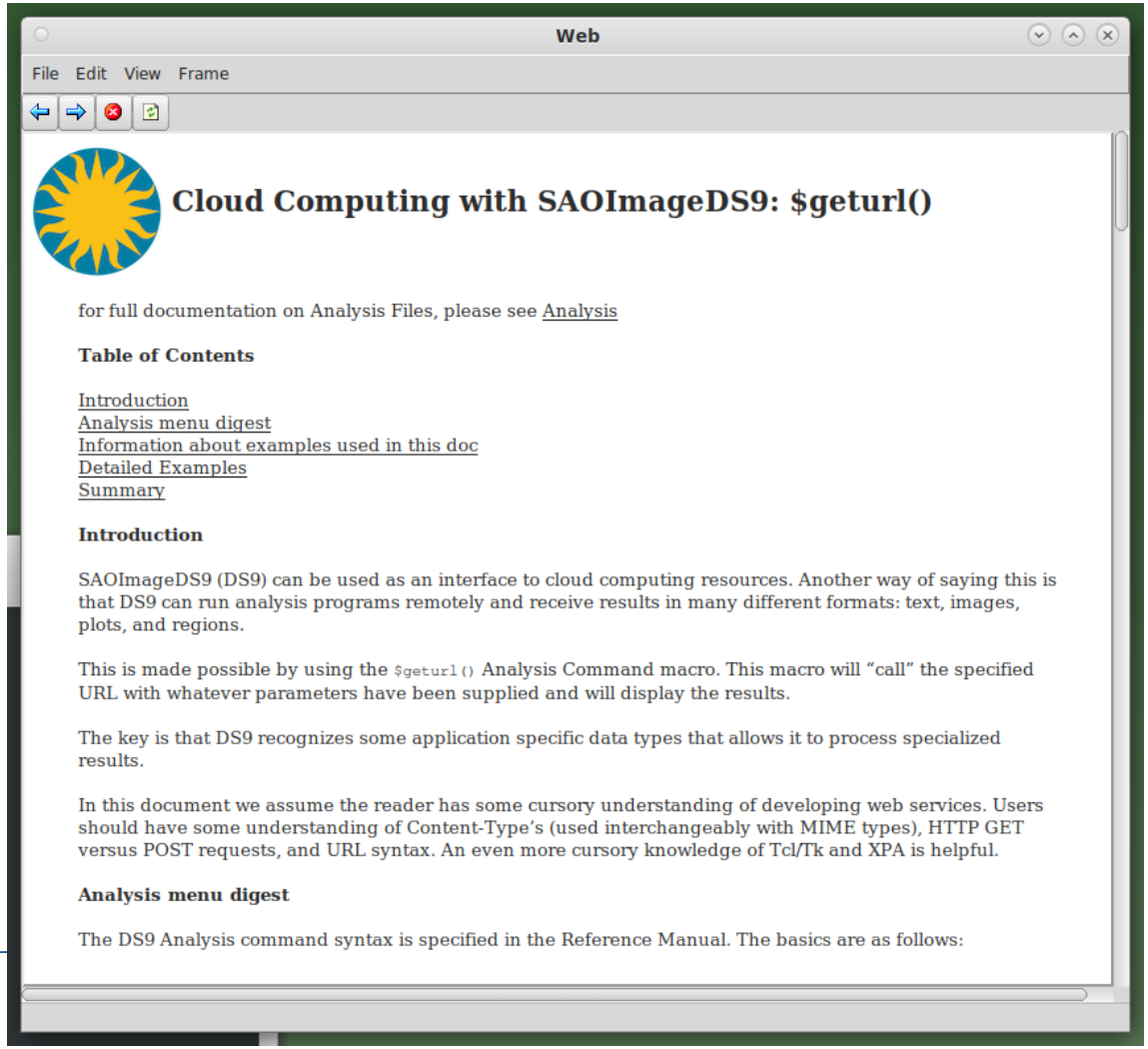
DS9 v 8.7 planned for release early 2026
Targeted upgrades:
- Upgrade to TCL/Tk 9
- Upgrade to SSL1.3

Focus on increasing longevity of code

Documenting DS9's cloud interface

DS9 has supported cloud computing before it was called "cloud computing". The DS9 $geturl() analysis macro allows users to run remote analysis tasks and display the results (images, regions, plots, text, etc.).

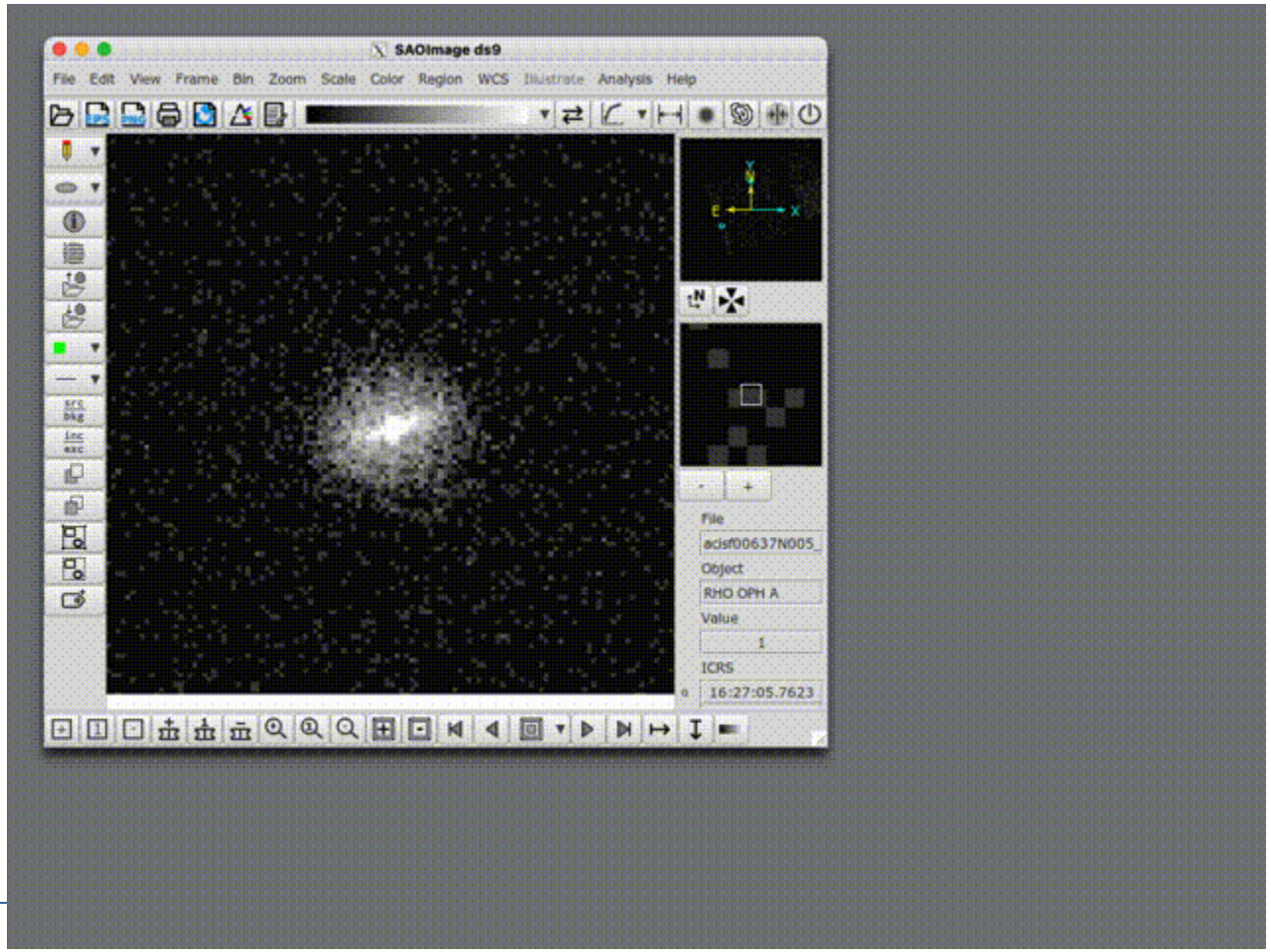
This new document describes how to setup a remote analysis service. It will be part of the DS9 8.7 release.



DAX - elastic ellipses

DS9 users can enable "elastic ellipses" in CIAO via DAX. The ellipse will resize, reposition, and reorient itself when moved or edited to match the image moments of the data in the region.

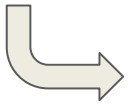
This is based on knowledge learned during DS9 cross training.



SAOImageDS9 + ds9samp

Simplify communication to DS9 via SAMP: https://pypi.org/project/ds9samp/

```
from astropy.samp import SAMPIntegratedClient
ds9 = SAMPIntegratedClient()
ds9.connect()
ds9.ecall_and_wait("c1","ds9.set","10",cmd="url http://ds9.si.edu/download/data/img.fits")
ds9.ecall_and_wait("c1","ds9.set","10",cmd="zscale")
print('Click anywhere in image:')
coord = ds9.ecall_and_wait("c1","ds9.get","10",cmd="imexam wcs icrs")
print('Coordinate is ', coord['samp.result']['value'])
ds9.disconnect()
```



```
from ds9samp import ds9samp

with ds9samp() as ds9:
    ds9.set("url http://ds9.si.edu/download/data/img.fits")
    ds9.set("zscale")

    print("Click anywhere in image:")
    coord = ds9.get("imexam wcs icrs", timeout=0)
    x, y = [float(c) for c in coord.split()]
    print(f"Coordinate is x={x} y={y}")
```

New DS9 Documentation

DS9 documentation may be found at ds9.si.edu under the 'Documentation' tab

New document: DS9 Interface and Internal Design
- 287 pages; comprehensive description correlating GUI menu commands, XPA control commands, and command line options.

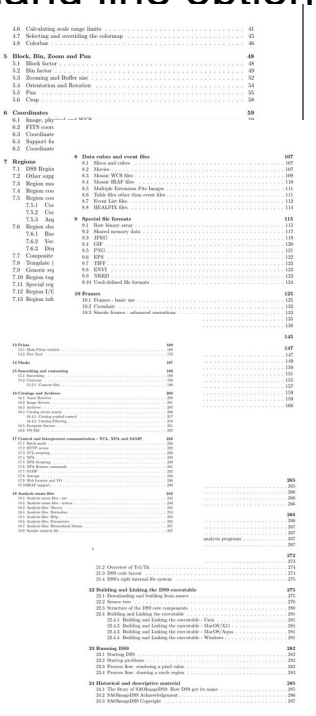
SAOImageDS9 Interface and Internal Design

Jonathan McDowell, William Joye, and the Chandra X-ray Center Science Data Systems Group

2025 Jul 21

Contents

1



4.5 Supported scaling functions

The scaling functions are:

linear	Linear	$s(r) = r$
log	Log	$s(r) = \log(pr+1)/\log(p)$, for a parameter p whose default is 1000.
power	Power	$s(r) = \left(\frac{b^r-1}{p}\right)$, for parameter p with default 1000.
sqr	Sq Root	$s(r) = \sqrt{r}$
sqr	Squared	$s(r) = r^2$
asinh	asinh	$s(r) = \sinh^{-1}(pr)/3$, where p = 10.
sinh	sinh	$s(r) = \sinh(3r/p)$, where p = 10.
histeq	Histeq	with $s(r)$ depending on the frequency of each r value.
logexp	Log exponent	

Command: scale [function]

Menu: *Scale - [function]*

Description: Allows the user to select which scaling function s(r) is used. For example, 'xpaset -p ds9 scale asinh' On the command line, one can use the functions as options directly, so 'ds9 -linear', 'ds9 -log', etc.

Command: scale log exp [value]

Menu: *Edit - Preferences - Scale - Log Exponent*

Description: Controls the value of p in the log and power functions

4.6 Calculating scale range limits

Command: scale open

Menu: *Scale - Scale Parameters*

Description: Generates a popup dialog which allows the user to enter the x_1 and x_2 values explicitly. The Scale menu also lets the user specify one of several range limit algorithms to calculate and apply suitable values.

41