Chandra X-ray Center

CIAO

Jonathan McDowell
(CXC Science Data Systems)

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Chandra data and software

I will report on CIAO (user software) and the standard processing pipeline software, which come into being thanks to:

CXC Data Systems team
software design, development, operation, archive, etc.

CXC Science Data Systems team
requirements, documentation, testing, helpdesk, interface with the science community

Current SDS Team

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SAO Scientists:

Jonathan McDowell	SDS lead, data model, coordinates
Antonella Fruscione (1/2 time)	SDS SAO deputy, Docs and Release lead
Aneta Siemiginowska	Sherpa, Astrostatistics, Catalog
Doug Burke	Scripts, Releases, Infrastructure, Sherpa, Visualization
Frank Primini	Catalog, Photometry, Source Detection, HRC

SAO IT Specialists:

Kenny Glotfelty	Helpdesk, scripts, docs, legacy expertise
Nick Lee	Helpdesk, scripts, docs
Bill Joye	ds9

MIT Scientists:

Dave Huenemoerder	Gratings, responses
Moritz Guenther	MARX, Sherpa
Dave Principe	Instruments and gratings
Melania Nynka	Instruments and gratings

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Community Support:

Downloads,
Documentation,
Helpdesk

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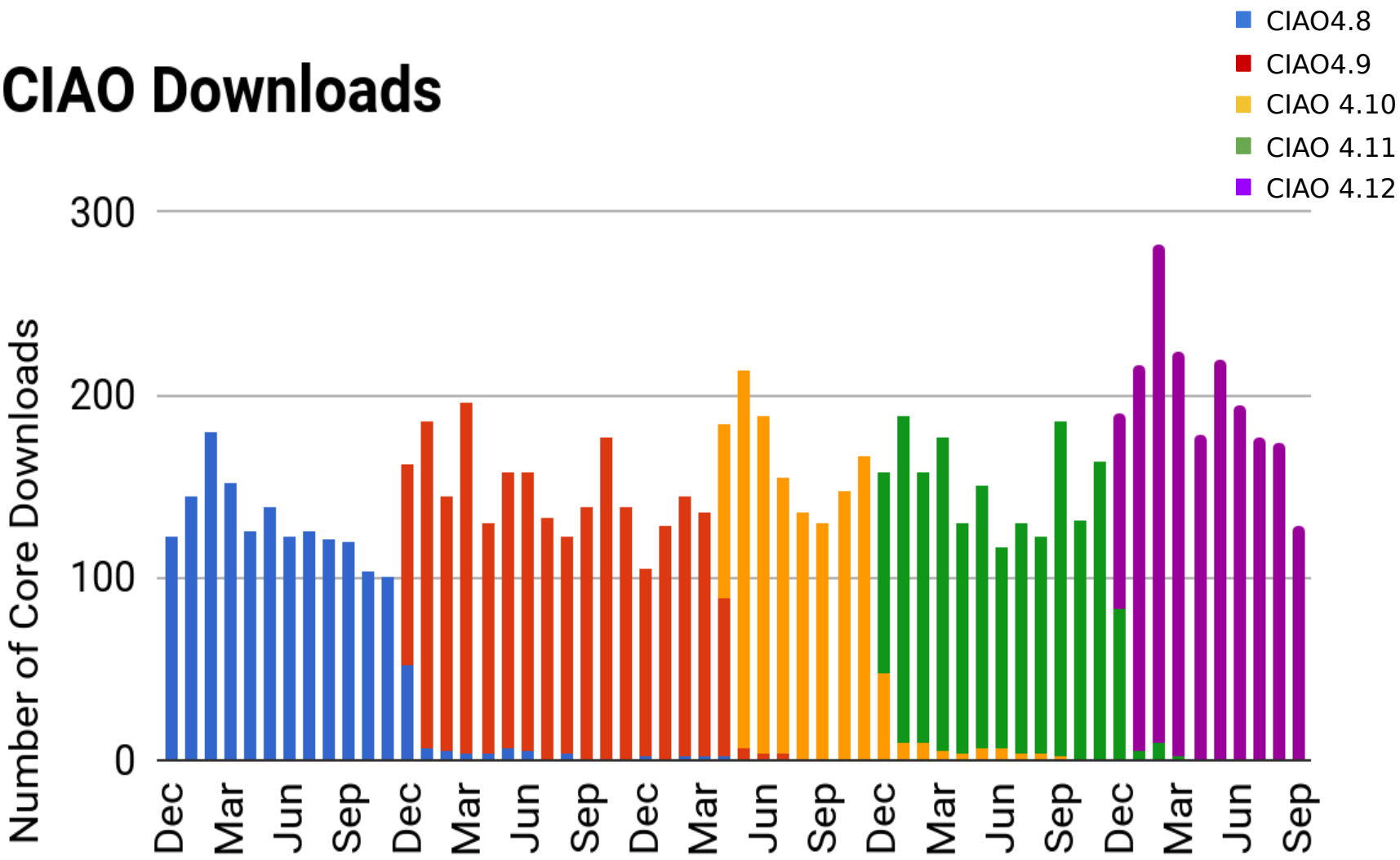
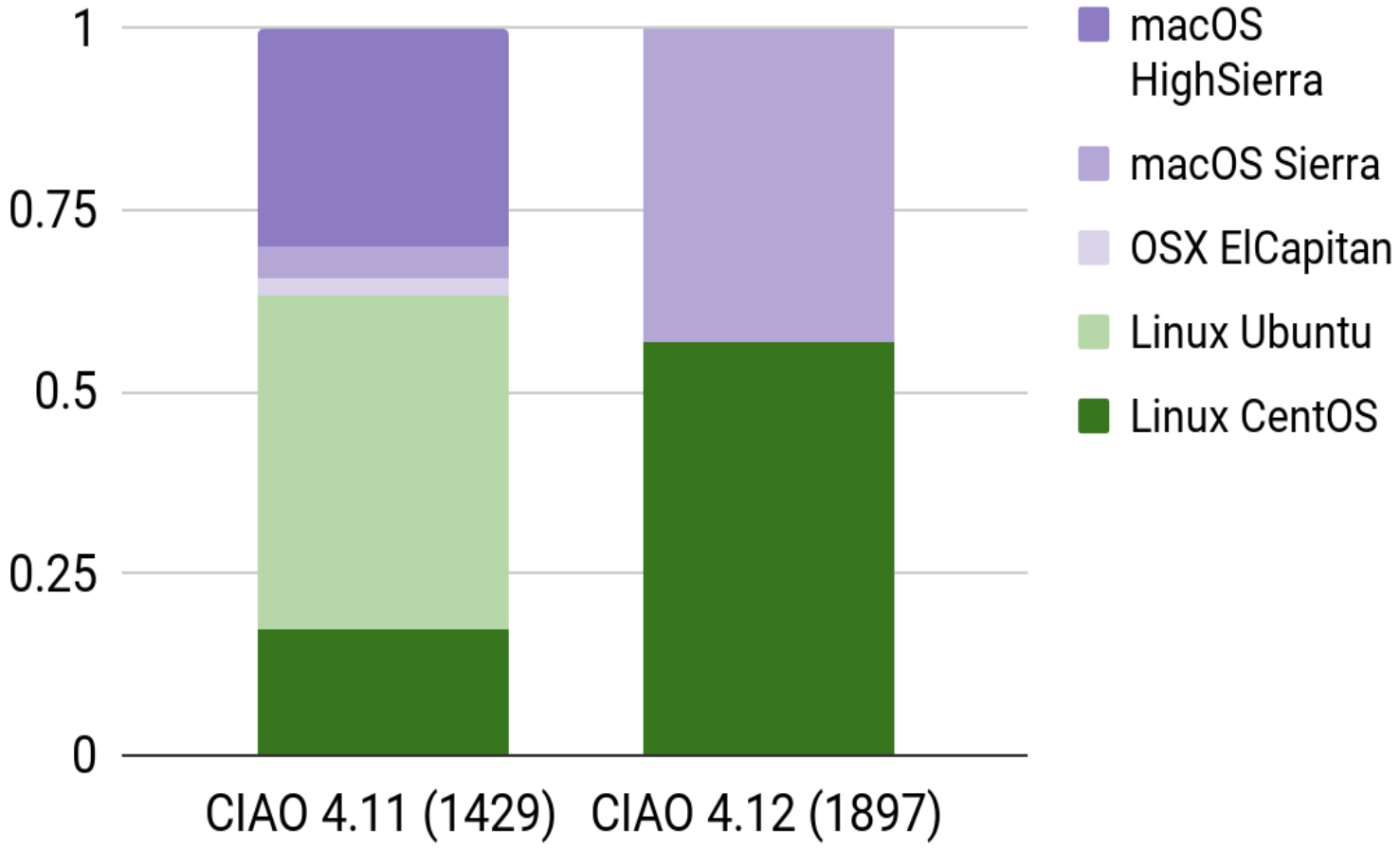
CIAO Downloads

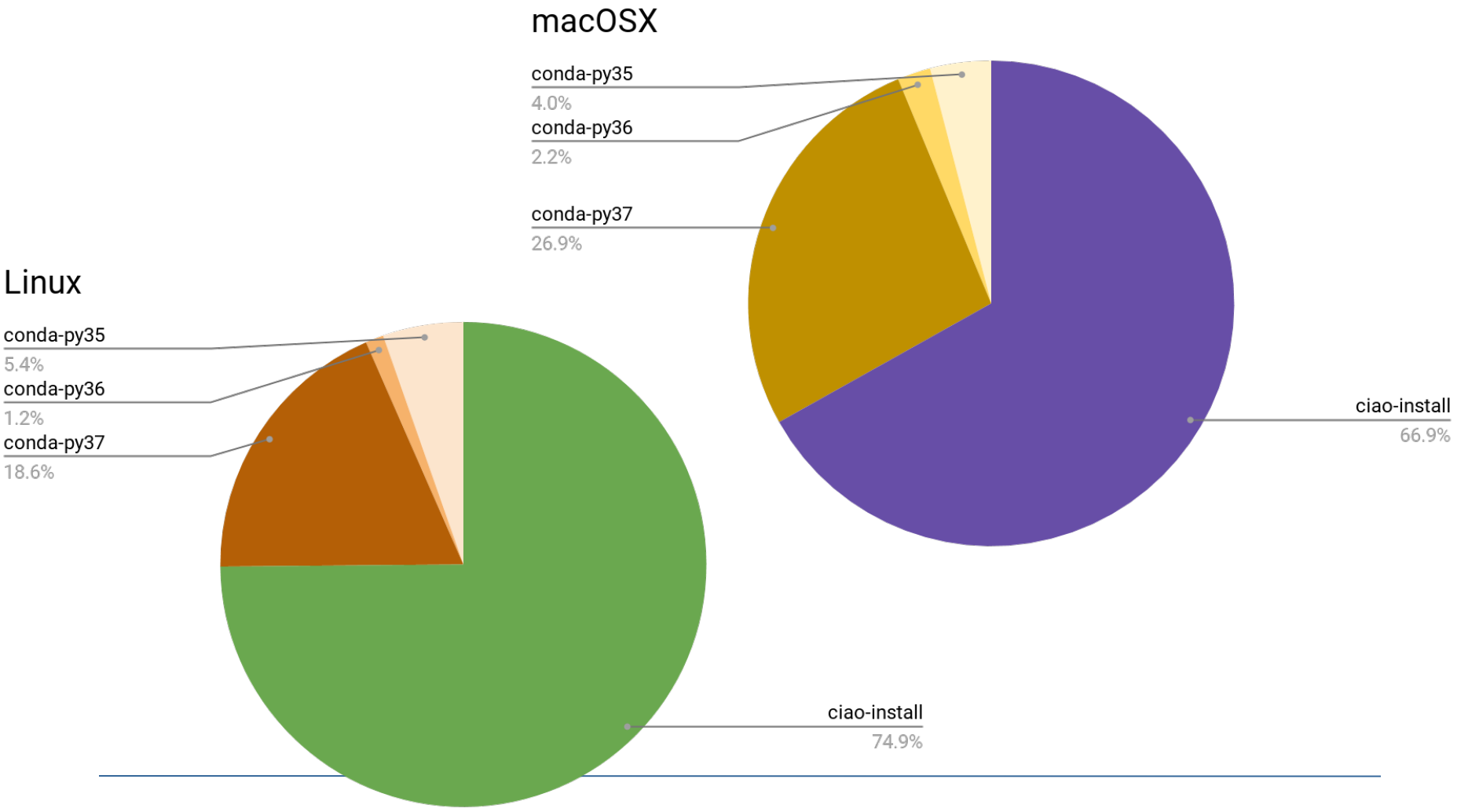


CIAO 4.12 switched from FTP to HTTPS. There are some differences in how the metrics are collected (bot filtering, incomplete d/l, internal d/l's).

Download by OS



CIAO Installation Options



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Downloads (lifetime)

OS	CIAO 4.11		CIAO 4.12	
Linux CentOS	249	904	1082	1082
Linux Ubuntu	655			
OSX ElCapitan	36	525		815
macOS Sierra	62		815	
macOS HighSierra	427			
Source	76		68	
Total	1505		1965	

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Documentation

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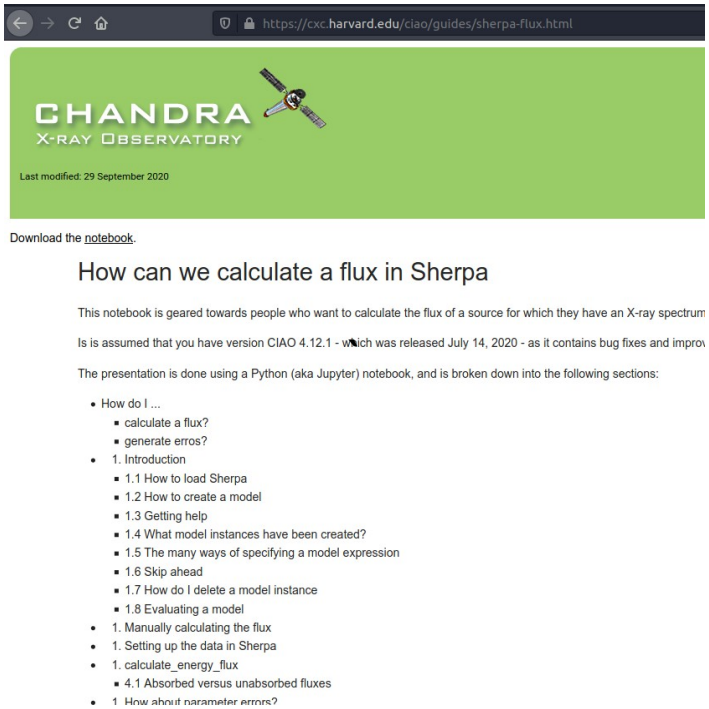
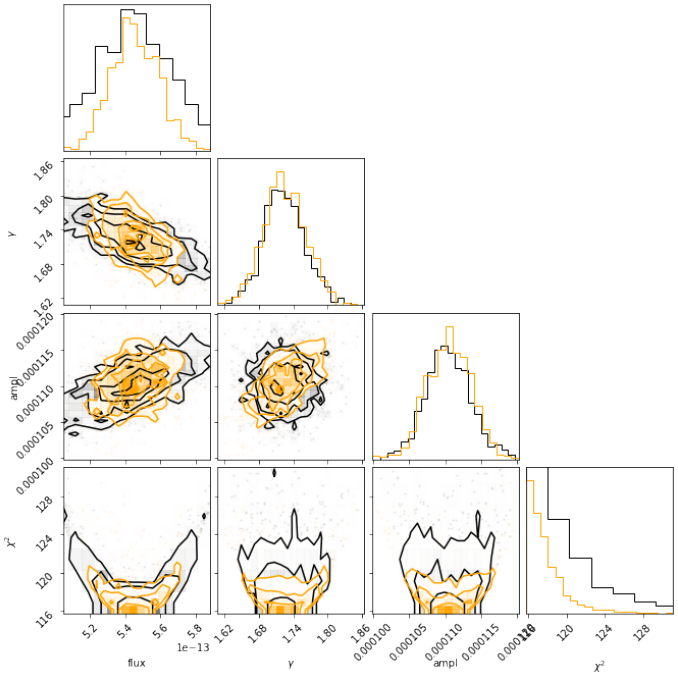
Documentation

- CIAO 4.12 routine roll-out and updates
- Updates to support change to secure https:// server
- Completed changes to use matplotlib in all ciao and sherpa threads.
- New feature added to publishing code to add banner to obsolete pages
- New dax users guide page.
- New ACIS Energy range Why topic
- New analysis topic: calculating fluxes with Sherpa
- Updates to chips to matplotlib conversion guide to help users modify plots created by sherpa

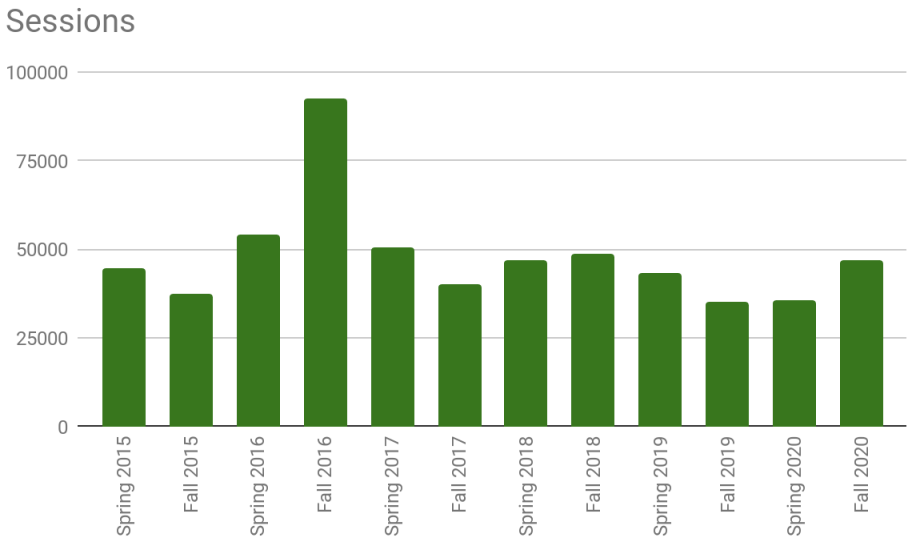
Our first Jupyter notebook embedded on a page!

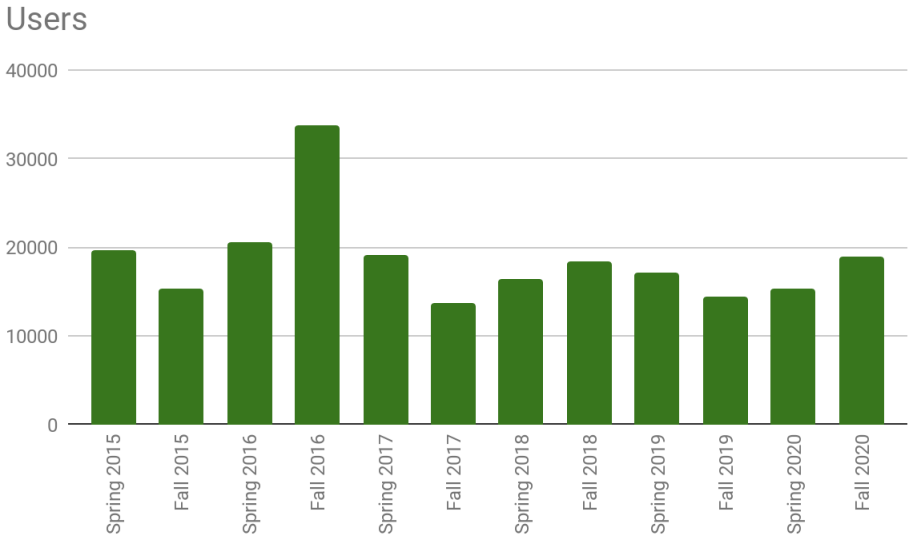




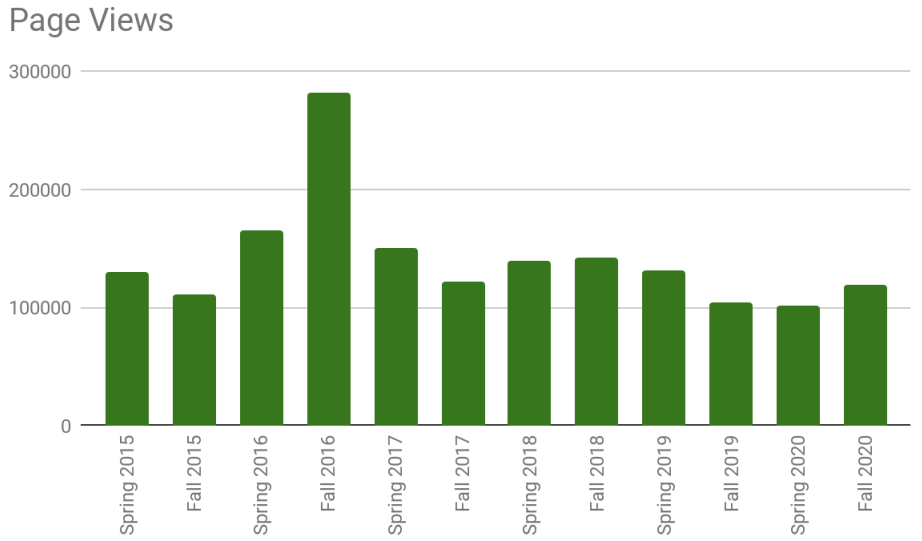
Comparing the flux distribution (top left) of uncorrelated (black) and correlated (orange) errors, using the conda-installed Python corner module for visualization.

Long Term Website Trends





No marked trend in website usage



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Helpdesk

Helpdesk Stats

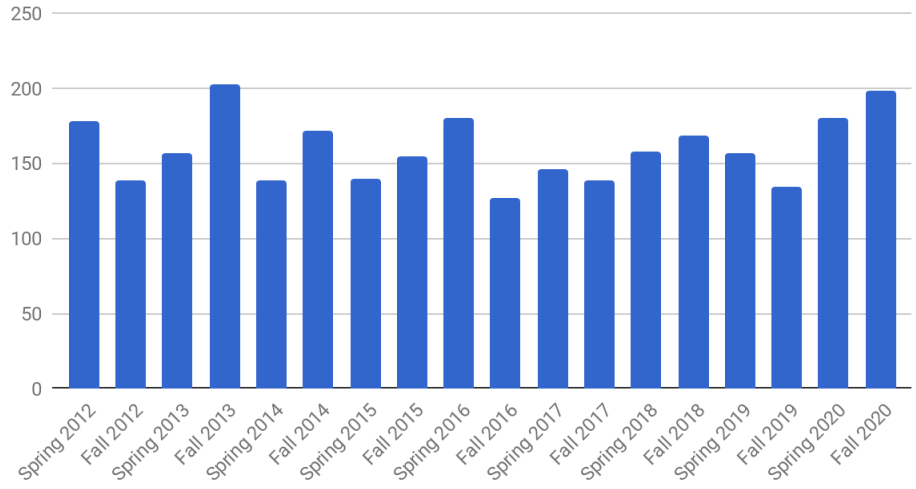
	2019: 2018-09-01 - 2019-08-31	2020: 2019-09-01 - 2020-09-15
Time period [months]	12	12.5
Number of TIckets	317	379
Median time to 1st contact [hrs]	1.67	1.12
Median time to close [hrs]	7.78	7.82
Maximum time to close [days]	46	84

15% increase in tickets/day
(previous year saw 6% increase)

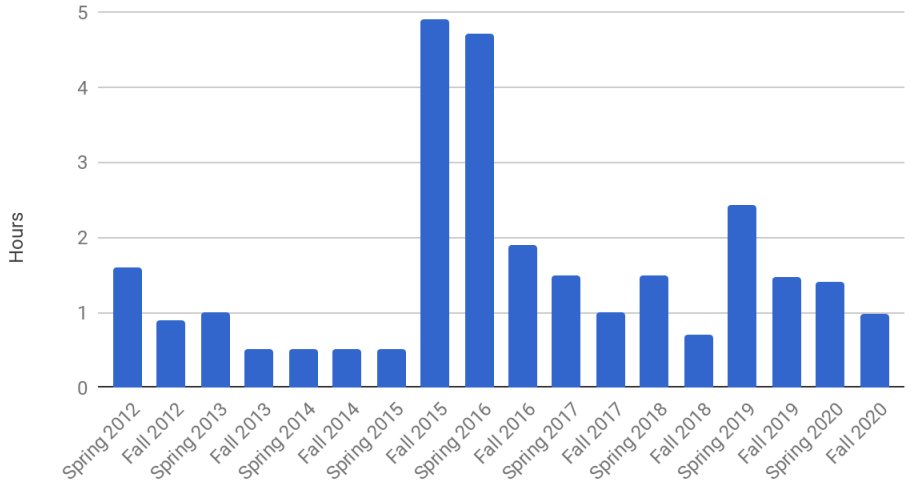
Longest ticket was for use who took 2 months to follow up on a specextract question.

Long Term Helpdesk Trends

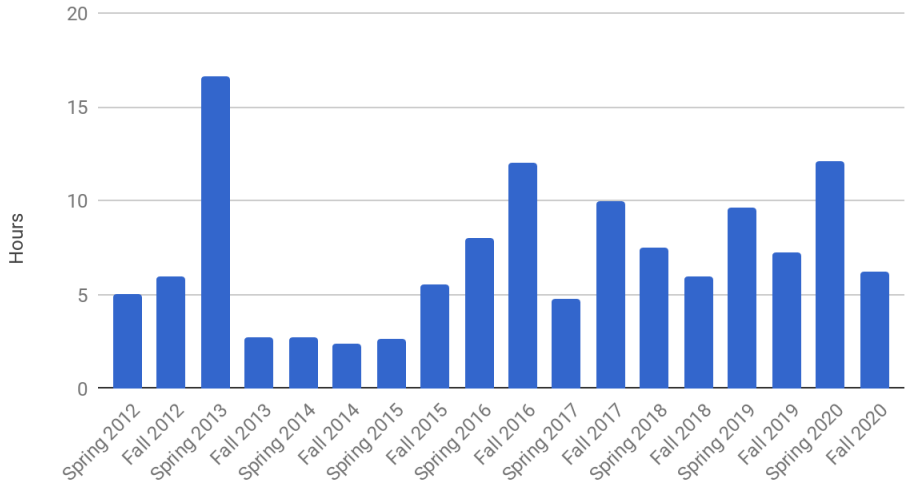
Number of Tickets



Time To Answer



Time To Close



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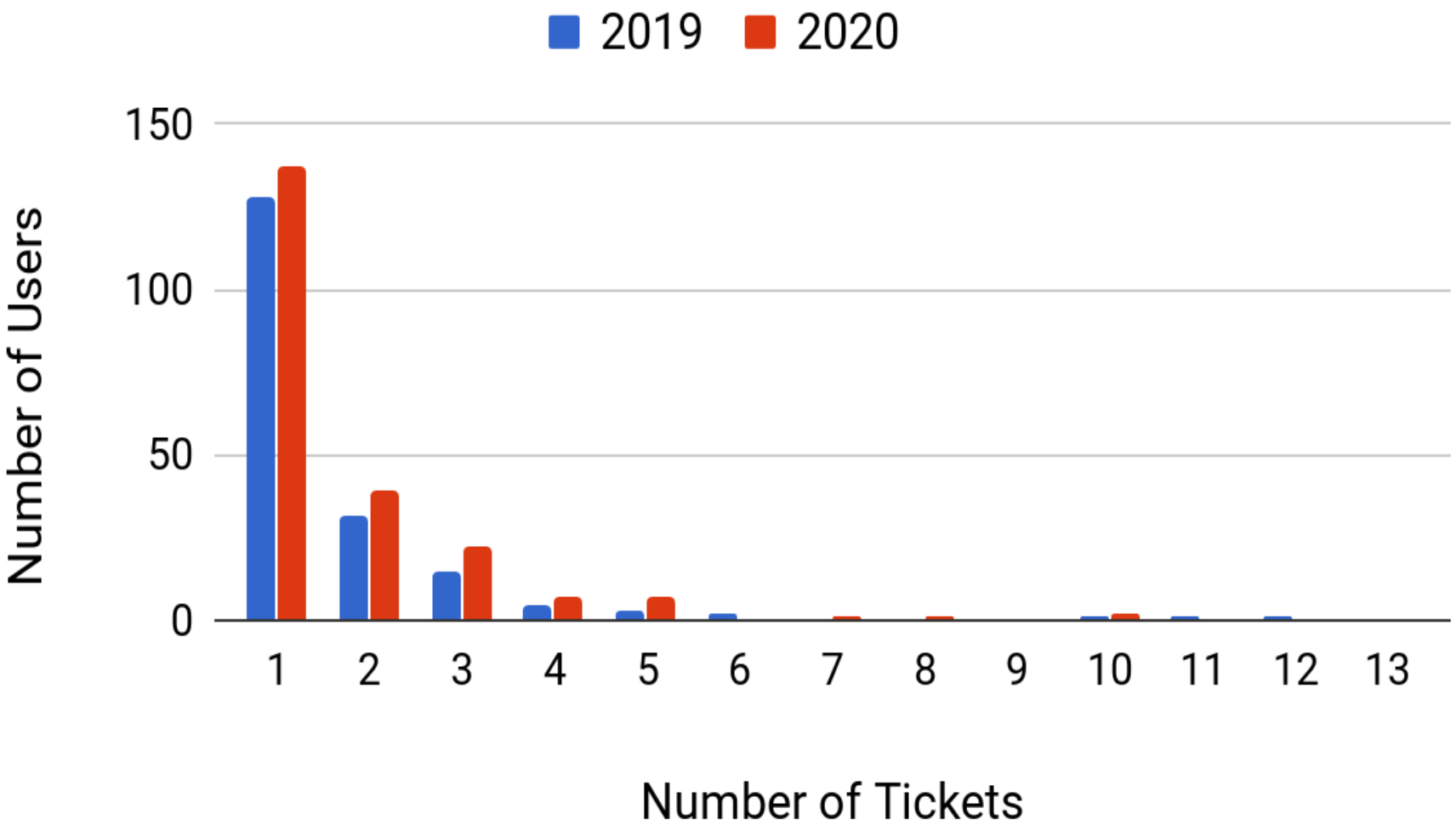
Tickets per User



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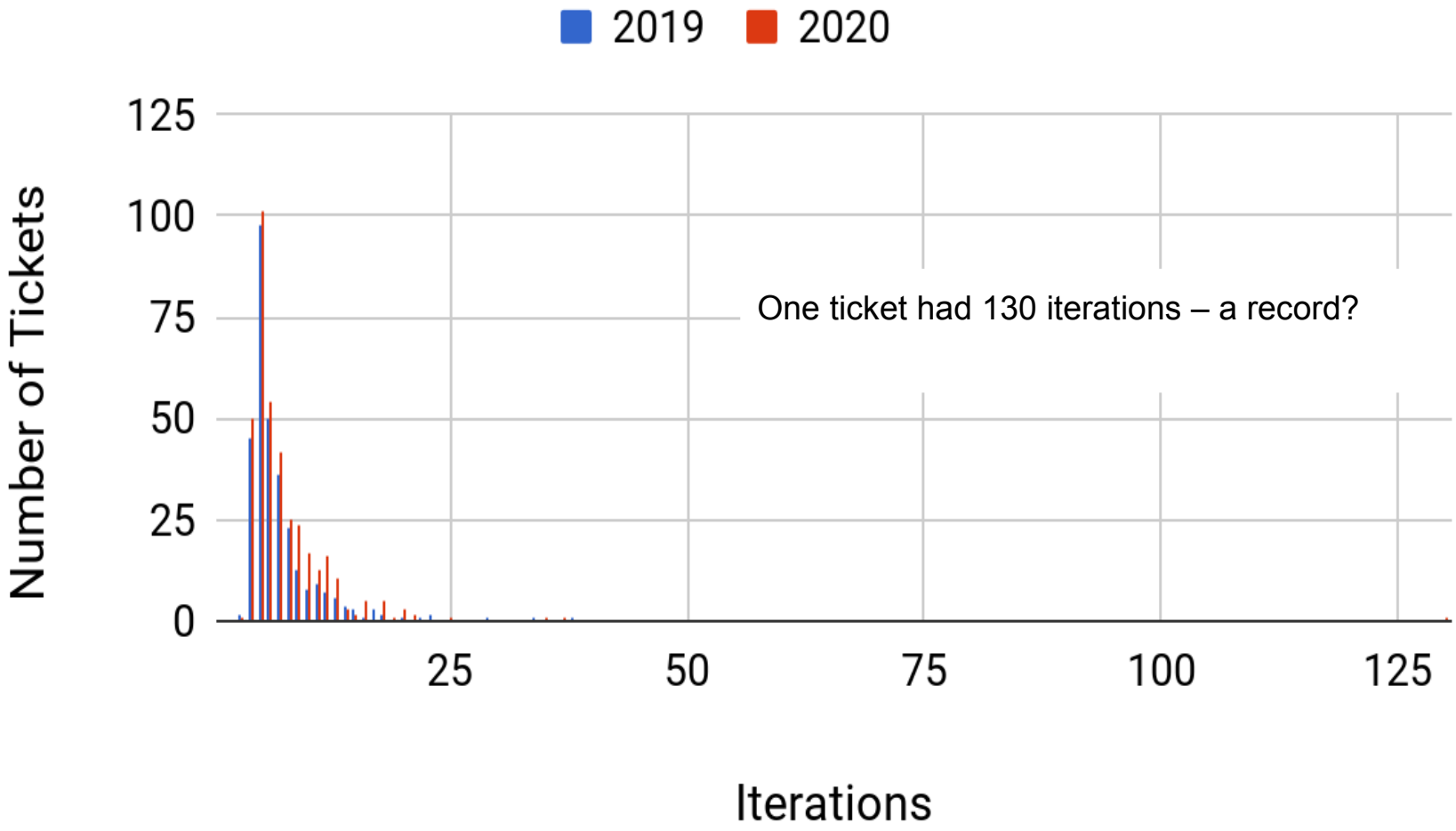
Iterations per Ticket



Helpdesk

- Examples of bugs
  - Issues combining type:II files created with tgextract2 (tgsplit bugs)
  - HEADAS|XSpec environment conflict with conda installs
  - sherpa bug (regression) when including multiple ARFs (HRC+LETG)
- Example of documentation updates
  - Updated Chips conversion guide to include modifying plots generated by sherpa, eg change axis labels.
  - new conda download page
  - new Why topic discussing on-orbit ACIS energy filters
  - new Watchout topic discussing macOSX Catalina security features preventing terminal access to user files and folders.
- Examples of calibration questions passed on to science staff
  - Continued discussions regarding latest ACIS contamination updates
  - MARX subpixel calibration
  - HETG wavelength calibration

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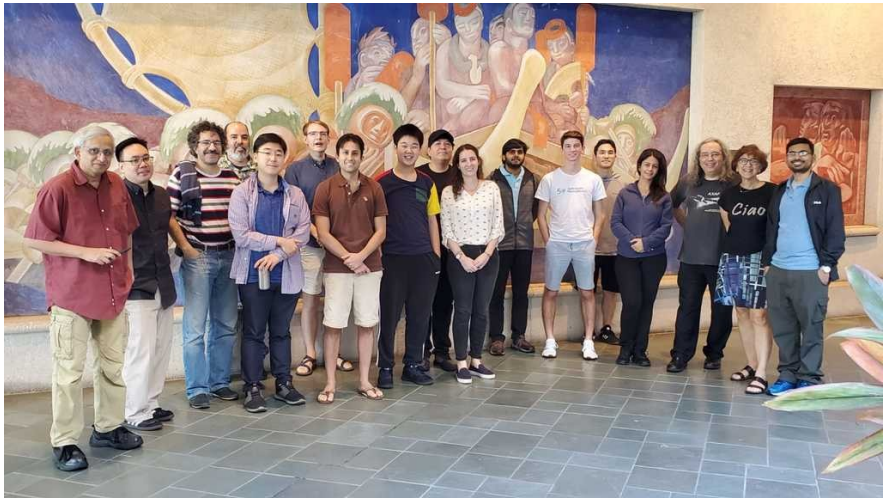
Community

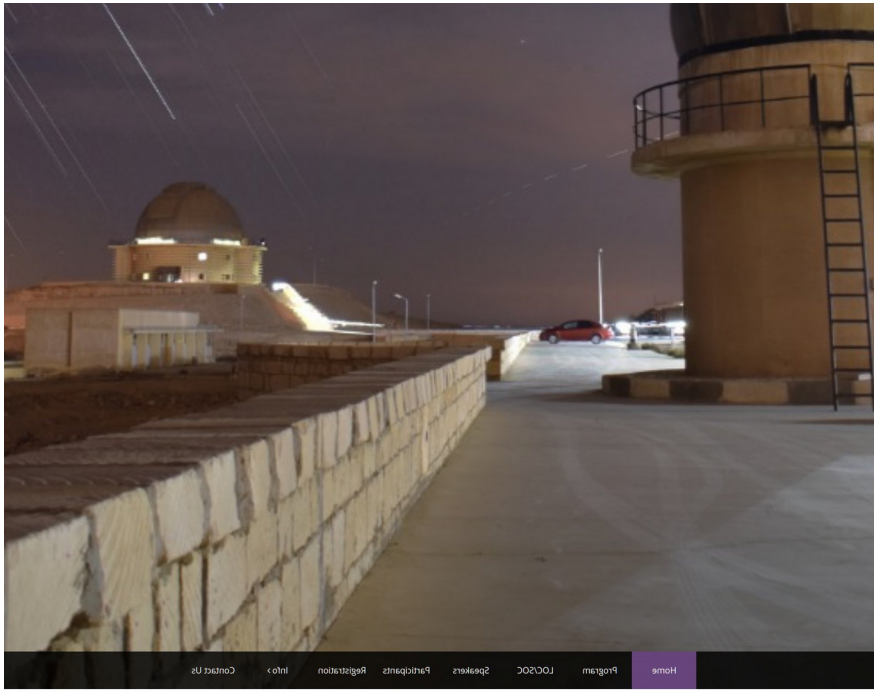
CIAO Workshop #17 at AAS235/Honolulu Jan 2020



- 1.75 days workshop held on Friday and Saturday before conference.
- Morning talks, afternoon hands on.
- Mostly beginners
  - Many competing workshops

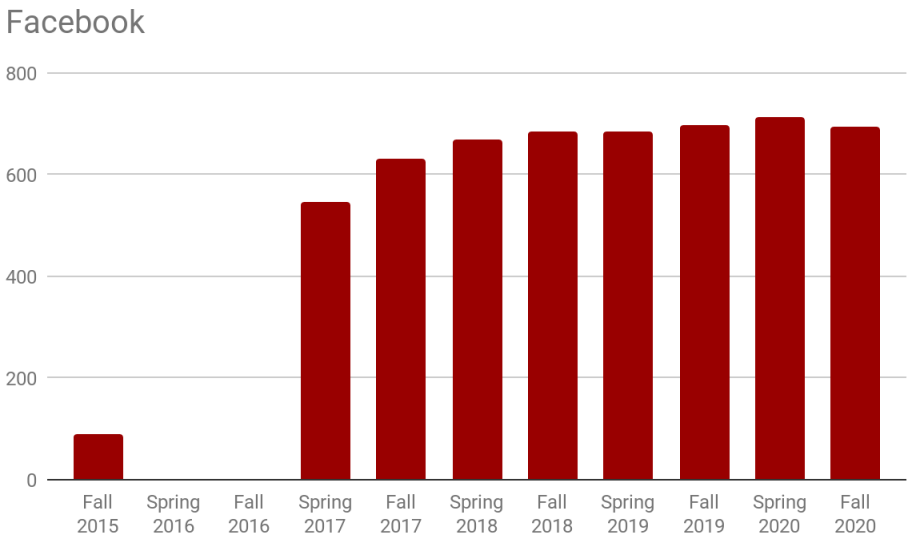
CIAO Workshop #18 (planning)

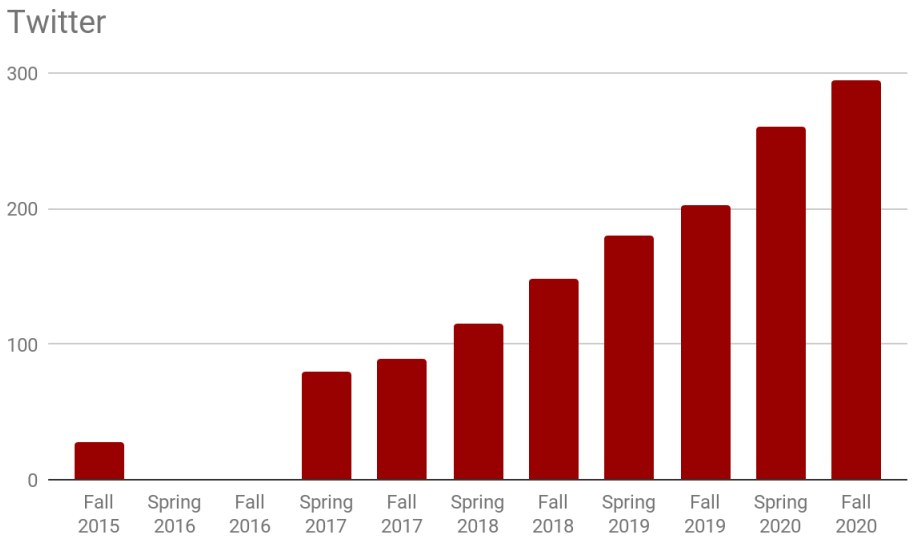
- 3 days of Chandra/CIAO to be presented (remotely) at the Fifth ArAS School for Astrophysics (ArAS SfA-5) in the Kottamia Astronomical Observatory, Egypt, on October 16-23, 2020.



Also planning to have virtual workshop as part of AAS #237

Long Term Social Media Trends





Facebook | ChandraCIAO	695 followers	(down 3)
Twitter | @chandraCIAO	294 followers	(up 92)

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CIAO 4.12 and Scripts Overview

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CIAO 4.12 Highlights

- Single Linux and Single macOSX distribution
- New installation using **conda** package manager
  - Supports multiple python versions: 3.7, 3.6, and 3.5
- CIAO 4.12 requires CALDB 4.9.0; and CALDB 4.9.0 requires CIAO 4.12
- chips plotting package withdrawn; prism (file browser) has been updated to use matplotlib for plotting and GtK+3 (for the user-interface)
- Changes related to Repro-5
  - ACIS now identifies bottom rows of each CCD as bad (acis_build_badpix updates)
  - Updates to support new per-OBI ASOL files with update boresight corrections (a_p_e)
  - New field-of-view algorithm (skyfov)
  - Updates for HRC gain calibrations (pending calibration updates) (h_p_e)
  - Updates for ACIS CTI calibrations (pending calibration updates) (a_p_e)

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Contributed Scripts

- Highlights
  - 4.12.1
    - changes consistent with Repro-5
    - changes to plotting to use matplotlib and drop chips support
  - 4.12.2
    - updates to access secure https://cxc and https://cda resources (drop FTP)
  - 4.12.3
    - changes to work better with CALDB 4.9.2.1 indexing scheme
    - blank sky particle background scaling
  - 4.12.4
    - DAX updates
- CIAO 4.13 Planning
  - Multi-OBSID srcflux
  - parallelized specextract

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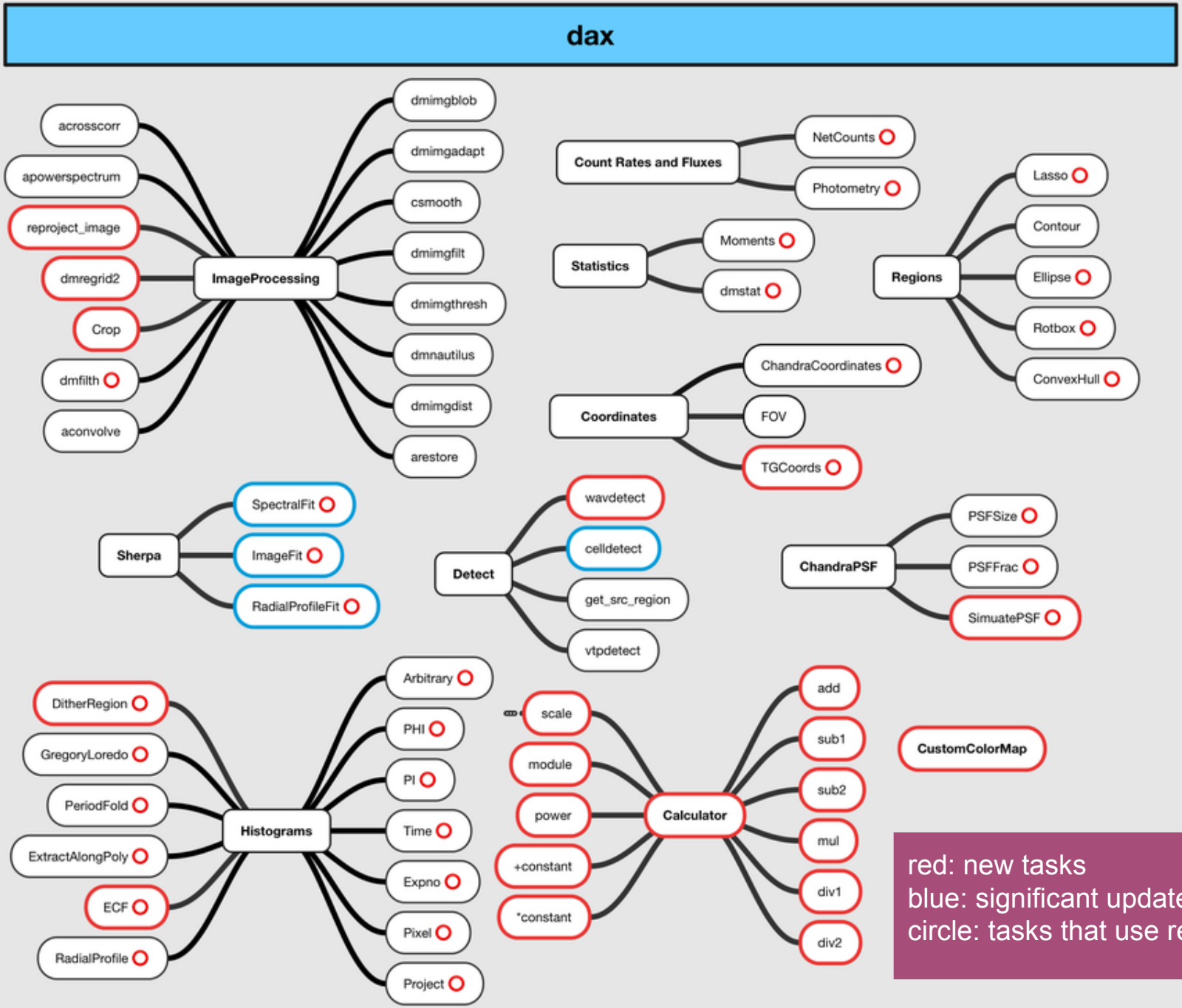
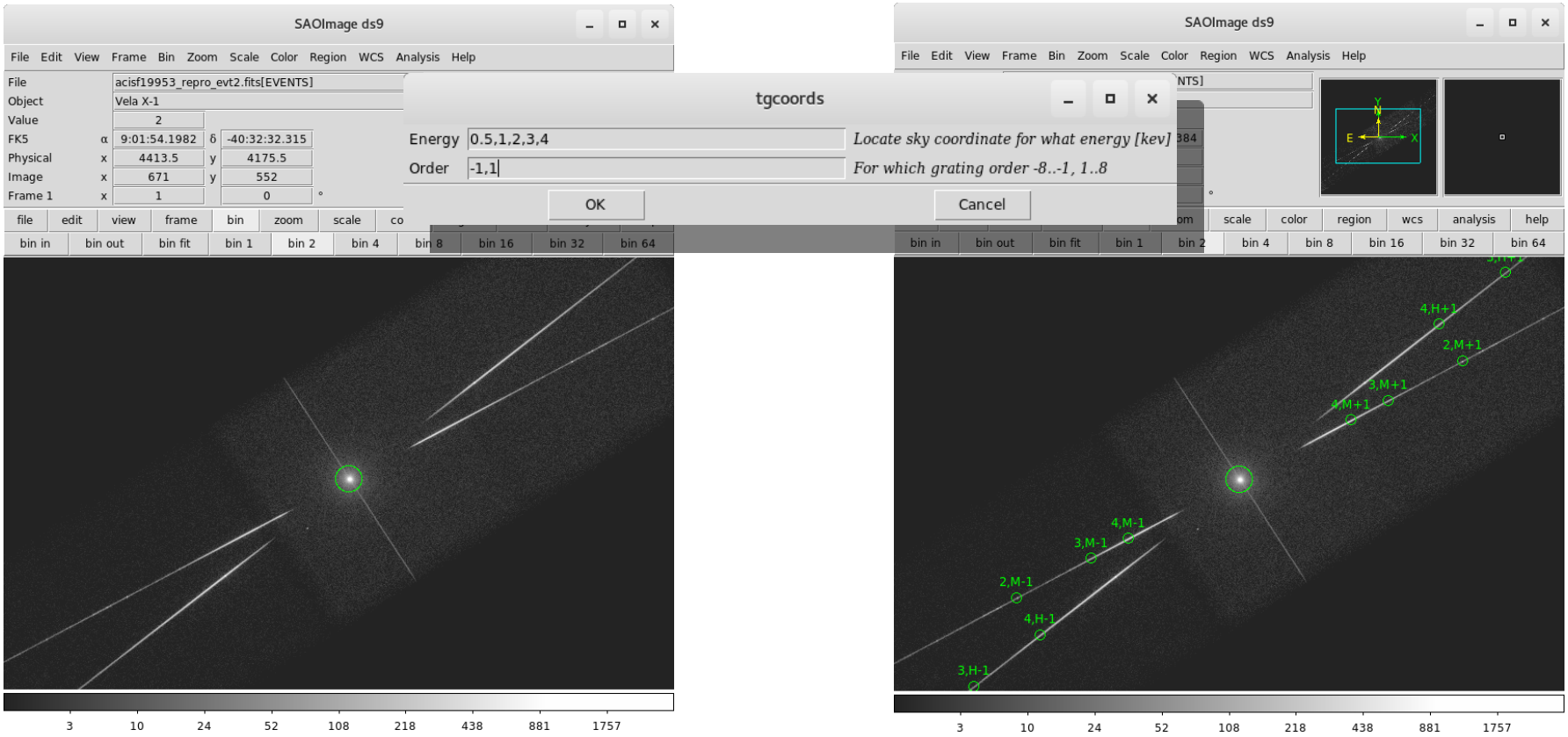
DAX : aka The CIAO Analysis Menu in DS9

- Major updates including
  - New Sherpa model parameter editing GUI
  - New image calculator (eg add|subtract|multiply|divide frames)
  - Tasks now start a progress bar and provide more details about specific tool parameters (equivalent of plist)
  - Various new tools have been added including: wavdetect, dmregrid2, ecfcalc, dither_region, simulate_psf, and reproject_image.
  - Under the hood: many of the individual scripts have been combined into a single driver script which provides for more consistent look-n-feel to the tasks.
- 20 new instructional videos have been added to the 4ciaodemos YouTube channel.

  https://www.youtube.com/playlist?list=PLFvAcNFOvWLgF0cYv-m6jmsWEDo_qqnT1


dax
acrosscorr
apowerspectrum
reproject_image
dmregrid2
Crop
dmfilth
aconvolve
ImageProcessing
dmimgblob
dmimgadapt
csmooth
dmimgfilt
dmimgthresh
dmnautilus
dmimgdist
arestore
Count Rates and Fluxes
NetCounts
Photometry
Statistics
Moments
dmstat
Regions
Lasso
Contour
Ellipse
Rotbox
ConvexHull
Coordinates
ChandraCoordinates
FOV
TGCoords
Sherpa
SpectralFit
ImageFit
RadialProfileFit
Detect
wavdetect
celldetect
get_src_region
vtpdetect
ChandraPSF
PSFSize
PSFFrac
SimuatePSF
DitherRegion
GregoryLoredo
PeriodFold
ExtractAlongPoly
ECF
RadialProfile
Histograms
Arbitrary
PHI
PI
Time
Expno
Pixel
Project
scale
module
power
+constant
*constant
Calculator
add
sub1
sub2
mul
div1
div2
CustomColorMap
red: new tasks
blue: significant updates
circle: tasks that use regions

DAX : grating coordinates



Q: Is that feature in my spectrum at 2keV because I'm near a chip gap? Now you can easily find out.

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powlaw1d.mdl1

Parameter	Value	Frozen?	Min	Max	Units
gamma	1.5617	☐	-10	10	
ref	1	☒	-3.4028e+38	3.4028e+38	
ampl	0.0019894	☐	2.8745e-09	0.028745	

gauss1d.mdl2

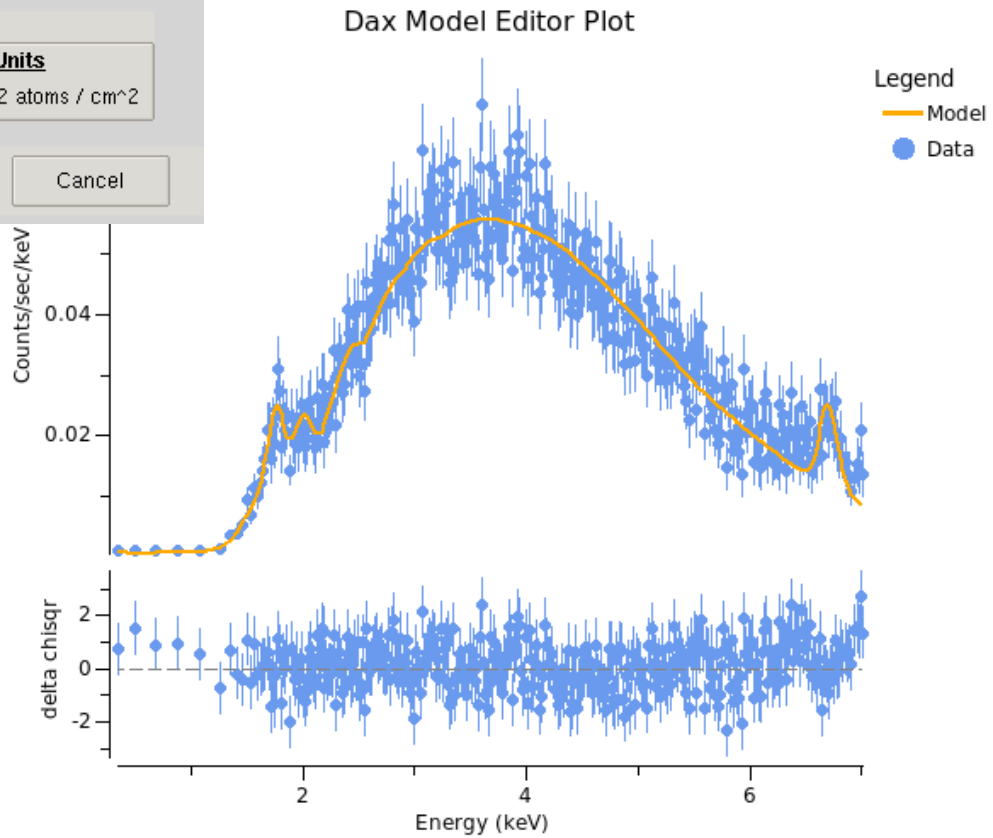
Parameter	Value	Frozen?	Min	Max	Units
fwhm	0.0015357	☐	0.0012994	12994	
pos	6.7	☒	0.2628	7.008	
ampl	0.016939	☐	1.541e-05	15.41	

xswabs.abs1

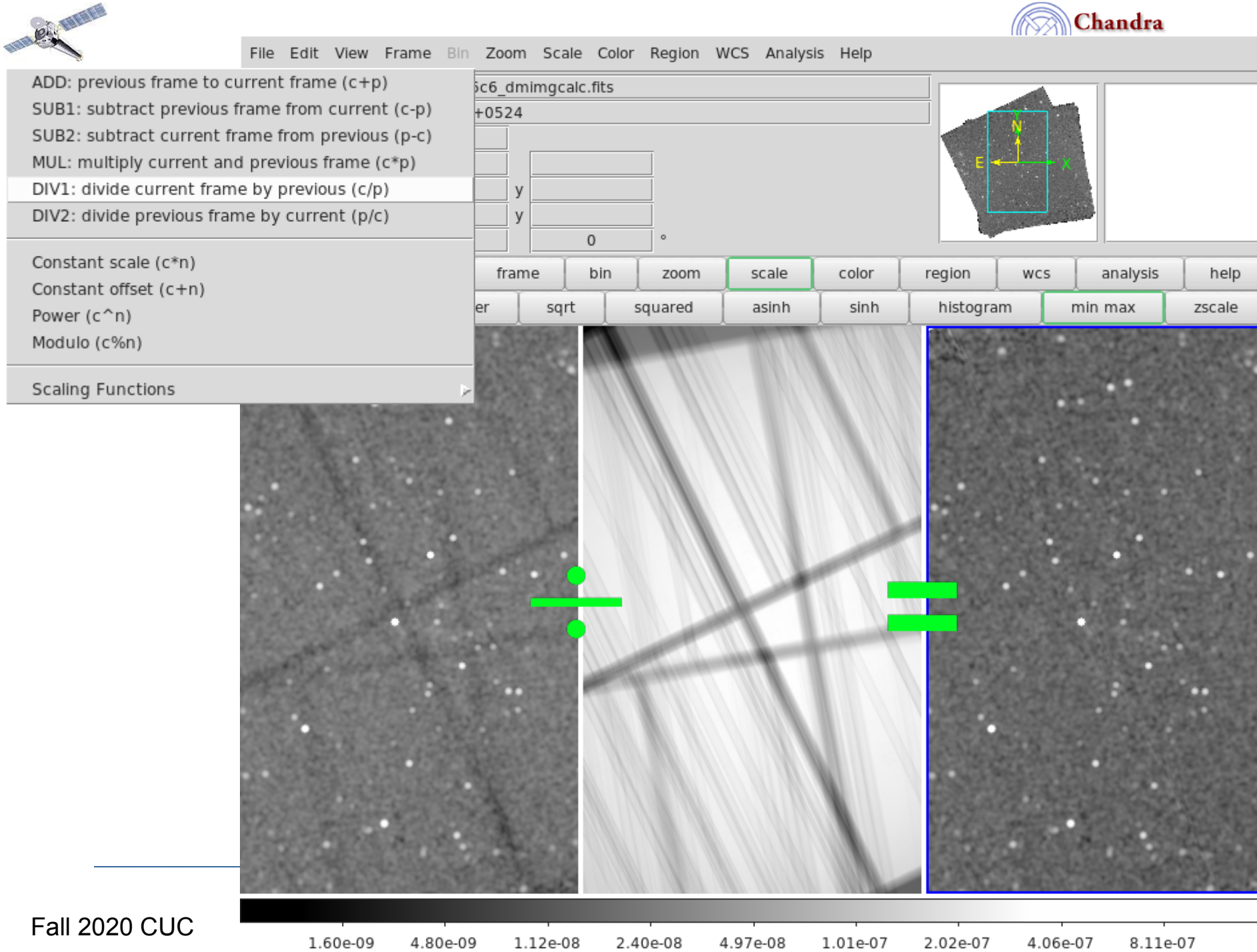
Parameter	Value	Frozen?	Min	Max	Units
nH	5.308	☐	0	1e+05	10^22 atoms / cm^2

Fit | Exit | Plot | Reset | Cancel

Graph Data



Users can iteratively "Fit" and "Plot" tweaking parameter values, freezing/thawing parameters, until they get a good fit. Exit then resumes script to compute confidence intervals.


Chandra
File Edit View Frame Bin Zoom Scale Color Region WCS Analysis Help
ADD: previous frame to current frame (c+p)
SUB1: subtract previous frame from current (c-p)
SUB2: subtract current frame from previous (p-c)
MUL: multiply current and previous frame (c*p)
DIV1: divide current frame by previous (c/p)
DIV2: divide previous frame by current (p/c)
Constant scale (c*n)
Constant offset (c+n)
Power (c^n)
Modulo (c%n)
Scaling Functions
5c6_dmimgcalc.fits
+0524
y
y
0
°
N
E
X
frame bin zoom scale color region wcs analysis help
er sqrt squared asinh sinh histogram min max zscale
1.60e-09 4.80e-09 1.12e-08 2.40e-08 4.97e-08 1.01e-07 2.02e-07 4.06e-07 8.11e-07

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srcflux

- Updated to compute combined (merged) rates and fluxes from multiple observations.

```
% srcflux @evt.list pos="9:42:32.2119,+12:20:51.349" out=srcflux/out
...
Summary of merged source fluxes

Position                                    0.5 - 7.0 keV
                                                   Value    90% Conf Interval
#0001|9 42 32.21 +12 20 51.3  Rate          0.00252 c/s        (0.00218,0.00286)
    NumObi=2                 Mod.Flux       2.31E-14 erg/cm2/s (2E-14,2.62E-14)
                             Unabs Mod.Flux 2.44E-14 erg/cm2/s (2.11E-14,2.76E-14)
```

- using aprates tool to compute uncertainties and upper-limits for merged quantities similar to CSC1 approach.
  - uncertainties will be less accurate in very crowded fields with significant source overlap but for well resolved sources the results are consistent.

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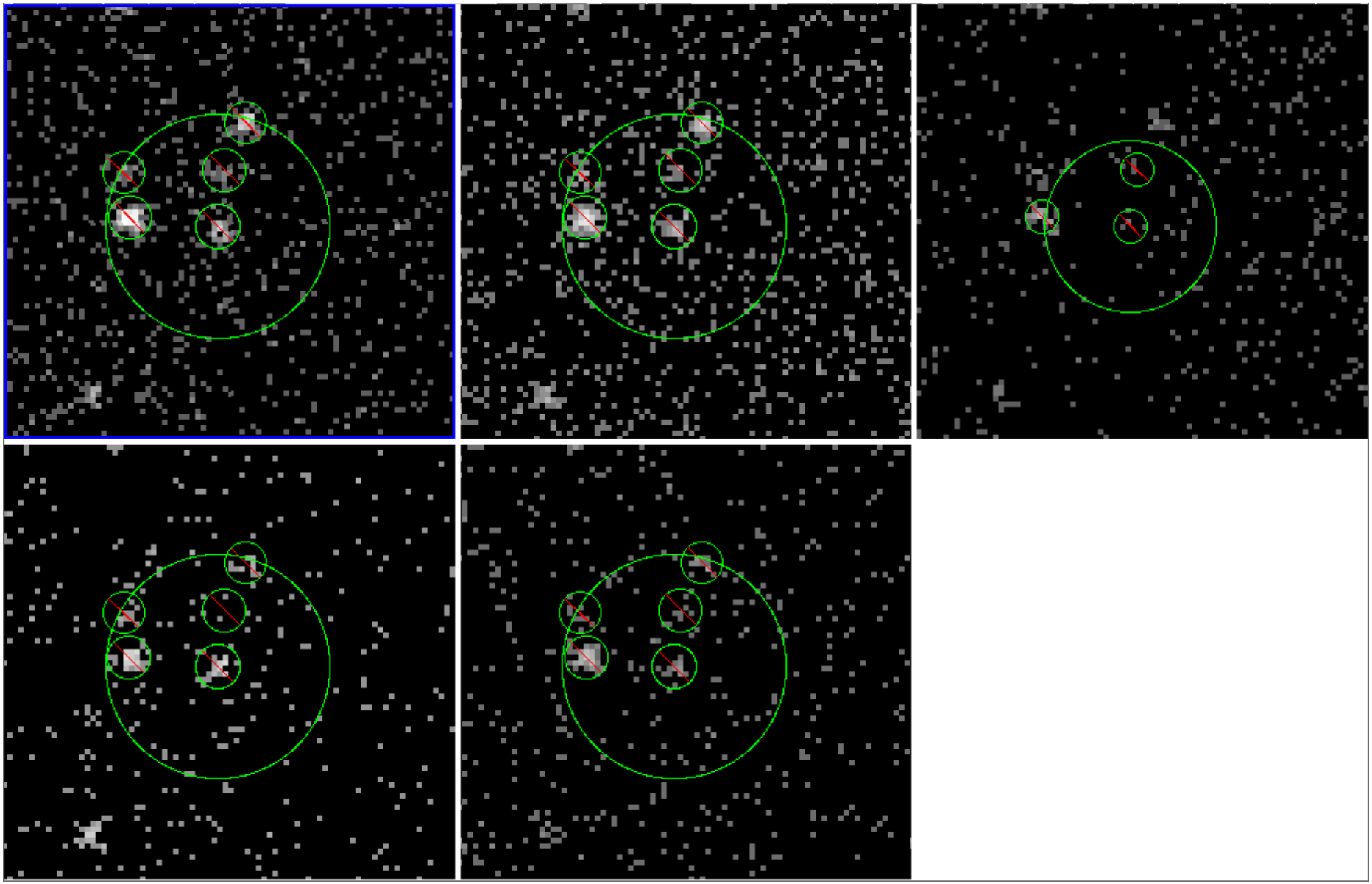
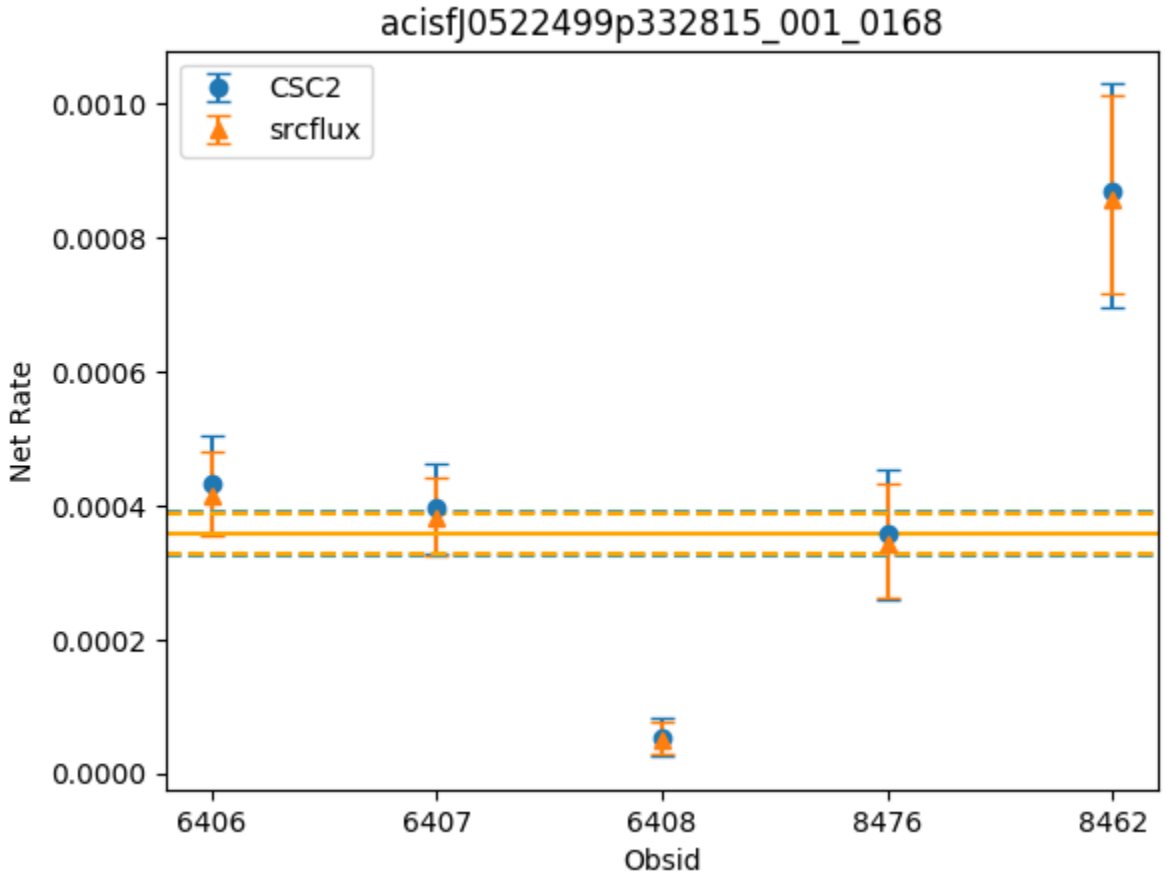


Example: compare srcflux with CSC2



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CIAO 4.13 Planning

- Document conda as the primary installation method; ciao-install method still available.
  - Dropping python 3.5, now including python 3.8 as the default for conda.
- Continued bug fixes
  - Grating coordinate via dmcoords
  - Nasty bug when accessing virtual columns (eg RA,Dec) and filtering at the same time.
  - Fixes to support XMM response files
- Maintenance aimed at supporting extended mission
  - Newer OS/compilers
  - Updates to C++ standards

Repro 5 (2020)

- First complete archive reprocessing in 6 years (Repro 4 was 2012-2014)
- Update header keywords etc (like running chandra_repro on all archive data)
- Improved off-axis angles
- Other algorithm improvements
- Pre-compute grating responses
- Uniformly processed archive

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Catalog Support

SDS Support for Catalog

SDS supports the catalog at 2.0 FTE level (Primini, Burke, Lee, with some additional relevant work by others)

Details of progress in I Evans presentation

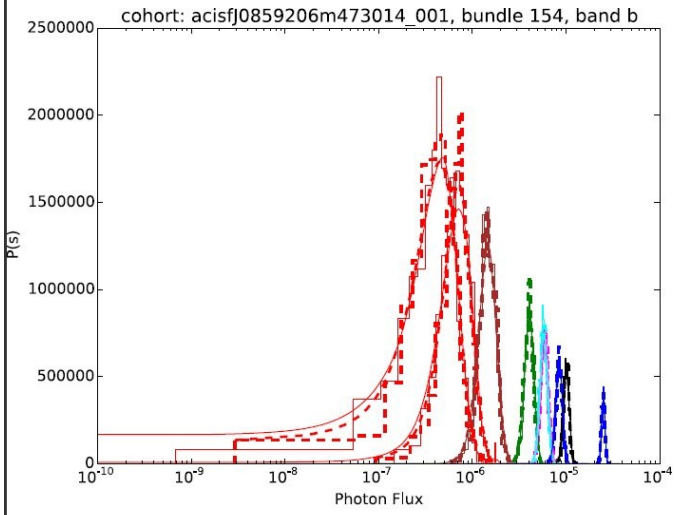
Primini:
- Statistical Characterization of the catalog
- Aperture Photometry
- Quality assurance and reviews on data, detect list and data products

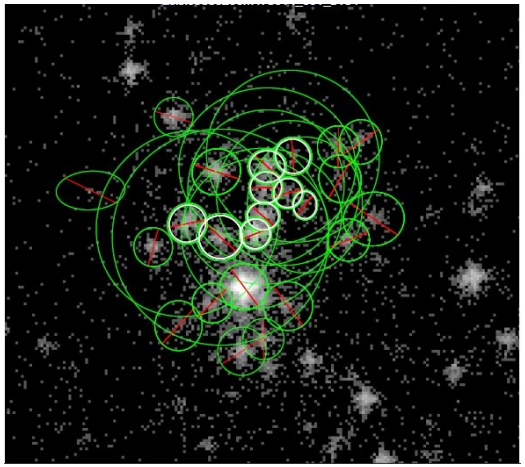
Burke
- convex hull support,
- quality assurance/reviews of source properties pipeline
- visualization (catalog display in WWT)

Siemiginowska
- fitting

Nynka
- simulations

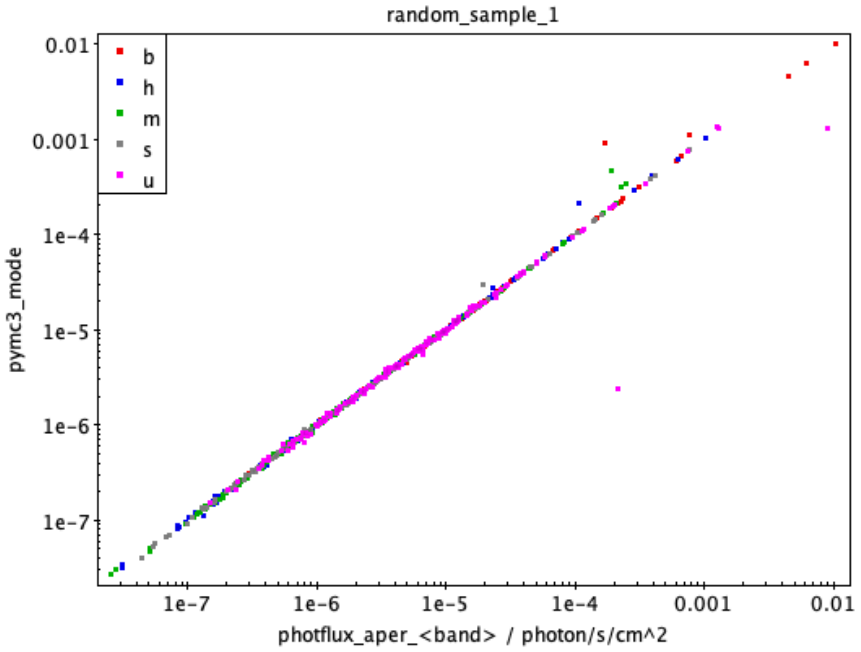
Burke, McDowell, Lee, Primini, Siemiginowska
- Documentation.

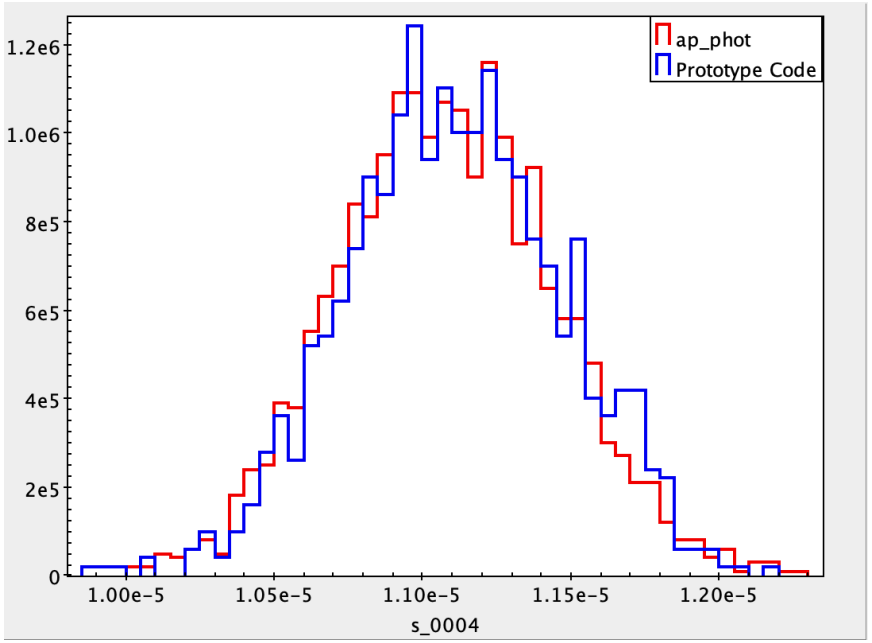




CSC 2.1 Aperture Photometry Upgrades

- Replace *Sherpa/get_draws() MCMC* sampler with *pymc3* package
- *pymc3* uses a more sophisticated sampling algorithm, leading to more robust results and fewer cases where traces fail to converge
- Specification and prototype code delivered to DS at the beginning of August
- Testing of implementation in L3 pipeline underway





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Sherpa

Sherpa Development

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- Sherpa 4.12.0 standalone was released on Jan 30, 2019 and included functionality based on the CIAO 4.12 (Dec.2019) release and additional bug fixes and improvements.
- Sherpa 4.12.1 was released on July 14, 2020 as part of the CIAO patch release to fix several issues that affected some users analyzing grating data.
  - Sherpa runs under Python 3.5 (when installed with ciao-install) or Python 3.7, 3.6, 3.5 (when installed using conda package manager). It is expected that it will work with Python 3.8 but testing has been limited.
  - The main updates in 4.12.1 include:
    - Improvements to the flux calculation code (e.g. calculating the unabsorbed flux of a source)
    - Continued improvements for regrid support (using a higher-resolution model which gets re-binned to match the data)
      - Support NumPy version 1.19 for conda users
- Sherpa 4.12.2 planned for release Oct 15

Sherpa in CIAO 4.13

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- Major updates:

- Further improvements to support models on arbitrary grid (i.e. regridding models).
- Continued improvements to flux calculation seen in CIAO 4.12.1, this time for the sample_energy_flux and sample_photon_flux commands, which allow users to calculate realistic errors on fluxes.
- Fixed a number of annoying corner cases when grouping and filtering PHA data and handling background datasets.
- Fix and updates to the resample_data command, which estimates how asymmetric measurement errors can affect fit results and parameter uncertainties.
- Many improvements to plotting (now using matplotlib), including support for the alpha parameter for displaying semi-transparent data or models plots.
- XSPEC convolution models are now supported in Sherpa.
- XSPEC support up to 12.11.1, but CIAO 4.13 will remain with XSPEC 12.10.1 to support our build platforms. Note, license issues in the XSPEC code.
- Updates for the Python ecosystem (matplotlib and Python).
- Documentation: Threads —> Notebooks, synchronize docstrings —> ahelp files

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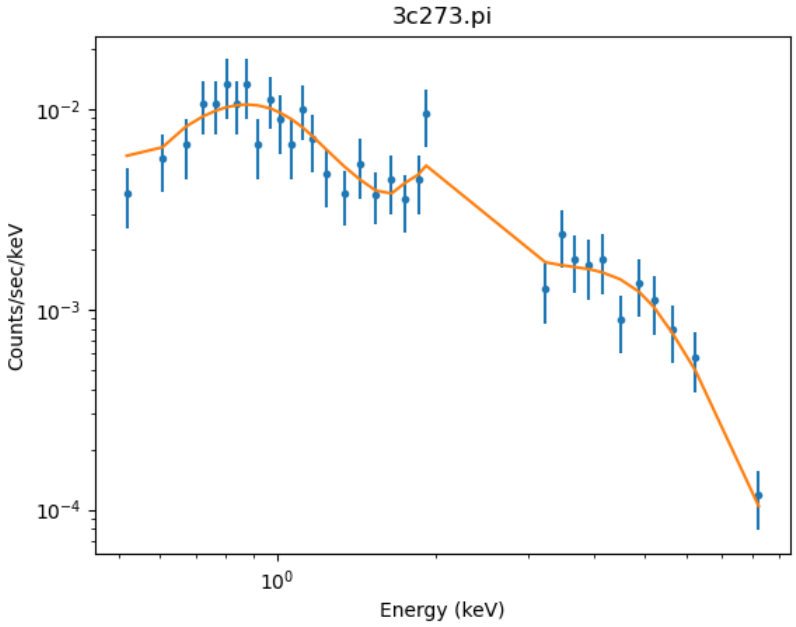
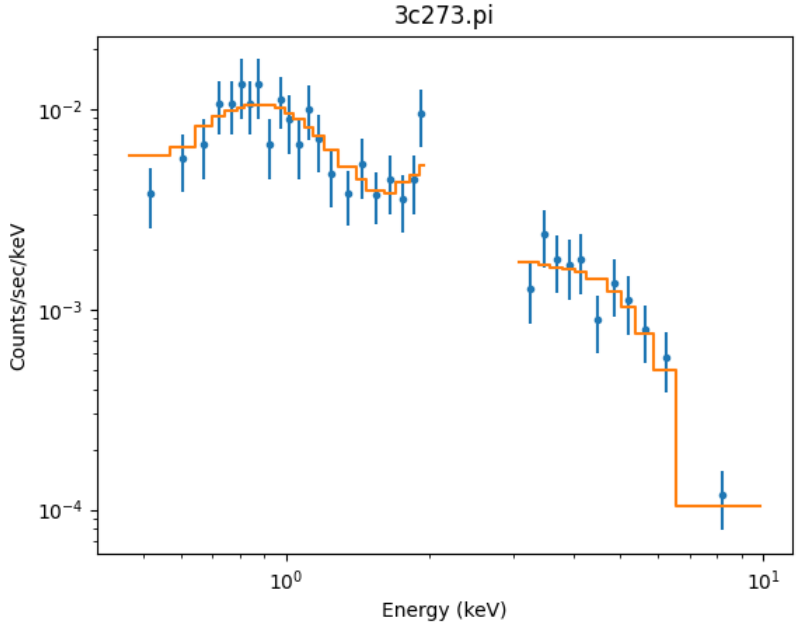
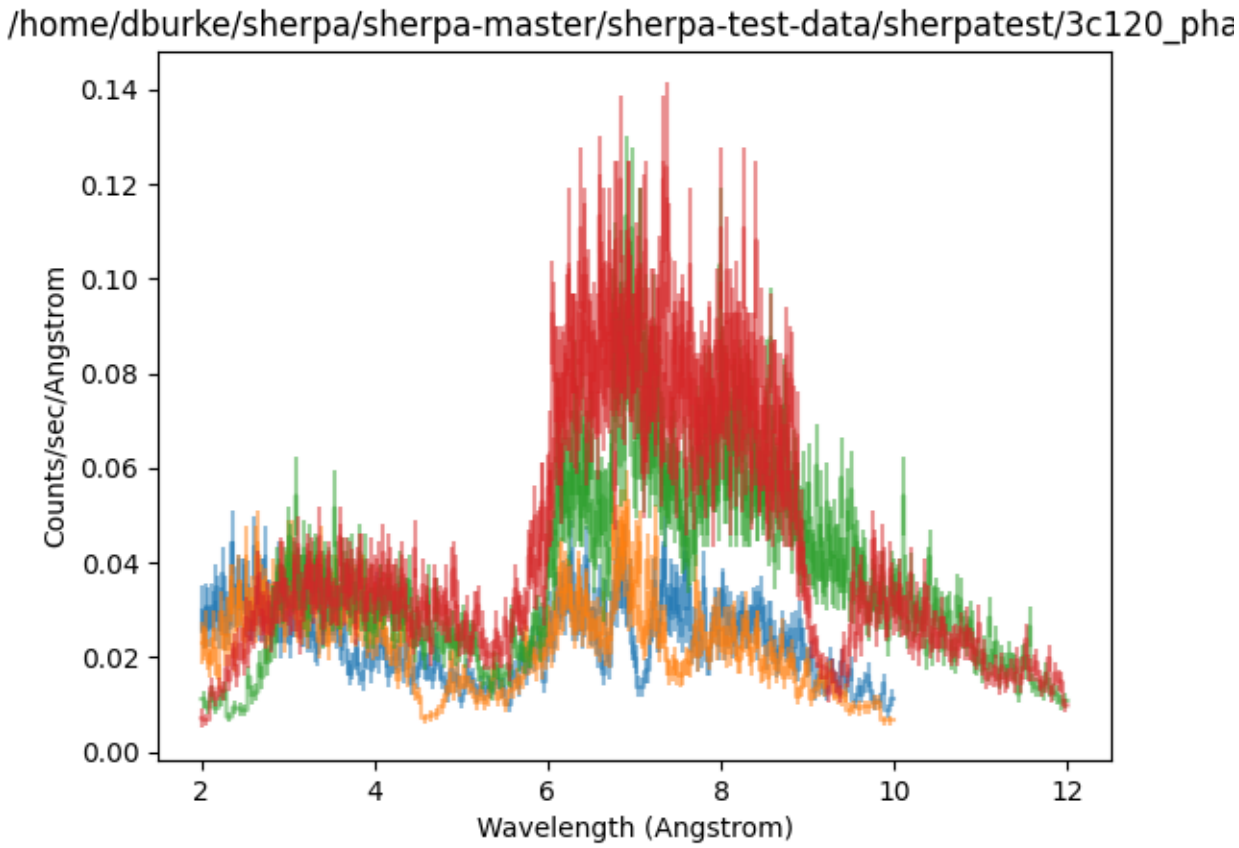




Improvement to Sherpa PHA plots (plot_fit):
use histogram mode and show gaps for ignored ranges



Improved multi order (PHA2) plot showing use of plot opacity and improved handling of start and end bins

Using Sherpa in Astronomy Research

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1299 publications in ApJ, AJ, MNRAS and A&A use Sherpa (since 2001 and including astro-ph abstracts)

293 citations to Freeman et al 2001 SPIE paper

68 research papers published in 2020

7 PhD theses listed in ADS that used Sherpa

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Instruments
Gratings

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Pipeline / Event processing tools:

HRC-S/LETG: calibration files have been updated which implement improved time-dependent gain correction which will lower the non-X-ray background.

This is automatically applied by hrc_process_events, given the current Calibration Database.

(A User-applied spatial/spectral filter file is still required from the Calibration Group to achieve full benefit, this will be released as a stand-alone file when ready, but also included in future CALDB releases.)

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Calibration support:

We participated in a study of HETG response dependence (QE and order-sorting) on CCD temperature. No significant effects were found (<3%) allowing CXO operations to use HETG at warm attitudes. The result also means that we do not need to include any new temperature-dependent effects into our standard suite of ACIS event processing software.

PCA analysis of ACIS gains carried out, suggests possible simplification of gain map creation (Gunther).

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Responses:

Grating responses ("ARFs" and "RMFs") are now computed in the pipeline. Repro-5 is underway, so the archive will be retroactively populated with these files over the next year.

TGCat:

- (still) undergoing porting to current OS (to fix non-back-compatible changes in underlying components (mysql and php) (this should be invisible to user);

- next: enhance plotting functions; start re-write in modern web language (e.g., Django), which is easier to maintain.

Future instrument/gratings work

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- Support odd detector/grating combinations by providing necessary calibration files, modifications to ciao tools, and analysis guides for when these are useful and how to propose. (E.g., HRC-I/HETG, for recovering the ability to obtain O VII He-like at high resolution, essentially lost to HETG due to ACIS filter contamination.)

- Support off-axis grating RMFs. Current grating calibration data is for on-axis point sources. Off-axis, dispersed lines are broadened, due to the off-axis PSF (and this is currently ignored by response software, and must be included in the source model).

- Improve hot/bad-pixel handling; some bad pixels (with long tails) get through current algorithms, and may lie on dispersed spectra. They are currently handled manually during V&V.

- Improve order-sorting by bringing to current CCD responses, and making more dynamic. The current order-sorting tables are static.

- Release HETG crowded-field confusion analysis code. This has been prototyped and is being applied to some cases of HETG observations of star clusters (e.g., Orion, and NGC 3603).

Future instrument/gratings work (continued)

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- Grating analysis cookbooks: Line shifts in HETG, simulating HETG spectra

- Document use of 2nd, 3rd order HETG spectra, providing tutorial examples and threads (given some deep observations available now, there can be useful information in 2nd and 3rd orders). - Document, through threads and examples, background handling in analysis for LETG/ACIS, since it is very important for some parts of the spectrum (much more than for HETG/ACIS).

- MARX: continue with improvements to sub-pixel grade distribution simulation.

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PSF

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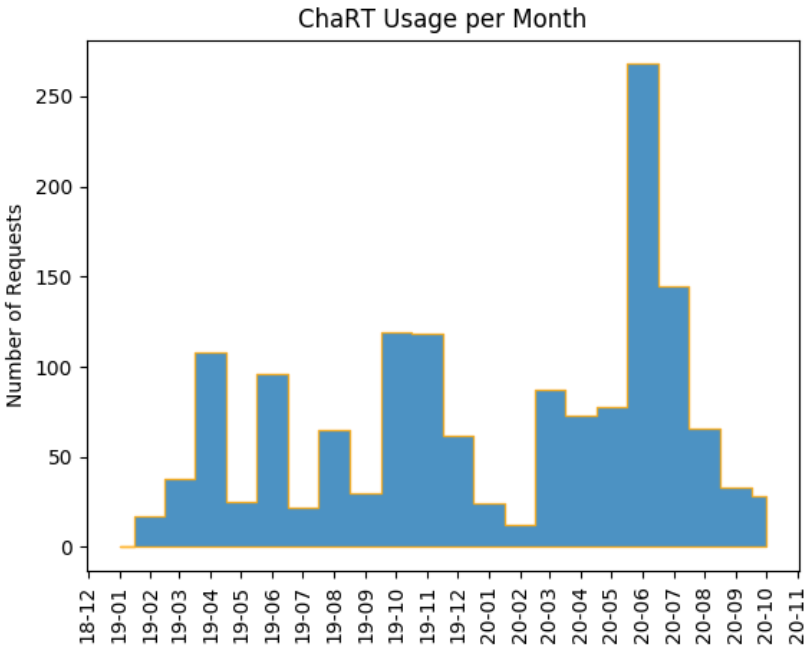
ChaRT

- Updated to CentOS 7
- Updated to CIAO 4.12 (Python 3)
- Drop ftp:// support; now using https://

ChaRT



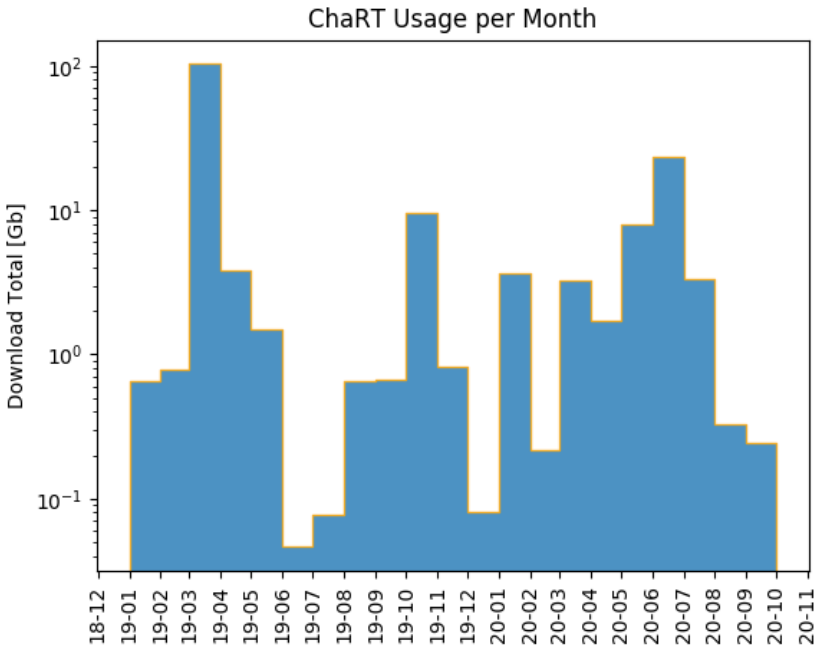


ChaRT server upgraded to CIAO-4.12, now running on CentOS7, and delivery of rays is now via https:// rather than ftp://.

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Visualization

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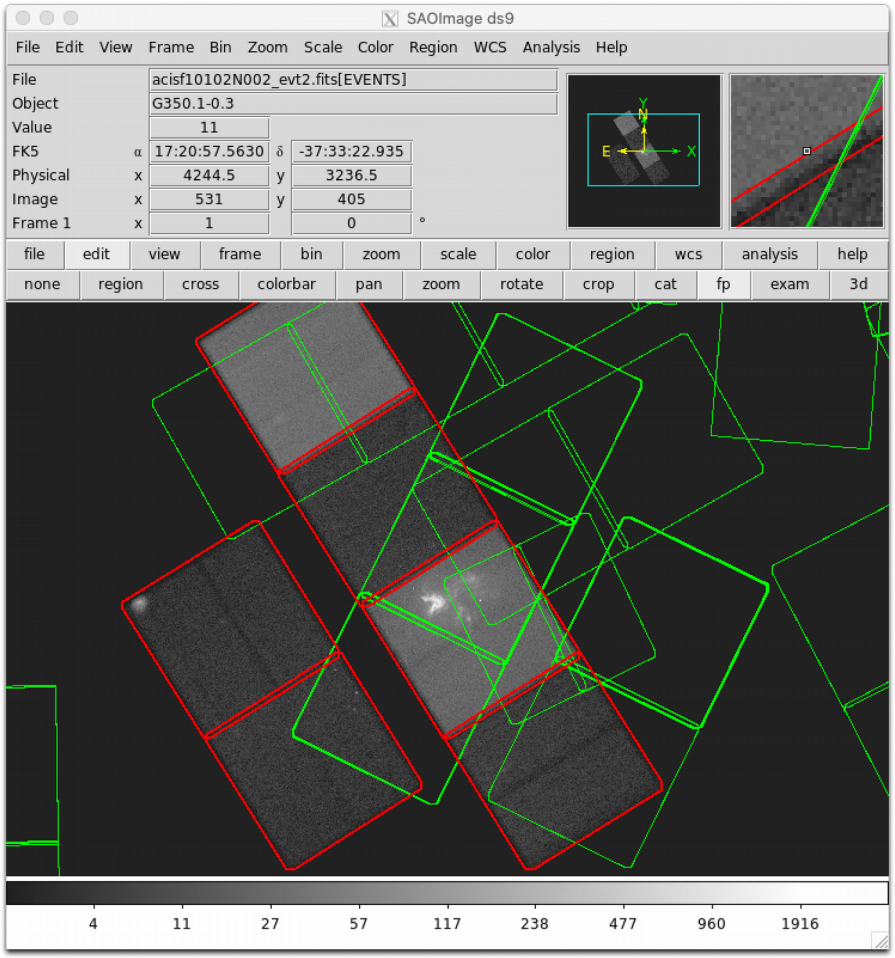
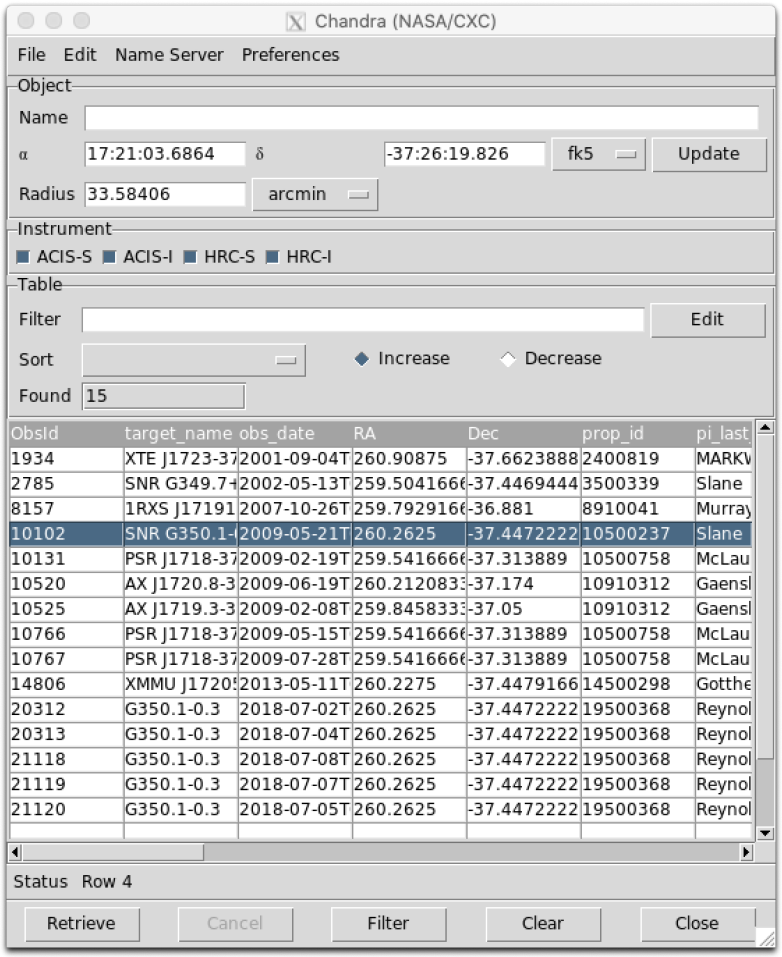
SAOImageDS9

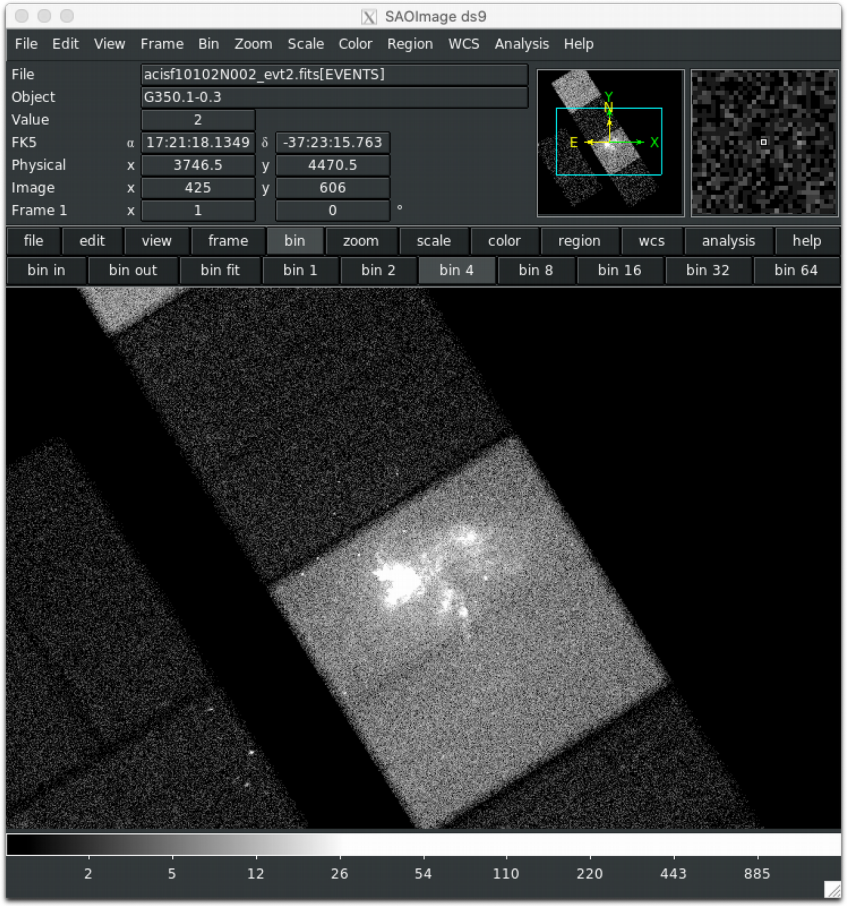
- Releases
  - Version 8.1 - released in Dec 2019 with CIAO 4.12
  - Version 8.2b1 - released in Feb 2020
  - Version 8.2rc - released in Sep 2020
- New Features 8.2
  - New Footprint Server support for Chandra and Hubble Legacy Archive
  - New built-in Prism feature, display and analyze FITS file structure, similar to CIAO Prism application
  - New Theme (Dark Mode) support for Linux and Windows ports
  - New Chandra Public Archive interface
  - Improved Mask support including blending of multiple masks
  - Support Catalog FITS Tables
  - Improved support for Analysis Task parameter dialogs
  - Improved support for Plot Dialogs, including new control panel GUI

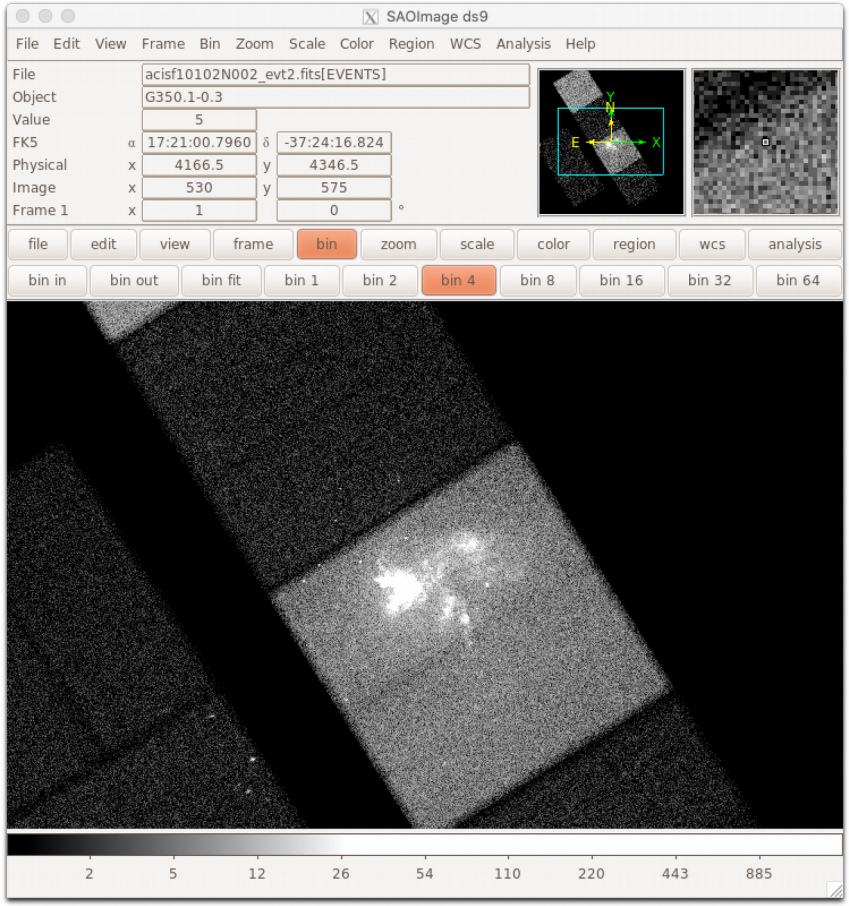
SAOImageDS9 - Chandra Footprint Server



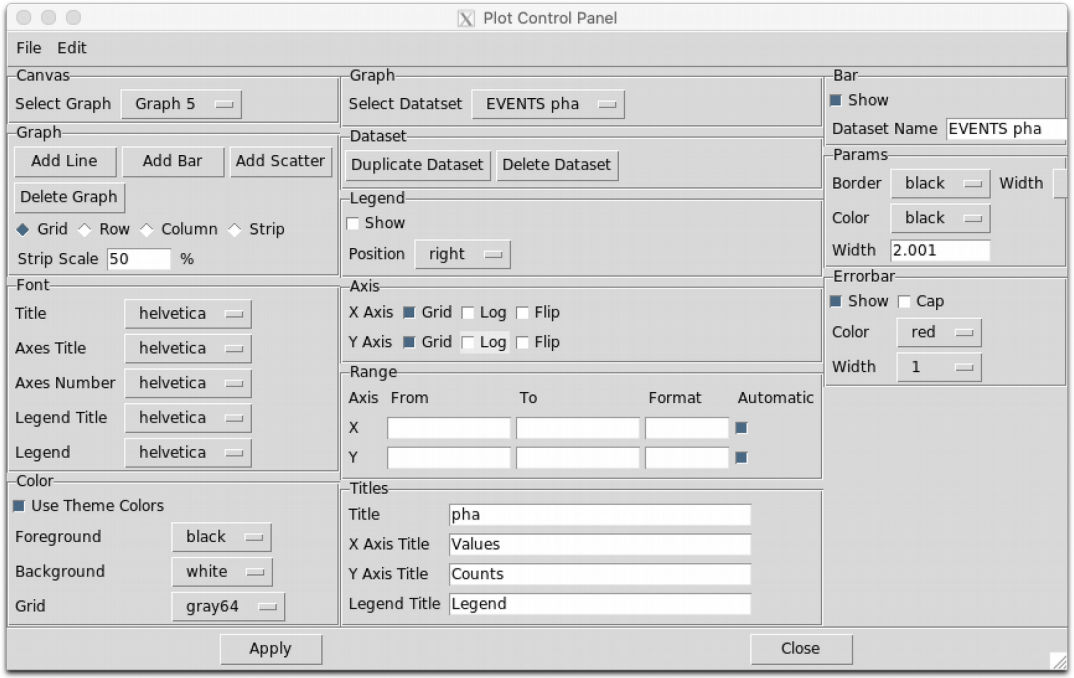


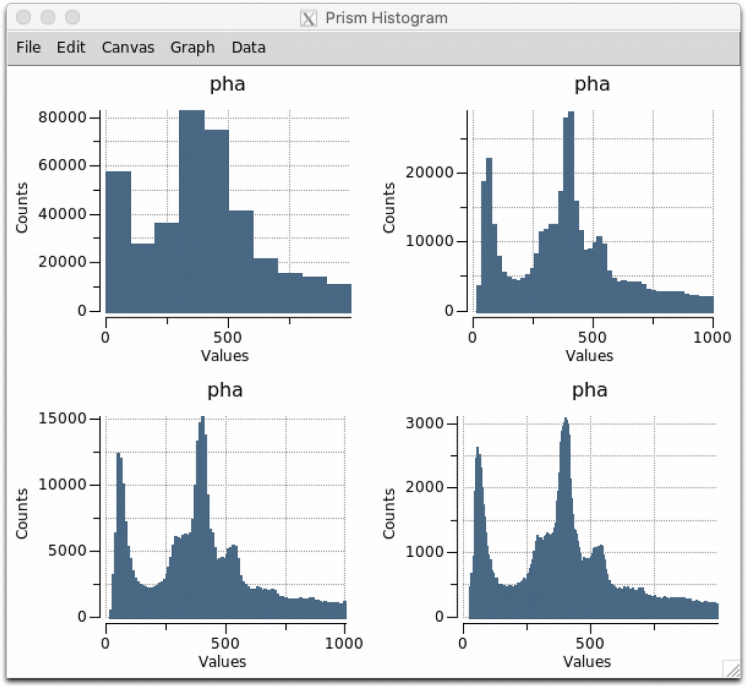
SAOImageDS9 - Themes (Dark Mode and Gnome)





SAOImageDS9 - Plot Control Panel





SAOImageDS9 – Prism (experimental support)