

2014 Senior Review

CHANDRA X-RAY OBSERVATORY

Jonathan McDowell

CXC Science Data System

2014 March 24

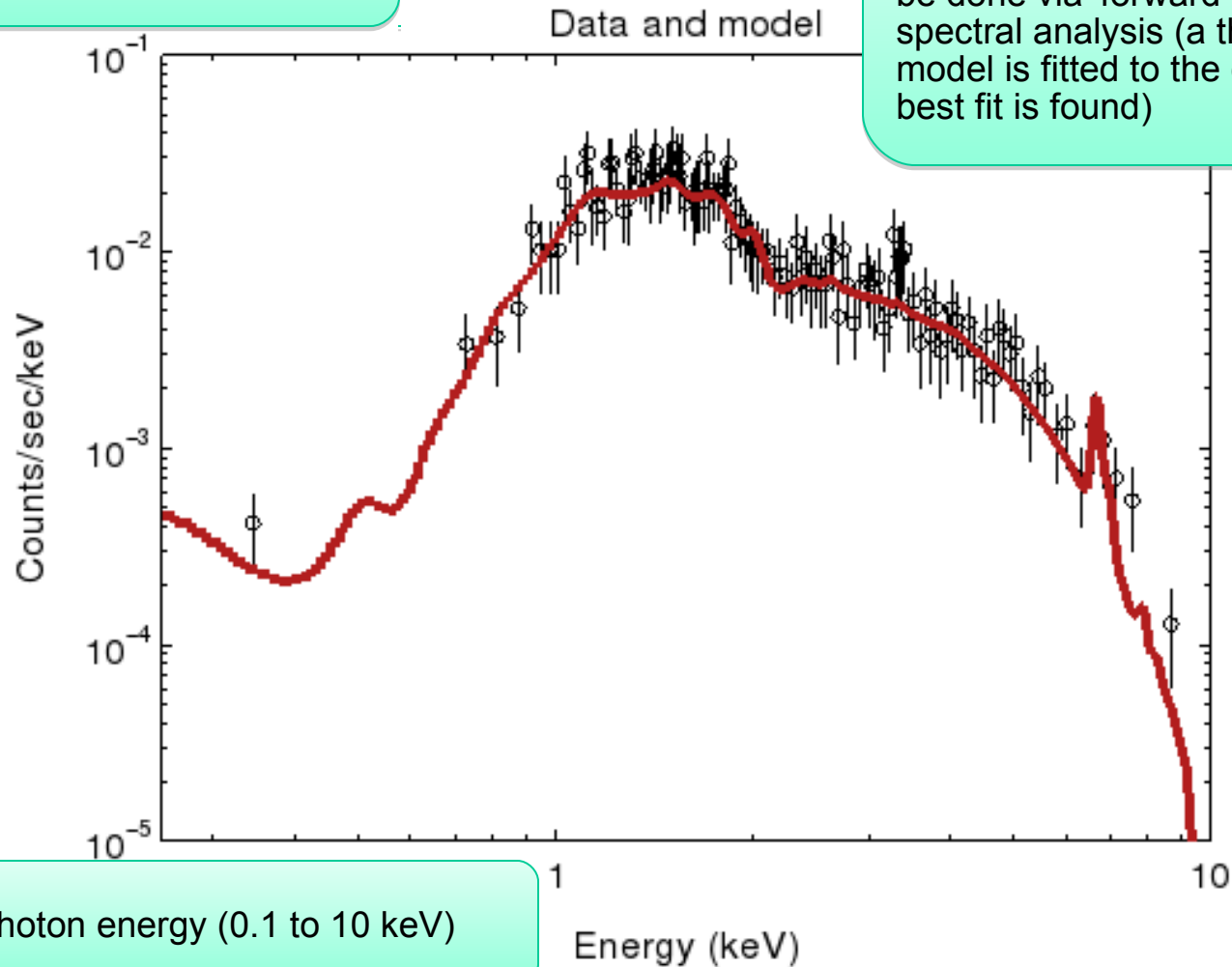


Chandra Interactive Analysis of Observations

Complexities in X-Ray and Chandra Data Analysis

In Poisson statistic regime because of the small number of photons

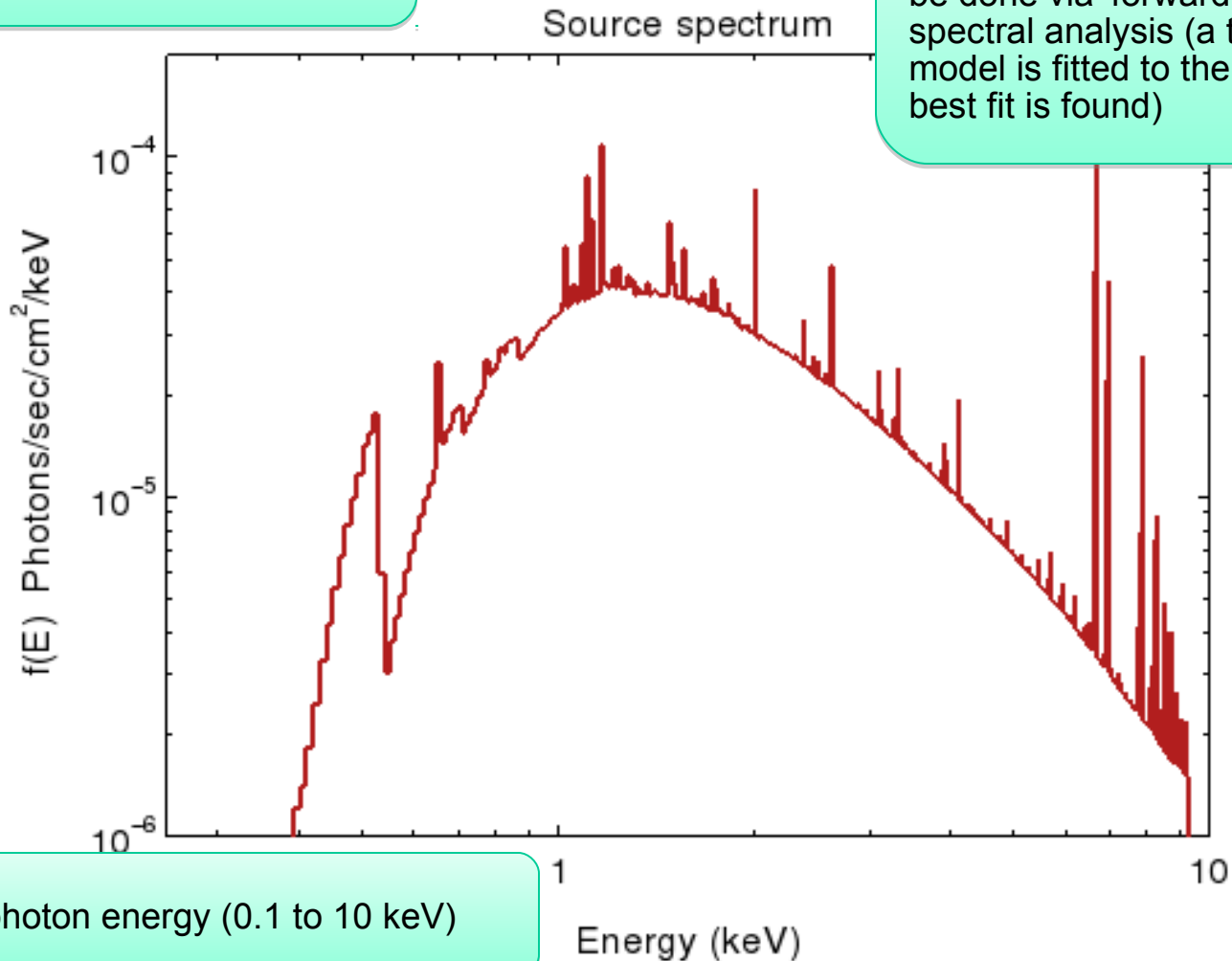
Imaging data has limited energy resolution and modeling can only be done via 'forward folding' spectral analysis (a theoretical model is fitted to the data until the best fit is found)



Complexities in X-Ray and Chandra Data Analysis

In Poisson statistic regime because of the small number of photons

Imaging data has limited energy resolution and modeling can only be done via 'forward folding' spectral analysis (a theoretical model is fitted to the data until the best fit is found)



2 decades of photon energy (0.1 to 10 keV)

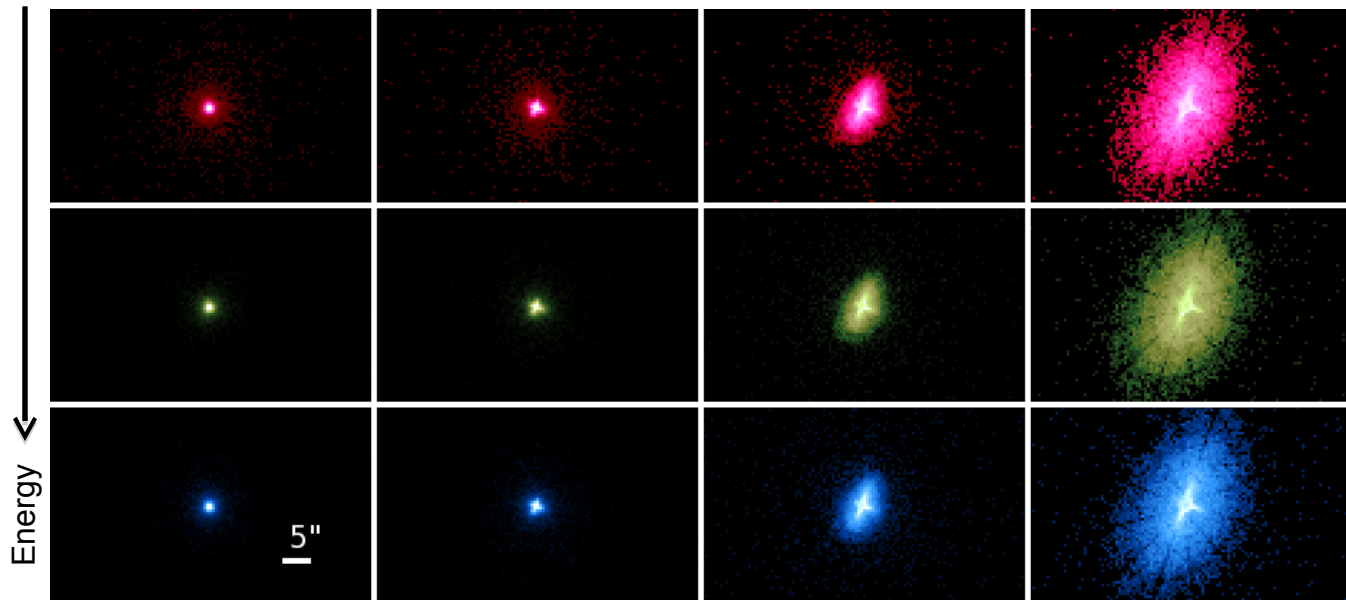
Complexities in X-Ray and Chandra Data Analysis

Every aspect of the observation varies with

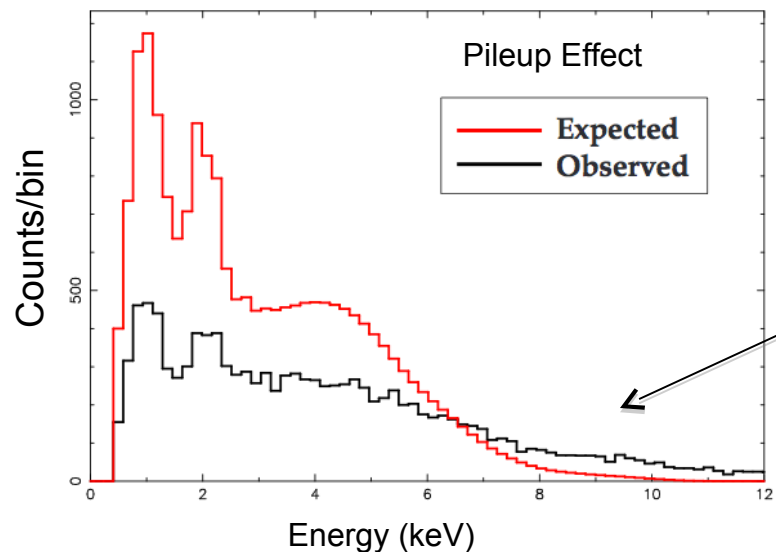
- energy
- position
- time

(e.g. image sharpness, sensitivity, instrumental energy scale)

The Chandra PSF



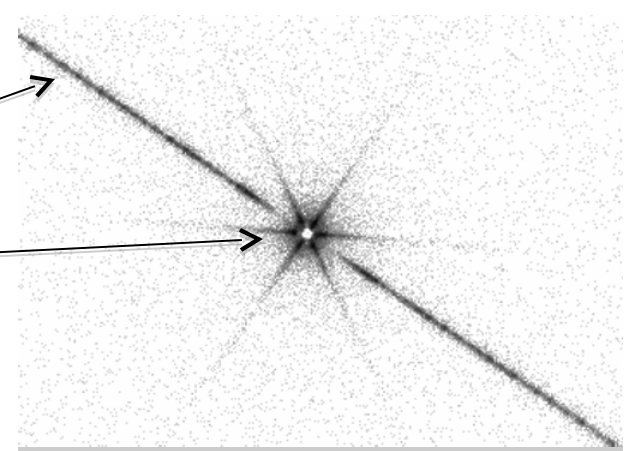
Q0836+7104 predicted vs. observed



Specific instrumental effects eg.

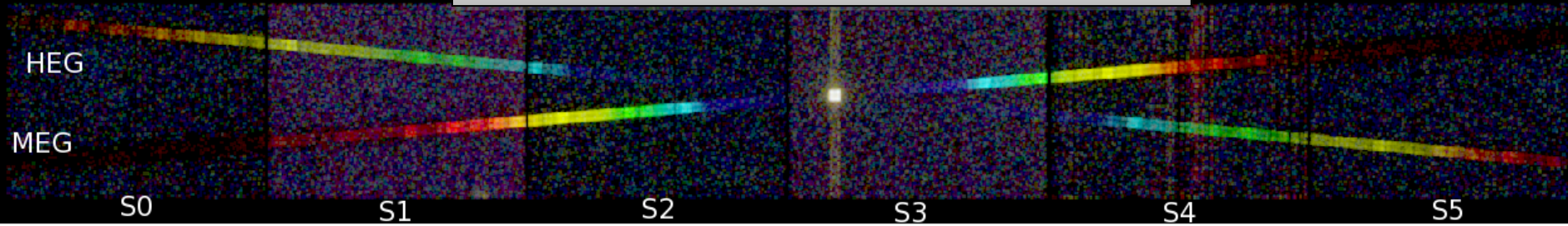
readout streak

pileup - two or more photons detected as single event

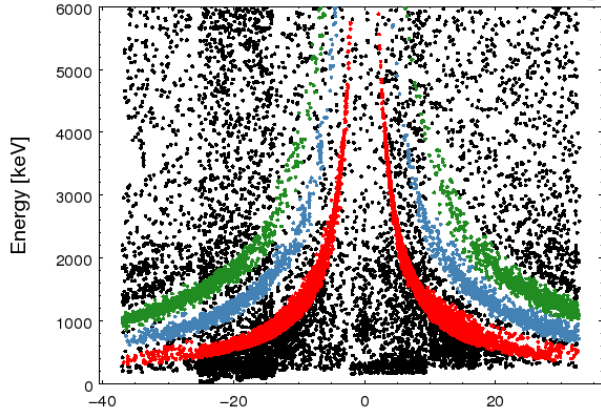


Complexities in X-Ray and Chandra Data Analysis

Capella: ACIS-S + HETG Raw Detector Image Color Coded

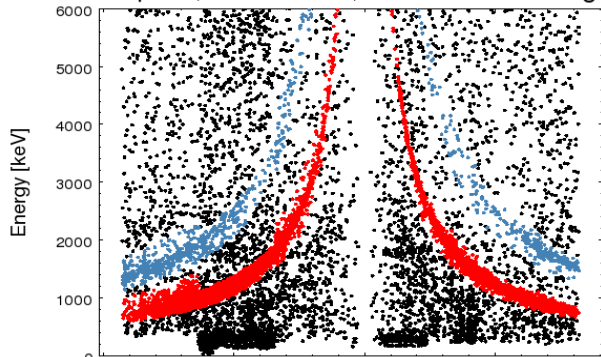


Capella, ObsId 9638, MEG Order Sorting



tg_mlam (order * wavelength [Angstrom])

Capella, ObsId 9638, HEG Order Sorting



tg_mlam (order * wavelength [Angstrom])

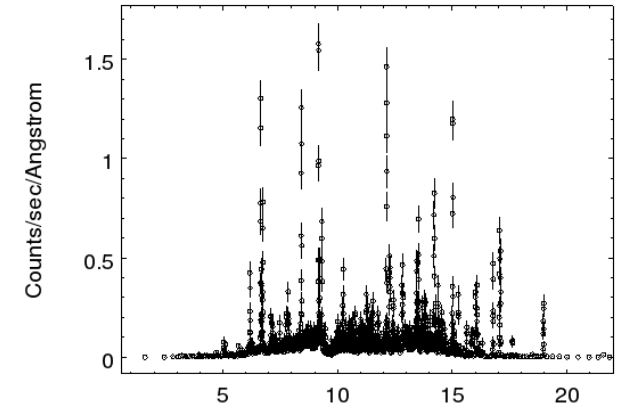
overlapping spectral orders
separation

complicated geometry –
need precise zero order
location

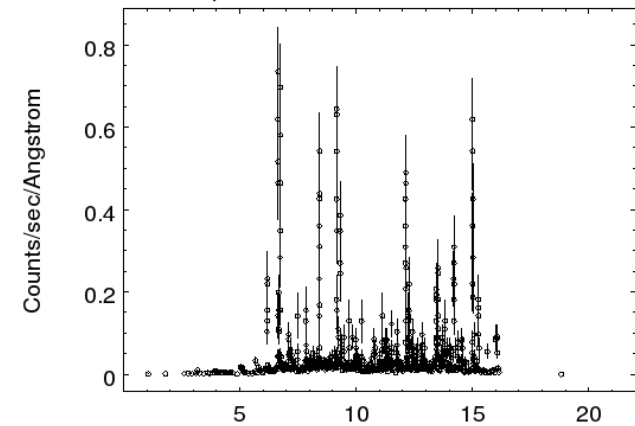
wavelength scale sensitive
to details of chip geometry

background different on
each chip

Capella, MEG +1, ObsID 9368



Capella, HEG +1, ObsID 9368



Chandra Users

We support users of Chandra data from around the world

- Both experienced and novice X-ray astronomers
- their graduate and undergraduate students
- archival users, many new to X-ray/Chandra data
- users with a large amount of resources and users from smaller countries and institutions

users with different science goals ...

- estimate the X-ray flux of my favorite object
- model fitting to spectrum to get velocity (line width) of material
- model fitting spectrum to find gas temperature, pressure in 100 different galaxies
- assess reality of a marginal detection (3 photons at the position of a gamma-ray burst)

.... and with widely varying datasets

- 20 minutes to 2 days (or even 1 month for coadded data)
- different configurations (chips, subarrays, gratings, special instrument settings)
- different targets (pointlike stars and quasars, fuzzy galaxies and clusters, moving solar system objects)

All this requires a wide variety of specialized software AND careful documentation



CIAO – Chandra Interactive Analysis of Observations

- A set of Unix command line tools and Python applications
- Shares code with standard processing pipeline
- Allows Chandra instrument specific data reduction
- Tailored to specialized X-ray astronomy data analysis, but not specific to Chandra
- Coded with attention to standards and interoperability so that generic tools can be (and are!) used for XMM, Nustar, and even optical and radio data (e.g. multiwavelength analysis)
- Easy for beginners, yet powerful for advanced users
- Linux and Mac, annual releases
- Installed 1200+ times per year (single users to large institutions)

CIAO: X-ray Data Analysis Software – CIAO 4.6

CXC Home Proposer Archive Data Analysis

Instruments & Calibration For the Public

Google™ Custom Search Search ×
Search the CIAO website or [contact the CXC HelpDesk](#)

Last modified: 28 January 2014

CIAO
X-RAY OBSERVATORY

CIAO 4.6.1 Homepage

Introduction
[Welcome](#)
[Tools & Applications](#)
[CIAO News](#)
Updated: 04 Feb 2014

Data Analysis
[Analysis Guides](#)
[Science Threads](#)
[Why Topics](#)
[Help Pages \(AHELP\)](#)
[Video Demos and Tutorials](#)

Documentation
["Watch Out" List](#)
[Bug List](#)
[Frequently Asked Questions \(FAQ\)](#)
[Manuals & Memos](#)
[Dictionary](#)
[Publications](#)
[Download the Website](#)

Download CIAO
[Download CIAO 4.6](#)
[Download CALDB](#)
[Scripts & Modules Package](#)
[System Requirements](#)
[Installation Instructions](#)
[Platform Support](#)
[Release Notes](#)
[Version History](#)
[Other Analysis Software](#)

Sherpa (Modeling and Fitting)
[Sherpa website](#)
[Threads](#)
[Help Files](#)

ChIPS (Plotting Package)
[ChIPS website](#)
[Threads](#)
[Help Files](#)

Scripting in CIAO
[Introduction](#)
[Modules](#)
[Running Tools from Python](#)

Data Products
[Data Basics](#)
[Data Products Guide](#)

CIAO

Chandra Interactive Analysis of Observations

from "s'sciavo", "I am your servant" in Venetian dialect:

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

Quick CIAO links: [Download CIAO](#) | [Science Threads](#) | [Help Files](#) | [Scripts](#)
Related CXC sites: [ChIPS](#) | [Sherpa](#) | [FSEs with ChaRT](#) | [CALDB](#)
[Chandra Source Catalog](#) | [TGCat: Chandra Gratings Catalog](#)

Install CIAO 4.6.1 & CALDB 4.5.9

Read the [CIAO 4.6.1 release notes](#) for detailed information on this release, including [How CALDB 4.5.9 Affects Your Analysis](#).

[Subscribe to the CIAO News RSS feed](#)

I've never used CIAO before. Where should I begin?

[Welcome to CIAO](#)
[Introduction to the Tools & Applications](#)

[Download CIAO 4.6.1](#)
[Installing CIAO 4.6.1 thread](#)

[Introductory Science Threads](#)

[Analysis Guides](#)

Has a new version of CIAO or CALDB been released? What has changed in the site recently?

[What's New](#)
["Watch Out" List](#)
[Version History](#)
[CIAO Release Notes](#)
[CALDB Release Notes](#)

CIAO isn't working correctly - I need help!

[CIAO Software Help Pages](#)
[Frequently Asked Questions \(FAQ\)](#)

CIAO: supports users from proposal to publication

Tools for proposal planning

Assessing feasibility and examining Chandra field-of-view



e.g. *obsvis*, *colden*

Tools for data discovery and access

Command line programs to complement the Archive and Catalog searches



e.g. *find_chandra_obsid*,
download_chandra_obsid,
search_csc

Tools for data inspection and exploration

What is this dataset? How many photons? What instrument configuration? Quick look visualization...



e.g. *ds9*, *prism*, *dmlist*,
dmstat, *dmcopy*

Tools for data reduction

Apply latest calibrations to observation
Locate sources and measure their properties (position, brightness)
For each source, generate tailored calibration files (e.g. spectral calibration)



e.g. *dmextract*,
wavedetect, *specextract*,
srcflux, *fluximage*

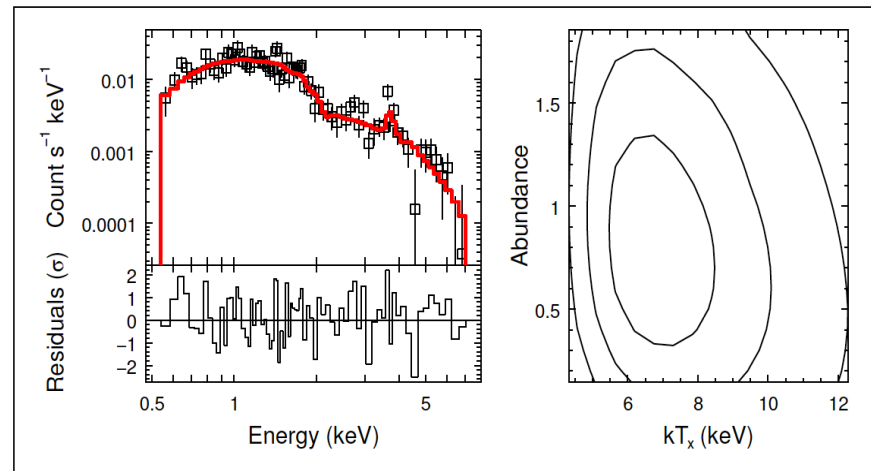
Tools for interactive data analysis

'sherpa' – 1D and 2D modeling and fitting
Python environment – familiar to the new generation of astronomers and used in other missions



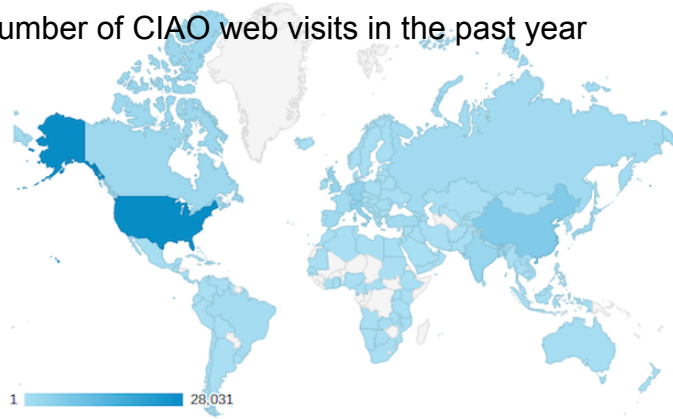
Tools to prepare for publication

'ChIPS' – publication quality graphics integrated with the analysis system



Documentation and Community Support

number of CIAO web visits in the past year



Documentation

- Science-task-oriented step-by-step, end-to-end analysis 'threads' (170+)
- 1000 help files for individual tools, concepts
- Over 2000 web pages including FAQ, plot galleries, dictionaries, caveats and bug notes etc.
- YouTube tutorials

Helpdesk

- About 450 CIAO tickets last year from all over the world
- Median time to respond 1 hour, to resolve 1 day
- Experienced help desk staff backed up by SDS scientists and other CXC staff when needed



One-on-One Community Support

- Chandra/CIAO Workshops hosted at CFA
- CIAO education and support at relevant meetings (e.g. X-ray schools, AAS)
- Undergraduate training via NSF REU program at SAO

You Tube Tutorials



4ciaodemos



U



CIAO



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26

Home

Videos

Playlists

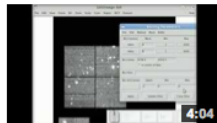
Discussion

About



SAOImage ds9

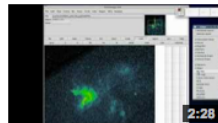
Examples of using SAOImage ds9 within CIAO.



4:04

[How to load images and event files into ds9](#)

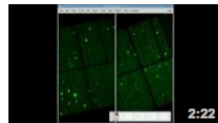
by 4ciaodemos 623 views



2:28

[Customizing the ds9 user interface](#)

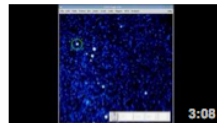
by 4ciaodemos 210 views



2:22

[Using multiple frames with ds9](#)

by 4ciaodemos 207 views



3:08

[Setting Source Properties in ds9](#)

by 4ciaodemos 190 views



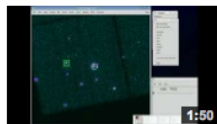
2:22

[Tri Color Images in ds9](#)

by 4ciaodemos

CIAO in ds9: dax

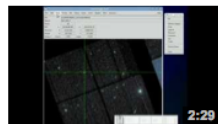
CIAO ds9 analysis extensions.



1:50

[Basic Statistics](#)

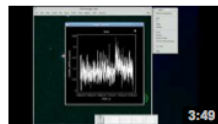
by 4ciaodemos 228 views



2:29

[Getting Chandra coordinates within ds9](#)

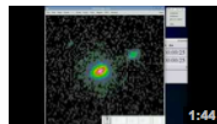
by 4ciaodemos 101 views



3:49

[Extracting Spectra, Light Curves, and Radial Profiles](#)

by 4ciaodemos 518 views



1:44

[CIAO Source Detect Tools](#)

by 4ciaodemos 129 views



1:44

[Image Processing](#)

by 4ciaodemos

Recent uploads



6:39

[Chandra Aperture Photometry](#)

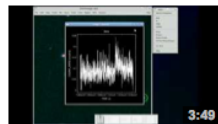
30 views 3 months ago



4:58

[Spectral Fitting from ds9](#)

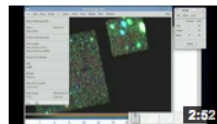
33 views 3 months ago



3:49

[Extracting Spectra, Light Curves, and Radial Profiles](#)

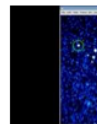
518 views 1 year ago



2:52

[Tri Color Images in ds9](#)

271 views 1 year ago



2:22

[Setting Source Properties in ds9](#)

190 views 1 year ago

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Maintenance and Responding to Change

Critical maintenance

updates to keep up with changes in spacecraft and/or instruments



eg. modify analysis tools to support temperature variation, combining shorter observations

support changes in users' hardware and operating systems



eg. Dec Alpha to Solaris to Linux to Mac

Address users' needs if/as resources allow...

support changes in users' needs (2014 is not 1999), incorporate changes in scientific approaches and computational approaches; compatibility with newer missions



eg. Bayesian methods, parallel processing

incorporate improved knowledge of best practices and special cases – enhance science, minimize mistakes



eg. applying custom background region for grating spectra

identify and prioritize areas needing additional support



eg. merging datasets split due to new thermal constraints
analysis tools for extended sources
support for alternate instrument configurations (e.g. continuous clocking readout mode)

CIAO scripts: analysis simplified

Recent emphasis on high level programs with easy interfaces – particularly helpful for users who are not X-ray astronomy specialists.

Wrap laborious thread analysis steps with a single command line script

Handle the various special cases by inspecting the metadata in the data files

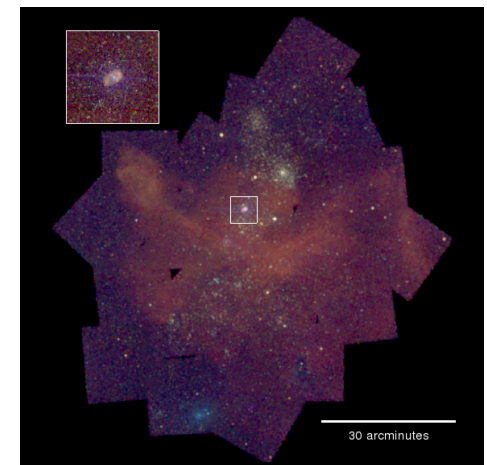
Scripts have parameters which allow the expert user to tune them

This new suite of scripts makes analysis quicker

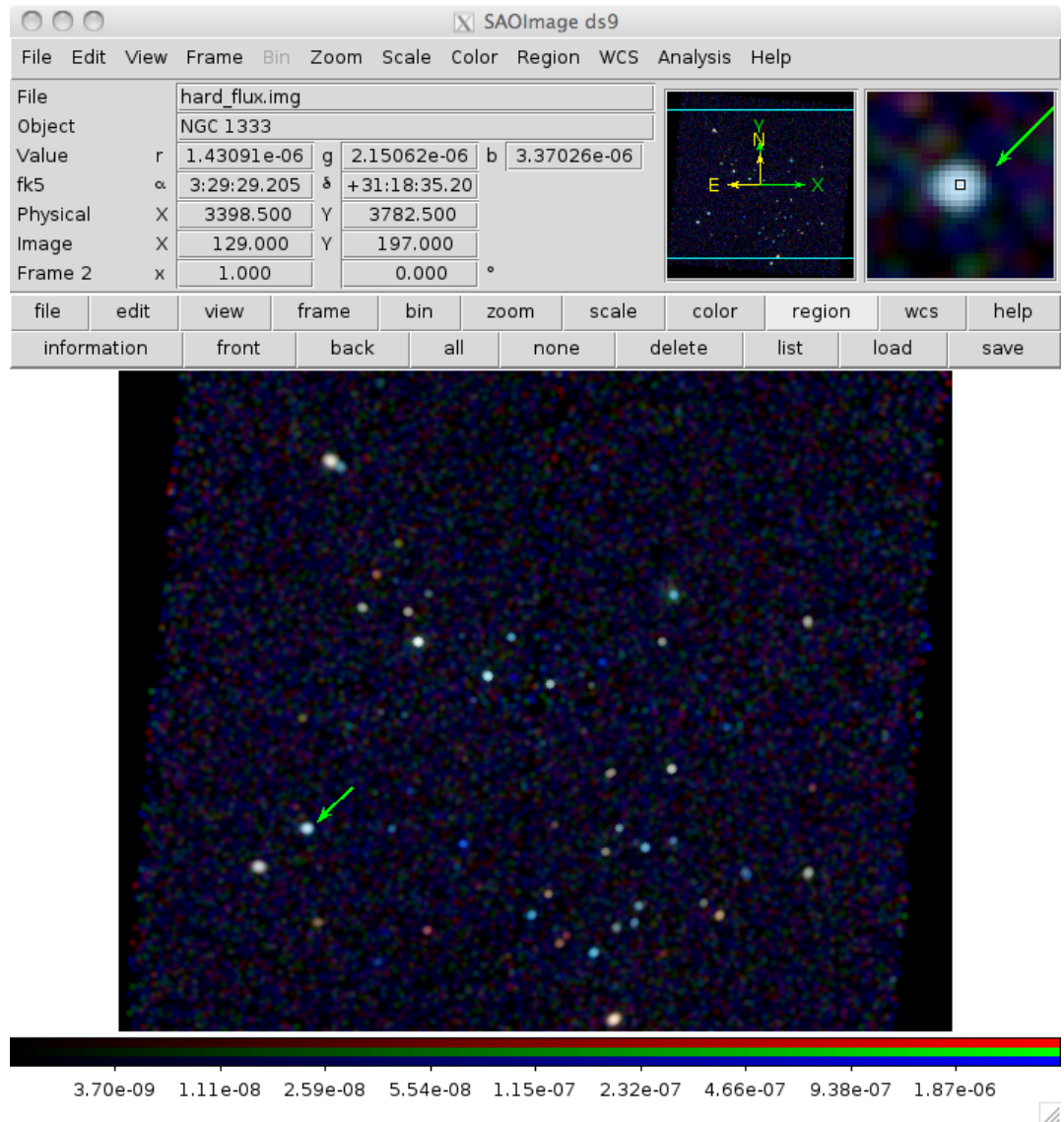


one script

Two examples: srcflux and merge_obs



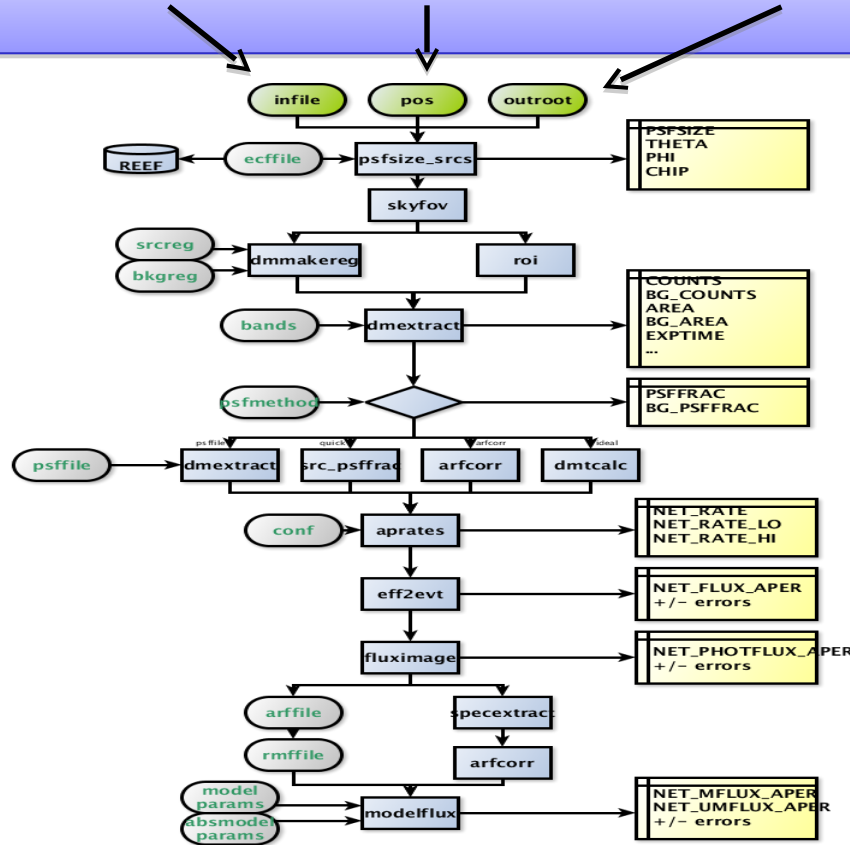
Calculating Source Flux



What is the X-ray flux of this source?

Calculating Source Flux

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



Encodes the logic described in six different CIAO threads.

Return count rates and fluxes and errors with all appropriate corrections.

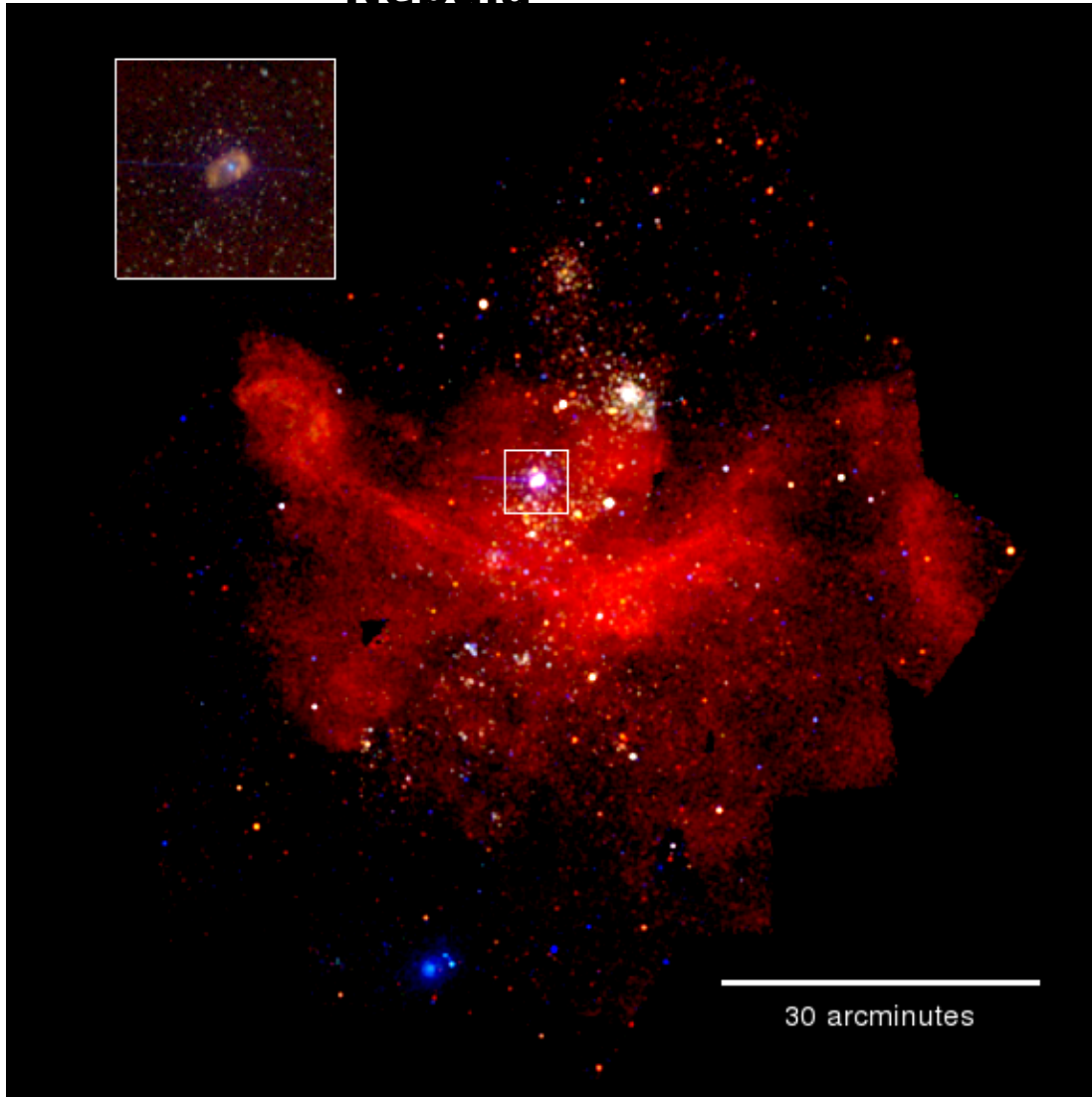
Uses many tools written for the Chandra Source Catalog.

Complementary to it for special cases and fields not covered by the catalog.

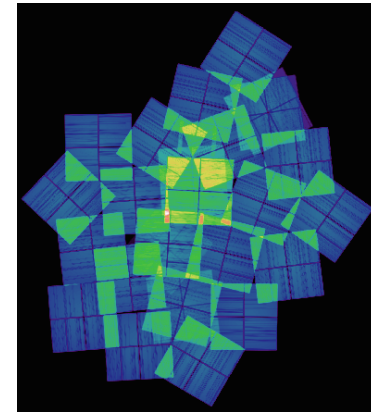
Summary of source fluxes

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)

Eta Carinae Nebula



Three-color image of 41 combined ACIS-I observations (0.5-7 keV)



Produced with four “simple” commands

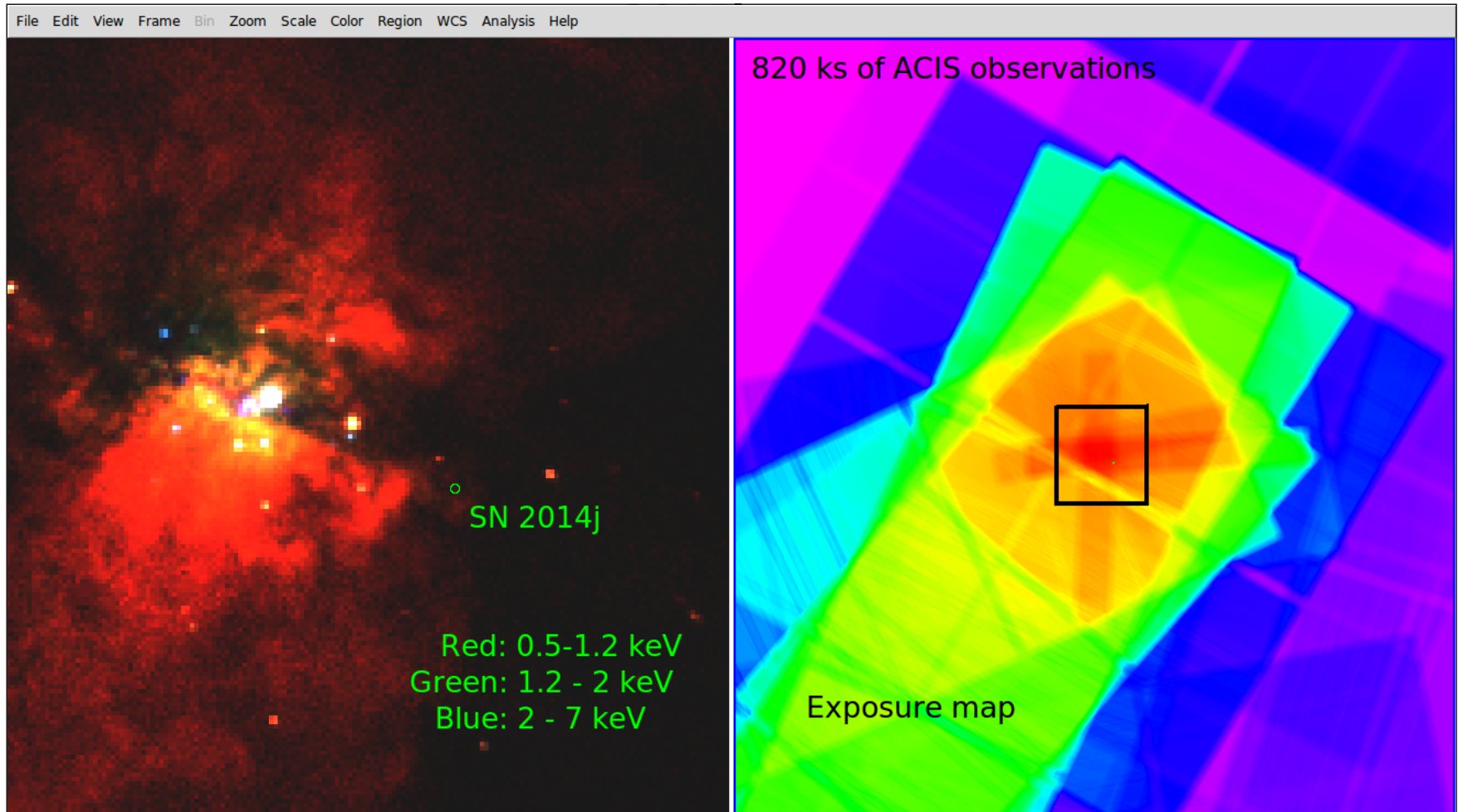
- 1.find and download the data
- 2.reprocess the observations
- 3.create the combined, exposure corrected images

```
%merge_obs “*evt2.fits”  
combined_data
```

- 4.create the three-color image to display

Merging Observations

M82 - SN

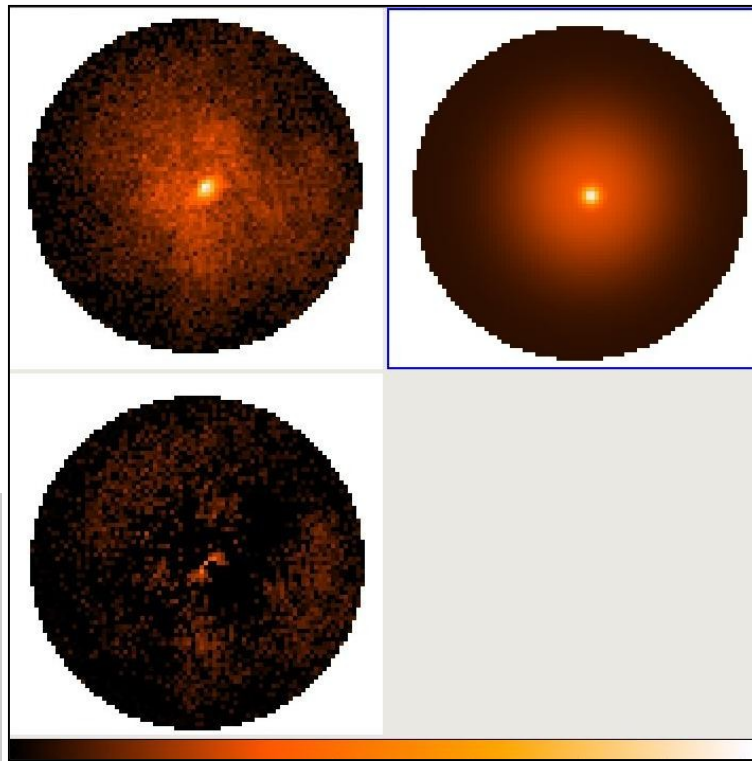
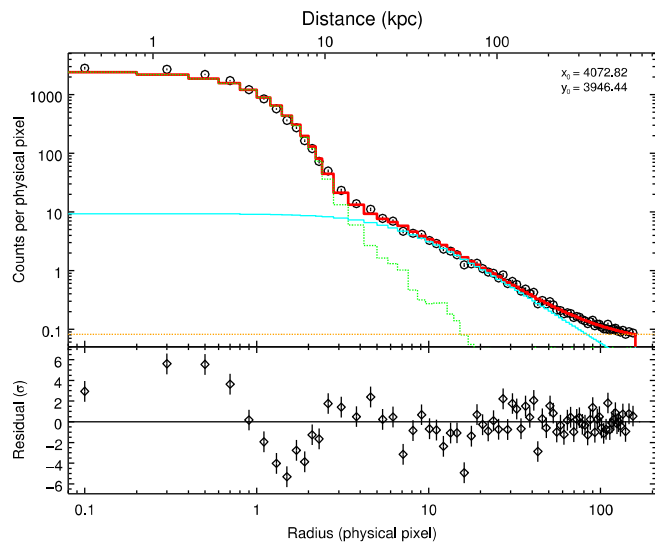


Combined 21 ACIS observations from 1999 to 2013
Created three color closeup image of central region
Allows setting upper limit to flux at SN location (ATel #5798)

Sherpa: Modeling and Fitting in Python

Sherpa

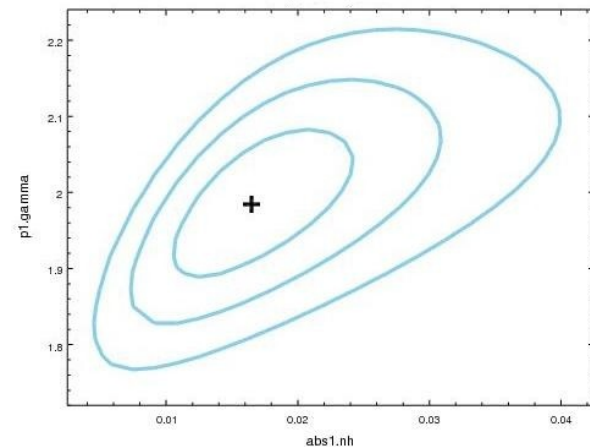
Modeling and fitting for 1-D and 2-D datasets **in any waveband** including: spectra, images, surface brightness profiles, light curves, general ASCII data.



Coded in a Python environment – familiar to the new generation of astronomers and used in other missions

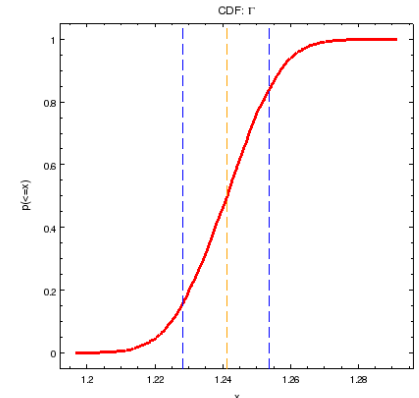
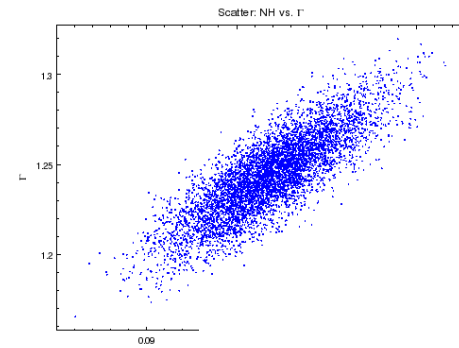
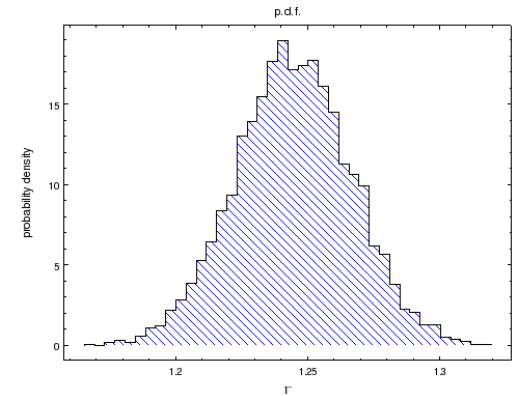
Model Poisson and Gaussian data

Calculate confidence levels on the best-fit model parameters

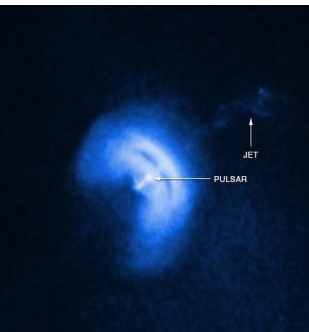
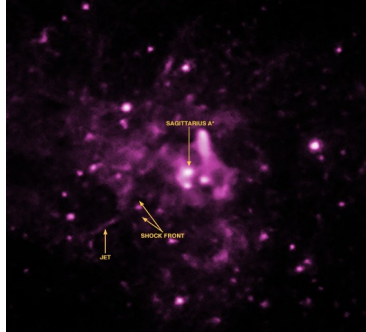
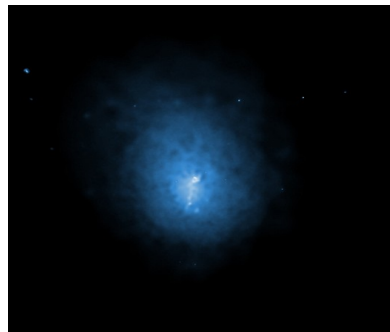
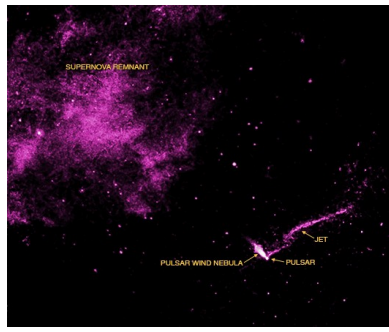
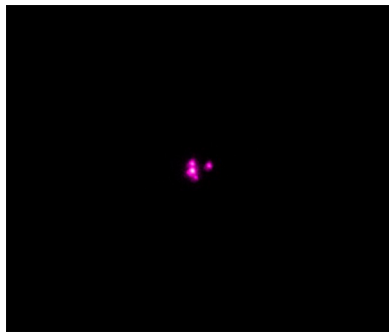
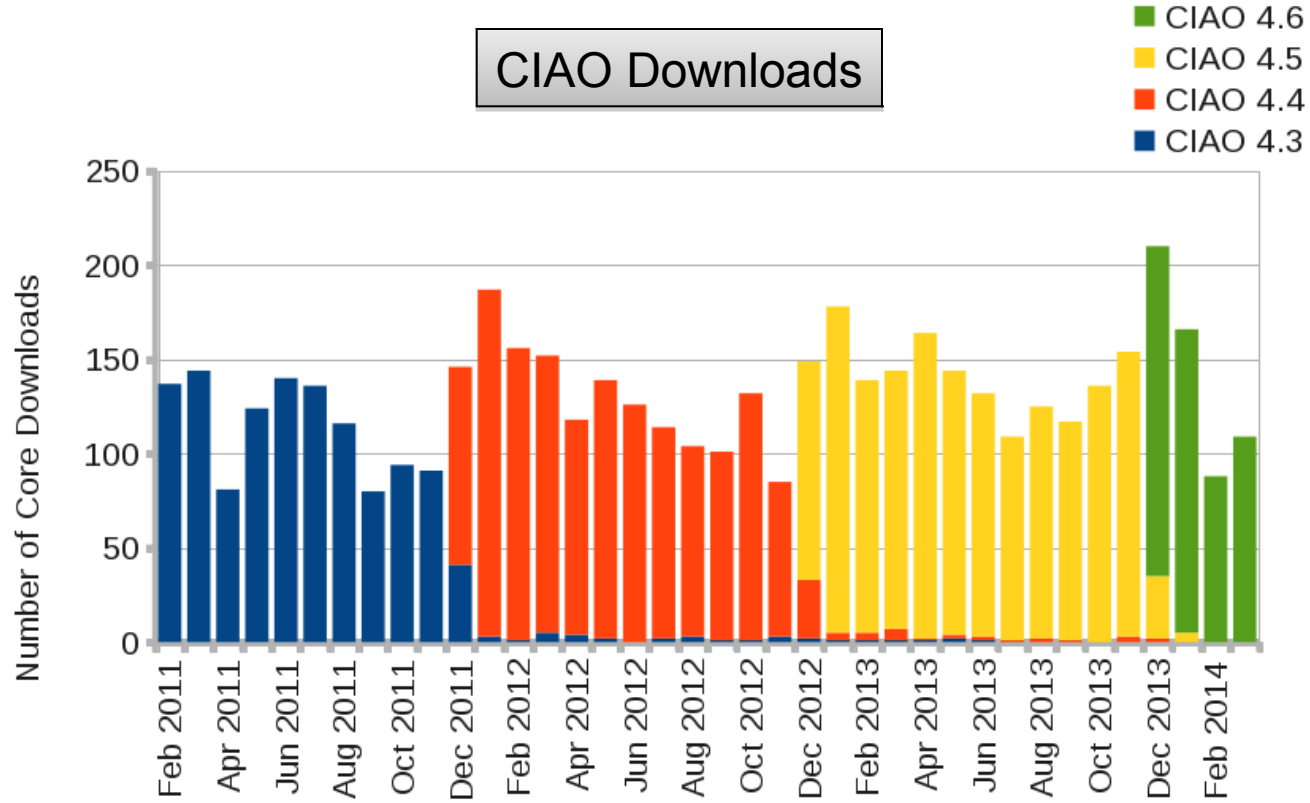


Sherpa

- comes with well-tested, robust optimization methods - e.g. Levenberg-Marquardt, Nelder-Mead Simplex or Monte Carlo/Differential Evolution
- comes with statistics for modeling Poisson or Gaussian data
- can perform Bayesian analysis with Poisson Likelihood and priors, using Metropolis or Metropolis-Hastings algorithm in the MCMC (Markov-Chain Monte Carlo); allows to include non-linear systematic errors (calibration uncertainties) in the analysis
- is extensible (with python and compiled code):
 - is used in CIAO tools and scripts
 - in the Xija Chandra thermal modeling code
 - is used in the TeV HESS data analysis software
 - is used in the IRIS spectral energy distribution program



CIAO continues to support Chandra science



2013-14 Press Release Images