CHANDRA X-RAY CENTER

Science Data Systems

One year of CIAO, Sherpa, DS9, and user support

Antonella Fruscione, SDS Lead

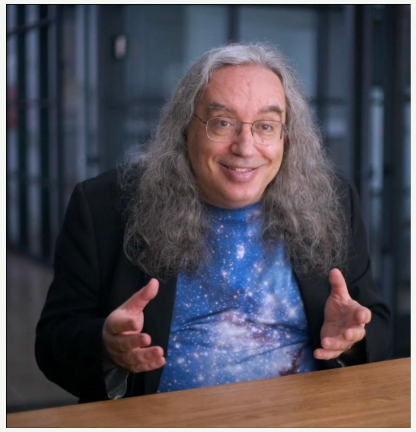
on behalf of the CXC Science Data Systems team

Chandra Users' Committee · 5 November 2026

CIAO

Chandra X-ray Center

Thank you, Jonathan and Bill!



Jonathan McDowell

SDS Lead 2005 – Jan 2026

- Helped shape the mission's data systems and analysis infrastructure from its earliest days
- Created the foundations of the CIAO Data Model
- Wrote the definitive reference on Chandra data analysis coordinate systems



Bill Joye

SAOImageDS9 engineer 1997 – Apr 2026

- Central figure in developing DS9, now indispensable to the global astronomical community
- ADASS Prize 2024 for "the outstanding contribution of SAOImageDS9 to the astronomical software community"

SDS team

Lead

Antonella Fruscione (since Jan 2026)

SAO · 4.5 FTE

Douglas Burke (Deputy Lead)

Kenny Glotfelty (IT, DS9 lead)

Nick P. Lee (IT)

Aneta Siemiginowska

MIT · 3.6 FTE

David Huenemoerder

Hans Moritz Günther

Melania Nynka

David Principe

All scientists devote 20–40% of their time to independent research.

Our goal Ensure the science community can turn Chandra data products into scientific results and papers

Specify and validate CIAO · Codify best practices in threads and scripts · Run the helpdesk and web pages

The year at a glance Nov 2025 – Nov 2026

Four
software releases
since Dec 2025

147
helpdesk tickets
fewer, more complex

Two
reference papers
CIAO (ApJ), DS9 (AJ)

153
technical documents
on Zenodo

Releases

CIAO 4.18, Scripts 4.18, Sherpa 4.18, DS9 8.7b2, MARX 6.0.1 (Dec);

DS9 8.7 (Mar) and 8.8 (Oct);

Scripts 4.18.1 (Apr) and 4.18.2 (Jul);

Sherpa 4.19.0 (Oct)

CIAO 4.19

On track for December 2026

Helpdesk

147 tickets, fewer but more complex; median first response 1.0 hr

Legacy

Technical documents archived on Zenodo with DOIs; CIAO and DS9 papers published

Transitions

New SDS lead, new Sherpa lead, new DS9 lead

Minimum-cost mission

Every SDS task inventoried, documented and assessed

Minimum Cost Mission

What the 2025 CUC asked · Preparing · Legacy package · Zenodo

Chandra X-ray Center

What the 2025 CUC asked of us

From the CUC Report, 2025 November 10, on mission closeout planning

> *It is imperative that any closeout plan includes adequate resources to … maintain CIAO software for several years …*

SDS Keep CIAO buildable and installable: modern compilers and Python, fewer install dependencies, Sherpa 4.19 built for 5-year maintainability

> *The CUC emphasized that ensuring the longevity and broad accessibility of the CIAO 'legacy' package is essential for maximizing its long-term scientific impact.*

SDS Every proposed component is being tracked (next slides); technical documents now permanently archived on Zenodo with DOIs

> *The CUC is very concerned about any transition of the CDA, the CSC, and the CIAO software to NASA's High Energy Astrophysics Archive (HEASARC).*

SDS Capture our expertise in writing: every SDS task inventoried, documented, and assessed for efficiency or closeout

Preparing for the future

1 Preserve our documentation

- Zenodo “Chandra technical information”: 153 records, DOIs, versions, ADS indexing
- Websites designed to be relocatable and viewable offline
- Citable references: CIAO (ApJ) and DS9 (AJ) papers, Fruscione et al. 2026
- TGCat archive copy

2 Software Longevity

- CIAO 4.19: newer compilers and C/C++ standards; Xcode dependency removed
- DS9 built from source in conda; AI-assisted maintenance
- Sherpa 4.19: meson build, Python 3.11–3.14
- Smaller CALDB: −1.6 GB (contamination models), −700 MB (TGAIN)

3 Keep knowledge

- All SDS tasks inventoried, documented, and assessed for efficiency or closeout
- DS9 knowledge transfer after Bill Joye’s retirement
- Leadership handovers: SDS (Jan 2026), Sherpa (Feb 2026)

4 Help users work on their own

- Easier installs: new macOS .dmg; Xcode no longer needed
- Helpdesk lessons become threads and FAQs (crisscross thread, DS9 FAQs)
- New scripts automate complex analyses (crisscross, acis_split_evt_by_fptemp)

CIAO legacy package: status

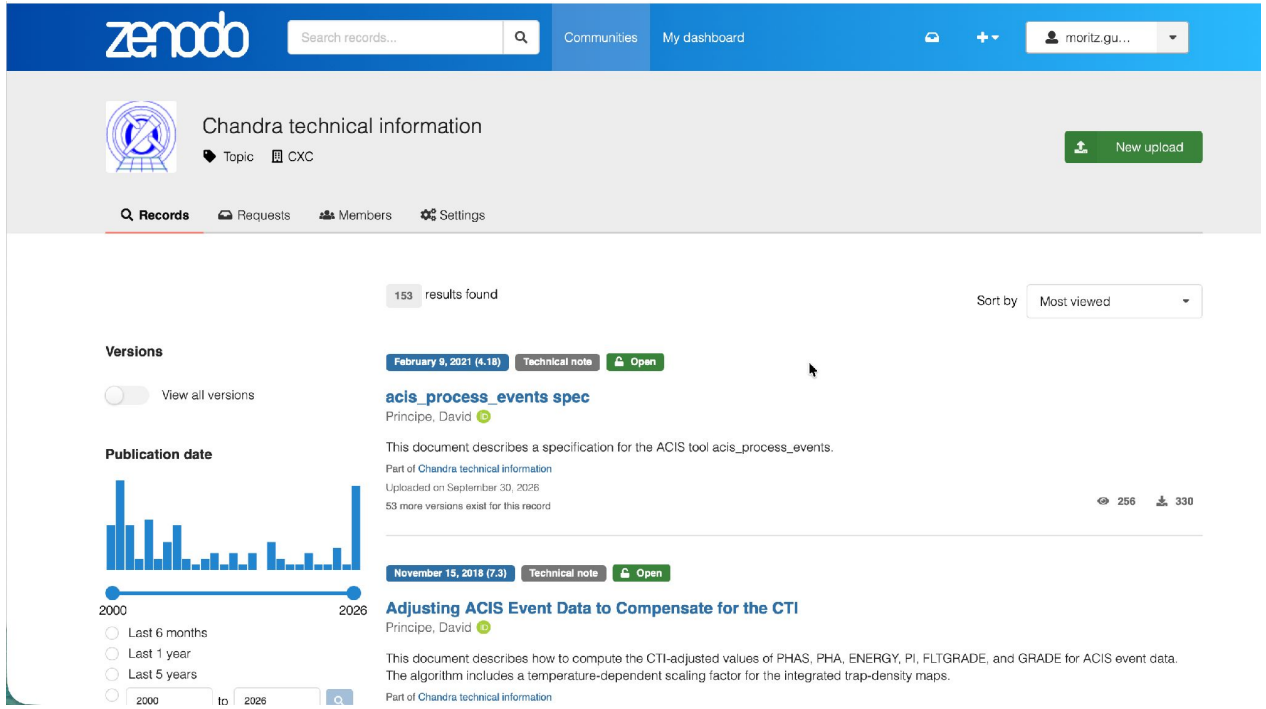
2025 CUC: “strong support for inclusion of all proposed components.” Status one year later:

COMPONENT	STATUS (NOV 2026)
Archived CIAO & MIT HETG memos, specs, ICDs	● Zenodo community with DOIs and versions; ADS indexing underway
CIAO & DS9 description and citation	● Fruscione et al. 2026: CIAO (ApJ 1005, 116) and SAOImageDS9 (AJ 172, 116)
Sherpa standalone code + website	● Sherpa 4.19: meson build, focused on 5-year maintainability
DS9 source package & docs	● DS9 8.8 released; DS9 built from source in conda (CIAO 4.19)
MARX code & docs; ChaRT	● MARX 6.0.x on GitHub; ChaRT container available
TGCat archive copy	● TGCat migrating to new OS/infrastructure (back online mid-December 2026)
Relocatable CIAO/Sherpa/CALDB websites	● Designed to be relocatable

● done ● in progress

Preserving technical knowledge: Zenodo

- **Problem** memos, tool specs and ICDs scattered over CXC pages, hard to find, no central archive or versioning
- **Needed** permanent archive, citable DOIs, old versions kept
- **Solution** “Chandra technical information” Zenodo community
  - listed in NASA’s open-science guidance as an accepted repository
  - EU-backed for decades; will outlive Chandra and the CXC
  - indexed by ADS (in progress)
- PDFs of everything, plus .tex sources and images where available



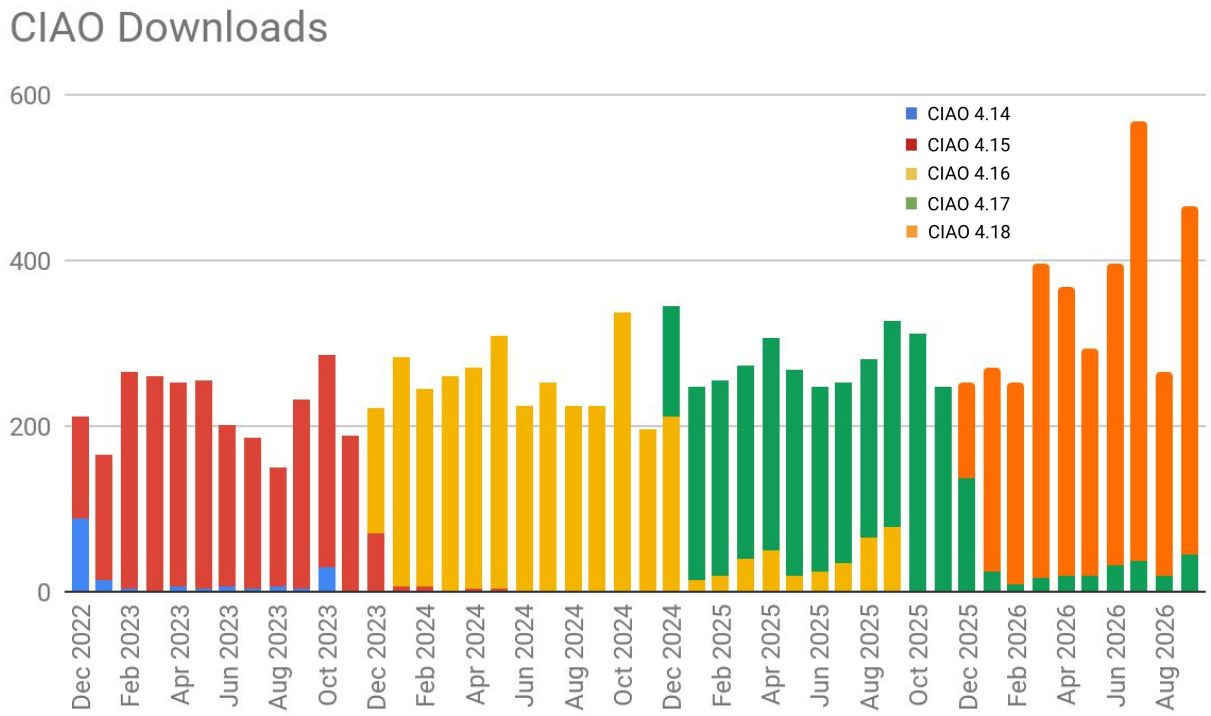
153 records, e.g. the acis_process_events spec (54 versions)

Community support

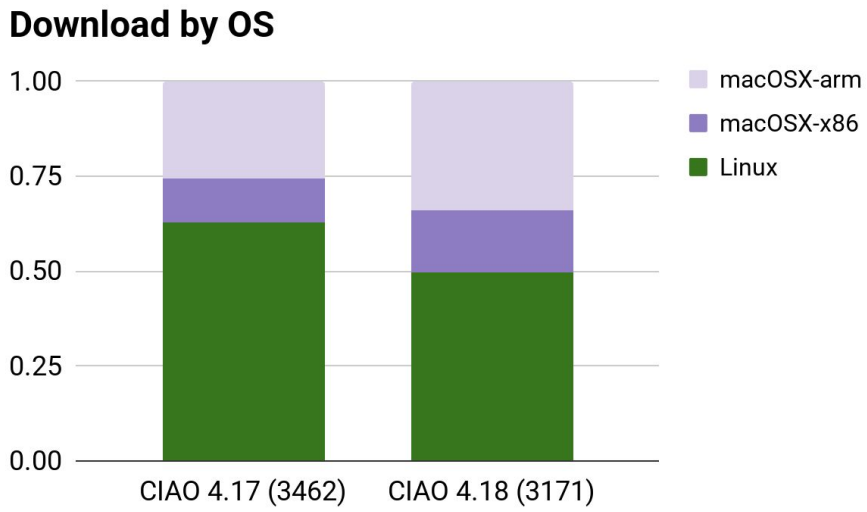
Downloads · Helpdesk · Documentation · Outreach

Chandra X-ray Center

CIAO downloads demand remains strong



Monthly downloads by CIAO version, Dec 2022 – Sep 2026



By OS: CIAO 4.17 (3462) vs 4.18 (3171)

macOS is now slightly ahead of Linux; the new .dmg is very popular. AWS/Azure conda spikes (May, Sep 2026) de-duplicated.

Chandra Helpdesk fewer tickets, harder questions

147
tickets
(193 last year)

1 hour
median first response
(2.7 h last year)

10 hours
median time to close
(11.4 h last year)

- Main gateway between users and the CXC; most tickets handled by SDS, ~20% by the Director's Office
- Tickets on data analysis problems drive fixes to software and documentation
- Maximum time to close: 739.8 h (747.6 h last year)

Why fewer tickets?

- **Our hypothesis:** our documentation is good enough that LLM-based tools give users correct, understandable answers to routine questions
- **What still reaches us is more complex,** e.g. exposure maps in time units that keep vignetting and effective area, merged across many years of data

User feedback & continuous improvement

User interactions are mutually beneficial: users get guidance; we find bugs and improve software and docs.

Bugs found through the helpdesk

- CSCView: Java version incompatibility (fixed)
- Chaser unreachable after URL/security change (fixed)
- DS9 on Ubuntu 25.10: incompatible libxml2; patched DS9 8.7v3 + docs
- chandra_repro: early (1999) secondary-mode data without aspect; clobber=no with patch_hrc_ssc=yes
- specextract hitting OS open-file limits with large stacks
- flux_obs running out of memory on large clusters

Resulting changes

- specextract and flux_obs handle large stacks and memory limits (Scripts 4.18.2)
- RFE: dmstat standard deviation in DAX statistics
- Python header-module deprecation warning fixed (relocated installs)
- New DS9 FAQs: Bin/Block/Zoom; Save/Save As/Export/Print
- Instructions for replacing an incompatible library in existing DS9 installs

Documentation & publications cxc.harvard.edu/ciao

- Routine roll-out of the CIAO 4.18 website; CIAO 4.16 site retired
- **New:** CrissCross notebook thread for crowded HETG observations
- **Updated:** ACIS QE Contamination “why” page; reproject_aspect (visualization); radial profile fitting with aperture correction
- New ahelp files: ds9, pypixlib, pycaldb4 (online)
- DS9 workaround for Ubuntu 25.10+ (libxml2)
- **Reach beyond our pages:** well-structured docs are what LLM tools draw on to answer users correctly

TWO REFERENCE PAPERS PUBLISHED

ApJ

CIAO: Chandra’s Data Analysis System for X-Ray Astronomy and Beyond

Fruscione et al. 2026, ApJ, 1005, 116

AJ

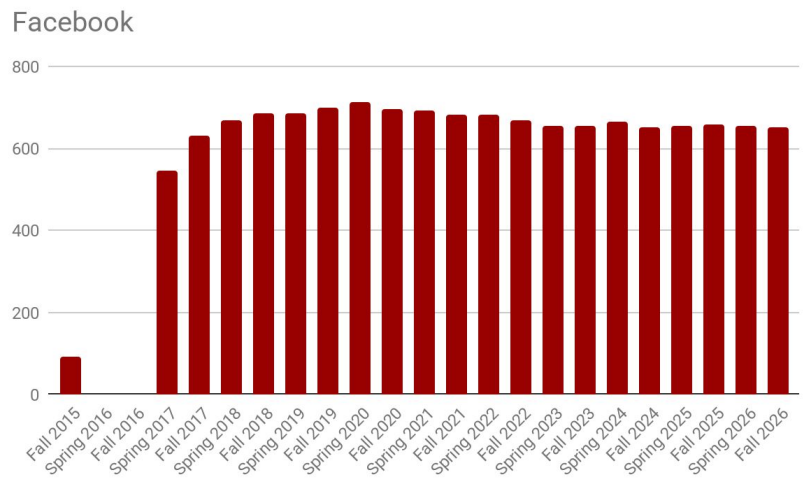
SAOImageDS9: An Essential Tool for Astronomical Exploration

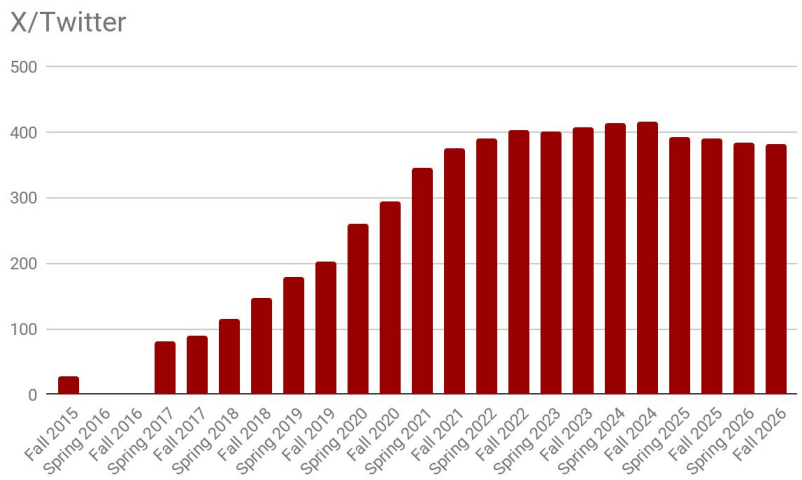
Fruscione et al. 2026, AJ, 172, 116

Citable references for CIAO and DS9, and part of their long-term record

Outreach & interactions with users

- **AAS 247 (Jan) and AAS 248 (Jun 2026):** supported the Chandra booth
- **CfA Science Meeting:** CIAO poster; DS9 poster + lightning talk; CHASC astrostatistics poster
- **Chandra/CIAO workshop day** at the Sixth Advanced Arab Astrophysics School, 23–29 Oct 2026





Social media followers: Facebook 653 (−2), X 381 (−3)

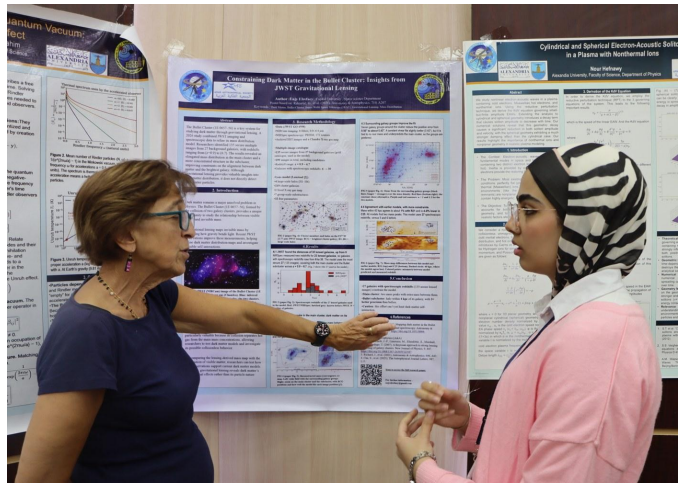
Chandra/CIAO workshop day

Sixth Advanced Arab Astrophysics School, Egypt, 23–29 Oct 2026

SDS lectures and demos

- **Vinay Kashyap:** X-ray Astronomy with Chandra
- **Antonella Fruscione:** Introduction to CIAO
- **Antonella Fruscione:** From events to science: imaging, imaging spectroscopy and the Chandra Source Catalog with CIAO
- **Kenny Glotfelty:** Introduction to SAOImageDS9 (recorded demo)
- **Vinay Kashyap:** Basics of high-energy astrostatistics











Software

CIAO · Contributed scripts · Sherpa · DS9 · TGCat

Chandra X-ray Center

CIAO 4.18 released 16 December 2025

Installation
ciao-install, conda, and a new macOS .dmg disk image

Python 3.12
modernized environment

FITS 64-bit integers
table tools updated; image and header tools follow in 4.19

acis_process_events
fixed temperature-dependent CTI correction for a few CC-mode events

glvary
fixed internal filtering (e.g. different GTIs on different CCDs)

Sherpa
external optimizers (SciPy, optimagic)

DAX
new interactive tasks incl. elastic ellipses; DS9 autosave

CIAO 4.19 December 2026 – in progress

- **FITS 64-bit integers:** remaining tools that handle header data and images
- **Installation & compatibility:** DS9 built from source in conda; Xcode no longer needed on macOS
- **Maintenance:** newer compilers and C/C++ standards; OTS updates
- **Bug fixes:** dmtcalc order of operations (“-”, “^”); destreak (last event, subarrays starting at row > 1); dmgroup/grouplib last-bin issues; mkosip

Calibration support

- **mkacisrmf:** new resp_temp parameter for responses at specified ACIS focal-plane temperatures (time-dependent P2_RESP)
- **acis_process_events:** new TGAIN handling saves ~700 MB across ~170 CALDB files
- **Smaller CALDB:** old contamination models removed in CALDB 4.12.4 (~1.6 GB)

Contributed scripts three releases this year

4.18.0 16 Dec 2025

- acis_split_evt_by_fptemp: split ACIS data into calibrated FP_TEMP ranges
- sherpa kaastra17: CStat goodness of fit
- DAX: live region sums, spectra/light curves, elastic ellipses

4.18.1 23 Apr 2026

- chandra_repro: tg_orders parameter
- mkrprm: aperture corrections with MARX 6.0.1
- patch_hrc_ssc: bad time at start of obs
- acis_split_evt_by_fptemp: warn if outside calibrated range

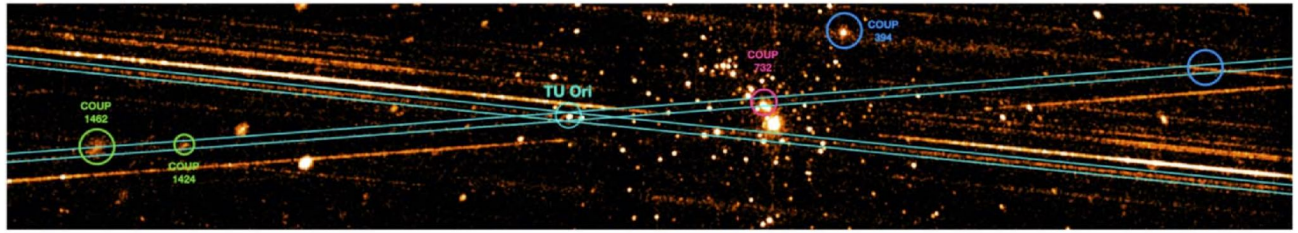
4.18.2 13 Jul 2026

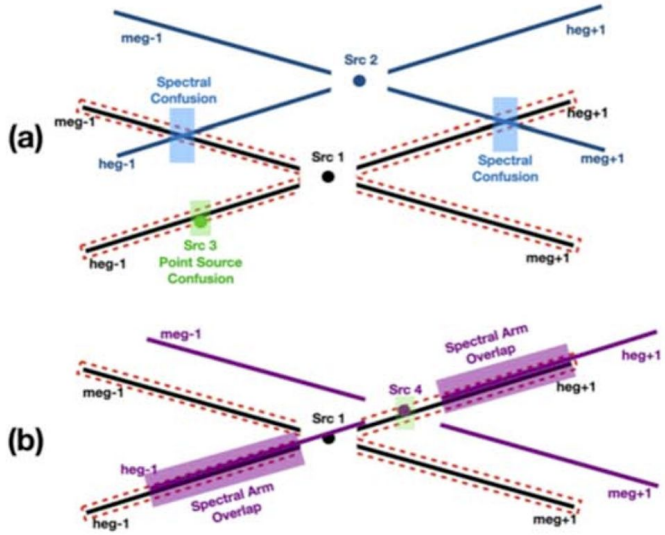
- New crisscross, clean_spec (crowded HETG fields)
- New parse_wcs_match_log, xmatch_viz (astrometric cross-matches)
- Automatic loading of HETG/LETG PHA2 responses in Sherpa
- specextract, flux_obs: large stacks

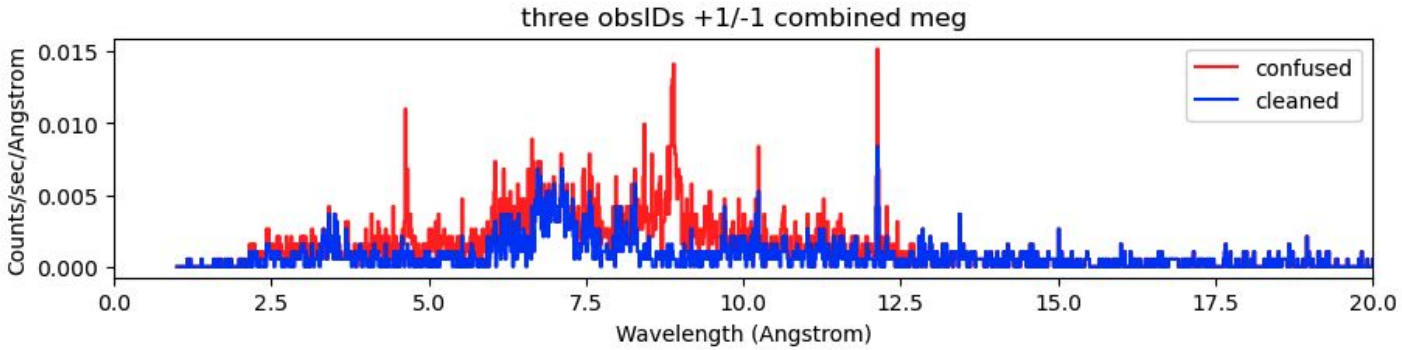
Next tools that use the empirical HRC PSF; CSC 2.2 updates

crisscross & clean_spec HETG spectra in crowded fields

Analyze HETG spectra from fields with many X-ray sources (Orion Nebula Cluster, M31, Sgr A*, Carina): find where other sources contaminate the spectral arms and ignore those regions when fitting.







Makes it possible to stack faint HETG sources in crowded fields. New notebook thread: "CrissCross: Help with Analyzing Crowded HETG Observations"

SOFTWARE

Sherpa cxc.harvard.edu/sherpa

New lead: Doug Burke since Feb 2026, succeeding Aneta Siemiginowska, who led Sherpa since 1995 (thank you!)

Releases: 4.18 (16 Dec 2025, in CIAO 4.18); 4.19.0 (12 Oct 2026, for CIAO 4.19)

4.19: built to last

- Maintainability for the next five years as Python changes fast
- Build moved from setuptools to meson (consistent with CIAO)
- Python 3.11 – 3.14
- Continued adding type annotations

Enhancements & fixes

- XSPEC 12.15.1 (13 new additive models); initial XSPEC 13.0 support
- LaTeX-like rendering of model documentation
- Fixes: plot-data access, save_all with radial PSF models, image titles, ArviZ changes

Sherpa cannot simply be frozen

It must keep pace with Python, NumPy, compilers and XSPEC. Without that small, steady effort:

- it stops building with current CIAO, operating systems and hardware
- new XSPEC models and fixes no longer reach CIAO users
- catalog, thermal-model and calibration work is stranded on old environments

OUTSIDE THE CXC

1870 publications use Sherpa

(+73 this year)

A library for Gammapy, BXA, 3ML and Naima

Sherpa inside the CXC mission infrastructure

Sherpa is not only a CIAO science tool: core CXC products and operations depend on it.

Chandra Source Catalog

Every source property (significance, position, flux, spectrum) comes from a Sherpa fit, for every catalog source.

No non-Sherpa path exists

Spacecraft thermal models

Fitting engine of xija for the 14 flight thermal models used in mission planning; ~1 re-fit per month.

Without it, planning problems within months

— T. Aldcroft

ACIS gain calibration

~7,000 fits per year (ECS, Cas A, Perseus) produce the CALDB gain file that sets the energy scale of all ACIS data. Also sets FP-temperature limits.

No realistic alternative

— L. David

Grating line-spread functions

Tens of thousands of fits for new CALDB LSF parameters: off-axis grating RMFs (>100 sources) and HETG/HRC-I.

“It just wouldn’t be done”

— M. Günther

SAOImageDS9 ds9.si.edu

- **Bill Joye retired 3 April 2026;** full support (incl. Windows) ended. Kenny Glotfelty is the new DS9 lead.
- **Releases:** 8.7 (15 Mar), 8.8b1 (15 Jul), 8.8b2 (26 Aug), 8.8 (1 Oct 2026)
- **Agentic AI tools** (Codex/ChatGPT, Claude Code) now used for DS9 development, with great success

Visualization & regions

- Multicolor frames, per-frame colorbars
- Reveal frames, bookmarks
- Live region statistics, pixel masks
- 3D surface region analysis
- CIAO composite regions

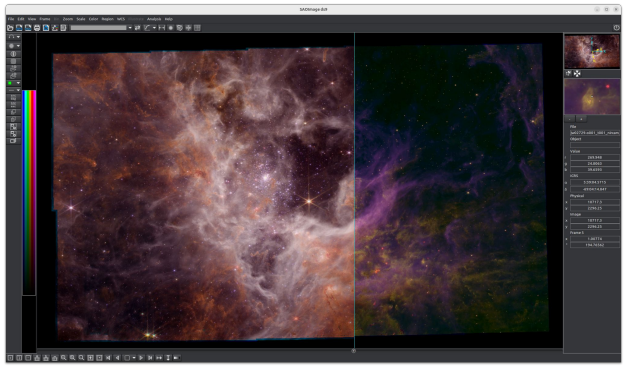
Services & formats

- VO Simple Image Access
- Better HEALPix and MOC support
- Updated image/catalog services
- PDF export, movie scripting
- In progress: ASDF for Roman (next slide)

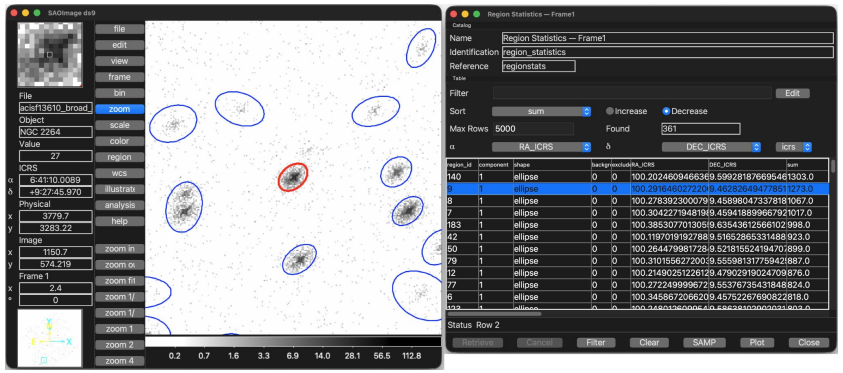
Platform & system

- Tcl/Tk 9 and other packages
- Updated SSL
- Display & interface improvements
- Platform updates
- Developer documentation

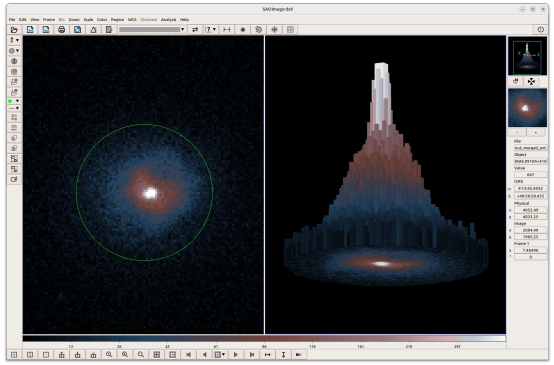
DS9 8.8 in pictures



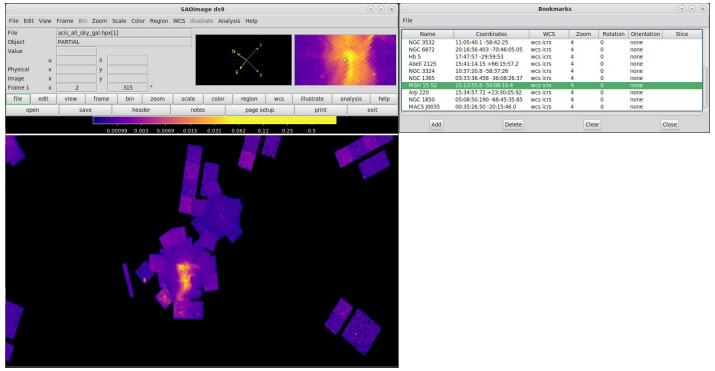
Multicolor frames: any number of color layers, each with its own color, transparency, stacking order and blend mode; each frame has its own colorbar. Reveal Frames: wipe between two frames with a draggable slider



Make Catalog: statistics (sum, area, minimum, maximum, centroid) for every region at once, as a catalog table to sort, filter, plot or cross-match. It is live: move, add or delete a region, or smooth the image, and it updates



3D Surface: the pixels inside a 2D region become a live 3D cube in a new frame. New FIP rendering stops at the first real value, so the cube looks like a solid surface; optional shading and lighting

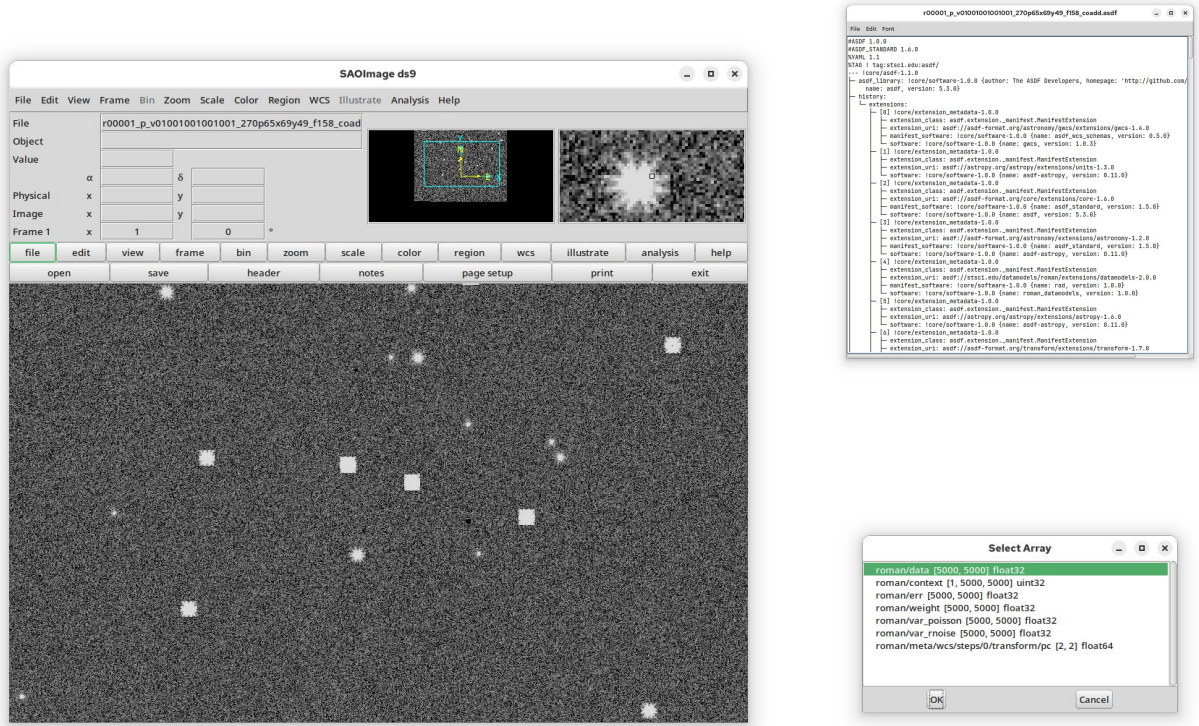


Partial HEALPix, MOC and Bookmarks: HEALPix support extended to Partial HEALPix images and Multi-Order Coverage maps; bookmarks (press m) store position, zoom, rotation and cube slice

DS9 for Roman: ASDF support work in progress

Roman, NASA's latest flagship, distributes its data in ASDF, not FITS

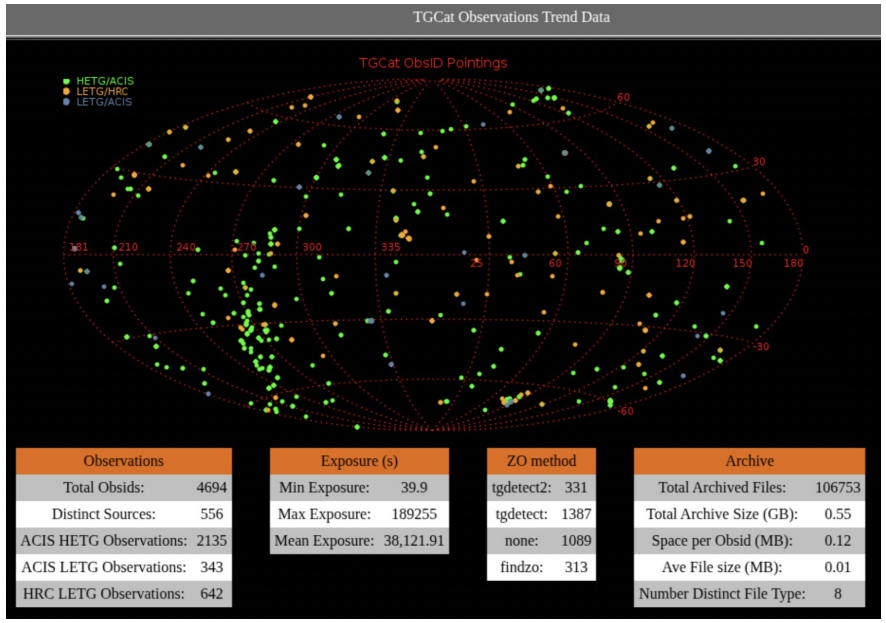
- DS9 is the image viewer of choice across astronomy; reading ASDF keeps it essential for the Roman community
- **Status:** working prototype displays Roman ASDF images and metadata; release expected Jan–Feb 2027
- Extends the reach of CXC-maintained software well beyond Chandra

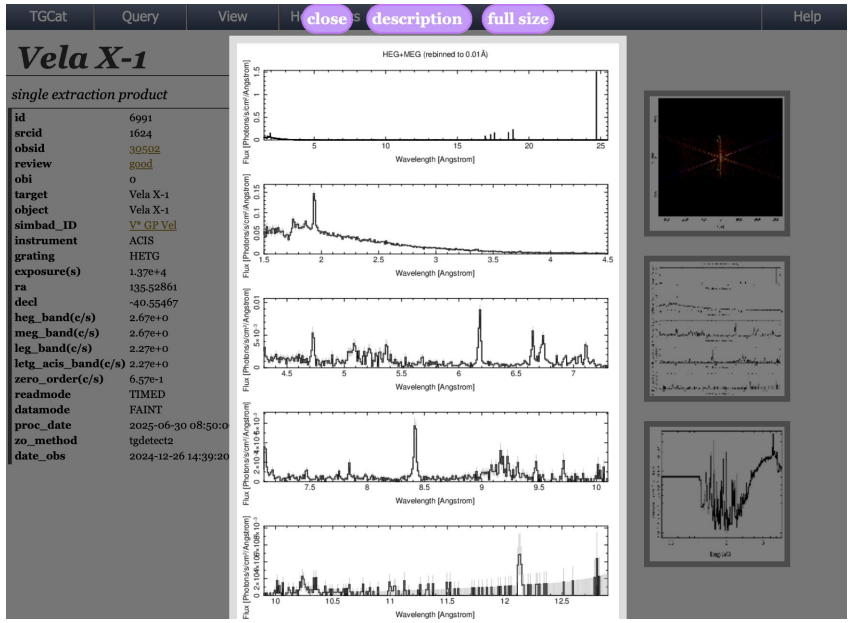


Prototype: a Roman ASDF image and its metadata in DS9

TGCat tgcat.mit.edu

- **Down for maintenance:** moving to a new OS, updating outdated software, and reviewing the risks of web features, to address security issues
- Back online in mid-December 2026 with most functionality; meanwhile primary data are available from the Chandra Data Archive





4694 ObsIDs, 556 distinct sources; a copy of the archive is part of the CIAO legacy package

The coming year

- **Dec 2026** CIAO 4.19 + Sherpa 4.19 + DS9 8.8
- **Scripts** empirical HRC PSF tools, CSC 2.2 support
- **DS9** ASDF support for Roman, NASA's latest flagship (Jan–Feb 2027); AI-assisted maintenance
- **TGCat** back online in mid-December on the new infrastructure
- **Legacy package** finish relocatable websites, test suites, archives; keep adding to Zenodo
- **Minimum-cost mission** carry out the task inventory, keeping CIAO, helpdesk and documentation

Topics for discussion

- Legacy package: priorities among components
- SDS services that matter most to users as resources shrink
- Sherpa: continued maintenance
- Long-term CIAO distribution: conda, dmg, containers, SciServer, FORNAX