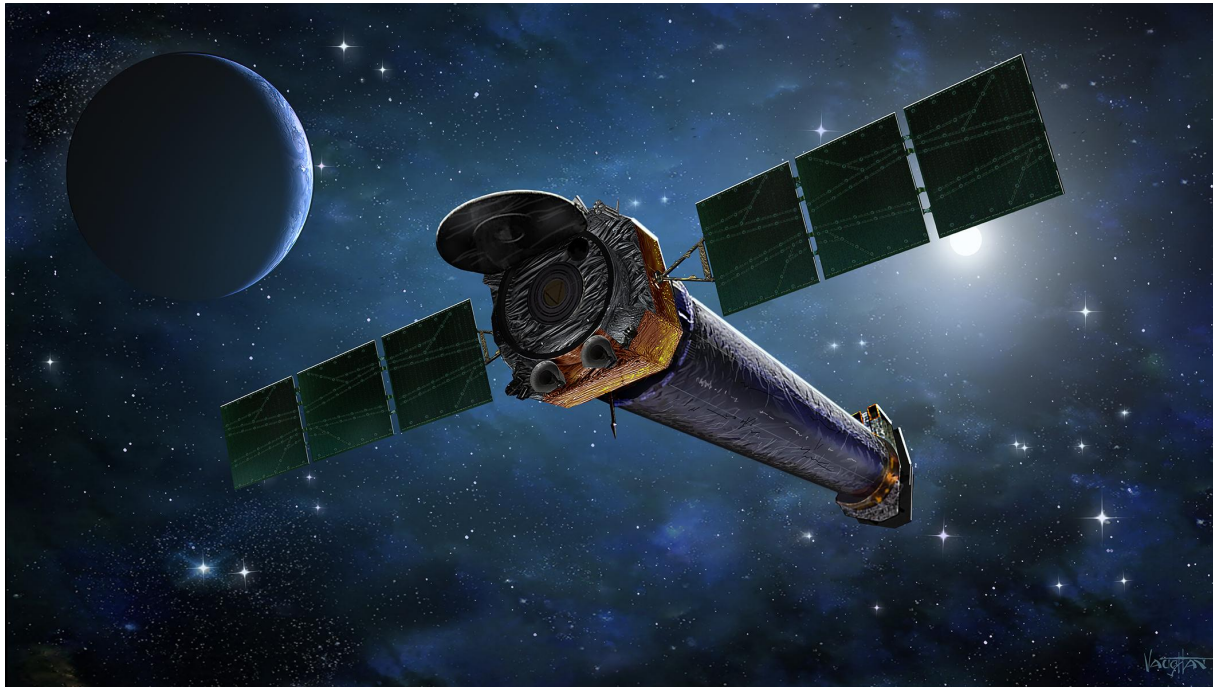
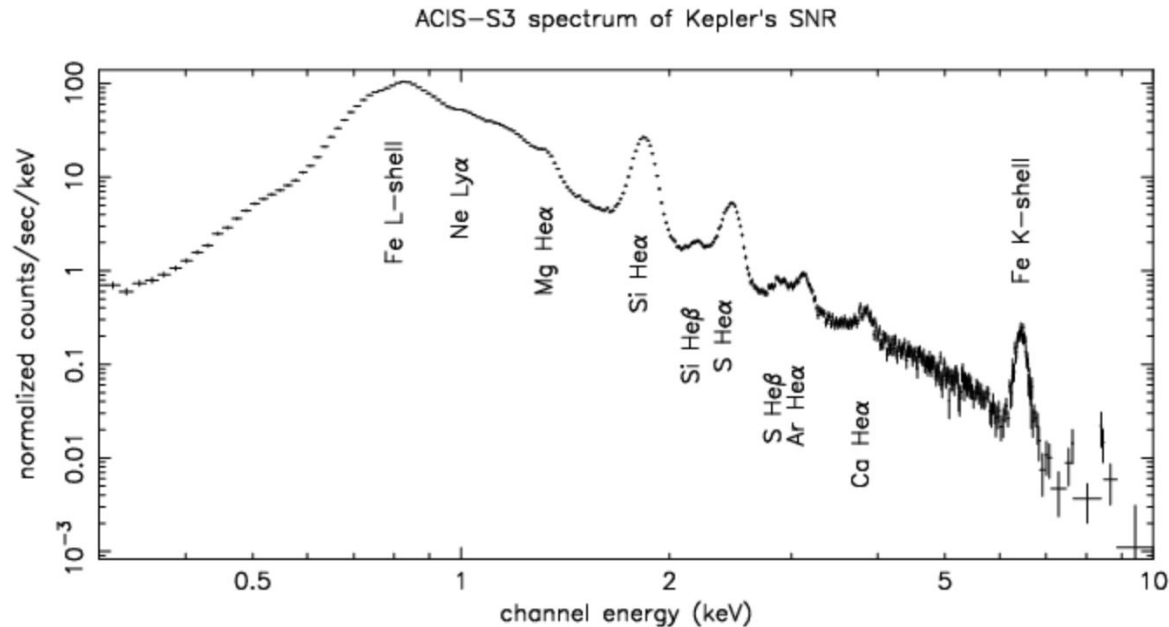


Imaging Spectral Analysis Flux Calculation

and a bit more



1. Imaging Spectral Analysis



- A **spectrum** is a chart or a graph that shows the intensity of light being emitted over a range of energies.
- Spectroscopy is crucial to understand how different objects emit x-ray light, what elements they are mostly composed of, the temperature and the density, the velocity of the material and so forth.
- I am concentrating here on imaging spectroscopy, while spectroscopy with the Chandra gratings will be covered in a different talk.

What is the goal?

- Extract an X-ray spectrum of a source detected in an ACIS imaging observation (very limited energy information on the HRC instrument) or a zeroth-order grating observation
- Create the appropriate response files (which describe the effects of the instrument on the input spectrum)
 - ✓ [ARF: Ancillary Response File](#)
 - ✓ [RMF: Response Matrix File](#)

So that the spectrum can be modeled and fit to derive physical information about the source (spectral slope, temperature, abundances, absorption, etc.)

REMINDER!

When starting from an event file which has information on **(x,y,E,t)** for each event

Spatial Analysis (*lose time and energy information*)

Spectral Analysis (*lose time and spatial information*)

Timing analysis (*lose spectral and spatial information*)

An entire section of the CIAO Data Analysis Threads is devoted to this subject

- **READ THE THREADS** line by line at least the first time!
- **READ THE AHELP** line by line at least once!

Imaging Spectroscopy

[WHAT'S NEW](#) | [WATCH OUT](#)

[Top](#) | [All](#) | [Intro](#) | [Data Prep](#) | [Imag](#) | [Imag_Spec](#) | [Grating](#) | [Timing](#) | [psf](#) | [TTT](#) | [ChIPS](#) | [Sherpa](#) | [Proposal](#) | [PSF Central](#)

After extracting source and background PI or PHA spectra from an imaging observation, the appropriate response files ([ARF](#), [RMF](#)) are created so that the data may be modeled and fit. In the case of multiple or extended sources, a weighted ARF and RMF are built for the spectral analysis.

- **Extracting ACIS Spectra & Creating Response Files:**

- [Extract Spectrum and Response Files for a Pointlike Source](#)
- [Extract Spectrum and Response Files for an Extended Source](#)
- [Extract Spectrum and Response Files for Multiple Sources](#)
- [Coadding Spectra and Responses](#)
- [A Note on Responses for XSpec Users](#)



- **Special Science Cases:**

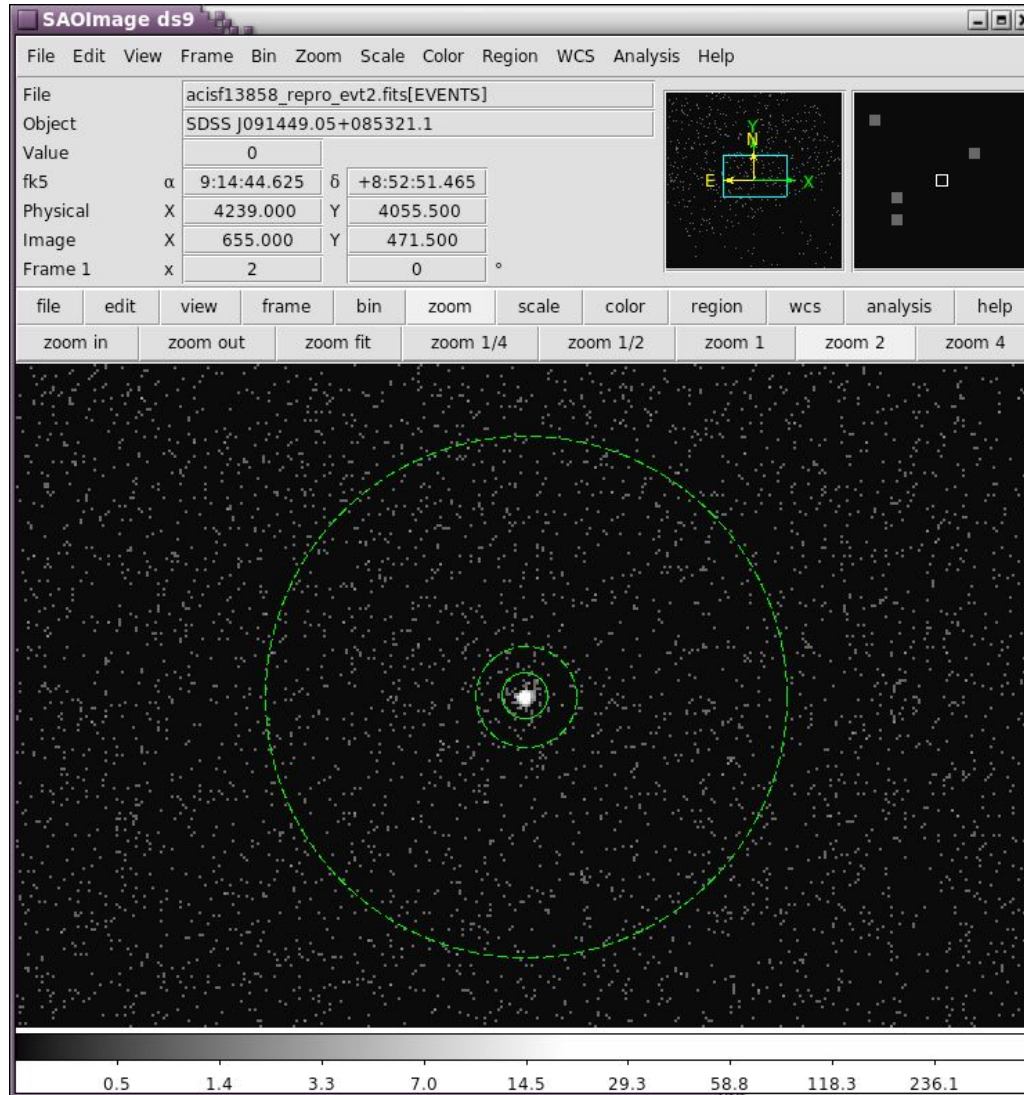
- [Analysing the ACIS Background with the "Blank-Sky" Files](#)
- [Extract a Spectrum from the ACIS Readout Streak](#)
- [Extracting a Spectrum of a Solar System Object](#)
- [A Note on HRC Spectra](#)
- [Adding Old Chandra Calibration Data to PIMMS](#)

- **Modeling & Fitting Spectral Data with Sherpa (from the Sherpa analysis threads):**

- [Introduction to Fitting PHA Spectra](#)
- [Changing the grouping scheme of a data set within Sherpa](#)
- [Introduction to Fitting ASCII Data with Errors: Single-Component Source Models](#)
- [Simultaneously Fitting Two Data Sets](#)
- [Simulating 1-D Data: the Sherpa FAKE_PHA Command](#)
- [Simulating Chandra ACIS-S Spectra with Sherpa](#)
- [Fitting PHA Data with Multi-Component Source Models](#)
- [Independent Background Responses](#)
- [Using A Pileup Model](#)

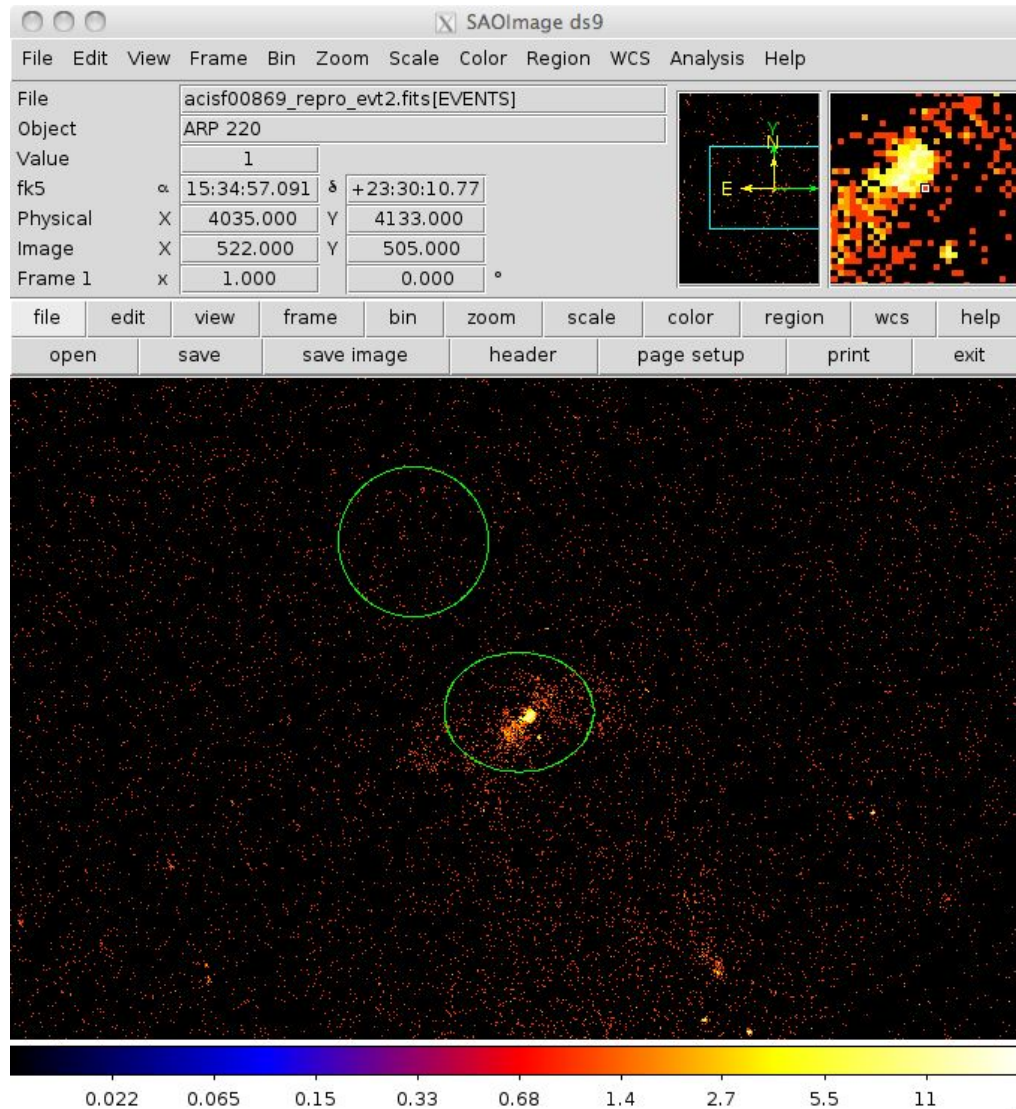
Extract Spectrum and Response Files for a Pointlike Source

<https://cxc.cfa.harvard.edu/ciao/threads/pointlike/>



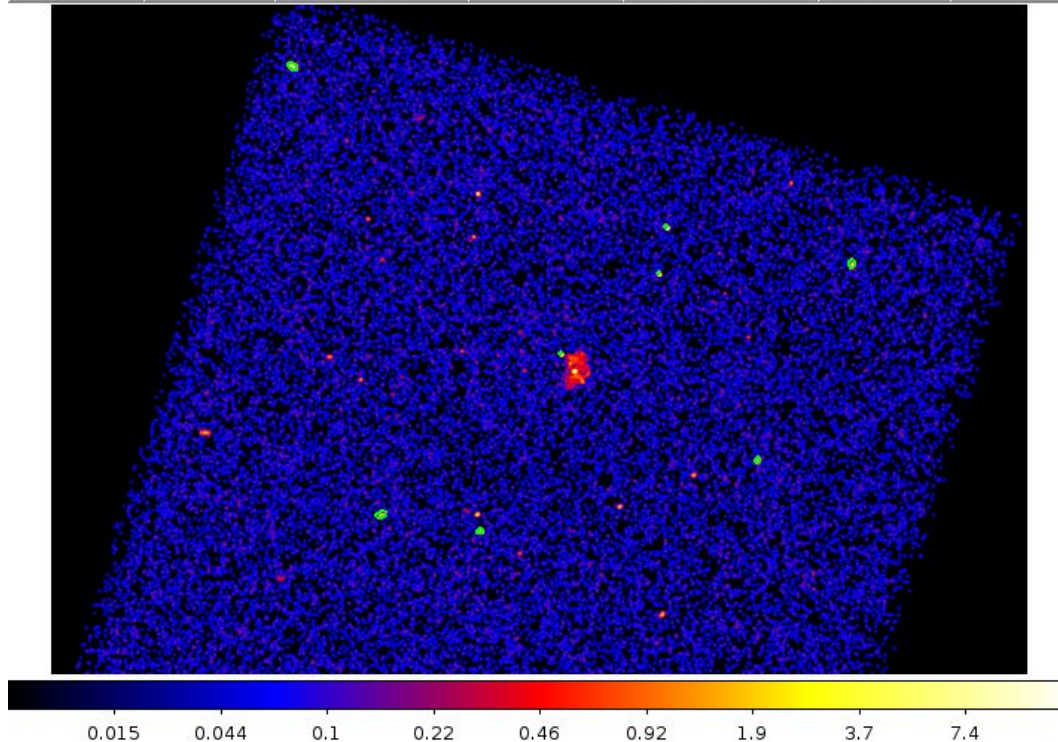
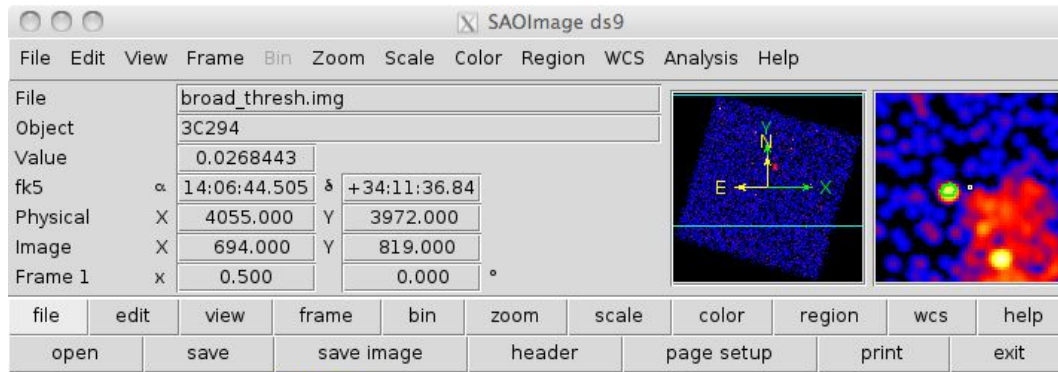
Extract Spectrum and Response Files for an Extended Source

<https://cxc.cfa.harvard.edu/ciao/threads/extended/>



Extract Spectrum and Response Files for Multiple Sources

https://cxc.cfa.harvard.edu/ciao/threads/wresp_multiple_sources/



You can achieve this goal by

- A. running *many* different tools to perform the various steps
- B. running one “script”

SPECEXTRACT

<http://cxc.harvard.edu/ciao/ahelp/specextract.html>

<http://cxc.harvard.edu/ciao/bugs/specextract.html>

However...

- Run the Step-by-Step Guide at least once!
- You also want to use the step-by-step guide as reference in case you have a special case, you want to check a specific output, etc.
- You want to understand some of the **specextract** parameters in more depth

But in general...

1. Open **ds9** and identify the extraction regions for the source and the background (**src.reg**, **bkg.reg**)
2. Set the **specextract** parameters and run the tool

specextract evt2.fits[sky=region(src.reg)] output

Main decisions a user has to make

- Is a background spectrum needed? (is the source much brighter than the background? is my source extended?) (**bkg*** parameters)
- Should the ARF be corrected for events falling outside the finite size and shape of the aperture (**correctpsf** parameter)
- Is the source extended enough or far off-axis so that the responses need to be weighted by the count distribution within the aperture? (the **weight** and **weight_rmf** parameters)
- useful but computationally expensive
- Do I want a single spectrum or many spectra (for multiple regions) (**combine** parameter)

Parameters in specextract.par

| | |
|--|--|
| infile = | Source event file(s) |
| outroot = | Output directory path + root name for output files |
| (bkgfile =) | Background event file(s) |
| (asp =) | Source aspect solution or histogram file(s) |
| (dtffile =) | Input DTF files for HRC observations |
| (mskfile =) | Maskfile (input to mkwarf) |
| (rmffile = CALDB) | rmffile input for CALDB |
| (badpixfile =) | Bad pixel file for the observation |
| (dafile = CALDB) | Dead area file (input to mkwarf) |
| (bkgresp = yes) | Create background ARF and RMF? |
| (weight = yes) | Should response files be weighted? |
| (weight_rmf = no) | Should RMF also be weighted? |
| (refcoord =) | RA and Dec of responses? |
| (correctpsf = no) | Apply point source aperture correction to ARF? |
| (combine = no) | Combine ungrouped output spectra and responses? |
| (groupype = NUM_CTS) | Spectrum grouping type (same as groupype in dmgroup) |
| (binspec = 15) | Spectrum grouping specification (NONE,1:1024:10,etc) |
| (bkg_groupype = NONE) | Background spectrum grouping type (NONE, BIN, SNR, NUM_BINS, NUM_CTS, or ADAPTIVE) |
| (bkg_binspec =) | Background spectrum grouping specification (NONE,10,etc) |
| (energy = 0.3:11.0:0.01) | Energy grid |
| (channel = 1:1024:1) | RMF binning attributes |
| (energy_wmap = 300:2000) | Energy range for (dmextract) WMAP input to mkacismf |
| (binarfcorr = 1) | Detector pixel binning factor for (arfcorr) to determine size and scale of PSF to derive aperture corrections at each energy step. |
| (binwmap = tdet=8) | Binning factor for (dmextract) WMAP input to mkacismf |
| (binarfmap = 1) | Binning factor for (sky2tdet) WMAP input to mkwarf |
| (tmpdir = \${ASCDS_WORK_PATH} -> /tmp) | Directory for temporary files |
| (clobber = no) | OK to overwrite existing output file? |
| (verbose = 1) | Debug Level(0-5) |
| (mode = ql) | |

Extract Spectrum and Response Files for a Pointlike Source

```
% pset specextract infile="acisf13858_repro_evt2.fits[sky=region(src.reg)]"  
  
% pset specextract bkgfile="acisf13858_repro_evt2.fits[sky=region(bkg.reg)]"  
  
% pset specextract outroot=spec  
  
% pset specextract correctpsf=yes  
  
% pset specextract weight=no  
  
% specextract
```

Source event file(s) (acisf13858_repro_evt2.fits[sky=region(src.reg)]):

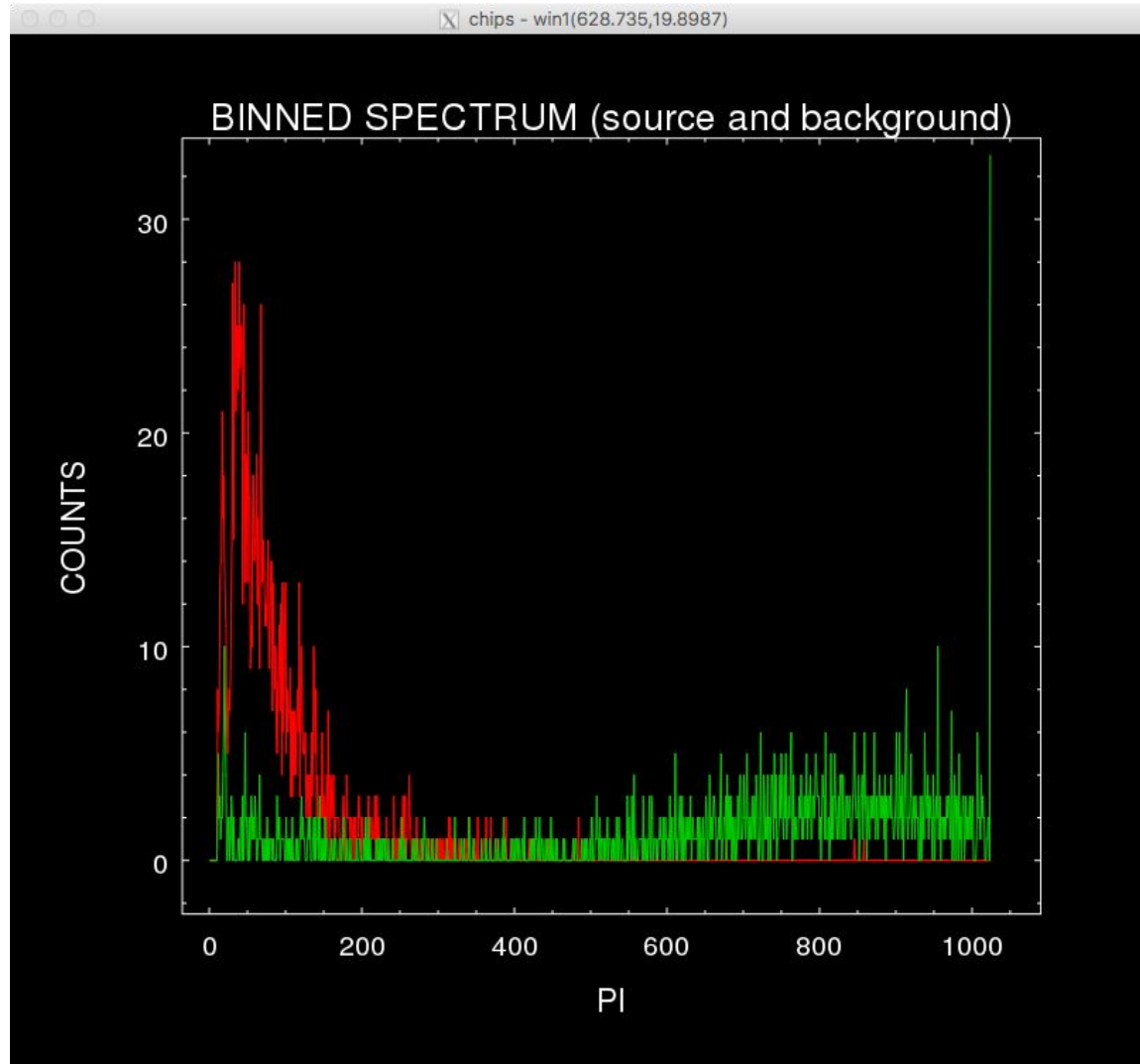
Output directory path + root name for output files (spec):

Running specextract

[...]

OUTPUT of SPEXTRACT

| | |
|-----------------|---|
| spec.pi | [source binned spectrum] |
| spec.arf | [source ARF] |
| spec.rmf | [source RMF] |
| | |
| spec.corr.arf | [corrected ARF] (if correctpsf=yes) |
| spec_grp.pi | [“grouped” source spectrum] (if grouptype is given) |
| spec_bkg.arf | [background ARF] (if bkgresp=yes) |
| spec_bkg.pi | [background binned spectrum] (if bkgfile is given) |
| spec_bkg.rmf | [background RMF] (if bkgresp=yes) |



spec.pi

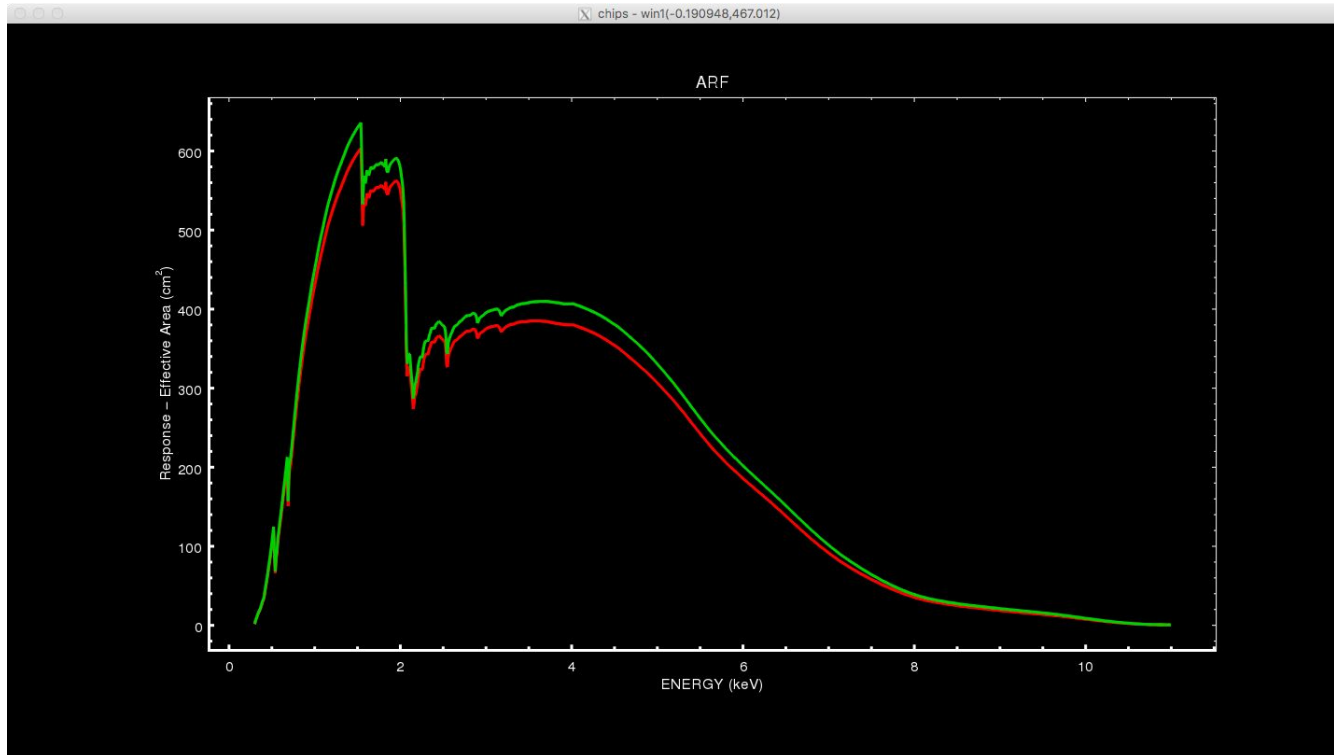
spec_bkg.pi

PI (pulse invariant) = $[(\text{energy}/14.6 \text{ eV}) + 1]$
<https://cxc.cfa.harvard.edu/ciao/dictionary/pi.html>

ARF: Auxiliary Response File

spec.arf

spec.corr.arf



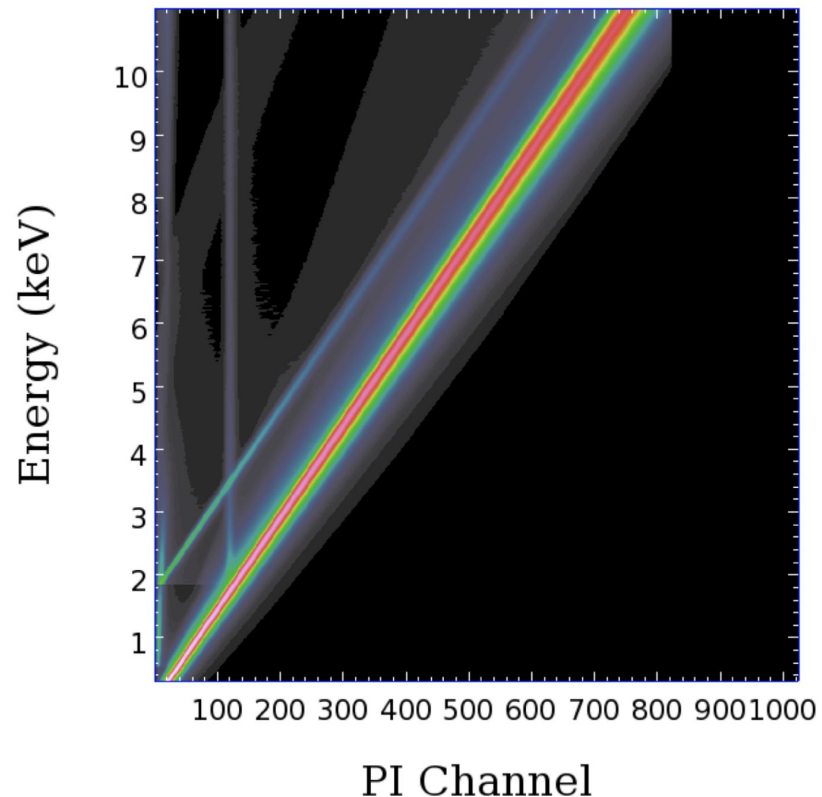
- combined telescope/filter/detector areas ("effective area") and the quantum efficiency (QE) as a function of energy. The effective area is [cm²] and the QE is [counts/photon]; they are multiplied together to create the ARF, resulting in [cm² counts/photon].
- When the input spectrum is multiplied by the ARF, the result is the distribution of counts that would be seen by a detector with perfect (i.e. infinite) energy resolution.
- The RMF (which describes the energy resolution) is then needed to produce the final observed spectrum.

RMF: Redistribution Matrix File

An image representation of spec.rmf (generated with **rmfimg**)

- Maps from energy space into detector channel (position) space.
- Since detectors are not perfect, this involves a spreading of the observed counts by the detector resolution, which is expressed as a matrix multiplication.
- For CCD detectors, such as **ACIS**, most of the response is almost diagonal, but escape peaks and low energy tails adding significant contributions.

Chandra/ACIS-I3 RMF

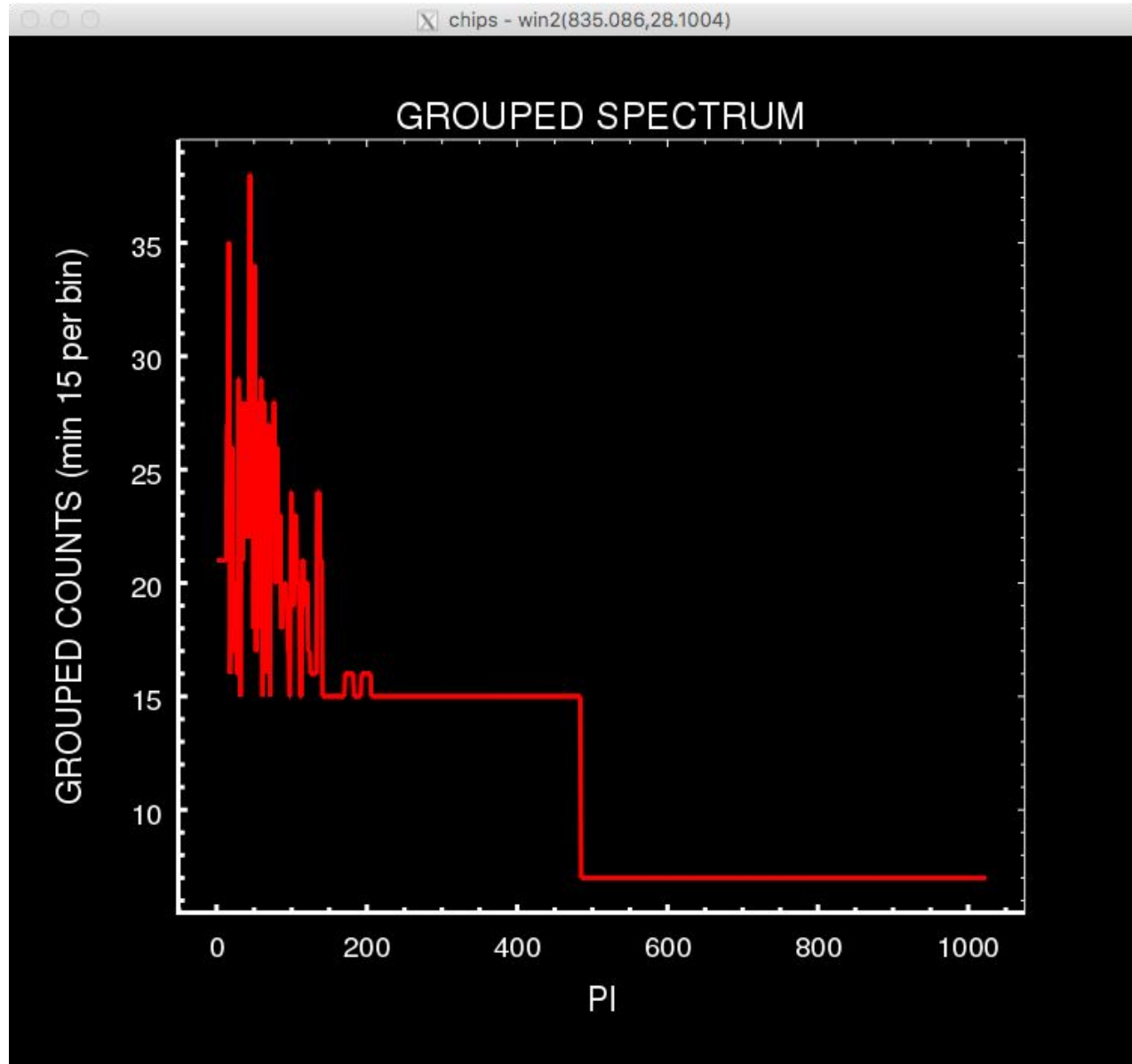


spec_grp.pi

To highlight certain features in the spectrum or certain portions of the spectrum counts can be “grouped” in arbitrary bins.

In this example each “group” contains at least 15 counts.

In the highest channels - where there are fewer counts - a single bin covers many channels.



Or...

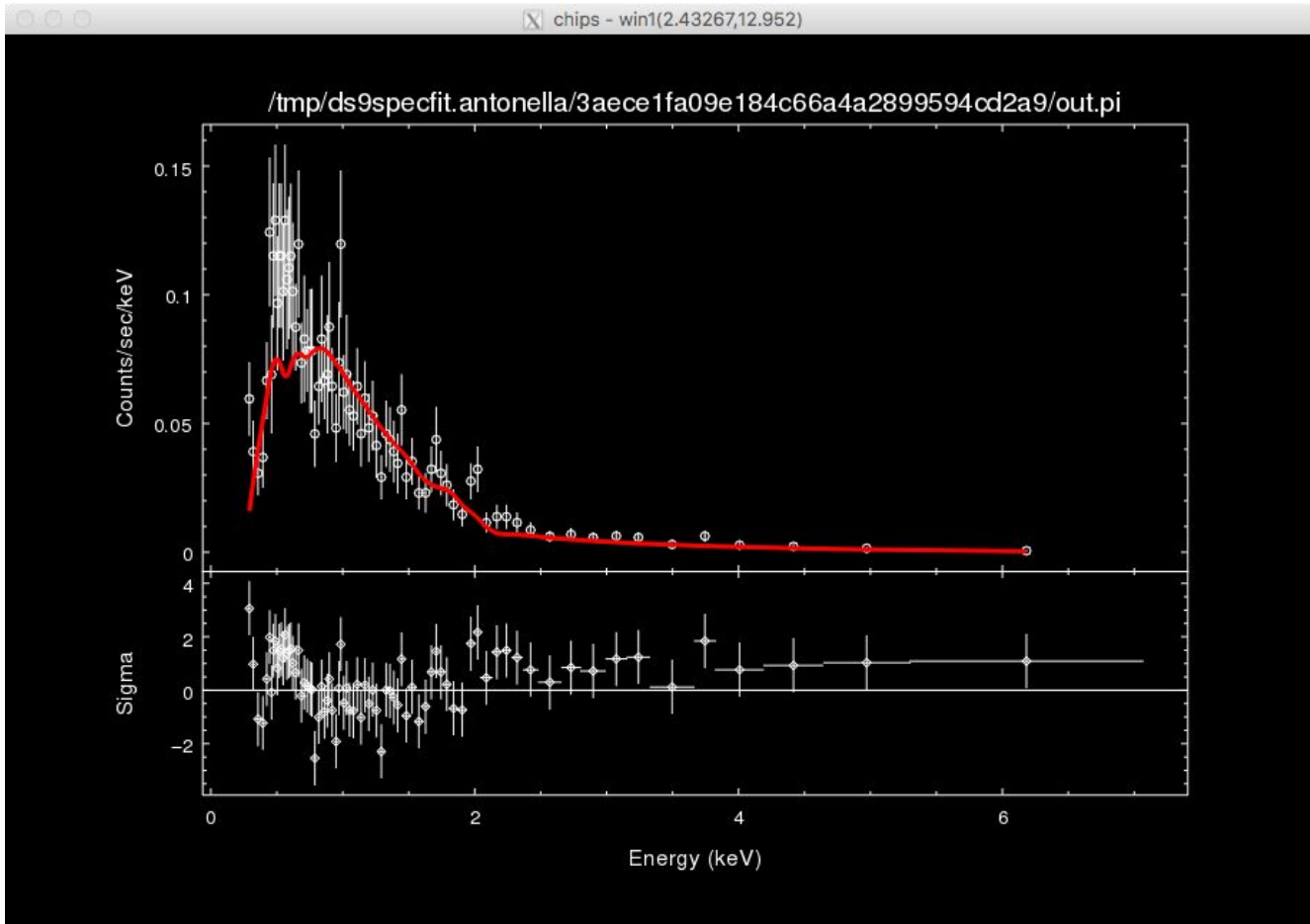
Do it all in ds9 via dax!

Quick demo

<https://www.youtube.com/user/4ciaodemos>

NEXT STEP

Go into the Sherpa application to perform modeling and fitting



2. X-RAY FLUX CALCULATION

or how bright is my source?

Luminosity (L) is the total amount of electromagnetic energy emitted per unit of time by an astronomical object
(L_x generally in [*erg/sec*])

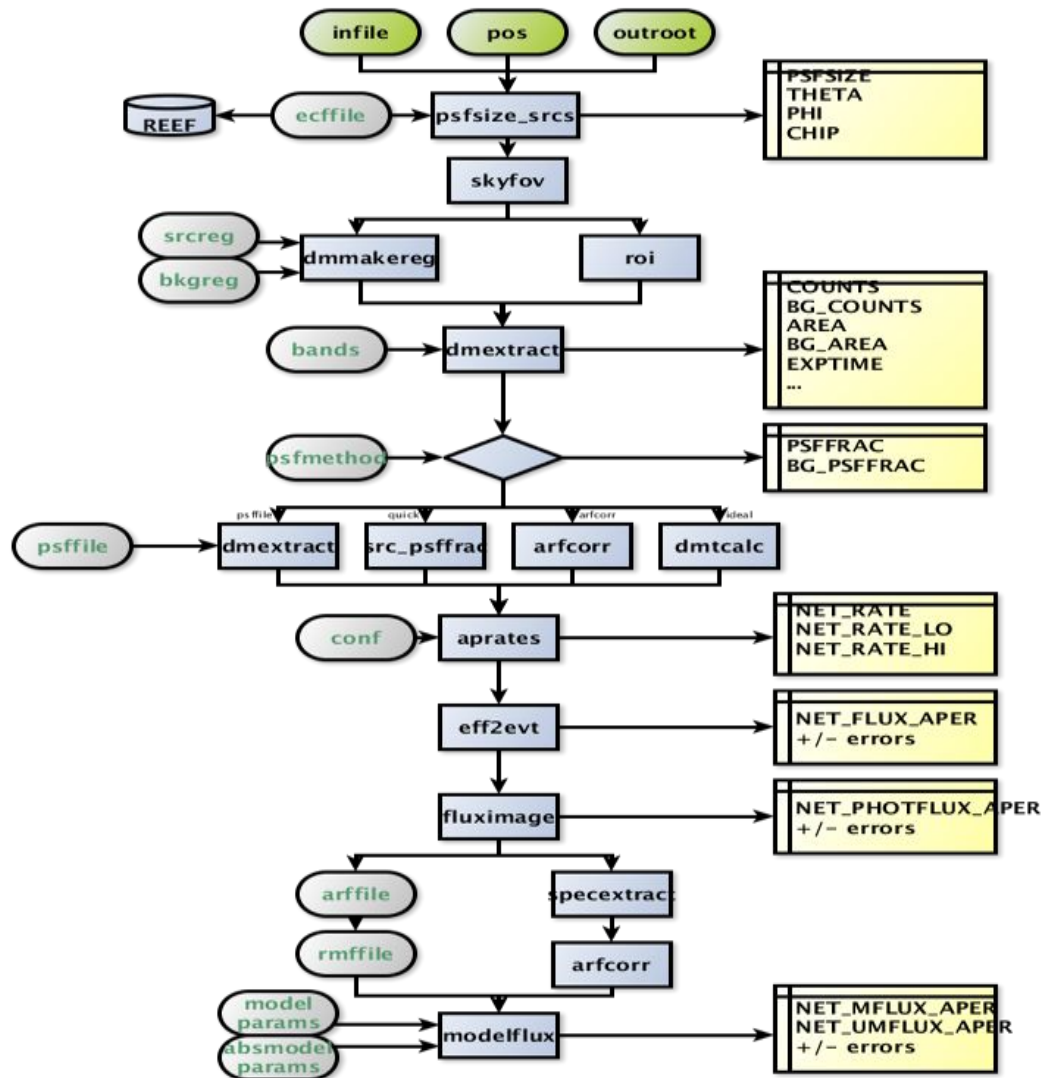
Flux (F) is the total amount of energy that crosses a unit area per unit time (F_x generally in [*erg/cm²/sec*])

$$F=L/4\pi d^2$$

So the flux of a source is one its main defining properties which (X-ray) observers want to calculate, but it is not so simple to calculate when all the instrumental and other effects are taken into account.

The most difficult part in the calculation is a correct estimate of the confidence interval.

Source Flux with `srcflux`



Source Flux with `srcflux`

```
$ srcflux myevt2.fits "03:29:29.250 +31:18:34.73" myflux
```

```
[...]
```

Summary of source fluxes

| | |
|------------------------|---|
| Position | 0.5 - 7.0 keV |
| | Value 90% Conf Interval |
| 3 29 29.25 +31 18 34.7 | Rate 0.0398 c/s (0.0381,0.0415) |
| | Flux 5.17E-13 erg/cm2/s (4.94E-13, 5.39E-13) |
| | Mod.Flux 4.38E-13 erg/cm2/s (4.2E-13, 4.57E-13) |

- Encodes the logic described in six different CIAO threads.
- Returns count rates, fluxes, and errors with all appropriate corrections.
- Can automatically determines PSF-appropriate extraction region size for source and background if user does not specify them
- Uses one of four methods to apply aperture correction
- Runs on multiple energy bands
- Accepts one position or a list
- Calculates fluxes in two different ways
- Calculates confidence intervals (including upper-limits)

On YouTube: [DAX Photometry with srcflux](#)

...and MORE

CIAO/CHANDRA on social media

<https://twitter.com/chandraCIAO>

<https://www.facebook.com/ChandraCIAO/>

<https://www.youtube.com/user/4ciaodemos>

<https://twitter.com/chandraCDO>

<https://www.facebook.com/chandraCDO>

<https://twitter.com/chandraarchive>

If you would like to subscribe to receive future Chandra Announcements, send any email message to the address:

chandra-announce+subscribe@cfa.harvard.edu

CHANDRA PROPOSALS

Call For Proposal ~December 15

Proposal Deadline ~March 15

THIS YEAR: Due Date: 16 March 2021, 6 p.m. EDT

Peer Review ~June

Results ~July

Observations start ~Nov

<http://cxc.harvard.edu/proposer/>



Chandra Proposal Information

- [Submit a Proposal \(CPS\)](#)
- [What's New this Cycle?](#)
- [Call for Proposals \(CfP\)](#)
- [Proposers' Observatory Guide \(POG\)](#)
- [FAQ](#)
- [DDT & TOO](#)
- [HelpDesk](#)

Announcements

12/16/20 The Cycle 23 deadline is **16 March 2021 at 6PM (US Eastern Daylight Time)**.

12/16/20 Cycle 23 CfP and POG released. See [What's New this Cycle?](#)

Proposal Submission

- [What's New this Cycle?](#) New
- [Call for Proposals \(CfP\)](#) New
- [Submit a Proposal \(CPS\)](#)
- [Guide to Proposing with CPS](#)
- [Science Justification LaTeX Template](#)
- [Generating a PDF Science Justification](#)
- [Team Expertise LaTeX Template](#)
- [DDT & TOO Requests](#)

Instrument & Observatory Information

- [Proposers' Observatory Guide \(POG\)](#) New
- [Chandra Instruments & Calibration](#)
- [Effective Area General Information](#)
- [Effective Area Plots](#)
- [Grating RMFs & ARFs](#)
- [ACIS Aimpoint & Off-Axis RMFs/ARFs](#)
- [PSF Central](#)
- [PSF General Information](#)

Count Rate Estimation & Simulators

- [Overview of proposal tools](#)
- [PIMMS: count-rate & flux prediction \(online version\)](#)
- [PIMMS: count-rate & flux prediction \(command-line version\)](#)
- [MARX: Chandra data simulator](#)
- [Sherpa: CIAO spectral analysis & simulation package](#)
- [XSPEC: HEASARC spectral analysis & simulation package](#)
- [WebSpec: web version of XSPEC](#)
- [Colden: NH Calculator](#)

Targets Observed & Scheduled with Chandra

- [ChaSeR: query Chandra observations](#)
- [Chandra Source Catalog \(CSC\)](#)
- [Accepted Proposal Search Tool](#)
- [Target Lists & Schedules](#)
- [Chandra Cool Targets \(CCTs\)](#)

Observation Visualization & Planning

- [ObsVis: visualizing Chandra field of view](#)
- [PRoVis: pitch, roll & visibility by date for celestial target](#)
- [PSF viewer: visualizing the on-/off-axis PSF behavior](#)
- [Spectrum Visualization Tool](#)
- [Precess: astronomical coordinate conversion tool](#)
- [Dates: calendar time & conversion tool](#)
- [Coordinate systems used in proposal tools](#)
- [Timescales used in proposal tools](#)
- [Future Chandra Orbits](#)
- [CIAO: Chandra data analysis package](#)

Cost Proposals & Grant Info

- [General grant information with Terms & Conditions](#)
- [Instructions for Stage-2 Cost Proposal Submission](#)
- [Keeping Track of Chandra Publications](#)

Call For Proposal (CfP)

<http://cxc.harvard.edu/proposer/CfP/>

Proposers' Observatory Guide (POG)

<http://cxc.harvard.edu/proposer/POG/>

Frequently Asked Questions

<http://cxc.harvard.edu/proposer/faqs.html>