



# Science Data Systems

Jonathan McDowell



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)

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# **Community Support:**

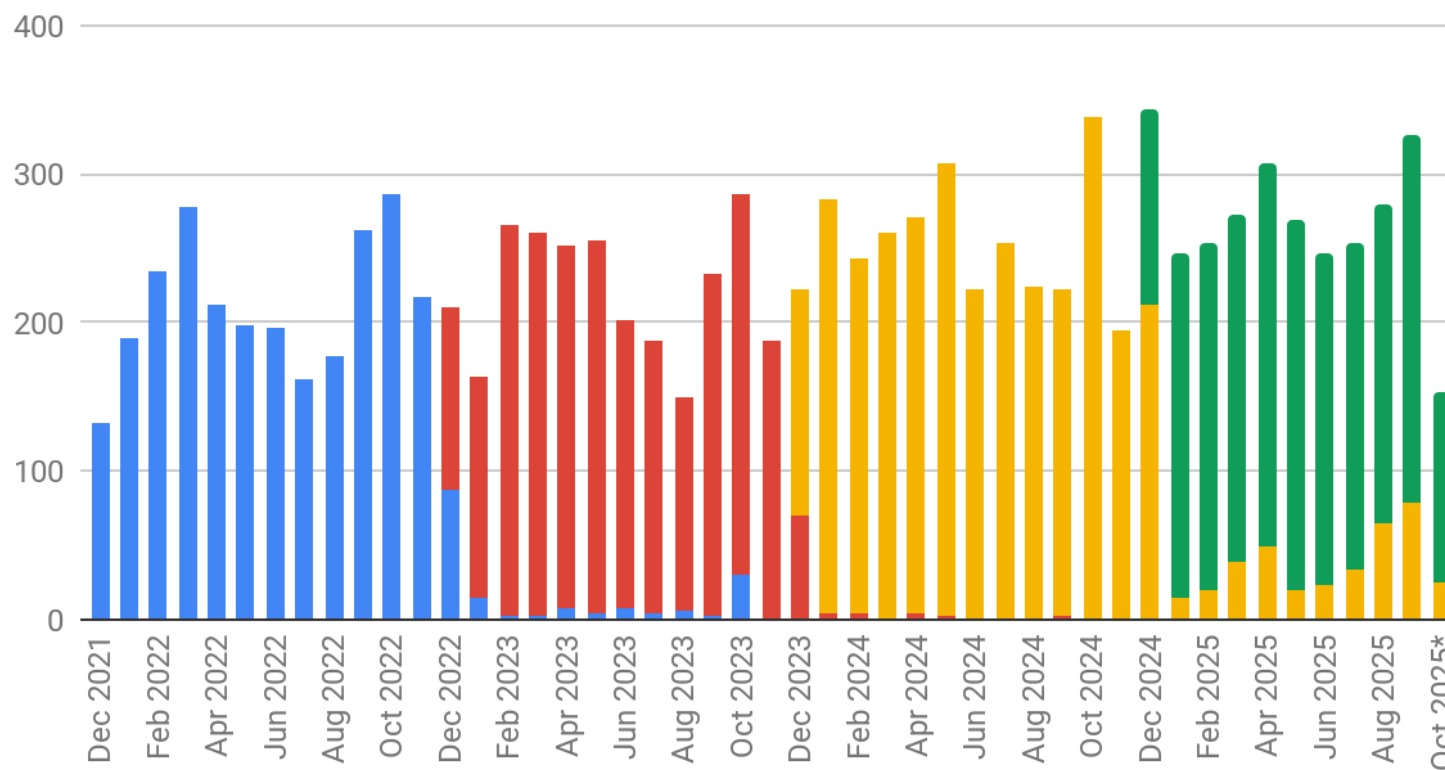
Downloads,  
Documentation,  
Helpdesk

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- CIAO 4.14
- CIAO 4.15
- CIAO 4.16
- CIAO 4.17

## CIAO Downloads



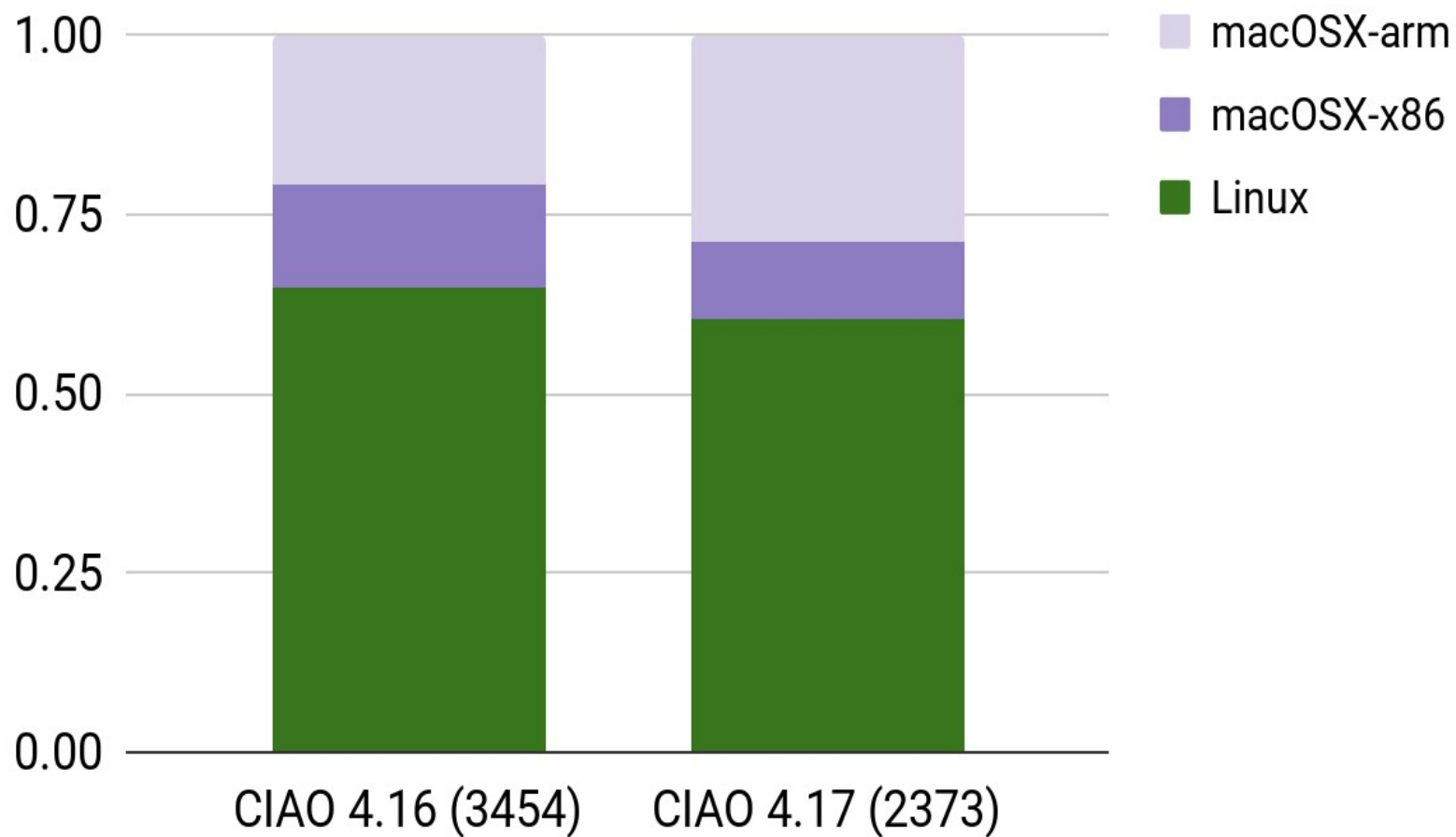


# Downloads (lifetime)

| 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      |

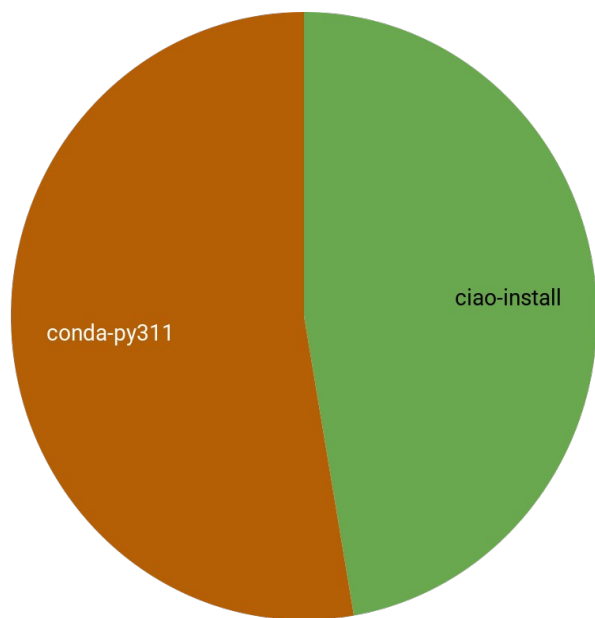


## Download by OS

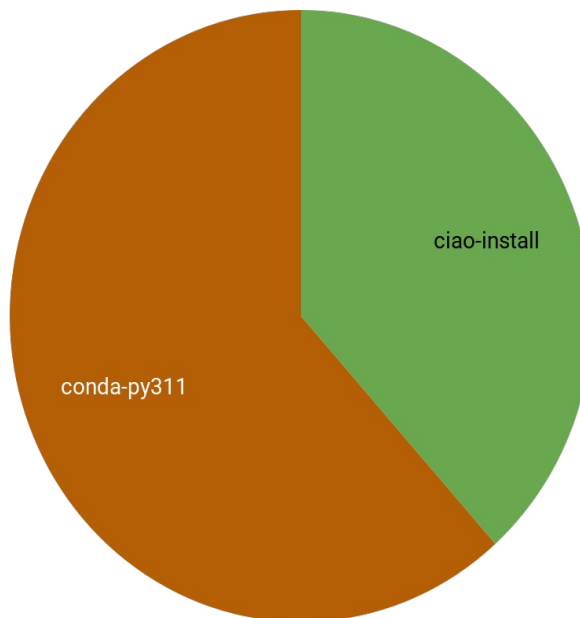




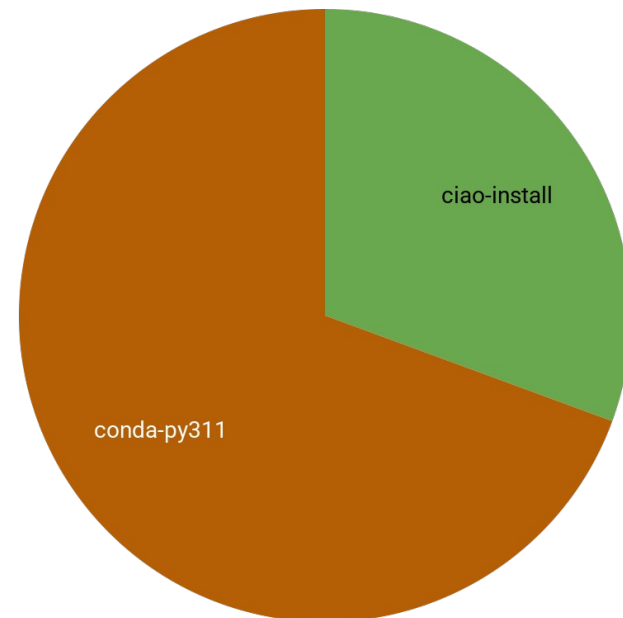
# CIAO 4.17 Installation Options



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.



# Documentation

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## Docs

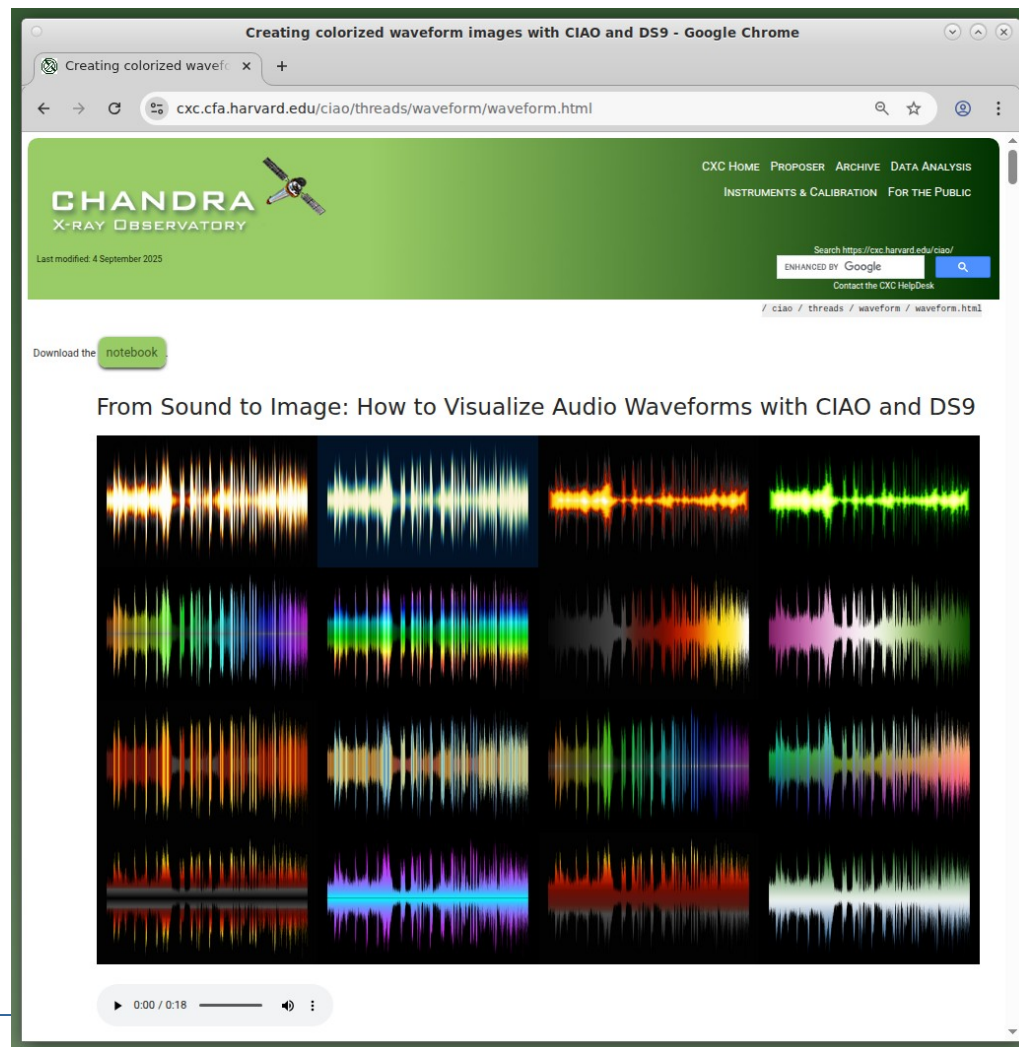
- Routine roll-out of CIAO 4.17 site; CIAO 4.15 site retired.
- Initial release of [Merge Central](#)
- **New** thread:  
[Extracting Spectra and Responses for ACIS Observations that Undergo Large Focal-plane Temperature Swings](#)
- Final Repro-5 obsids (early datasets) have been processed and threads 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.

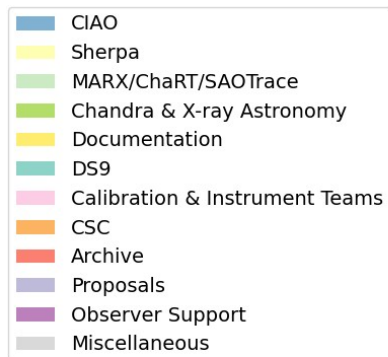
These techniques are applied to an image of the audio waveform from the STS-93 countdown and launch.





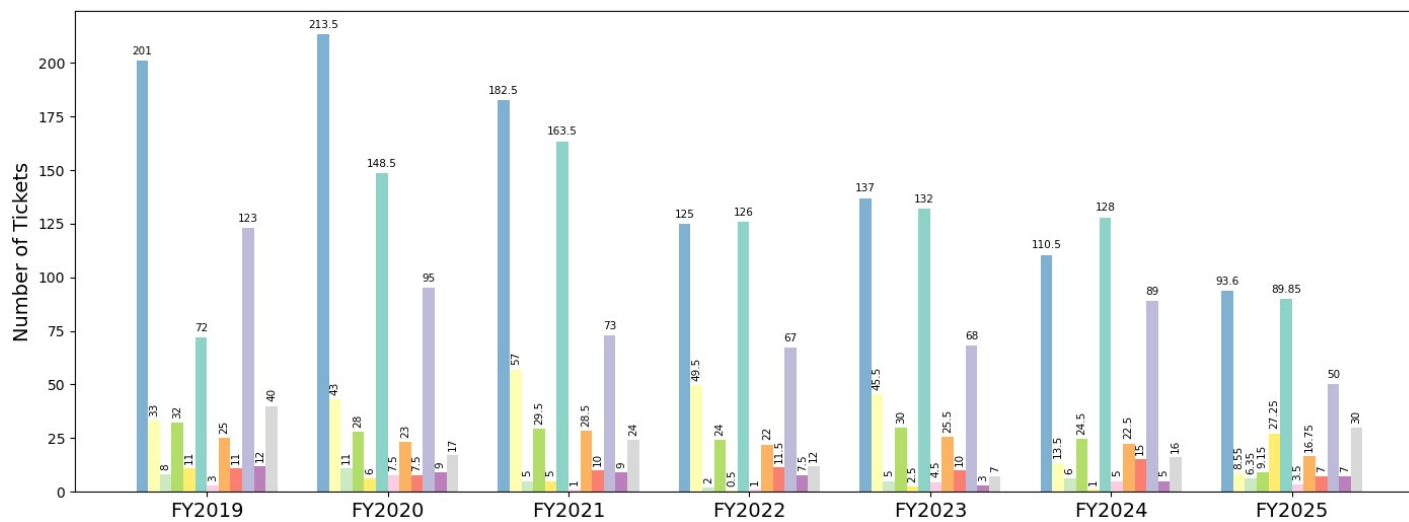
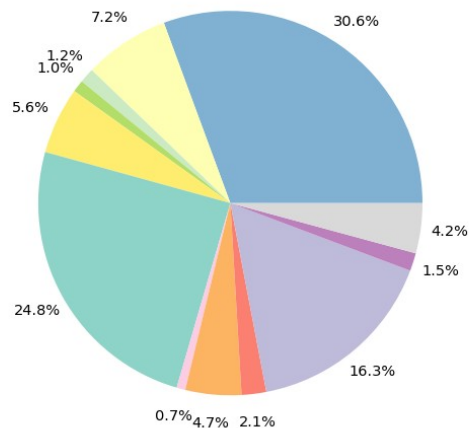
# Helpdesk

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## Ticket Categories: FY2019 – FY2025

3471 total tickets





# Helpdesk Stats

|                                             | <b>2023-10-15 to<br/>2024-10-15</b> | <b>2024-10-15 to<br/>2025-10-15</b> |
|---------------------------------------------|-------------------------------------|-------------------------------------|
| <b>Time period<br/>[months]</b>             | 12                                  | 12                                  |
| <b>Number of Tickets</b>                    | 210                                 | 188                                 |
| <b>Median time to 1st<br/>contact [hrs]</b> | 3.87                                | 2.86                                |
| <b>Median time to close<br/>[hrs]</b>       | 20.54                               | 11.18                               |
| <b>Maximum time to<br/>close [hrs]</b>      | 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 addressp 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.)



# 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).



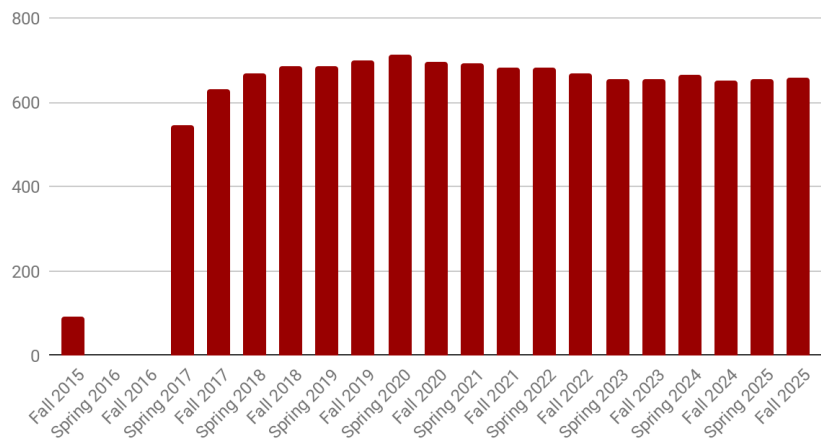
# Community

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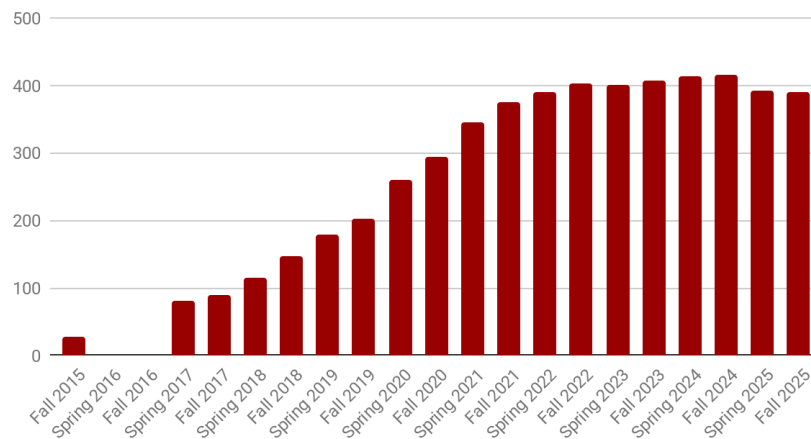


# Social Media

Facebook



X/Twitter



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



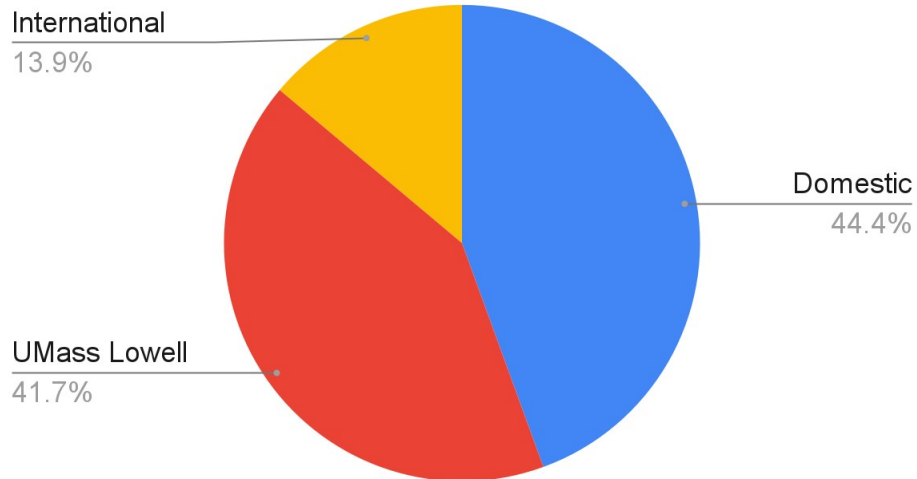
# Community

- 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

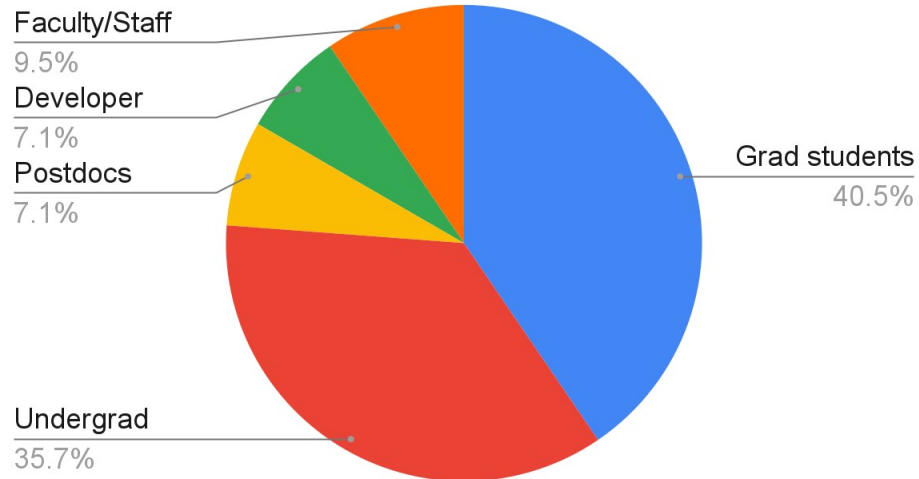


# Workshop Cohort Summary

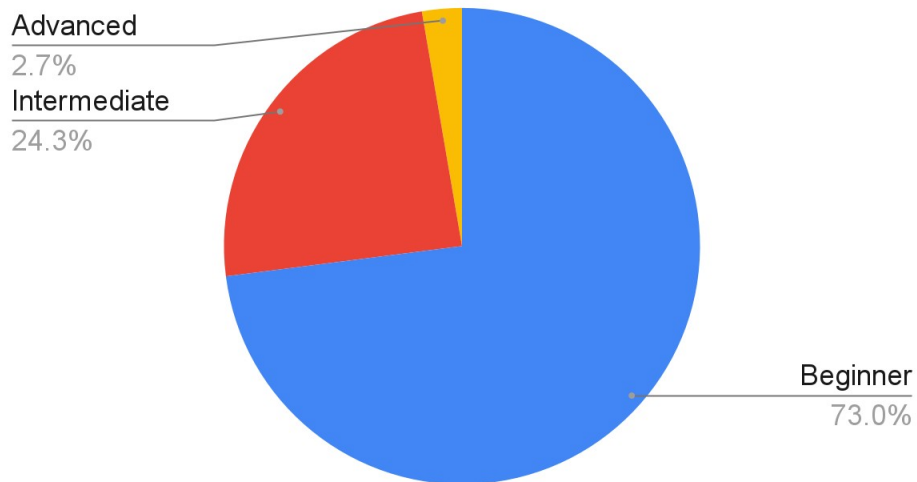
Affiliation



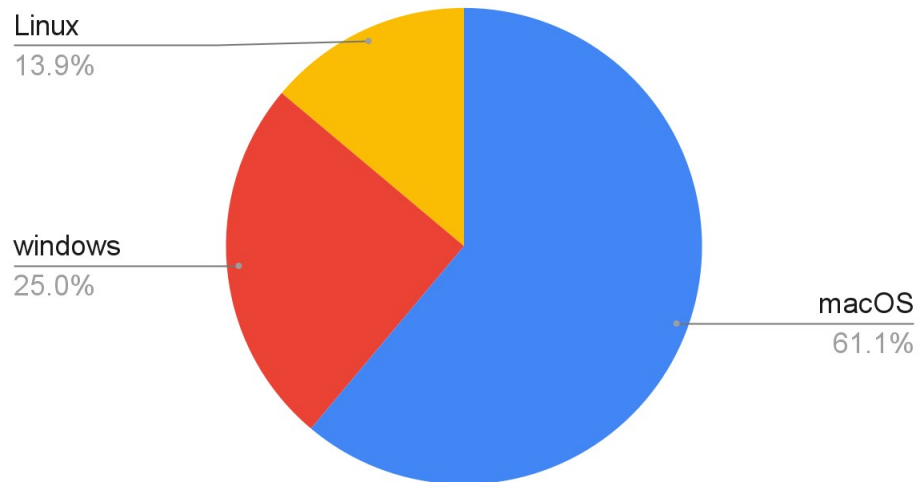
Position



Experience



Operating System





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# Program Summary

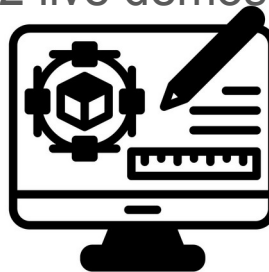


5 days



25 Presentations

2 live demos



17

presenters



875+ slides



975+ minutes of  
instruction

2 off-site  
excursions



10+ hours of  
hands-on sessions

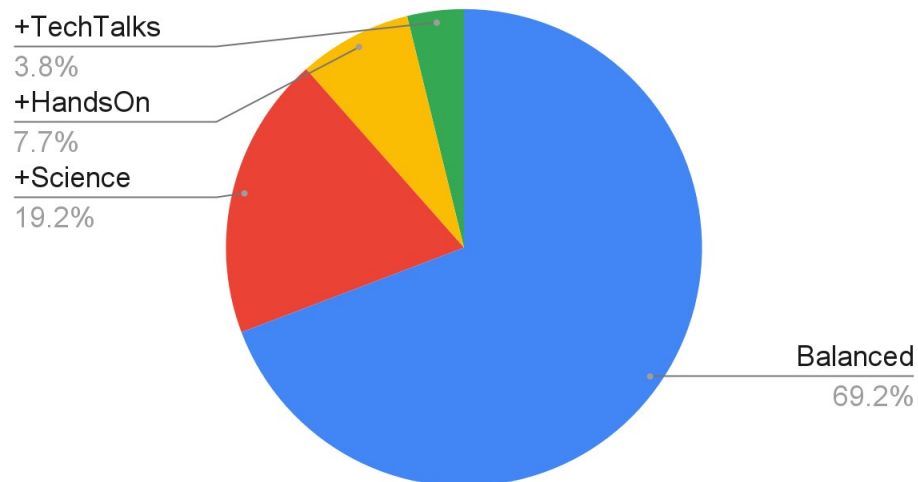


Daily Kahoot!  
quizzes with  
75+ questions

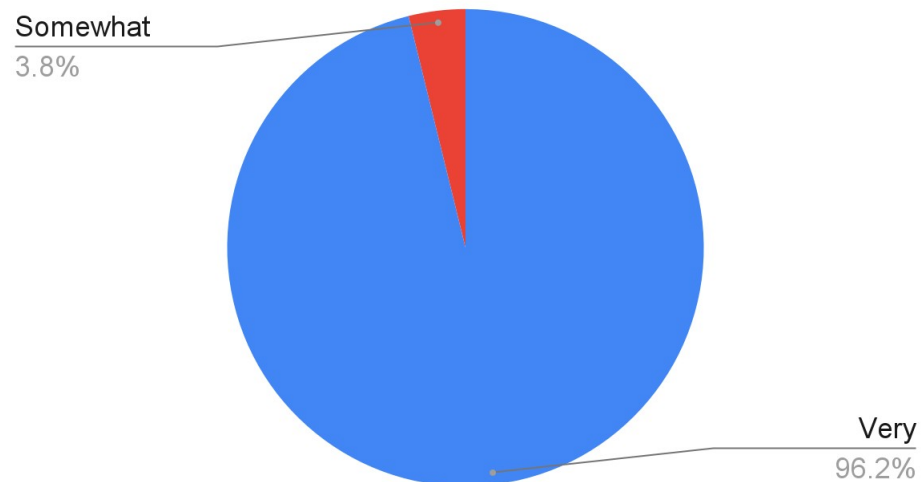


# Satisfaction Survey

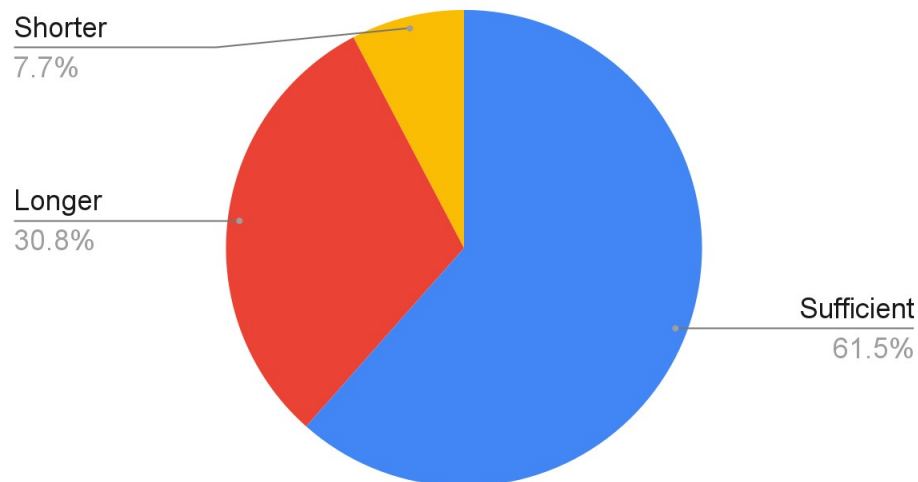
Program Balance (26)



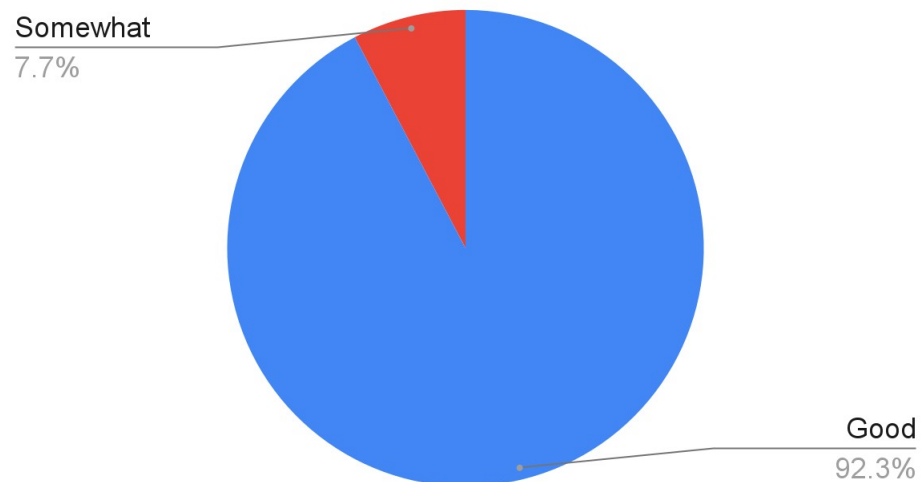
Beneficial (26)



Duration (26)



Support (26)

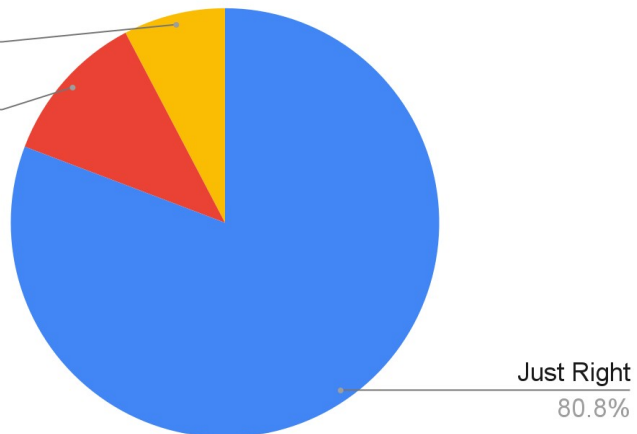




# Satisfaction Survey, continued

Pace (26)

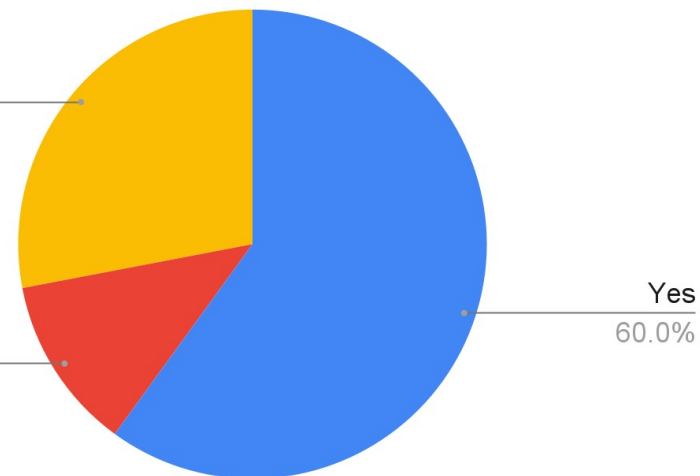
Too Slow  
7.7%  
Too Fast  
11.5%



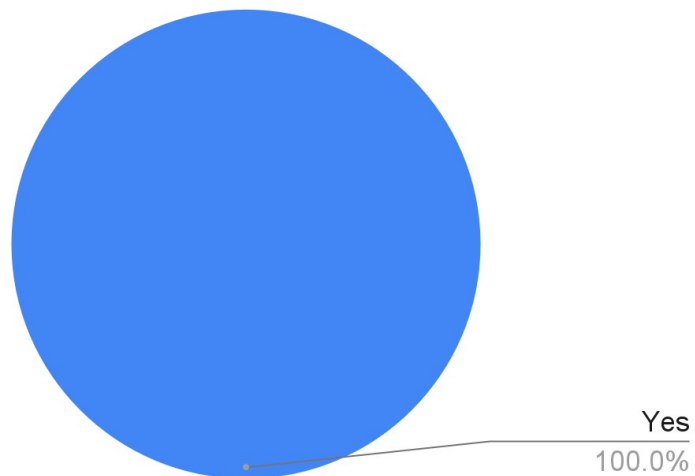
Questions Answered (25)

No Questions  
28.0%

Not Entirely  
12.0%



Recommend to Others (26)





# Quotes

Food was excellent,  
loved the vegetarian  
options

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

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

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  
workshop, big thanks  
to all the organisers

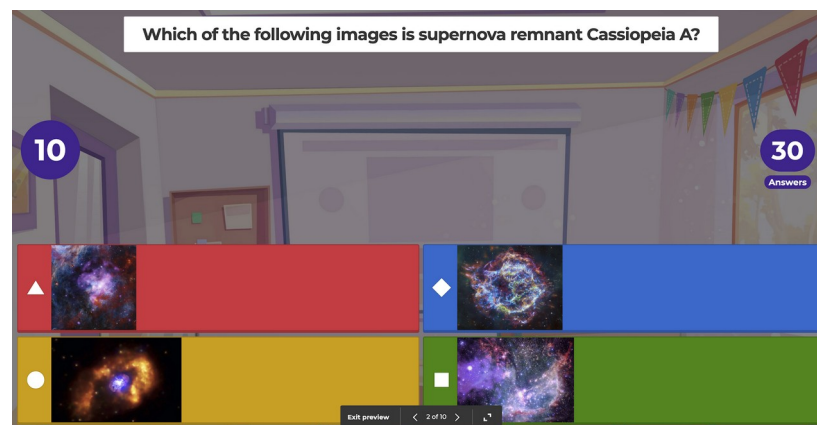
I hope to see more  
CIAO support for  
sciserver



## 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.



## 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)



# CIAO 4.17/4.18 and Scripts Overview

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# 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
-



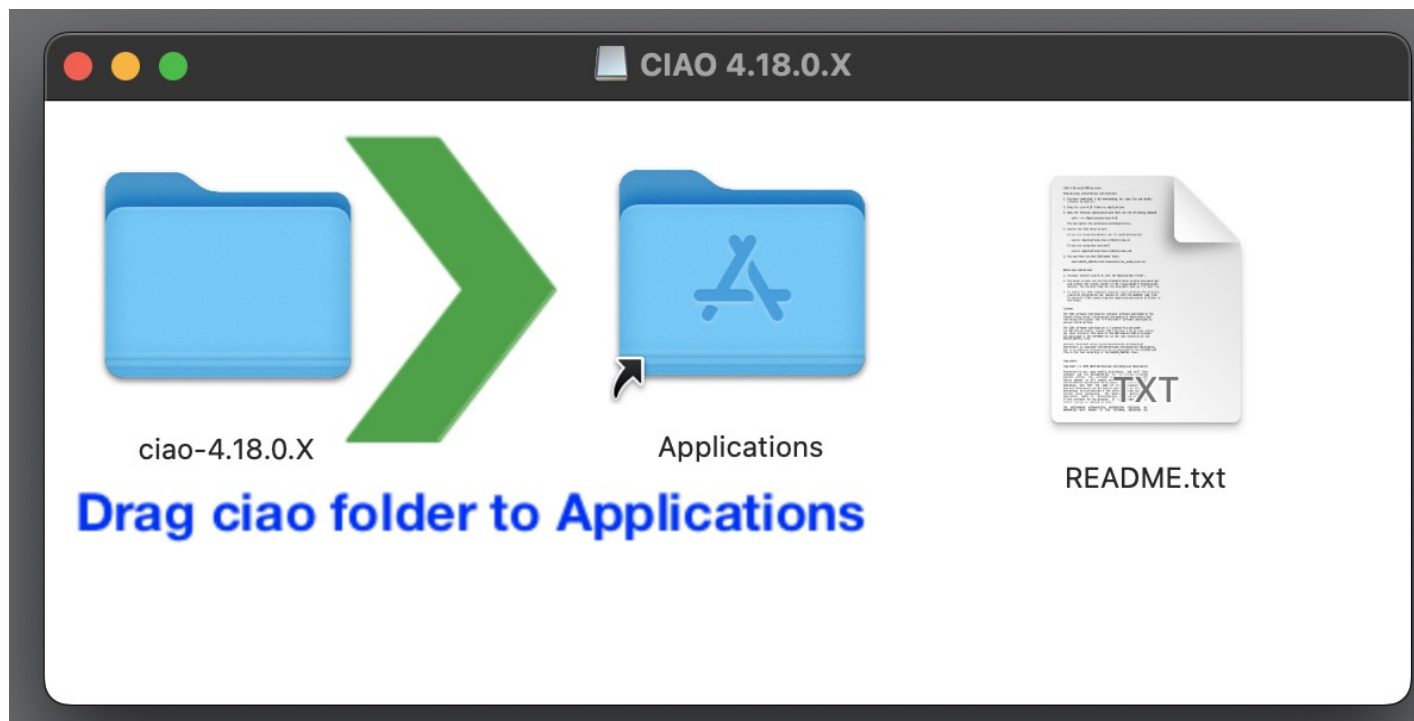
# CIAO 4.18 Planning

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. glvray 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. glvray 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.





# 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.
-



# 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)
-



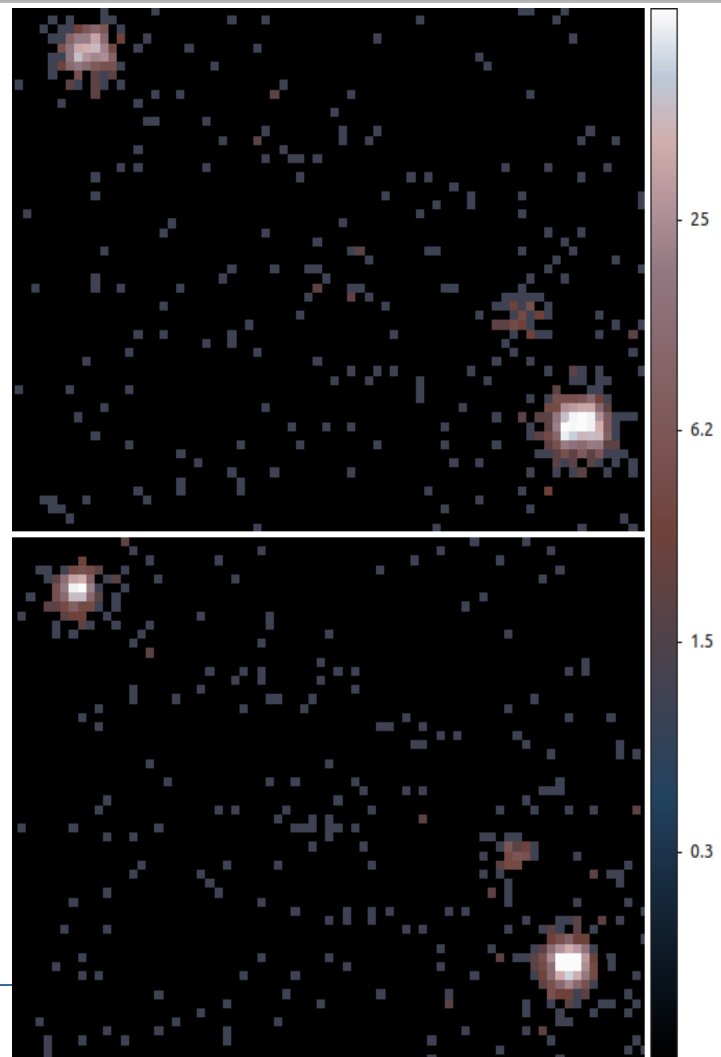
## fine\_astro

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.

```
~/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
%
```





# 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.

SciServer - CIAO 4.17 - Google Chrome

SciServer - CIAO 4.17 x +

cxc.cfa.harvard.edu/ciao/download/sciserver.html

← → ↻ 🔍 ☆ ⓘ New Chrome available

  
CHANDRA  
X-RAY OBSERVATORY



CXC HOME PROPOSER ARCHIVE DATA ANALYSIS  
INSTRUMENTS & CALIBRATION FOR THE PUBLIC

Last modified: 29 April 2025

Search <https://cxc.harvard.edu/ciao/>  
ENHANCED BY Google 🔍

[Contact the CXC HelpDesk](#)

/ [ciao](#) / [download](#) / [sciserver.html](#)

## Using CIAO on SciServer

### What is SciServer?

*[SciServer](#) is a fully integrated cyberinfrastructure system encompassing related tools and services to enable researchers to cope with scientific big data. SciServer enables a new approach that will allow researchers to work with Terabytes or Petabytes of scientific data, without needing to download any large datasets.*

More specifically, SciServer is an online analysis platform that allows users to remotely perform data analysis. SciServer uses the Jupyter Labs framework to allow users to create and run Jupyter notebooks as well as Terminal/Shell commands.

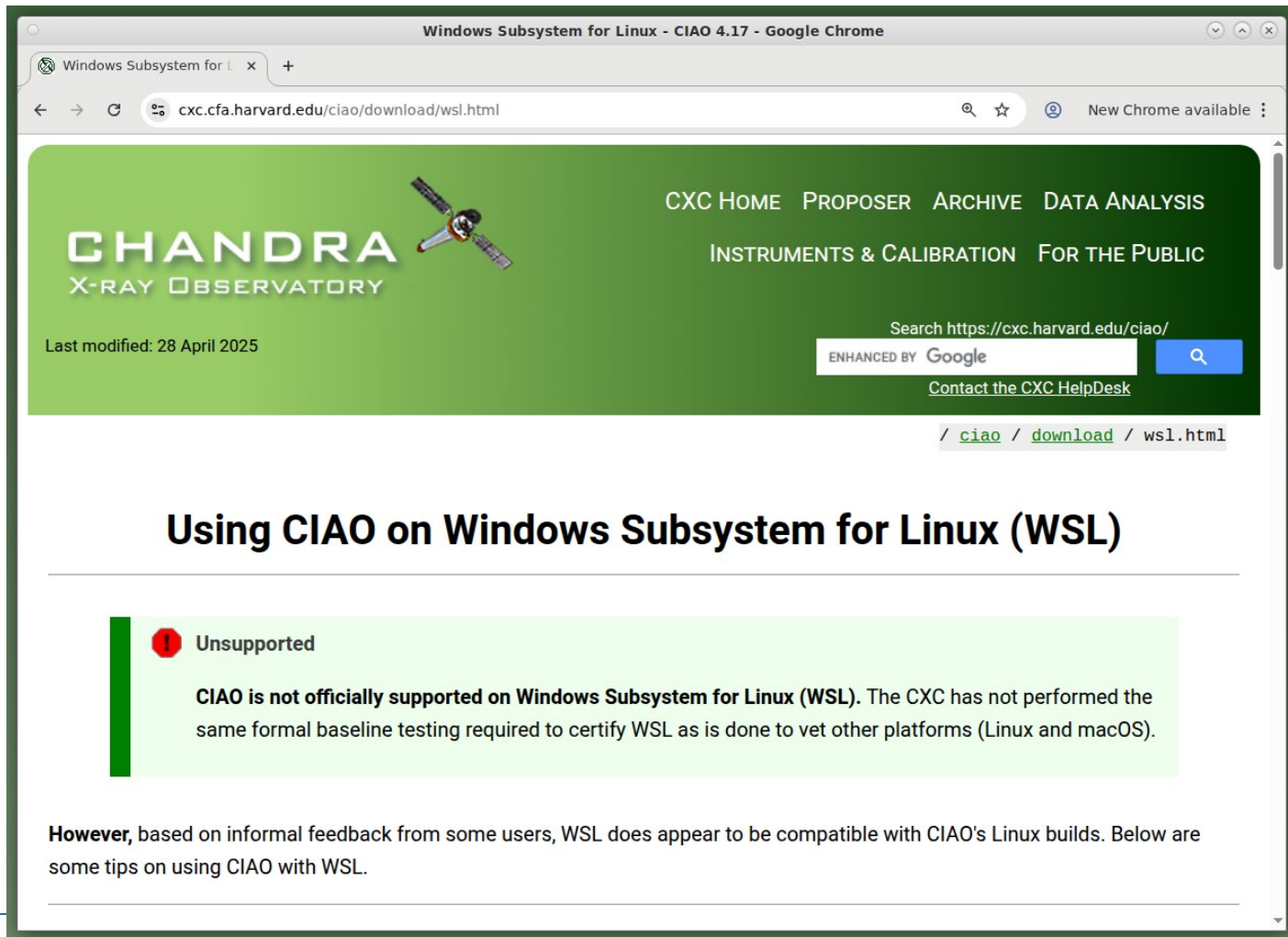
The [High Energy Astrophysics Science Archive Research Center \(HEASARC\)](#) has made CIAO and all public Chandra data available on the SciServer Science Platform.



# 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.



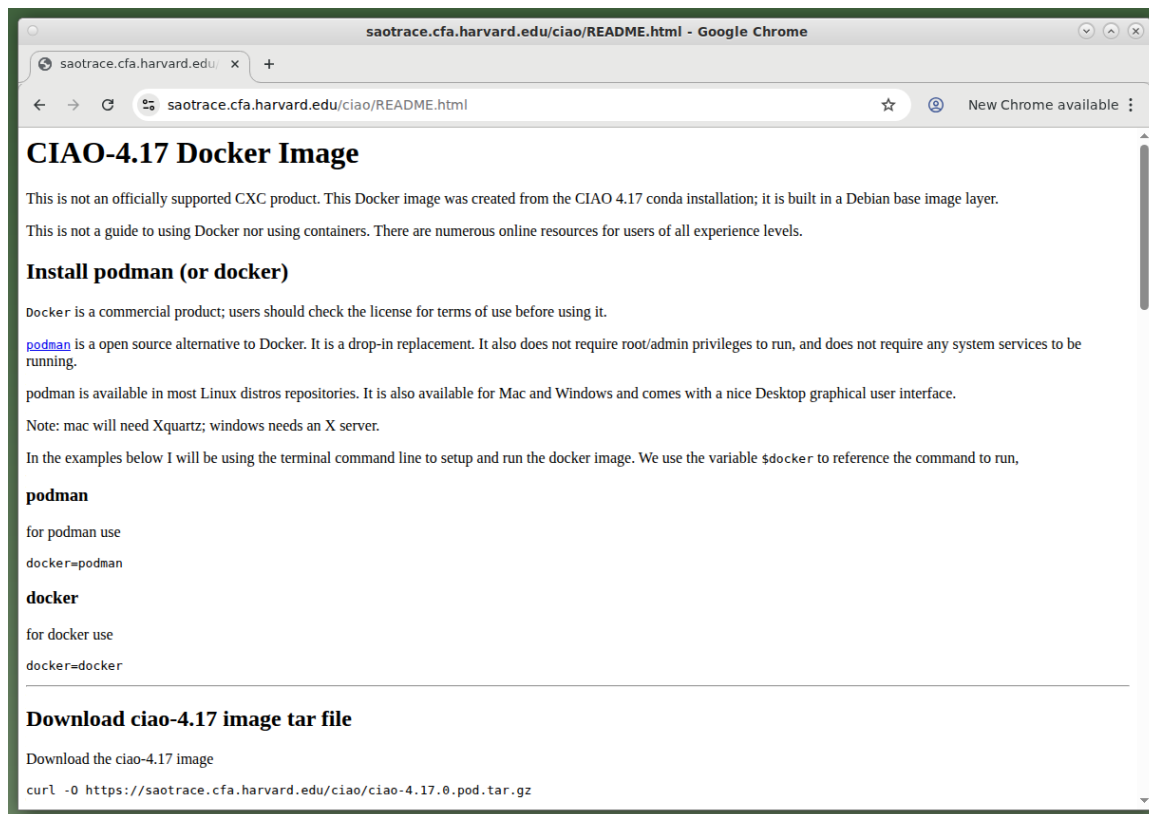
The screenshot shows a web browser window titled "Windows Subsystem for Linux - CIAO 4.17 - Google Chrome". The address bar shows the URL "cxc.cfa.harvard.edu/ciao/download/wsl.html". The page header is green with the Chandra X-ray Observatory logo and navigation links: CXC HOME, PROPOSER, ARCHIVE, DATA ANALYSIS, INSTRUMENTS & CALIBRATION, and FOR THE PUBLIC. A search bar is present with the text "Search https://cxc.harvard.edu/ciao/" and "ENHANCED BY Google". Below the header, the page title is "Using CIAO on Windows Subsystem for Linux (WSL)". A green box with a red exclamation mark icon contains the text: "Unsupported CIAO is not officially supported on Windows Subsystem for Linux (WSL). The CXC has not performed the same formal baseline testing required to certify WSL as is done to vet other platforms (Linux and macOS)." Below this, a paragraph states: "However, based on informal feedback from some users, WSL does appear to be compatible with CIAO's Linux builds. Below are some tips on using CIAO with 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).

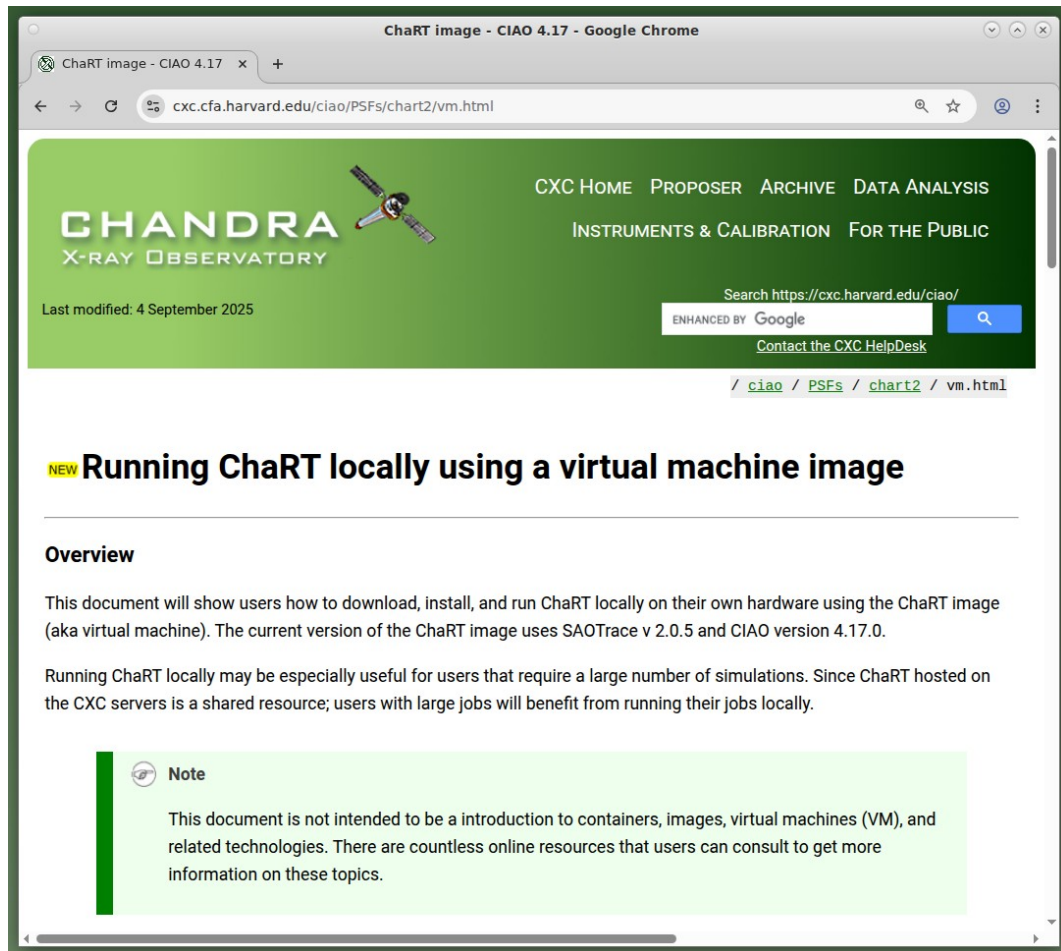
It was not used during workshop but good exercise for post mission planning activities.





# ChaRT container

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



The screenshot shows a web browser window titled "ChaRT image - CIAO 4.17 - Google Chrome". The address bar shows the URL `cxc.cfa.harvard.edu/ciao/PSFs/chart2/vm.html`. The page header features the Chandra X-ray Observatory logo and navigation links: CXC HOME, PROPOSER, ARCHIVE, DATA ANALYSIS, INSTRUMENTS & CALIBRATION, and FOR THE PUBLIC. A search bar is present with the text "Search https://cxc.harvard.edu/ciao/" and "ENHANCED BY Google". Below the header, the page content includes a "NEW" tag and the title "Running ChaRT locally using a virtual machine image". Under the "Overview" section, it states: "This document will show users how to download, install, and run ChaRT locally on their own hardware using the ChaRT image (aka virtual machine). The current version of the ChaRT image uses SAOTrace v 2.0.5 and CIAO version 4.17.0." A "Note" box at the bottom states: "This document is not intended to be an introduction to containers, images, virtual machines (VM), and related technologies. There are countless online resources that users can consult to get more information on these topics."



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.



# Sherpa

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# 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.



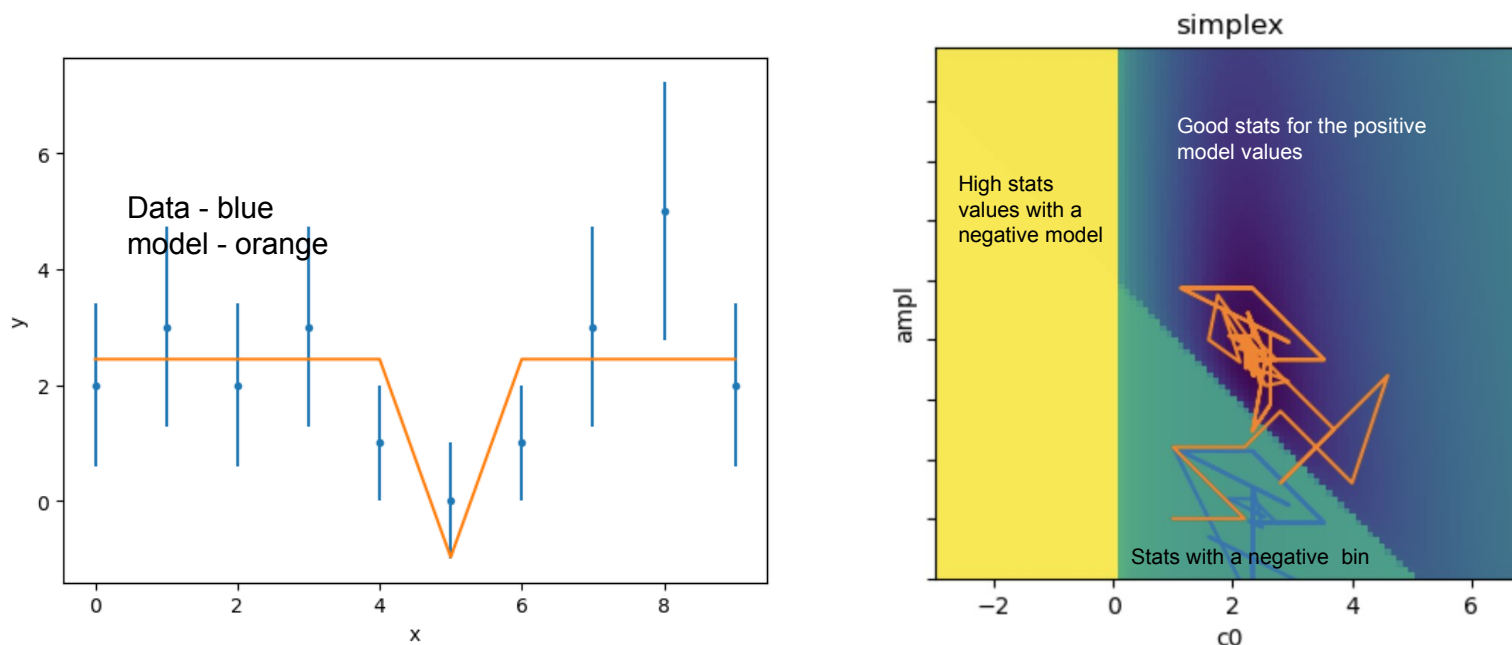
# Sherpa development 2025

## 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)



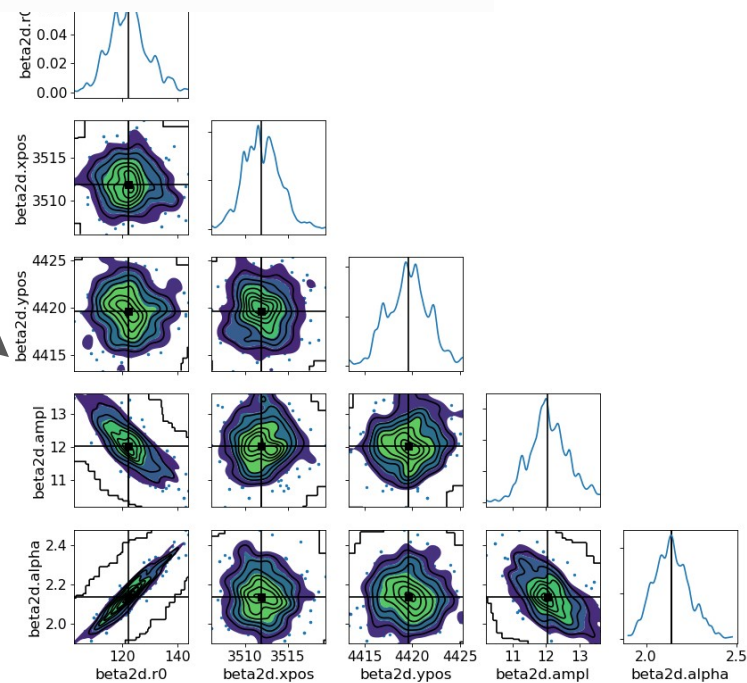
# Sherpa: Interface to Arviz

## 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 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

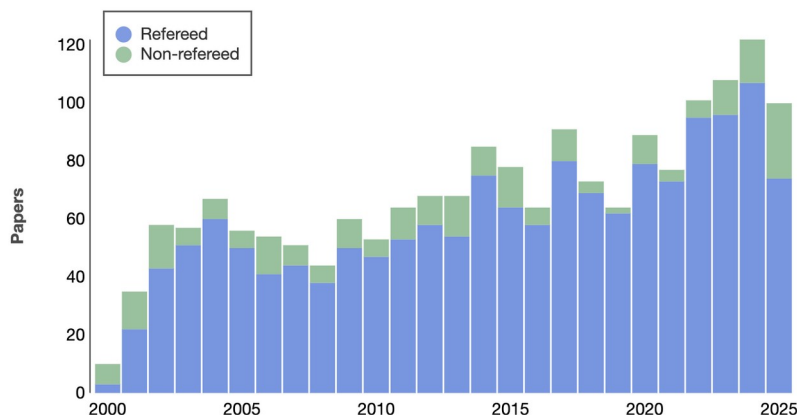
81 citations to zenodo releases: DOI: [10.5281/zenodo.593753](https://doi.org/10.5281/zenodo.593753)

7 PhD theses listed in ADS that used Sherpa

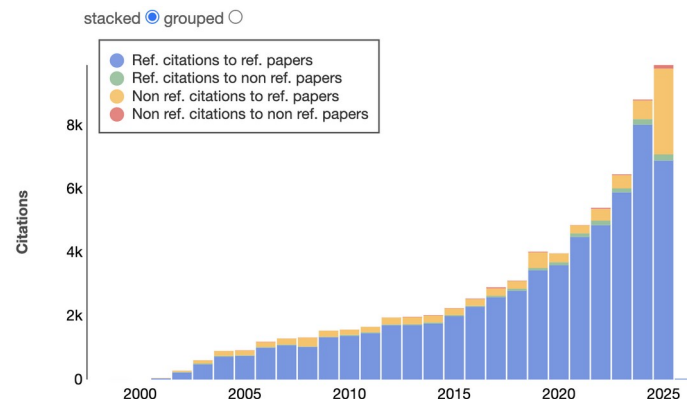
101 research papers published in 2025

## IMPACT 2001-2025 Statistics from ADS

Sherpa used in research



Cited Papers which used Sherpa





# 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).



PSF

---



# ChaRT

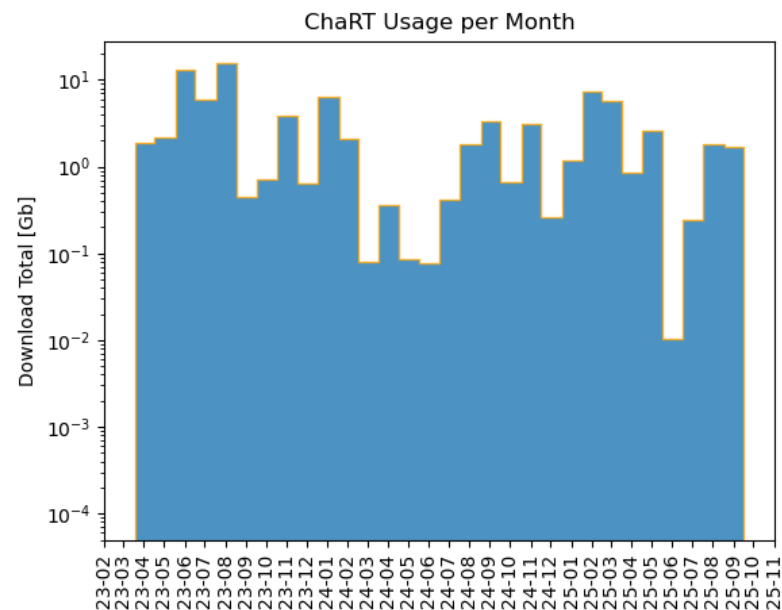
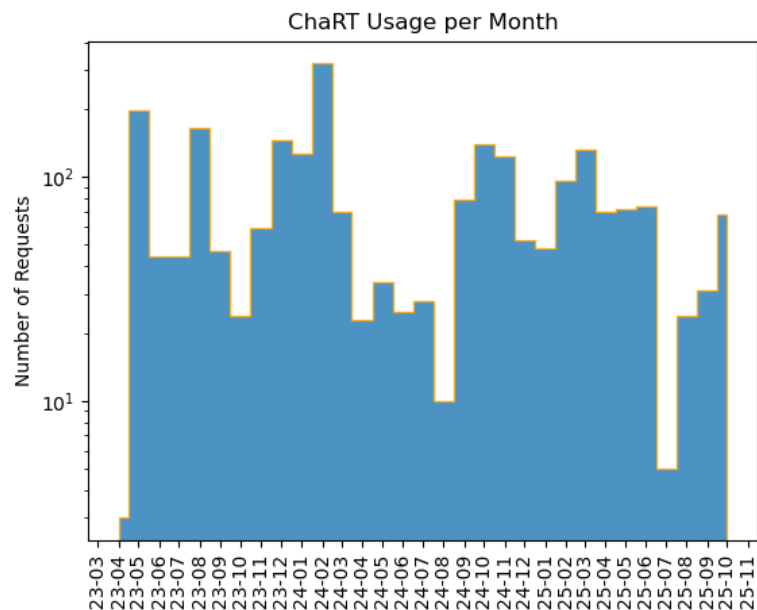


ChaRT updated to CIAO 4.17. Routine OS updates.



# 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

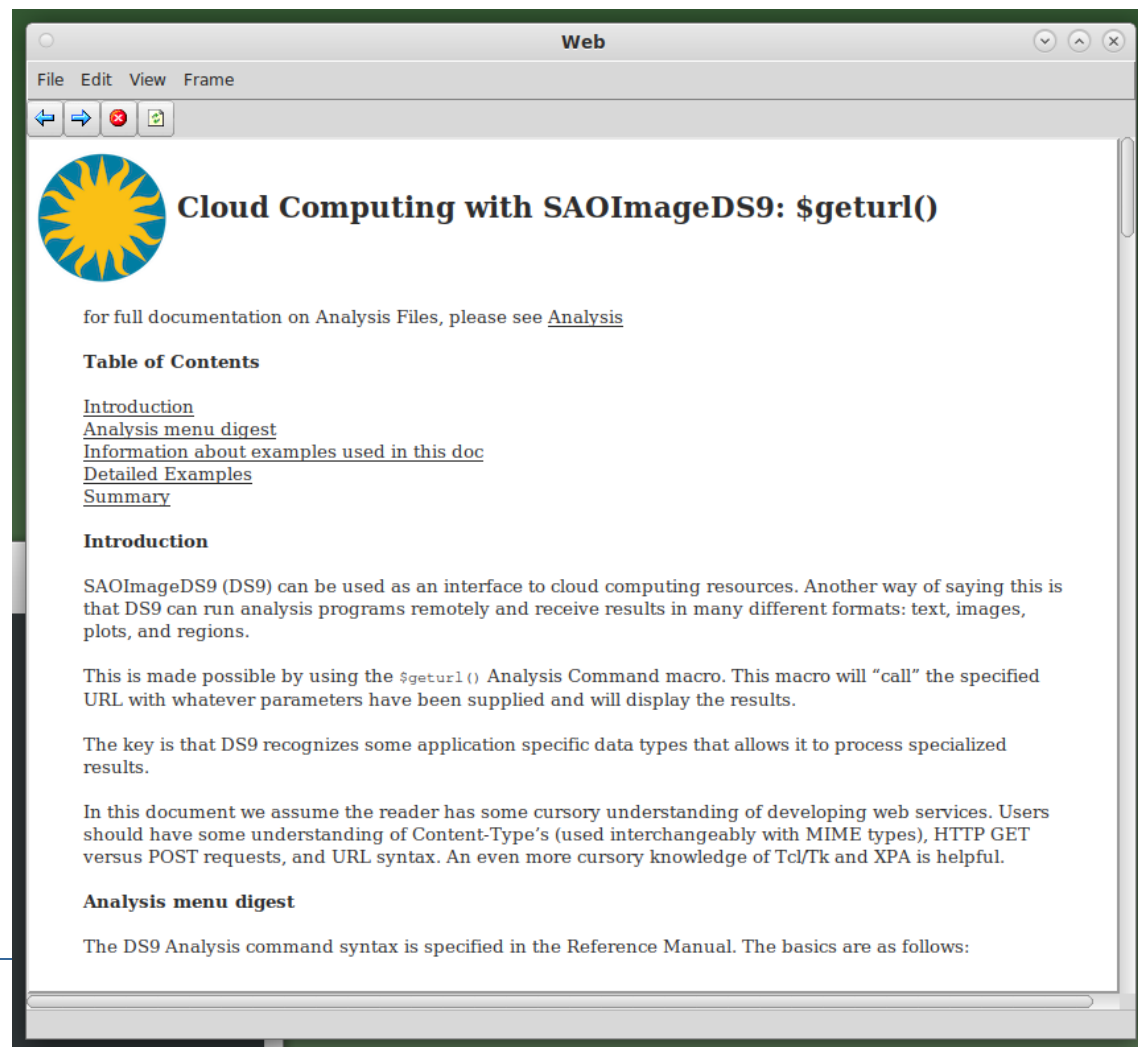
---



# 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.

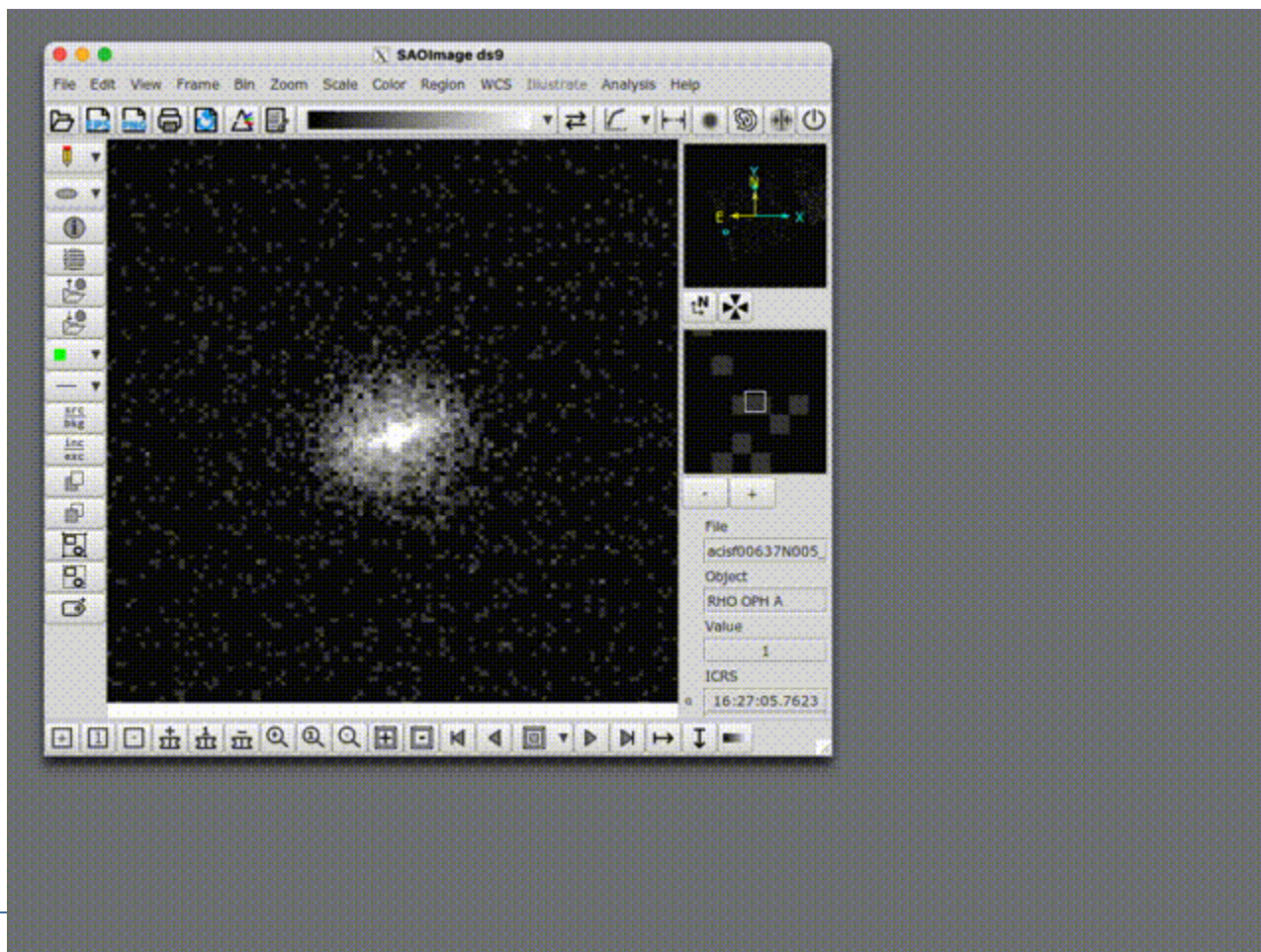




# DAX - elastic ellipses

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}")
```



DS9 documentation may be found at [ds9.si.edu](http://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 July 21

### Contents

|                                                |    |
|------------------------------------------------|----|
| 1 The DS9 main window                          | 6  |
| 1.1 DS9 commands                               | 6  |
| 1.2 Normal startup                             | 6  |
| 1.3 Layouts                                    | 10 |
| 1.4 Command line                               | 13 |
| 1.5 Main window default behaviour              | 16 |
| 1.6 Panner window                              | 16 |
| 1.7 Magnifier window                           | 17 |
| 1.8 Info panel                                 | 18 |
| 1.9 Button bar                                 | 22 |
| 1.10 Mouse actions                             | 22 |
| 1.11 Taking Notes                              | 23 |
| 1.12 Startup file                              | 24 |
| 1.13 Preferences files                         | 25 |
| 1.14 General customization - look and feel     | 26 |
| 2 Reading and writing data - simple FITS files | 30 |
| 2.1 Qualified filenames                        | 32 |
| 3 Overall program control                      | 32 |
| 3.1 Backup and restore                         | 32 |
| 3.2 Parallelism and performance                | 33 |
| 3.3 Stopping DS9                               | 34 |
| 4 Scale and Color                              | 36 |
| 4.1 Color visuals                              | 36 |
| 4.2 Main window pixel values                   | 36 |
| 4.3 Color tags                                 | 37 |
| 4.4 Detailed derivation                        | 39 |
| 4.5 Supported scaling functions                | 41 |

|                                           |    |
|-------------------------------------------|----|
| 4.6 Calculating scale range limits        | 41 |
| 4.7 Selecting and overriding the colormap | 45 |
| 4.8 Colormap                              | 45 |
| 5 Block, Box, Zoom and Pan                | 48 |
| 5.1 Block factor                          | 48 |
| 5.2 Box factor                            | 49 |
| 5.3 Zooming and Block size                | 49 |
| 5.4 Observation and Rotation              | 54 |
| 5.5 Pan                                   | 55 |
| 5.6 Crop                                  | 58 |
| 6 Coordinates                             | 59 |
| 6.1 Image, plot, and zoom view            | 59 |
| 6.2 Coordinates                           | 59 |
| 6.3 Support for                           | 59 |
| 6.4 Coordinates                           | 59 |
| 7 Regions                                 | 60 |
| 7.1 DS9 Region                            | 60 |
| 7.2 Other map                             | 60 |
| 7.3 Region map                            | 60 |
| 7.4 Region map                            | 60 |
| 7.5 Region map                            | 60 |
| 7.6 Region map                            | 60 |
| 7.7 Region map                            | 60 |
| 7.8 Region map                            | 60 |
| 7.9 Region map                            | 60 |
| 7.10 Region map                           | 60 |
| 7.11 Region map                           | 60 |
| 7.12 Region map                           | 60 |
| 7.13 Region map                           | 60 |
| 7.14 Region map                           | 60 |
| 7.15 Region map                           | 60 |
| 7.16 Region map                           | 60 |
| 7.17 Region map                           | 60 |
| 7.18 Region map                           | 60 |
| 7.19 Region map                           | 60 |
| 7.20 Region map                           | 60 |
| 7.21 Region map                           | 60 |
| 7.22 Region map                           | 60 |
| 7.23 Region map                           | 60 |
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| 7.25 Region map                           | 60 |
| 7.26 Region map                           | 60 |
| 7.27 Region map                           | 60 |
| 7.28 Region map                           | 60 |
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| 7.30 Region map                           | 60 |
| 7.31 Region map                           | 60 |
| 7.32 Region map                           | 60 |
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| 7.35 Region map                           | 60 |
| 7.36 Region map                           | 60 |
| 7.37 Region map                           | 60 |
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| 7.39 Region map                           | 60 |
| 7.40 Region map                           | 60 |
| 7.41 Region map                           | 60 |
| 7.42 Region map                           | 60 |
| 7.43 Region map                           | 60 |
| 7.44 Region map                           | 60 |
| 7.45 Region map                           | 60 |
| 7.46 Region map                           | 60 |
| 7.47 Region map                           | 60 |
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| 7.49 Region map                           | 60 |
| 7.50 Region map                           | 60 |
| 7.51 Region map                           | 60 |
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| 7.56 Region map                           | 60 |
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| 7.58 Region map                           | 60 |
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| 7.86 Region map                           | 60 |
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| 7.90 Region map                           | 60 |
| 7.91 Region map                           | 60 |
| 7.92 Region map                           | 60 |
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| 7.94 Region map                           | 60 |
| 7.95 Region map                           | 60 |
| 7.96 Region map                           | 60 |
| 7.97 Region map                           | 60 |
| 7.98 Region map                           | 60 |
| 7.99 Region map                           | 60 |
| 8.00 Region map                           | 60 |

### 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        | $s(r) = \left(\frac{r-1}{p}\right)$ , 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, 'xpa-set 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.

DS9 development continued with Bill Joye as the developer and back including SAO's High Energy Department back and NASA/GSFC. DS9 resulting was provided for the PAST Mission Office at the Space. Joye, and Co. 2012AAS...23410170. In 2013, the Chandra X-ray Center of the DS9 project which had become a critical component (standard data processing Verification and Validation, production observation planning, and end-user data analysis). Chandra continues, with major anticipated reductions in the Chandra budget, as terminated.



used at the Astronomical Data Analysis Software & Systems division of papers is available in NASA's ADS (public library) (<https://ui.adsabs.org/abs/2013MNRAS...43...1017J>)

as changes to the code that addressed evolving community needs

... thing about 'standards' is that they change. While the original FITS standard was published in 1981, it has continued to evolve with the most recent major version, 4.0, being adopted in 2016/2018. Changes to the format include new data-types such as the 'short' long, and new extension types such as compressed image formats.

World Coordinate Systems (WCS): Not only has the format of FITS files changed, but the community established WCS conventions (meta-data) have also changed. New libraries needed to be integrated into the code to support the latest conventions.