Chandra Tutorial

Eleonora Torresi 2010
+
Giorgio Lanzuisi 2011/2014/2015
+
Fabio Vito 2012
+
Cristian Vignali 2013, 2016, 2017
+
Giulia Migliori 2018

- (quick) overview of the telescope and instrument capabilities (Chandra/ACIS);
- data acquisition & architecture: archive, file format;
- data reduction & manipulation: reprocessing, filtering, binning;
- obtain the science products for your analysis: images, spectra, lightcurves;

- [x] (quick) overview of the telescope and instrument capabilities (Chandra/ACIS);
- [ ] data acquisition & architecture: archive, file format;
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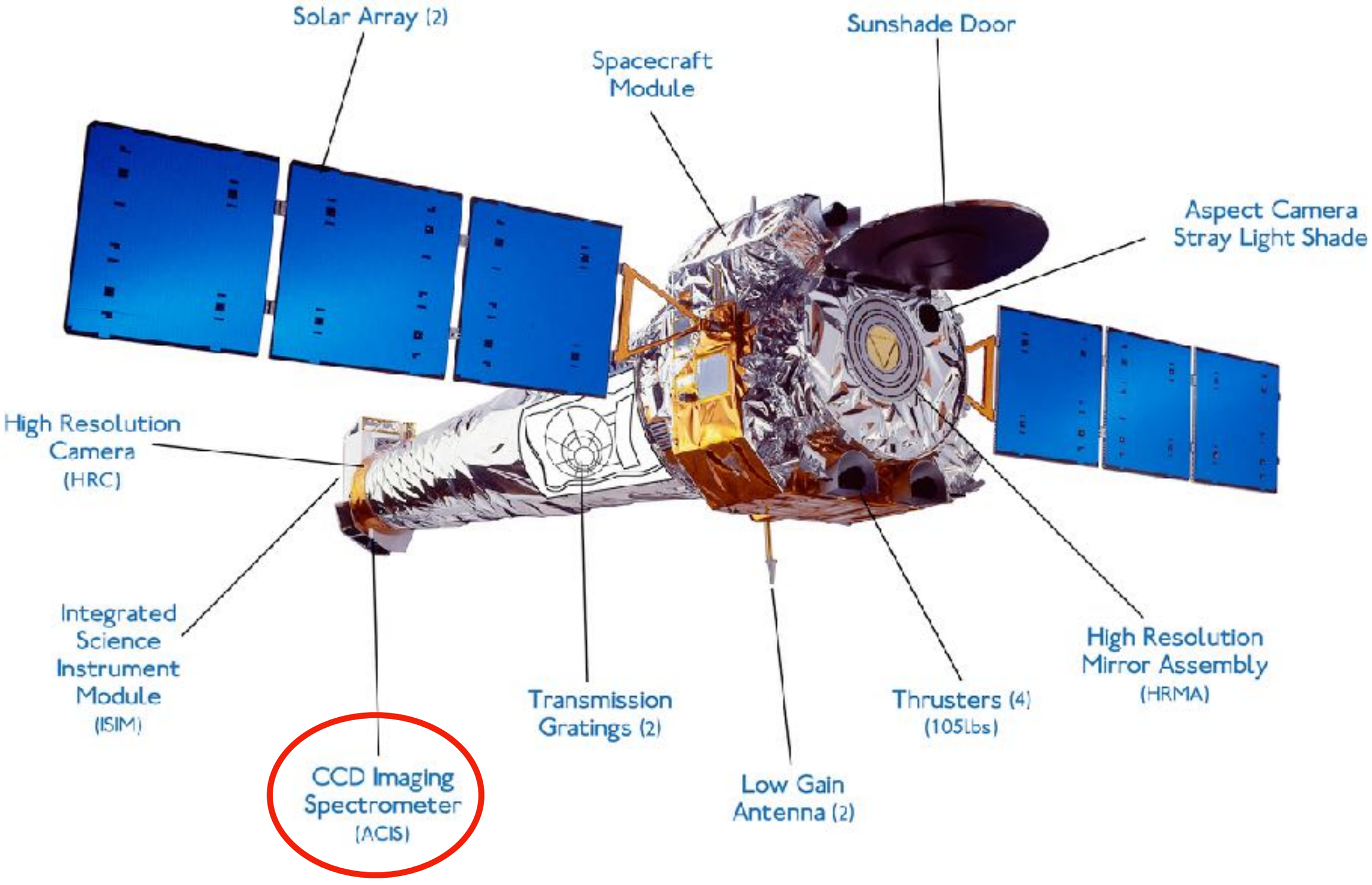


http://cxc.harvard.edu

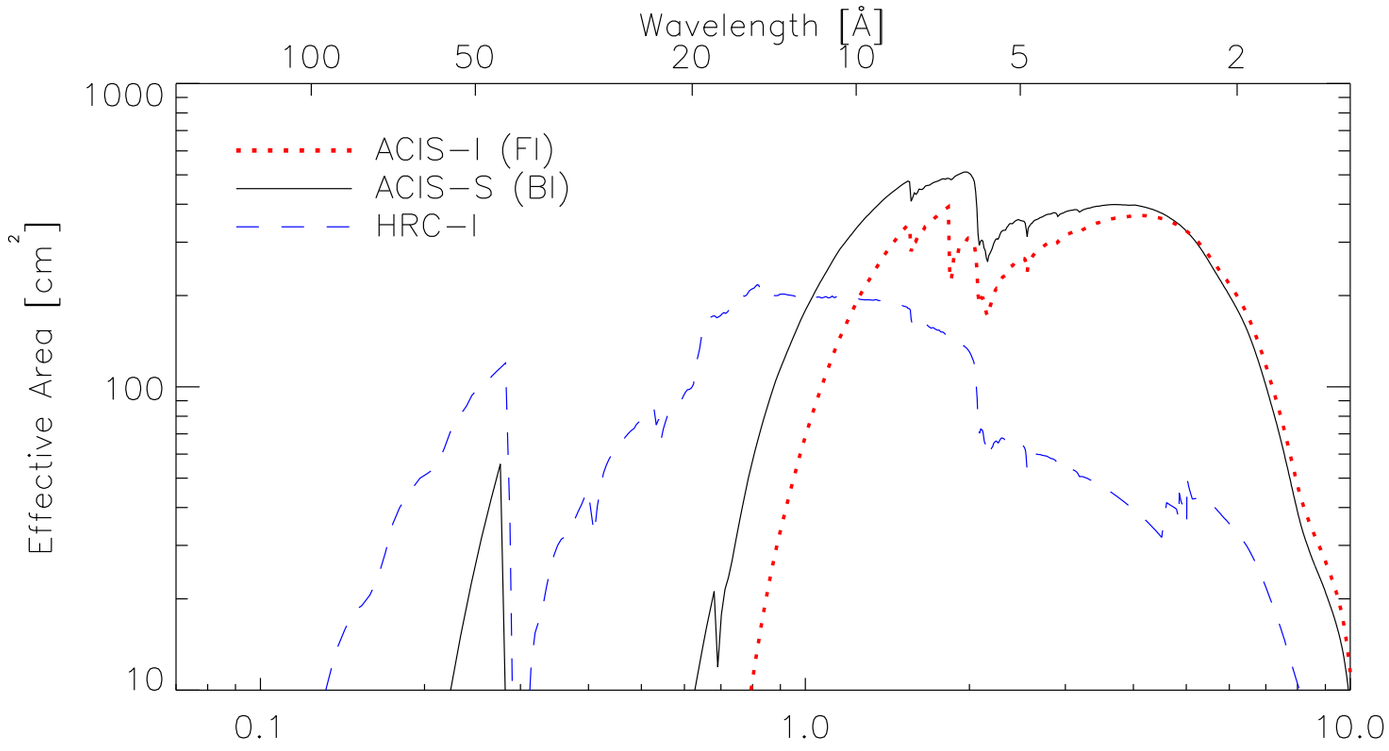
Strengths…

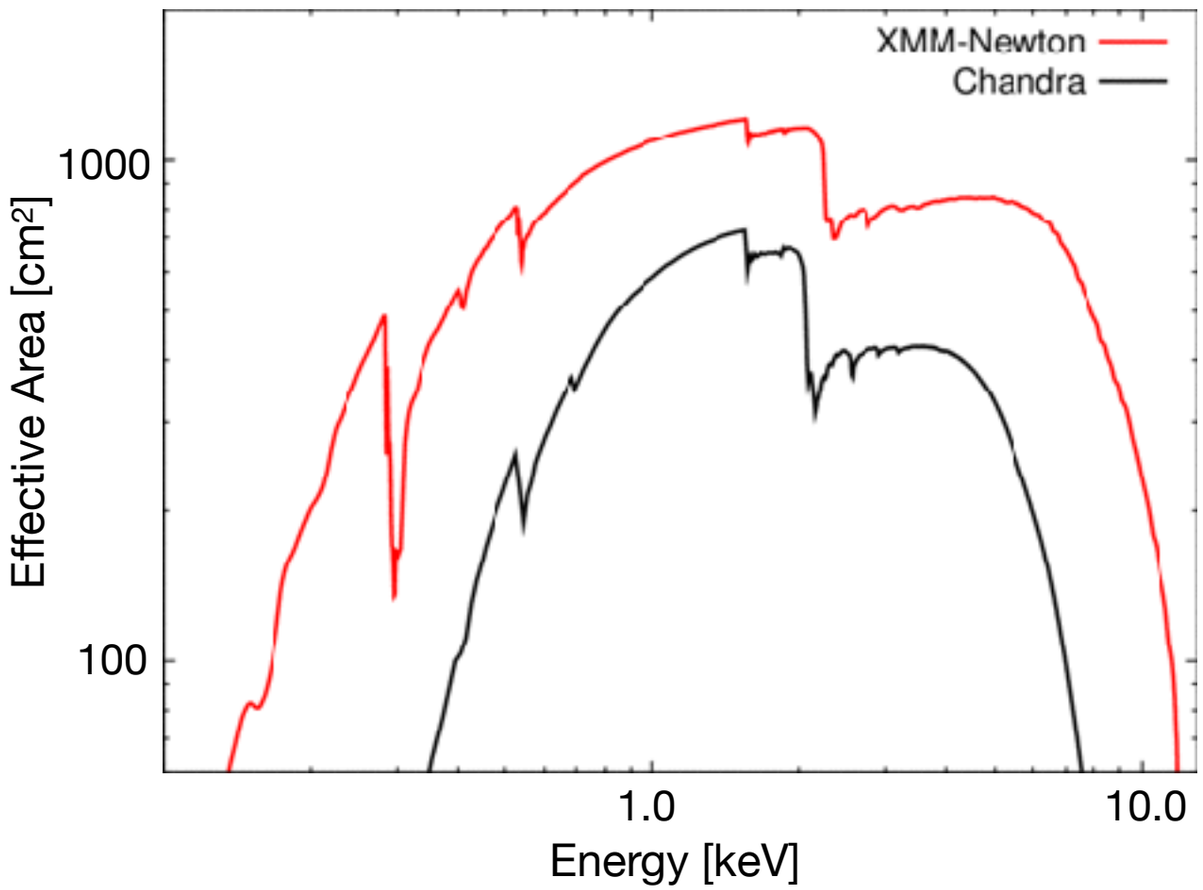
- ☑ Best spatial resolution of any X-ray satellite: ~1” (Hubble ~0.1”, next best X-ray satellite, XMM-Newton ~10”, ROSAT ~5”);
- ☑ good energy range (300 eV – 9 keV) & resolution (E/ΔE ~5 – 40);
- ☑ best energy resolution (Gratings) of any X-ray satellite: E/ΔE~1400 – 200 (Radio & Hubble ~20,000, next best X-ray satellite, XMM-Newton ~ 500 – 40);
- ☑ largest dynamic flux range of any satellite ever flown:11 orders of magnitude; 10^{-18} – 10^{-7} erg cm^{-2} s^{-1}.

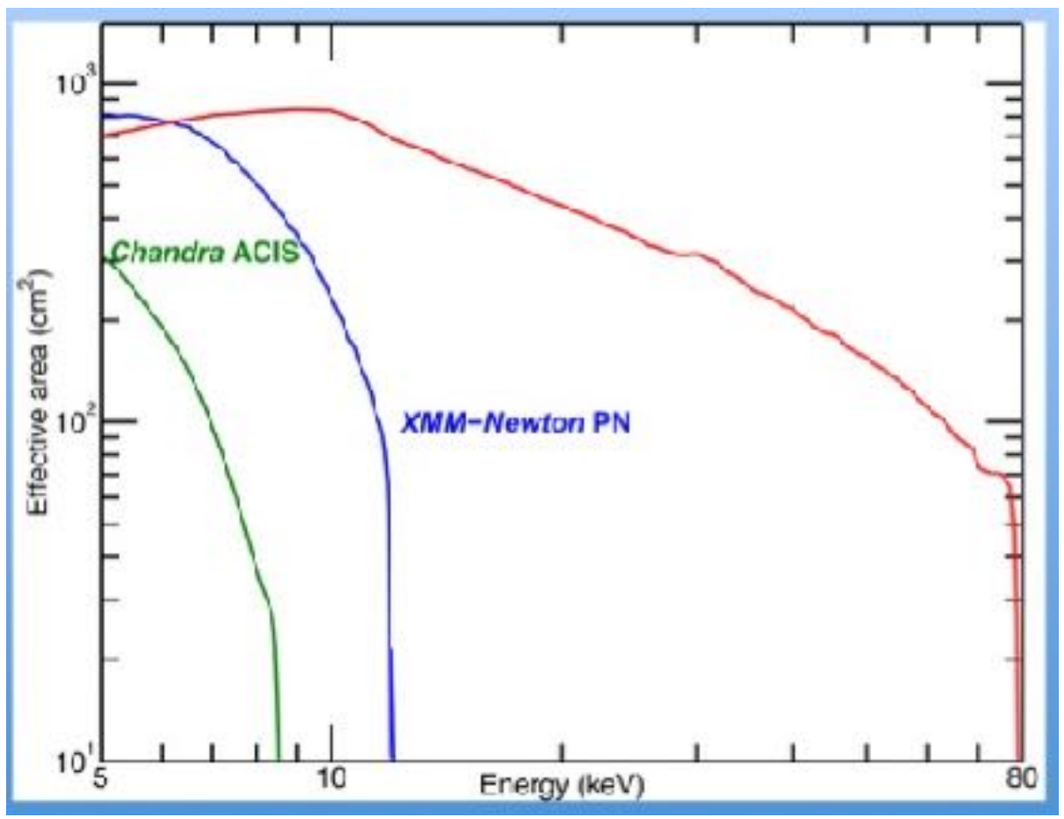
…and weaknesses

- small effective area:

$$
\begin{aligned}
@\ 0.25\ \mathrm{keV} \quad & 800\ \mathrm{cm}^2 \\
@\ 5.0\ \mathrm{keV} \quad & 400\ \mathrm{cm}^2 \\
@\ 8.0\ \mathrm{keV} \quad & 100\ \mathrm{cm}^2
\end{aligned}
$$

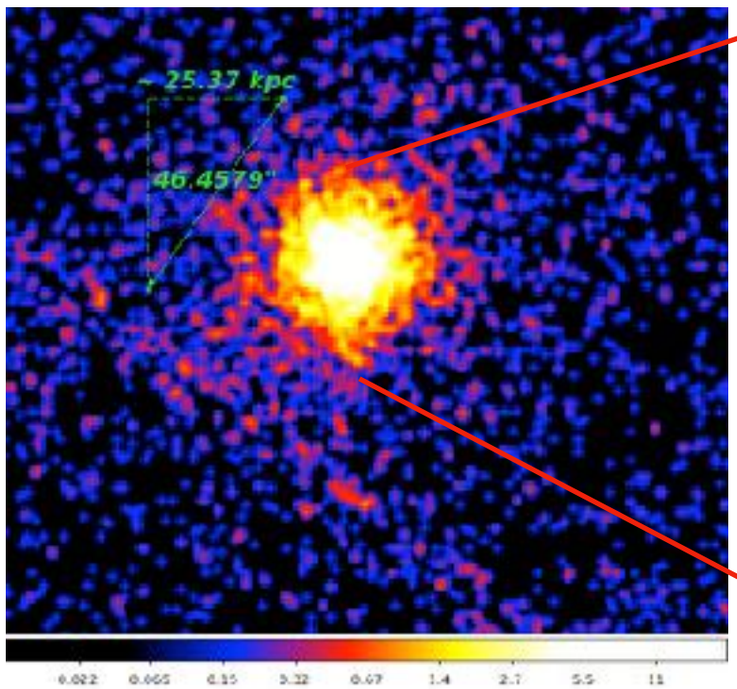




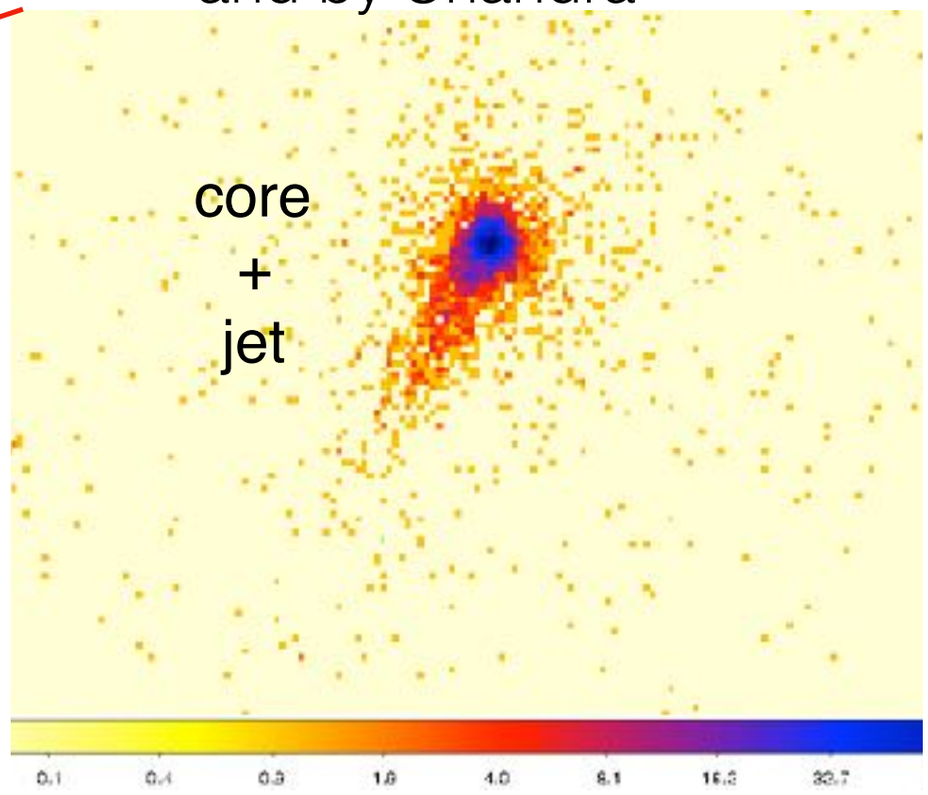


Ideal to study extended X-ray sources:

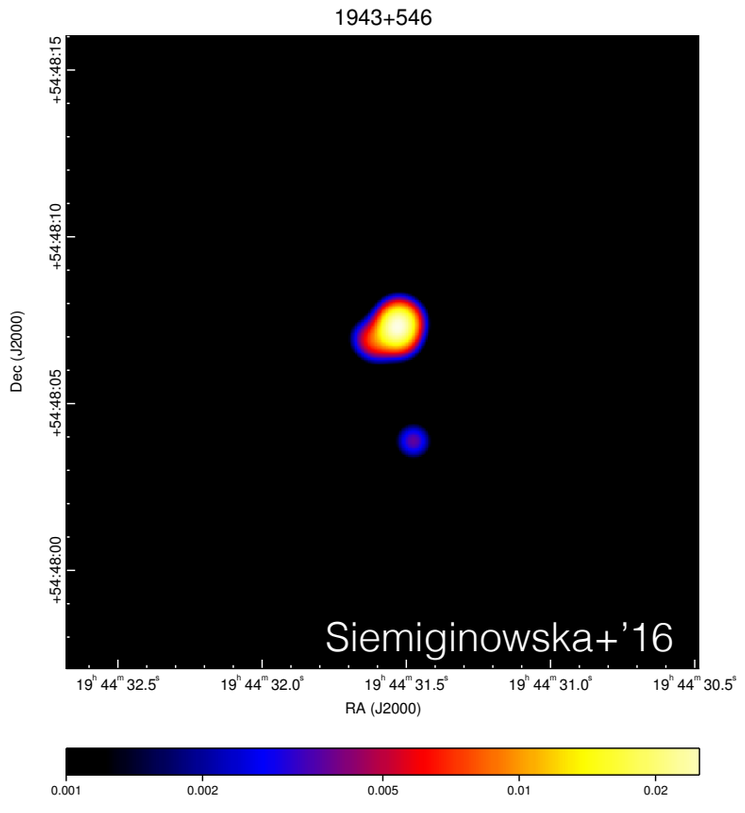
IC 1531 seen by XMM



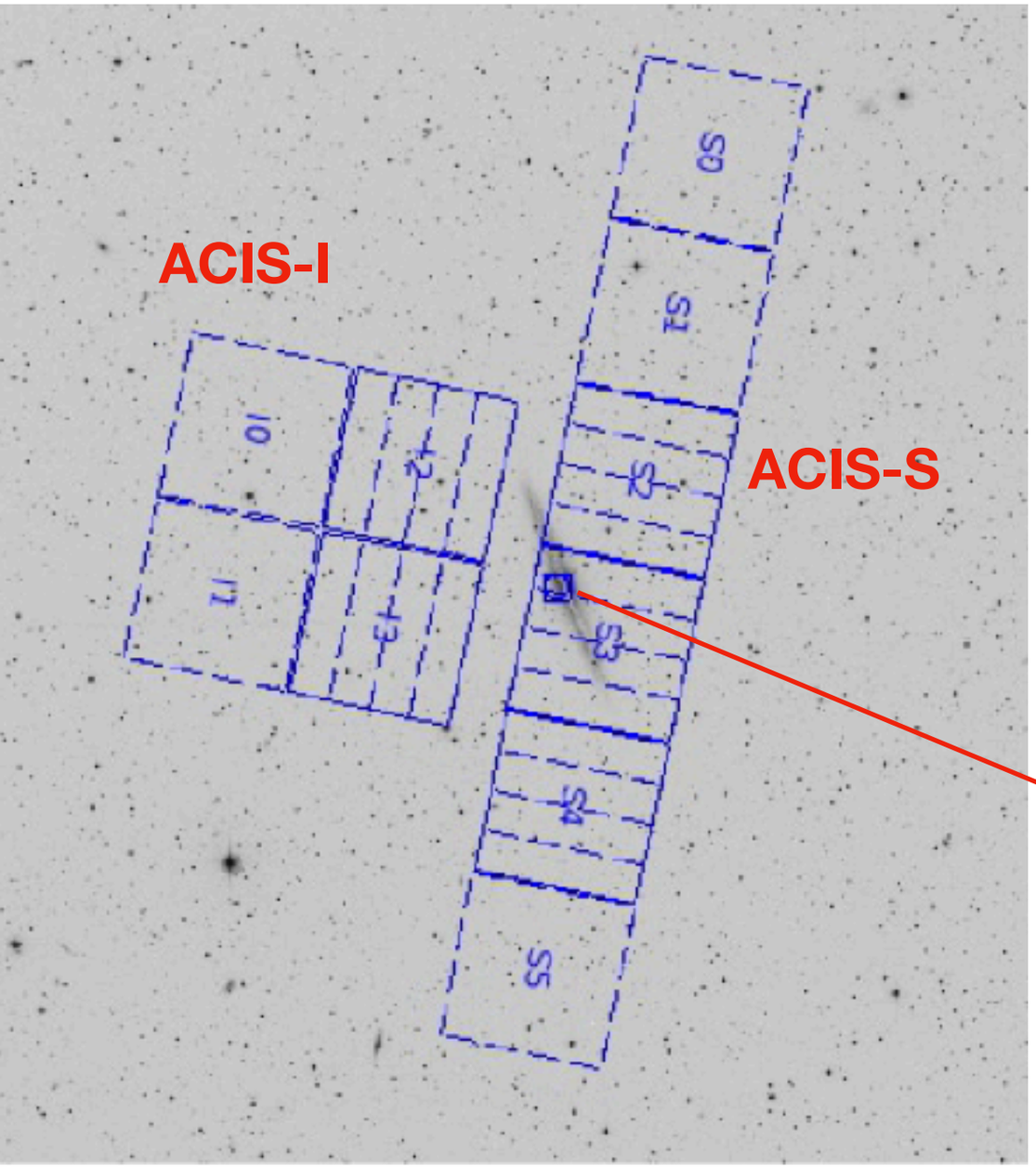
and by Chandra



and to detect sources in very low-count regime: 5 counts may be a detection!



Advance CCD Imaging Spectrometer (ACIS)



- ACIS simultaneously acquire high-resolution images and moderate resolution spectra
- ACIS-I is comprised of front-illuminated (FI) CCDs. ACIS-S is comprised of 4 FI and 2 back-illuminated (BI) CCDs
- ACIS-I is better when wider field (16'x16') and/or higher energy response is needed; ACIS-S imaging is better when low energy response is preferred and a smaller (8'x8') field of view is sufficient
- The BI S3 chip is at the best focus position and is normally used for ACIS-S imaging observations.

- ☐ (quick) overview of the telescope and instrument capabilities (Chandra/ACIS);
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- ☐ obtain the science products for your analysis: images, spectra, lightcurves;

How/Where to get the data:
Chandra X-ray Archive

One call for observing time per year
(deadline around March 15, depending on weather conditions..):
submit your proposal!

…and wait…

Proposals are evaluated by panels (divided by topic: AGN, clusters, stars..) at the end of June

…and wait…

results are released between July and August

…nope, my proposal has been rejected this time:
what do I do?

http://cxc.cfa.harvard.edu/proposer/

How/Where to get the data: Chandra X-ray Archive

http://cxc.harvard.edu/ → http://cxc.harvard.edu/cda/

CHANDRA X-RAY OBSERVATORY

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

Chandra Data Archive

ChaSeR
Chandra Source Catalog ♦ CSCview
Chandra Footprint Service
Request for Acknowledgement

SEARCH CXC.HARVARD.EDU
Google Custom Search Search

- The Archive
- Search and Retrieve Data
  - Synopsis of Tools
  - ChaSeR
  - FTP
  - Chandra Fast Image
- Advanced Data Services
- Archive User Services
- Chandra Aggregated Datasets
- Publishing Chandra Results
- Data Analysis Links

CXC → CDA

WELCOME TO THE CHANDRA DATA ARCHIVE

The Chandra Data Archive (CDA) plays a central role in the operation of the Chandra X-ray Center (CXC) by providing support to the astronomical community in accessing Chandra data. The CDA offers access to digital archives through powerful query engines, including VO-compliant interfaces and also serves as a permanent storage repository of contributed data products by authors who have processed images or other pertinent and valuable datasets that are essential to their publications.

Access the Chandra Data Archive

- ChaSeR: Search & Retrieval interface for scientists, allowing specification of detailed selection criteria. Chandra Fast Image is a simplified quick search tool for *Chandra* X-ray images and other data for the general public.
- FTP: Direct FTP access to the primary and secondary data products for all observations that are publicly released.
- Footprint Service: A search by position or object name overlays the footprints of *Chandra* Observations on Digital Sky Survey images, allowing further selection and retrieval of observations.
- Chandra MOCs: Multi-Order Coverage maps (MOCs) for public Chandra observations, that can be used to visualize and analyze the global Chandra footprint.
- Chandra Source Catalog: The most comprehensive catalog of sources detected in public Chandra Observations. The catalog can be accessed through CSCview.
- CIAO Tools: There are command-line scripts for finding and downloading publicly-available Chandra data from the Archive. Please note that proprietary data can only be accessed using ChaSeR.
  - find_chandra_obsid: The tool will find publicly available Chandra data that covers a circular region of sky (a point search can be used by setting the search radius to 0).
  - download_chandra_obsid: The tool will download public data by ObsId from the Chandra archive.
- SDSS Cross-Match Catalog: A cross-matching service linking *Chandra* and *SDSS* sources.
- Bibliography Search: Simultaneous browsing of the archive and the literature with a large repertoire of selection criteria.
- Processing Status: Information on the processing status of *Chandra* observations.
- Special Requests: Requests for services not available through standard interfaces such as requesting a custom dataset identifier; requesting a custom database query; and many others.

CDA STATUS

The archive is fully functional.

REPROCESSING STATUS

Reprocessing has been completed for
Phase I: 2005-11-13 to 2011-12-31
Phase II: 2000-01-30 to 2005-11-13

CURRENT SOFTWARE RELEASES

ASCDSVER: 10.7
CALDBVER: 4.8.0.1

ANNOUNCEMENTS

Chandra Footprint Service
2018-05-14
The new secure Footprint Service can be found here

Global Chandra Coverage
2018-02-14
Check out the new Chandra MOC page.

Browsers security warnings
2017-12-22
Are Chandra Data Archive pages safe? See full announcement.

Past Notices

This page maintained by the *Chandra Data Archive* (arcops@head.cfa.harvard.edu).

Last modified: 2016-11-08

How/Where to get the data: Chandra X-ray Archive

Chandra X-ray Center

Observation Search

New Search | Retrieval List | Help

Chandra Data Archive

Search | Reset

File Upload: Coordinates | Choose File | no file selected

Cone Search

Target Name: 3C 219 | Resolve Name | RA/Long: | Dec/Lat/b:

Name Resolver: SIMBAD/NED | Coord System: Equatorial J2000 | Equinox: 2000 | Radius: 10 arcmin

Observation ID		Sequence Number		Proposal Number	
Proposal Title		PI Name		Observer Name	
Start Date		Public Release Date			
Exposure Time (ks)		Approved Time (ks)		Avg. Count Rate (/z)	

Status	Archived Observed Scheduled Unobserved Untriggered	Science Category	Solar System Stars and WD WD Binaries and CV BH and NS Binaries SN, SNR and Isolated NS	Type	ER GO GTO TOO DDT CAL	Observing Cycle	00 01 02 03 04
Instrument	ACIS ACIS-I ACIS-S HRC	Grating	None LETG HETG	Exposure Mode	ACIS TE ACIS CC HRC Timing	Join Observatories	None HST NOAO NRAO NuSTAR

Proposal Cycle: 00 01 02 03 04 | Grid:

Customize Output:

Sort Order: Status | ascending descending

Row Limit: 50

Coord System: Equatorial J2000 | Equinox: 2000 | Format: Sexagesimal (hh/dd mm ss.ss)

Save As:

For online support please contact the CXC Helpdesk.

How/Where to get the data: Chandra X-ray Archive

Chandra X-ray Center

Search Results

New Search | Search Results | Retrieval List | Help

View Observation Information

Add Products to Retrieval List

Primary package
Secondary package
Custom selection

Select all | Unselect all

Select	Row	Seq Num	Obs ID	Instrument	Grating	Appr Exp	Exposure	Target Name	PI Name	RA	Dec	Status	Data Mode	Exp Mode	Avg Cnt Rate	Evt Cnt	Start Date	Public Release Date	Proposal	Type
☑	1	700132	827	ACIS-S	NONE	20.0	18.76	3C 219	Brunetti	09 21 08.60	-45 38 58.00	archived	VFAINT	TE	2.20	41236	2000-10-11 10:36:13	2001-10-18 10:45:00	01700398	GO

1 observation found
Position=cone of radius 10 arcmin around RA: 09 21 08.63, Dec: +45 38 57.35 (frame=j2000 equinox=2000)
Status=archived; observed; scheduled; unobserved; untriggered
Type=GO; GTO; TOO; DDT; CAL
Sort Order=Status ascending

For online support please contact the CXC Helpdesk.

Chandra X-ray Center

Observation Viewer

New Search | Search Results | Retrieval List | Help

Not logged in Login

Observation ID: **827**

Observation ID: 827

Add to Retrieval List

Primary package
Secondary package
Custom selection

→Summary
Details
V&V Report
Proposal Abstract
Images
Publications
Data packages
Primary
Secondary
External links
Processing Status
Sequence Summary
Related Observations
By Sequence
By Proposal
By Monitor/Followup
By Group
By Grid

Sequence Number:	700132	**Status:**	archived
Observation ID:	827	**Proposal Number:**	01700398
Type:	GO	**Proposal Cycle:**	01
PI Name:	Brunetti	**Observer:**	Brunetti
Science Category:	ACTIVE GALAXIES AND QUASARS	**Joint Observatories:**	None
Target Name:	3C 219	**Grid Name:**	
RA (J2000):	09 21 08.60		
Dec (J2000):	+45 38 58.00		
Instrument:	ACIS-S	**Data Mode:**	VFAINT
Grating:	NONE		
Start Date:	2000-10-11 10:36:13	**Observing Cycle:**	01
Approved Time:	20.00 ks	**Public Release Date:**	2001-10-18 10:45:00
Exposure Time:	18.76 ks		

the archive provides important informations on the observations (instrument settings/date of the observation & exposure time/last data processing date..)

How/Where to get the data: Chandra X-ray Archive

1)

Chandra X-ray Center

Search Results

New Search | Search Results | Retrieval List | Help

Chandra Data Archive

View Observation Information | Add Products to Retrieval List | Primary package | Secondary package | Custom selection

to download the data

Select all | Unselect all

Select	Row	Seq Num	Obs ID	Instrument	Grating	Appr Exp	Exposure	Target Name	PI Name	RA	Dec	Status	Data Mode	Exp Mode	Avg Cnt Rate	Evt Cnt	Start Date	Public Release Date	Proposal	Type
☑	1	700132	827	ACIS-S	NONE	20.0	18.76	3C 219	Brunetti	09 21 08.60	+45 38 58.00	archived	VFAINT	TE	2.20	41236	2000-10-11 10:36:13	2001-10-18 10:45:00	01700398	GO

1 **observation found**
Position=cone of radius 10 arcmin around RA: 09 21 08.63, Dec: +45 38 57.35 (frame=j2000 equinox=2000)
Status=archived; observed; scheduled; unobserved; untriggered
Type=GO; GTO; TOO; DDT; CAL
Sort Order=Status ascending

For online support please contact the CXC Helpdesk.

2)

Chandra X-ray Center

Retrieval List

New Search | Search Results | Retrieval List | Help

Chandra Data Archive

Not logged in Login

Browse Products | Retrieve Products | Remove All

Row	Seq Num	Obs ID	Instrument	Target Name	PI Name	Status	Public Release Date	Package	Product(s)	Description	Remove
1	700132	827	ACIS-S	3C 219	Brunetti	archived	2001-10-18 10:45:00	primary	all	---	Remove
2	700132	827	ACIS-S	3C 219	Brunetti	archived	2001-10-18 10:45:00	secondary	all	---	Remove

3)

Chandra X-ray Center

Retrieval Results

New Search | Search Results | Retrieval List | Help

Chandra Data Archive

Your requested data will be available at https://cda/tp.c/a.harvard.edu/pub/stage/zJ2FViqw/ .
It may take several minutes before your data are ready for retrieval.

Would you like to view the status of your retrieval?

Would you like to receive email notification when your data are ready?
Email: myemailaccount@gmail.com Notify Me

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How to reduce and analyzed Chandra data: CIAO software

http://cxc.harvard.edu/ciao/

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Last modified: 24 October 2018

Search http://cxc.harvard.edu/ciao/

Google Custom Search

Contact the CXC HelpDesk

CIAO

INTRODUCTION
- Home page
- Welcome
- Tools & Applications
- CIAO News
  Updated: 9 November 2018

DOWNLOAD CIAO
- Download CIAO 4.10
- Download CALDB
- Scripts & Modules Package
- System Requirements
- Installation Instructions
- Platform Support
- Release Notes
- Version History
- Other Analysis Software

DATA ANALYSIS
- Analysis Guides
- Science Threads
- Why Topics
- Help Pages (AHELP)
- Video Demos and Tutorials

DOCUMENTATION
- Gallery of Examples
- "Watch Out" List
- Help Pages (AHELP)
- Bug List

CHANDRA INTERACTIVE ANALYSIS OF OBSERVATIONS

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

CIAO

CIAO is the software package developed by the Chandra X-Ray Center for analysing data from the Chandra X-ray Telescope. It can also be used with data from other Astronomical observatories, whether ground or space based.

Sherpa | ChIPS | DS9 | ChaRT | MARX | CALDB || CSC 1.1 | CSC 2 | TGCat

Download CIAO/CALDB

Install CIAO 4.10 & CALDB 4.8.1

Read the CIAO 4.10 release notes for detailed information on this release, including How CALDB 4.8.1 Affects Your Analysis.

Does CIAO run on my operating system?

What are the requirements for running CIAO?

Note: CIAO 4.10 defaults to using Python 3.5, as support for Python 2.7 in the scientific-software ecosystem is coming to an end. Please read about the CXC's plan to only support Python 3.5 in the next release of CIAO.

Where should I begin?

Useful links for those people who have never used CIAO before.

Welcome to CIAO
Introduction to the Tools & Applications

Quick Start Guide

Download CIAO 4.10
Installing CIAO 4.10 thread

Introductory Science Threads
All CIAO Threads

Analysis Guides

Sherpa: Modeling and Fitting
ChIPS: Plotting and Imaging
DS9: Interactive image display and analysis

I need help!

For anyone having trouble using CIAO or analysing Chandra data.

CIAO Software Help Pages

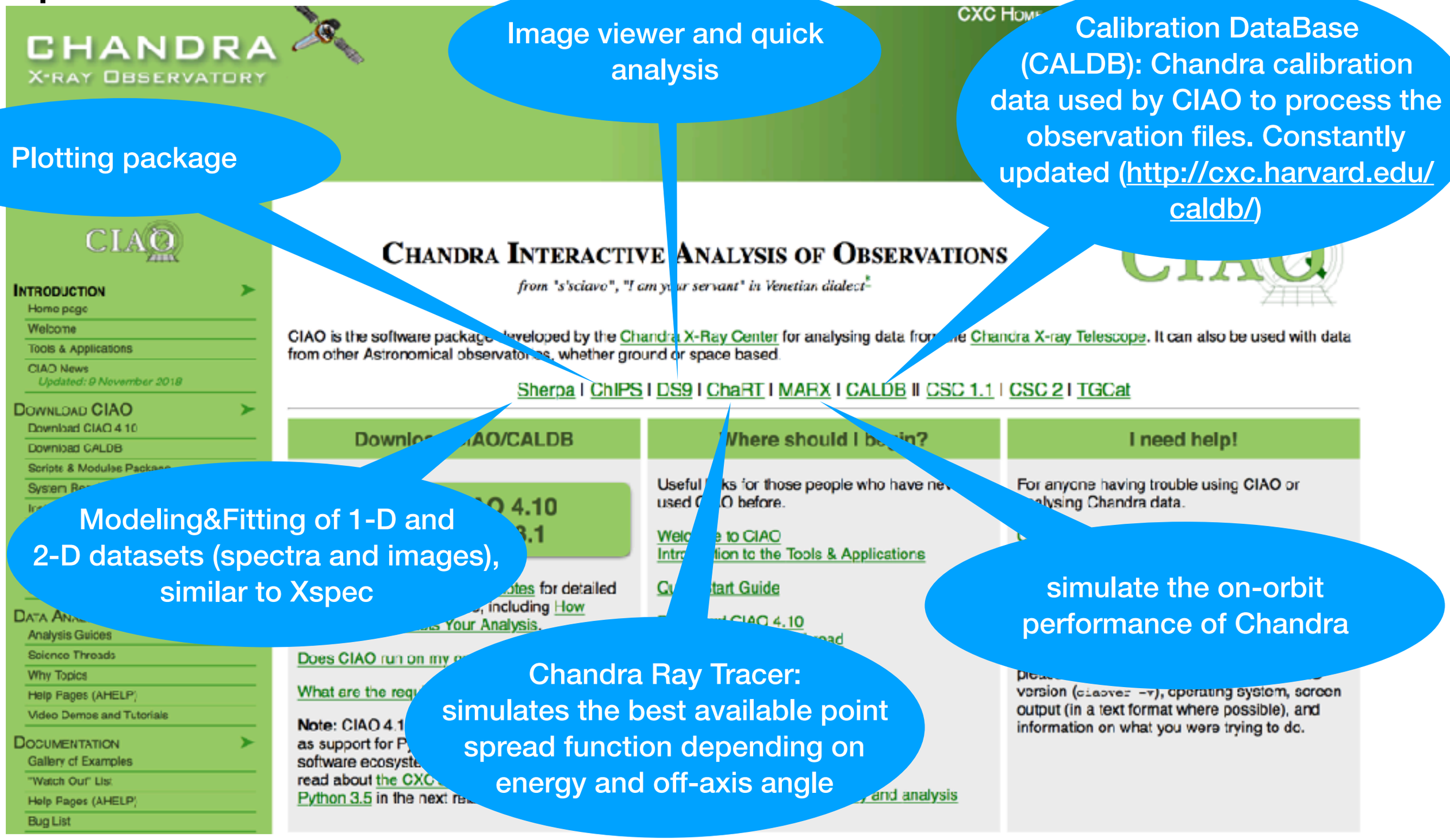
Frequently Asked Questions (FAQ)

Known CIAO Bugs and Tool Caveats

If the above links do not help you, then please contact the CXC Helpdesk. *To help us help you*, please include, where appropriate: the CIAO version (`ciaover -v`), operating system, screen output (in a text format where possible), and information on what you were trying to do.

How to reduce and analyzed Chandra data: CIAO software

http://cxc.harvard.edu/ciao/



DATA ACQUISITION WITH CIAO

1) Initialize CIAO:

```
gmiglior — -bash — 80×24
Last login: Sun Nov 18 18:22:33 on ttys006
sapmcm127:~ gmiglior$ ciao
CIAO configuration is complete...
CIAO 4.10 Thursday, April 12, 2018
  bindir      : /Users/gmiglior/AnalysisSoftwares/ciao-4.10/bin
  CALDB       : 4.7.9
sapmcm127:~ gmiglior$
```

2) search for data (alternative to go to the Chandra archive):

```
sapmcm127:~ gmiglior$ find_chandra_obsid "3C 219"
# obsid  sepn   inst grat   time    obsdate   piname          target
827       0.0 ACIS-S NONE   18.8 2000-10-11 Brunetti       "3C 219"
6803     11.8 ACIS-S NONE   10.1 2006-03-05  Strauss SDSSJ0920+4531
sapmcm127:~ gmiglior$
```

3) create your working directory and download the data:

```
sapmcm127:Chandra_tutorial gmiglior$ mkdir 3C219
sapmcm127:Chandra_tutorial gmiglior$ cd 3C219
sapmcm127:3C219 gmiglior$ download_chandra_obsid 827
Downloading files for ObsId 827, total size is 55 Mb.

Type     Format      Size  0........H.........1  Download Time Average Rate
-------------------------------------------------------------------------
readme   ascii       10 Kb  ####################          < 1 s  20.4 kb/s
oif      fits        23 Kb  ####################          < 1 s  37.2 kb/s
vv       pdf         32 Kb  ####################          < 1 s  51.9 kb/s
cntr_img fits        65 Kb  ####################          < 1 s  87.3 kb/s
```

http://cxc.cfa.harvard.edu/ciao/data_products_guide/

```
sapmcm127:3C219 gmiglior$ ls 827/
00README                                primary
axaff00827N002_VV001_vv2.pdf            secondary
oif.fits
```

data are stored in two directories:
scientific & housekeeping files

```
sapmcm127:3C219 gmiglior$ ls 827/primary/
acisf00827N003_cntr_img2.fits.gz        acisf00827_000N003_bpix1.fits.gz
acisf00827N003_cntr_img2.jpg            acisf00827_000N003_fov1.fits.gz
acisf00827N003_evt2.fits.gz             orbitf087566700N001_eph1.fits.gz
acisf00827N003_full_img2.fits.gz        pcadf08764824 1N003_asol1.fits.gz
acisf00827N003_full_img2.jpg
```

primary:

evt2.fits : Level 2 event file, fully calibrated, fully filtered primary science product.

.asol1.fits : Level 1 aspect solution file(s). Time resolved pointing information.

.bpix1.fits : Level 1 bad pixel file

.fov1.fits : Level 1 field-of-view file.

```
sapmcm127:3C219 gmiglior$ ls 827/secondary/
acisf00827_000N003_evt1.fits.gz         acisf087647802N003_1_bias0.fits.gz
acisf00827_000N003_flt1.fits.gz         acisf087648408N003_pbk0.fits.gz
acisf00827_000N003_msk1.fits.gz         aspect
acisf00827_000N003_mtl1.fits.gz         axaff00827N002_VV001_vvref2.pdf.gz
acisf00827_000N003_stat1.fits.gz        ephem
```

secondary:

.evt1.fits : Event file, fully calibrated **unfiltered** event file. Used when reprocessing.

.msk1.fits : Mask file to identify active part of detector

.flt1.fits : Good time interval based on mission time line parameters

.mtl1.fits : Mission time line. Important science and engineering values vs time

FILE FORMAT

- The event file is in FITS (flexible image transport system) format;
- A single Chandra file can contain multiple “datasets” (e.g. data, Good Time Intervals, weight map, regions) which are stored in “blocks”.
- Blocks can contain image or table data.
- the event file can be though as a 4-D array which stores for each event the informations about energy, position and time;
- however in practice it is more complicate and there are more parameters (multiple coordinate systems, times, channels/energy);
- CIAO tools to explore FITS files (dmlist, dmstat..) or fv (an heasarc package)

DATA REDUCTION & ANALYSIS WITH CIAO

dmlist event_file.evt opt=subspace(/header/blocks/cols/data)

```
sapmcm127:repro gmiglior$ plist dmlist

Parameters for /Users/gmiglior/cxcds_param4/dmlist.par

        infile = acisf00827N003_evt2.fits Input dataset/block specification
           opt = header           Option
      (outfile = )                Output file (optional)
         (rows = )                Range of table rows to print (min:max)
        (cells = )                Range of array indices to print (min:max)
      (verbose = 0)               Debug Level(0-5)
         (mode = ql)
```

```
sapmcm127:primary gmiglior$ dmlist acisf00827N003_evt2.fits cols

--------------------------------------------------------------------------------
Columns for Table Block EVENTS
--------------------------------------------------------------------------------

ColNo  Name                 Unit        Type          Range
   1   time                 s           Real8         87647837.5706280023: 87667996.7588890046 S/C TT corresponding to mid-exposure
   2   ccd_id                           Int2          0:9                  CCD reporting event
   3   node_id                          Int2          0:3                  CCD serial readout amplifier node
   4   expno                            Int4          0:2147483647         Exposure number of CCD frame containing event
   5   chip(chipx,chipy)    pixel       Int2          1:1024               Chip coords
   6   tdet(tdetx,tdety)    pixel       Int2          1:8192               ACIS tiled detector coordinates
   7   det(detx,dety)       pixel       Real4         0.50:     8192.50    ACIS detector coordinates
   8   sky(x,y)             pixel       Real4         0.50:     8192.50    sky coordinates
   9   pha                  adu         Int4          0:36855              total pulse height of event
  10   pha_ro               adu         Int4          0:36855              total read-out pulse height of event
  11   energy               eV          Real4         0:  1000000.0        nominal energy of event (eV)
  12   pi                   chan        Int4          1:1024               pulse invariant energy of event
  13   fltgrade                         Int2          0:255                event grade, flight system
  14   grade                            Int2          0:7                  binned event grade
  15   status[4]                        Bit(4)                             event status bits

--------------------------------------------------------------------------------
World Coord Transforms for Columns in Table Block EVENTS
```

Data reprocessing: chandra_repro

```
sapmcm127:3C219 gmiglior$ chandra_repro
Input directory (./): 827
Output directory (default = $indir/repro) ():
…….
Resetting afterglow status bits in evt1.fits file...

Running acis_build_badpix and acis_find_afterglow to create a new bad pixel
file...

Running acis_process_events to reprocess the evt1.fits file...
Filtering the evt1.fits file by grade and status and time...
Applying the good time intervals from the flt1.fits file...
The new evt2.fits file is
```

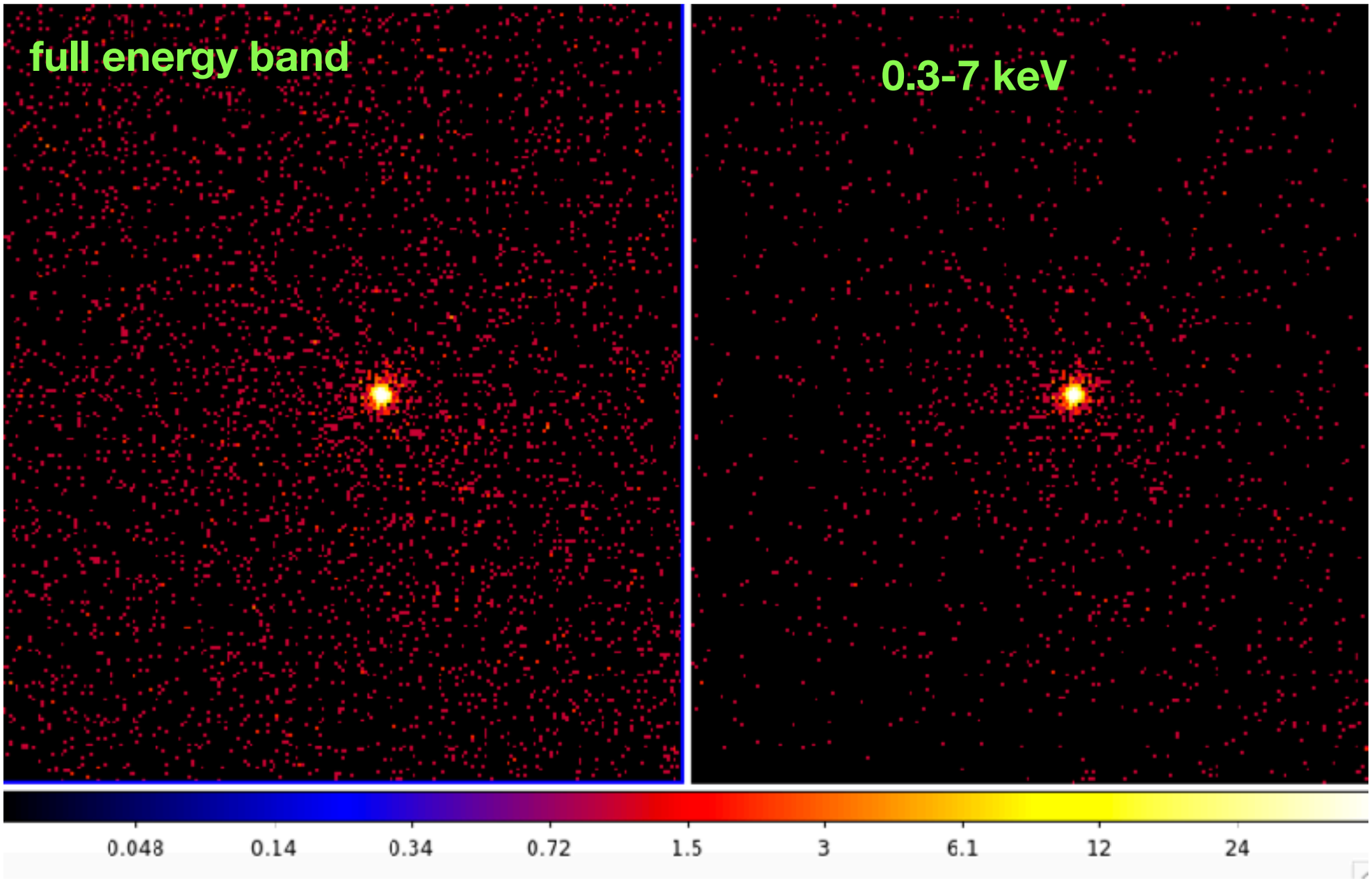
- removal of hot pixels or afterglows acis_run_hotpix
- creation of a new event file acis_process_events
- run *destreak* in case the ACIS-S4 chip (ccd_id=8) has been used
- filtering for bad grades and application of Good Time Intervals (GTI) creation the background light curve

http://cxc.cfa.harvard.edu/ciao/ahelp/chandra_repro.html

Filtering & Binning

Energy filter:

```
punlearn dmcopy
dmcopy "acisf00827_repro_evt2.fits[energy=300:7000]" evt_repro_0.3_7.0keV.fits
```

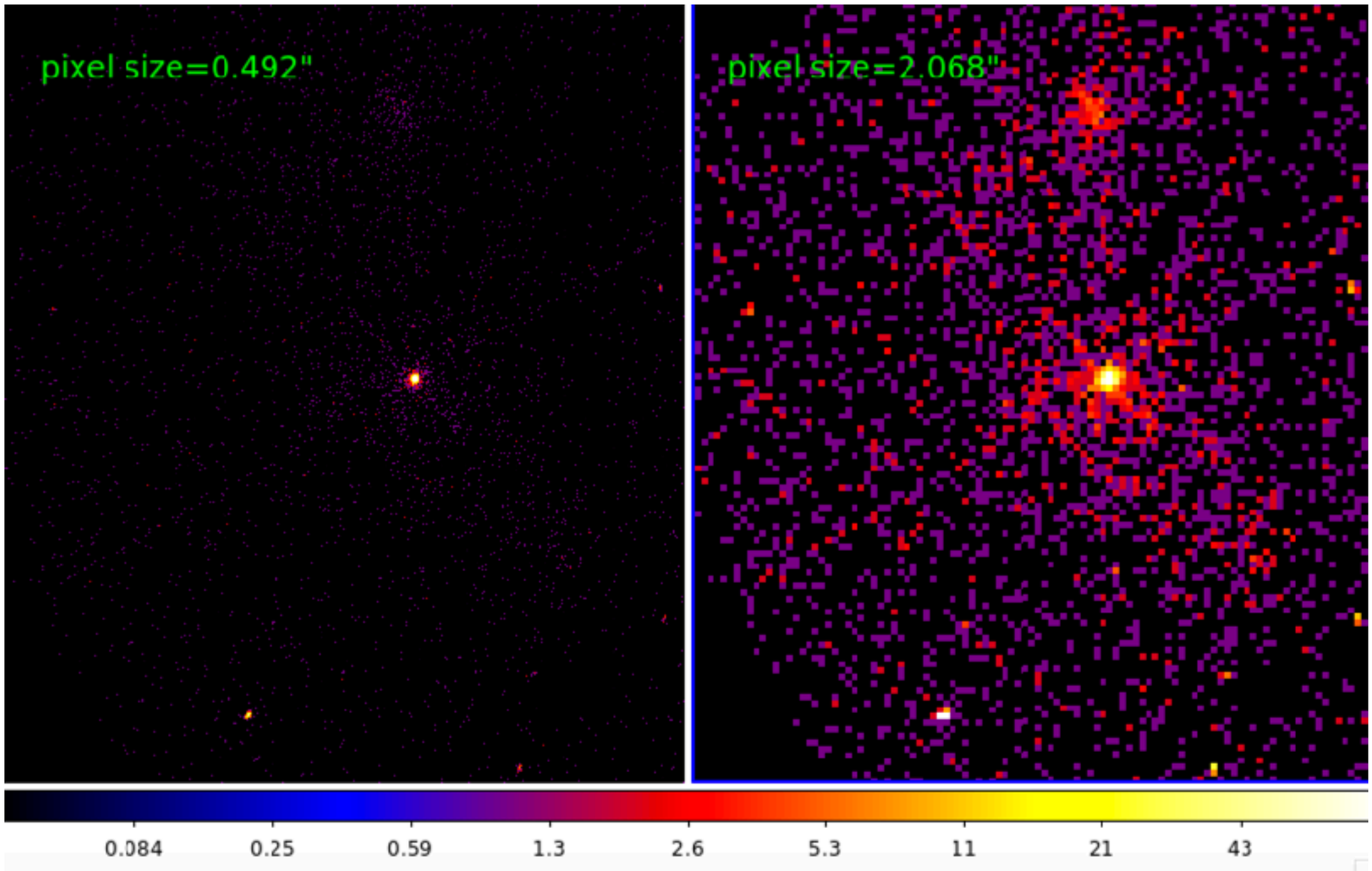


http://cxc.cfa.harvard.edu/ciao/threads/filter/
http://cxc.cfa.harvard.edu/ciao/download/doc/dmuser1.ps

Filtering & Binning

Spatial binning:

```
dmcopy "evt_repro_0.3_7.0keV.fits[bin x=::4,y=::4]" evt_repro_0.3_7.0keV_binsz4.img
```



http://cxc.cfa.harvard.edu/ciao/threads/filter/

http://cxc.cfa.harvard.edu/ciao/download/doc/dmuser1.ps

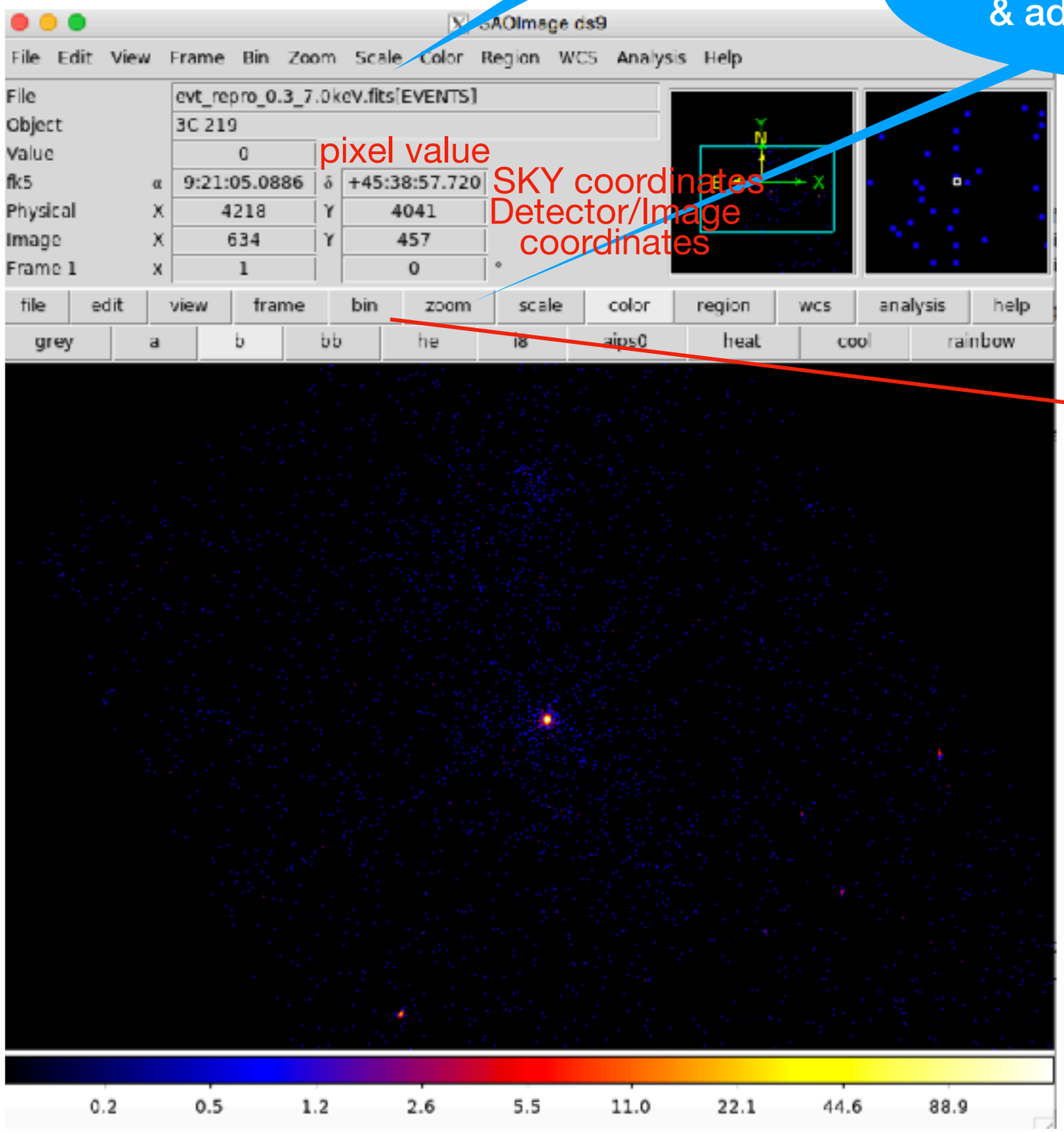
- ☐ (quick) overview of the telescope and instrument capabilities (Chandra/ACIS);
- ☐ data acquisition & architecture: archive, file format;
- ☐ data reduction & manipulation: reprocessing, filtering, binning;
- ☑ obtain the science products for your analysis: images, spectra, lightcurves;

Imaging with ds9

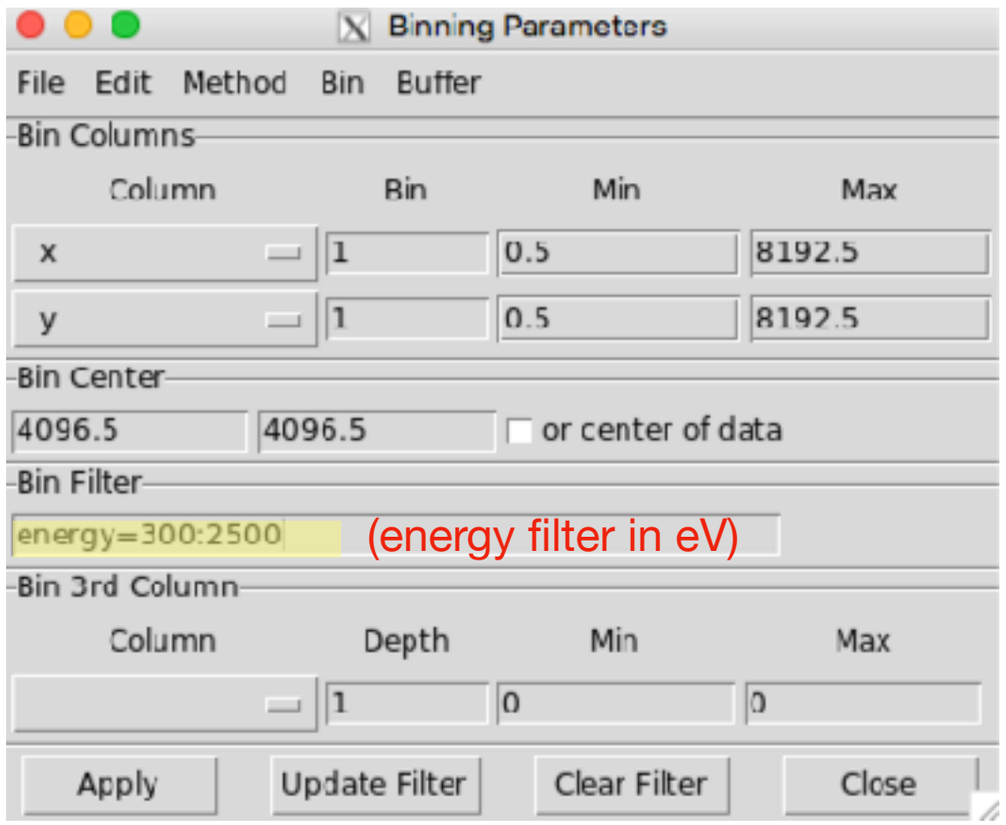
```
ds9 evt_repro_0.3_7.0keV.fits &
```

logarithmic scale

zoom in
& adjust the color (e.g. b)

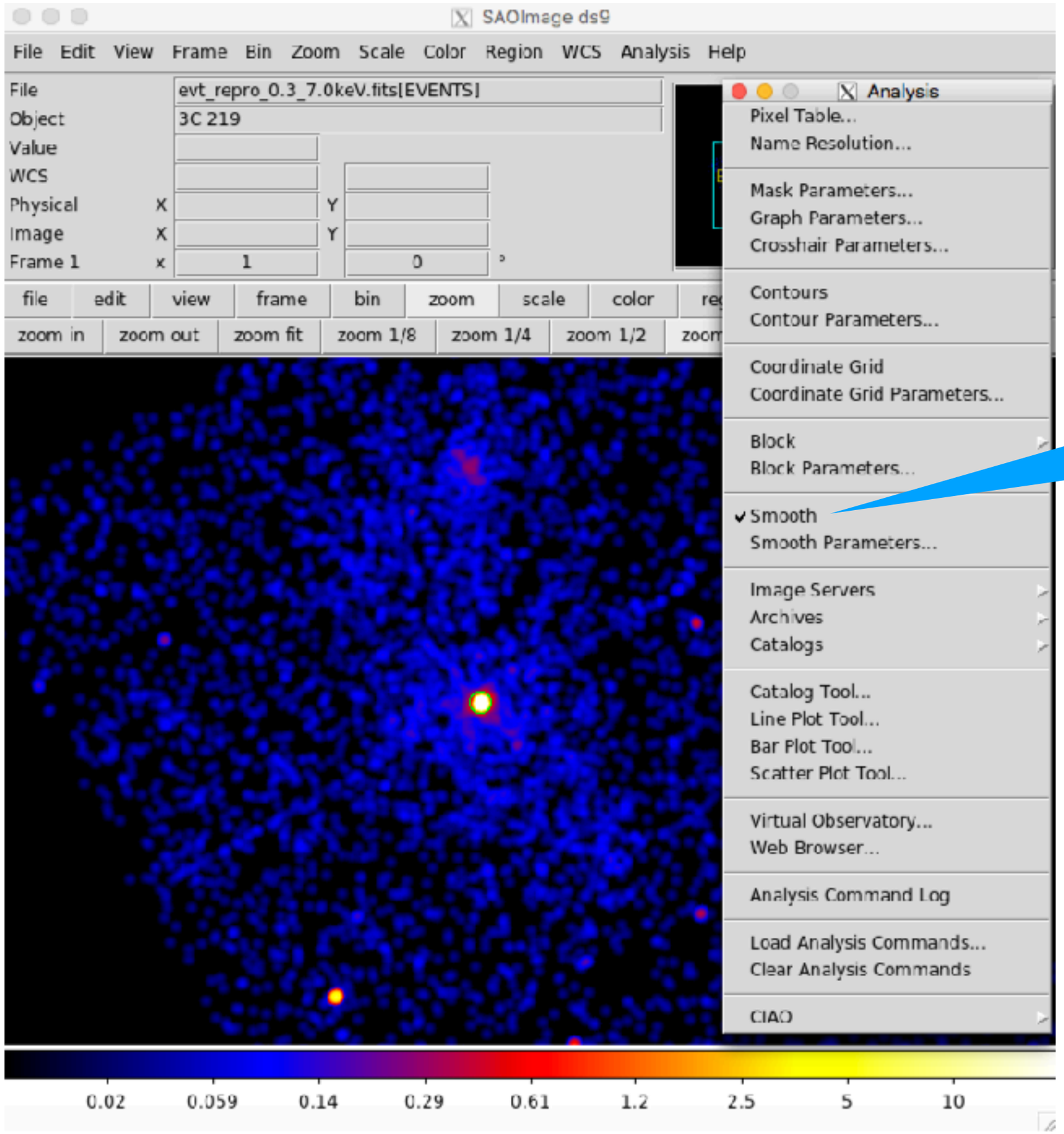


filtering/binning can be done going to:
bin=>binning parameters



http://cxc.cfa.harvard.edu/ciao/threads/ds9/

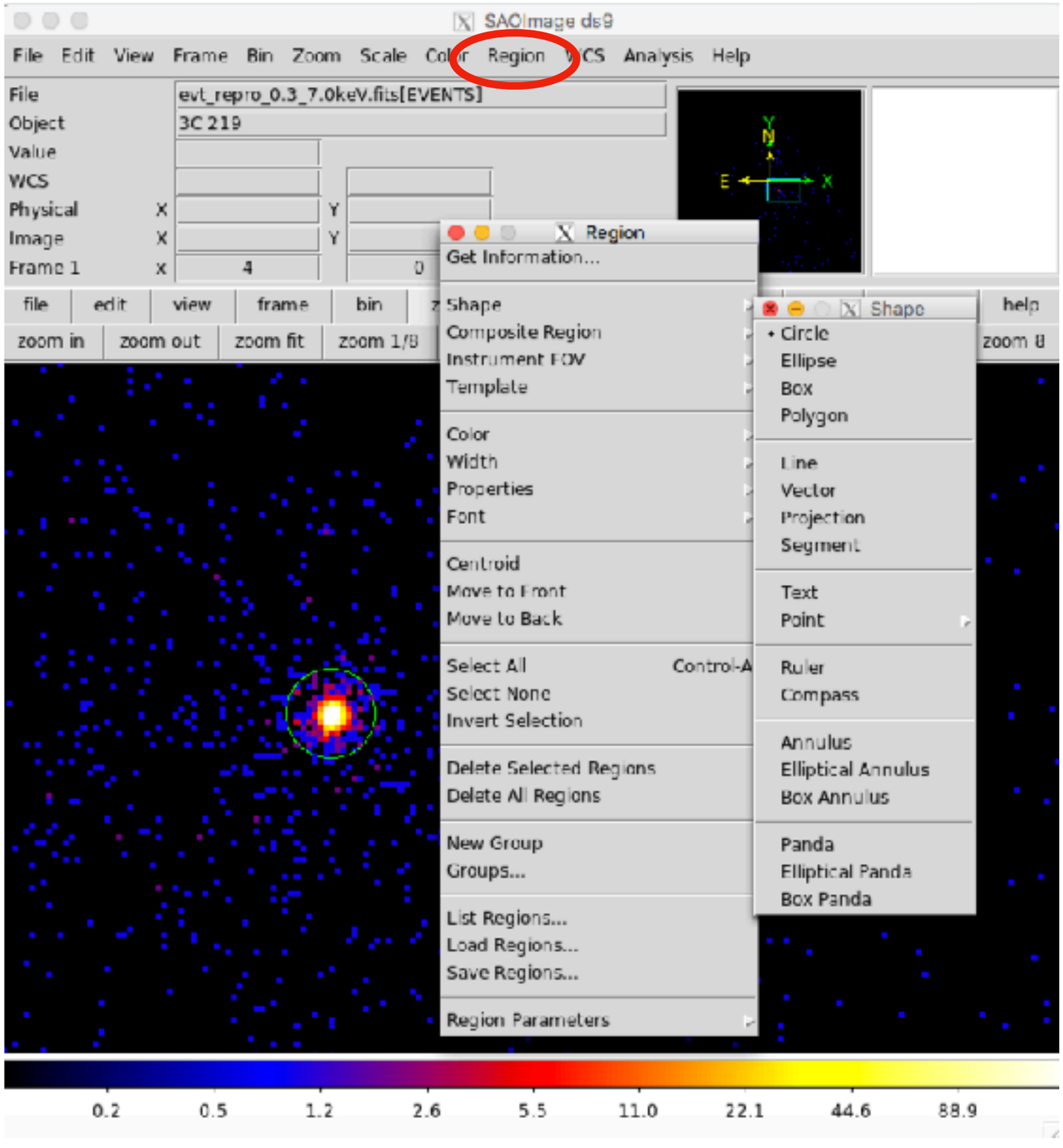
Imaging

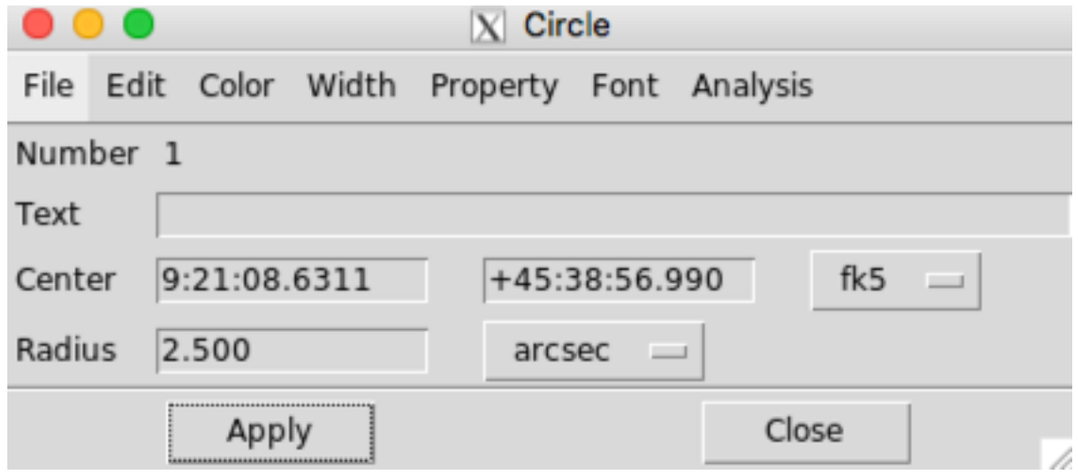


smoothing:

- means to substitute the value of each pixel for the value obtained by weighting the pixels nearby with a given function (generally a Gaussian);
- useful to identify extended emission.

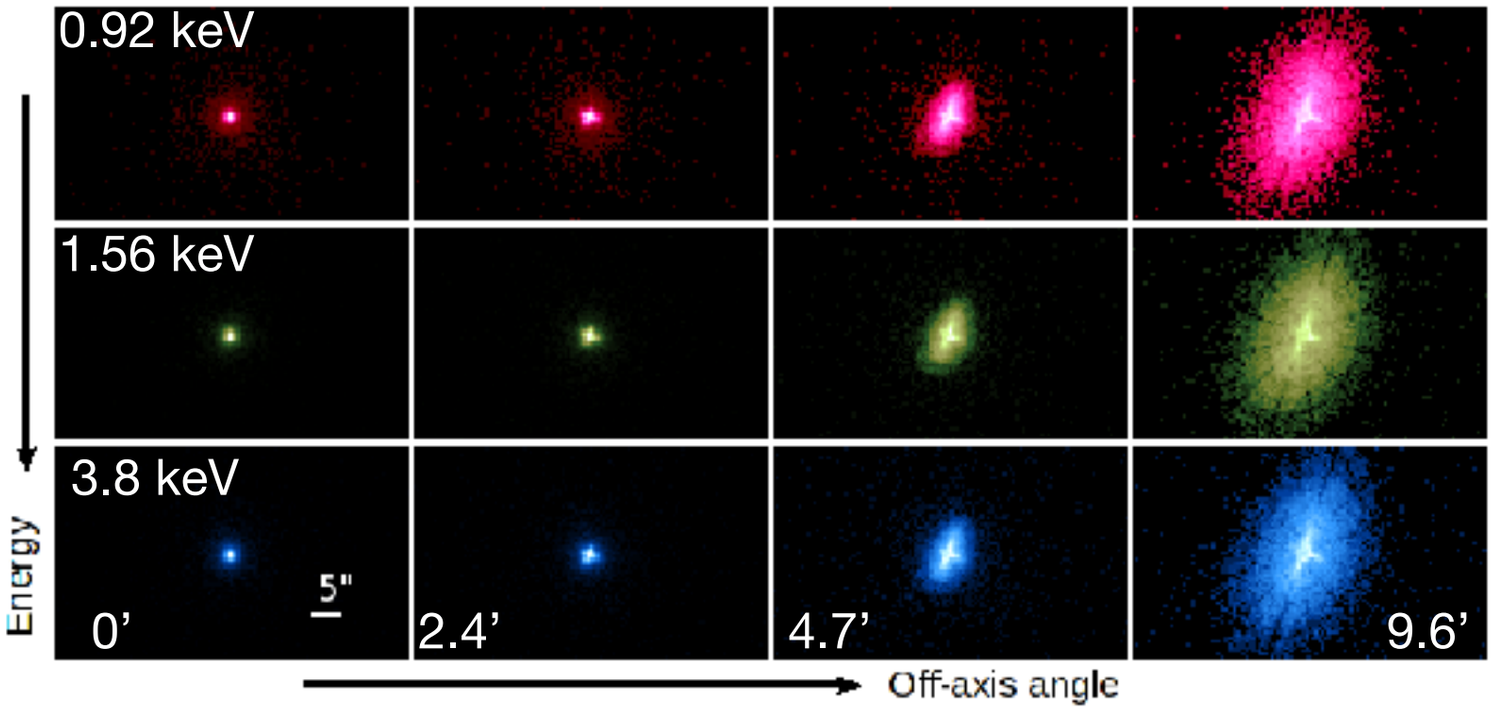
How to obtain the spectrum of the source (and background): selection of the extraction region





http://cxc.cfa.harvard.edu/ciao/threads/pointlike/

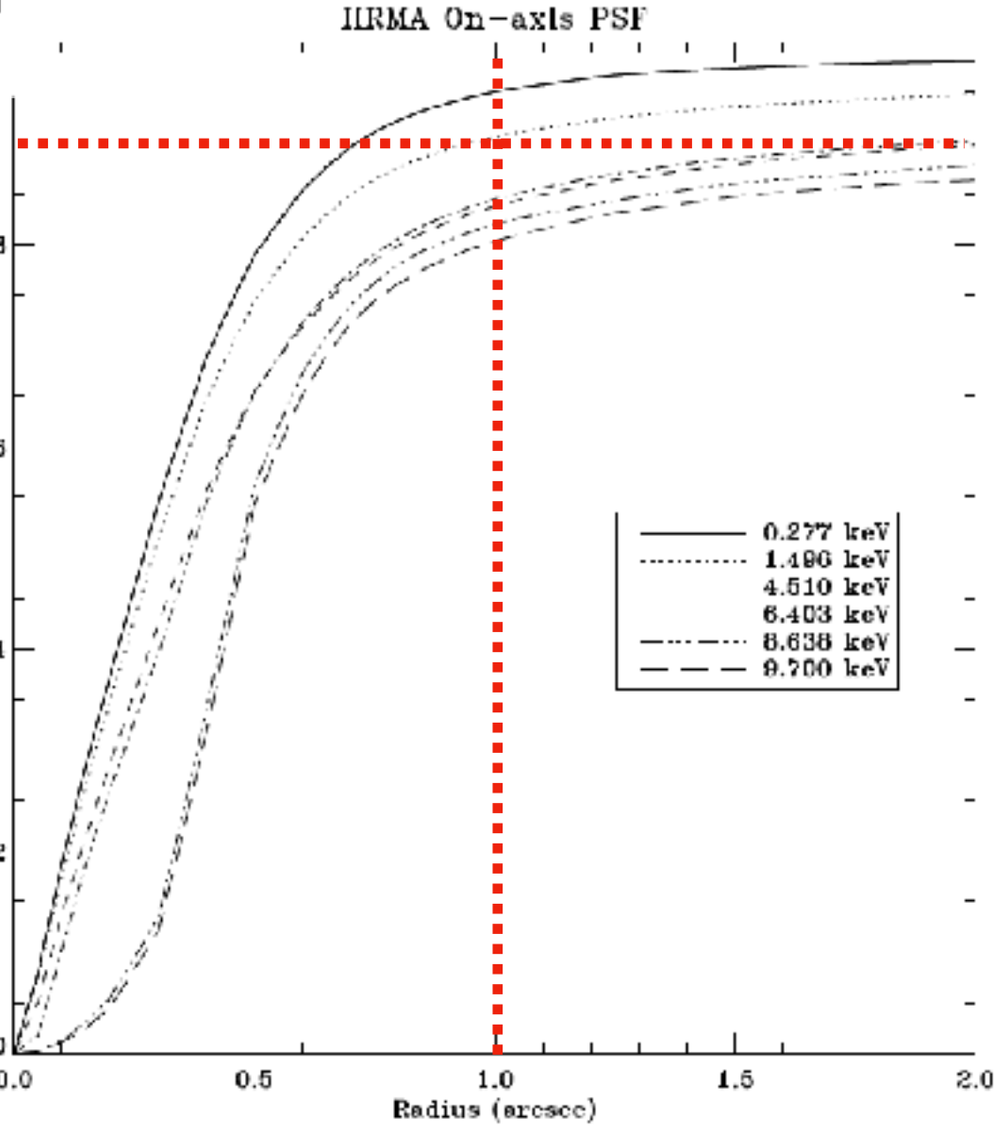
http://cxc.cfa.harvard.edu/ciao/PSFs/psf_central.html

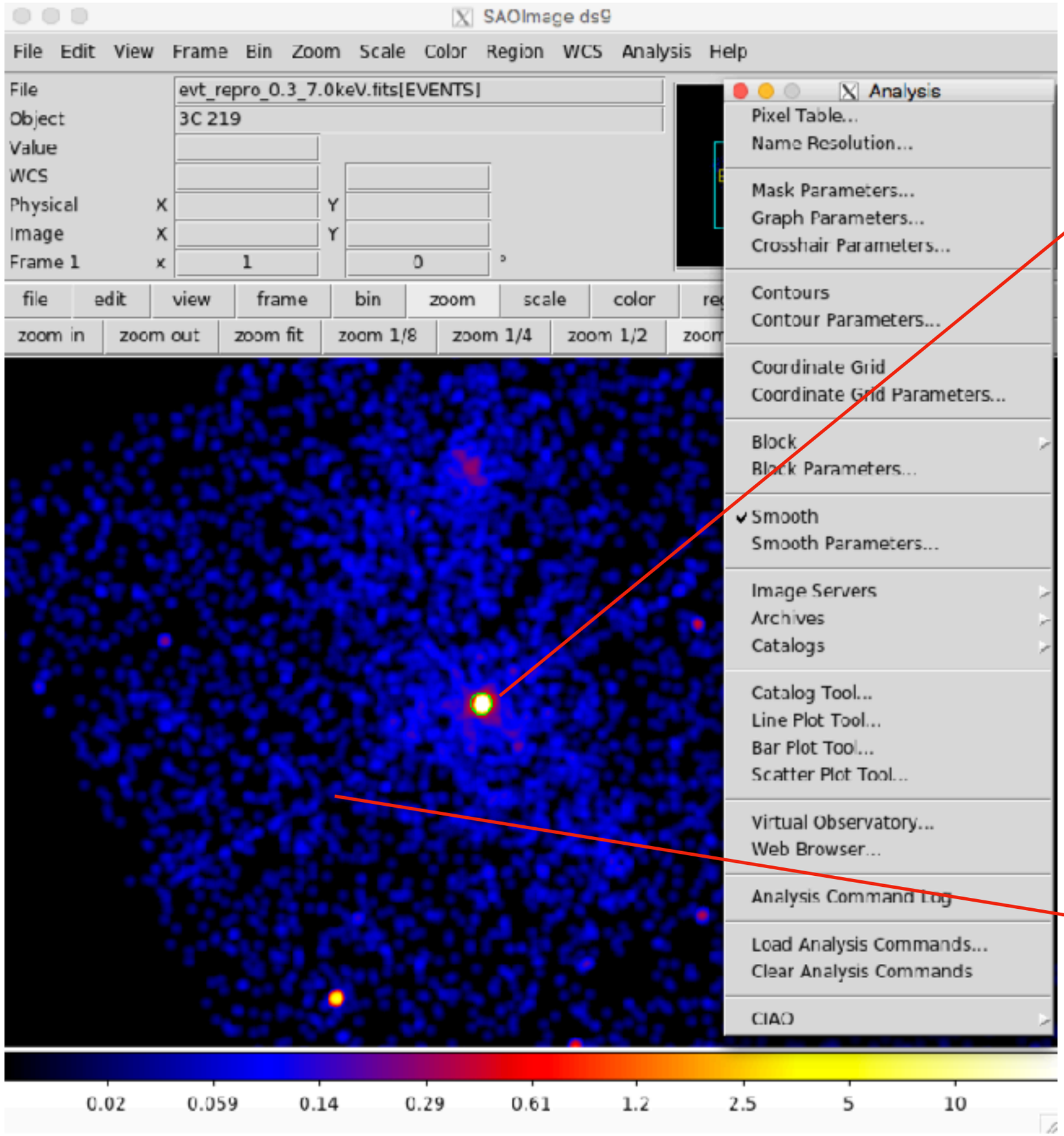


The **Point Spread Function** varies with the source's spectral **energy** distribution and the **position** in the telescope field of view

Encircled Energy Fraction:

- the fraction of flux from a point source contained within a given radius at a given energy (~90% of photons of a point source fall within a 1" radius);
- gives an indication on the dimension of the source extraction region for a spectrum.





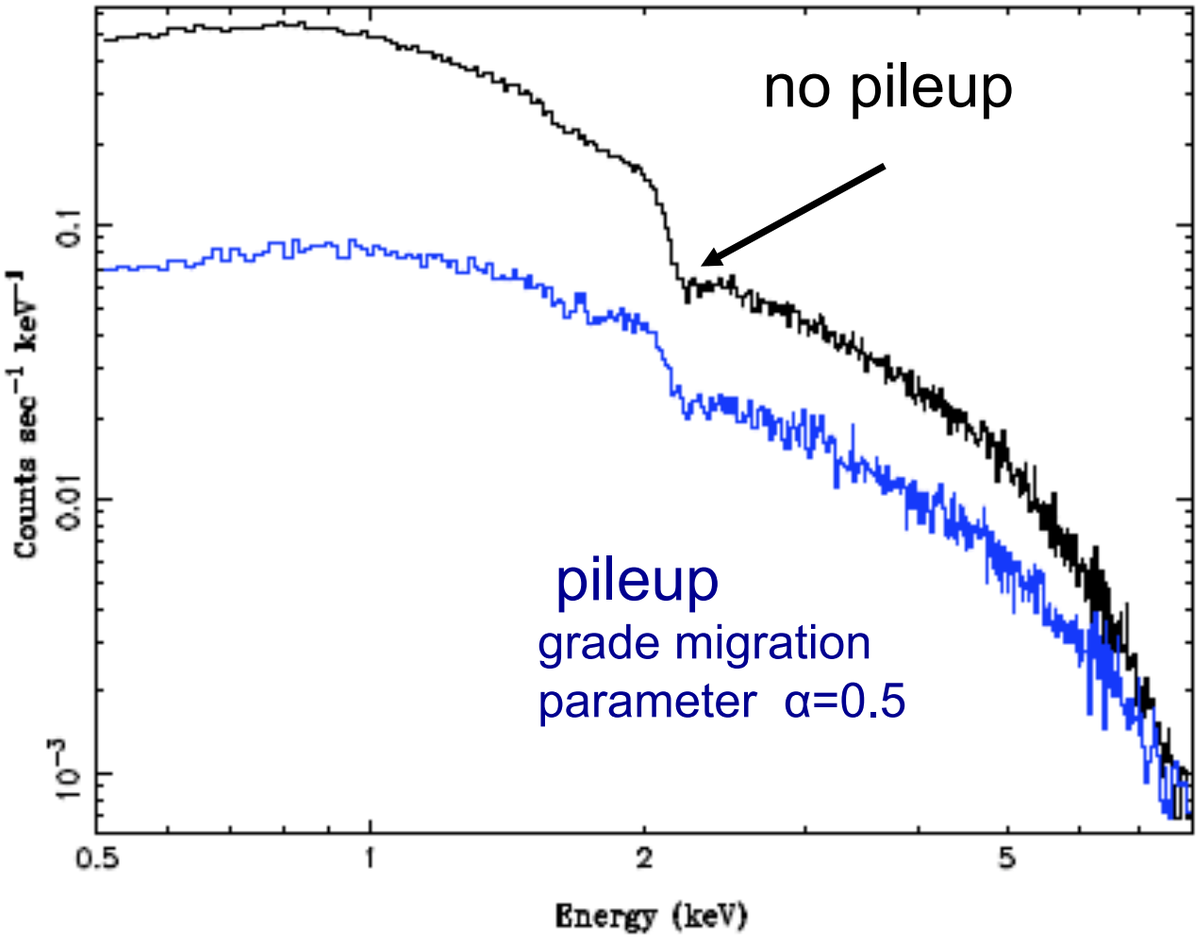
Pile-up: when the source's count rate is high, two photons or more photons falling on the same pixel may be read as one single event (with energy equal to the sum of the two photons).

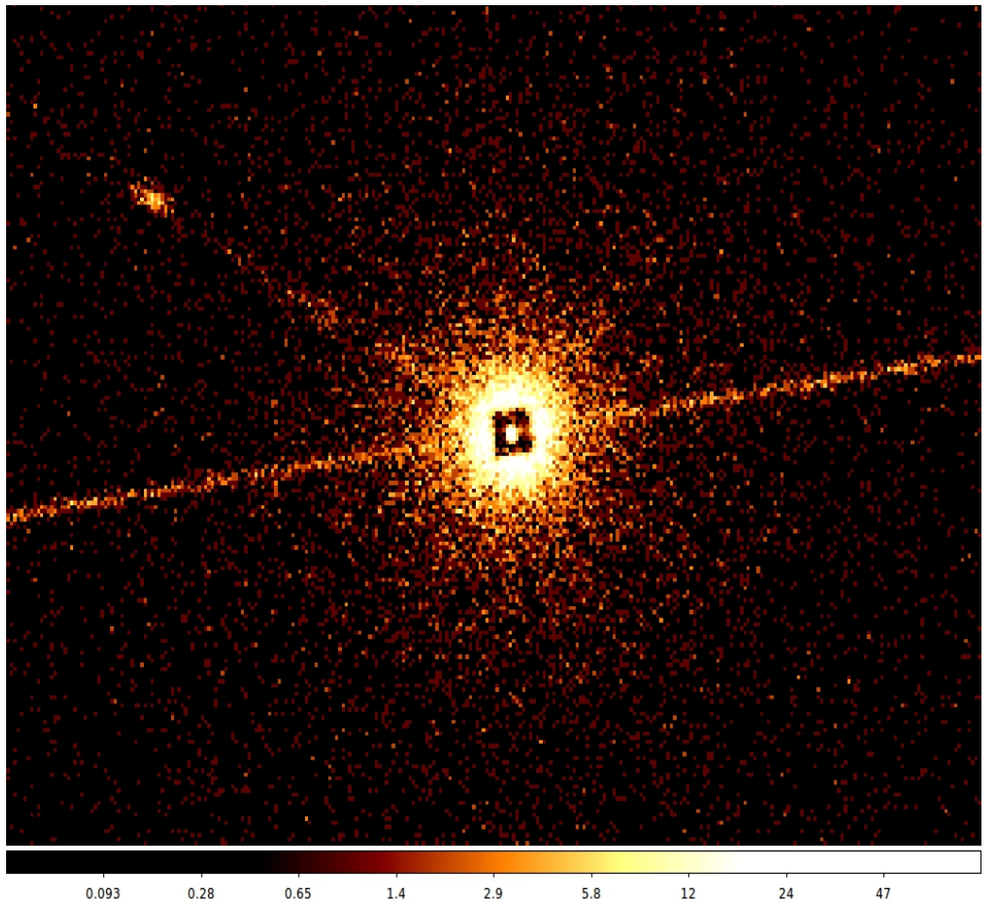
Read-out streak: the streak photons are clocked out in the wrong row and so have incorrect CHIPY values (http://cxc.cfa.harvard.edu/ciao/threads/acisreadcorr/)

http://cxc.cfa.harvard.edu/ciao/download/doc/pileup_abc.pdf

Effects of the Pile-up:

- distortion of the source spectrum: the source spectrum will appear harder/flatter than in reality;
- pulse saturation: if the energy of the summed photon is higher than a certain threshold (~13 keV), the event is rejected => may generate “holes” in the images;
- underestimate of the actual count rate.





How to avoid or limit pile-up issues:

- before the observation: 1-reduce the frame read-out time by selecting sub-arrays; 2- reduce the source effective area by using the diffraction gratings; 3- place the source off-axis;
- after the observation: 1- extract the spectrum from an annulus region (excluding the inner region of the source); 2- include a pile-up model in your spectral model (included in XSPEC); 3- extract the spectrum from the read-out streak

http://cxc.cfa.harvard.edu/ciao/download/doc/pileup_abc.pdf

Pile-up estimation with PIMMS

http://cxc.cfa.harvard.edu/toolkit/pimms.jsp

CHANDRA X-RAY OBSERVATORY

Proposal Planning Toolkit

PIMMS Colden Precess Dates

Main Proposer Page

PIMMS v4.8c: with ACIS Pile up and Background Count Estimation

Input	Output
Count Rate / Flux / Flux Density	Count Rate / Flux / Flux Density
Mission: CHANDRA-Cycle 20	Mission: CHANDRA-Cycle 20
Detector/Grating/Filter: ACIS-I/None/None	Detector/Grating/Filter: ACIS-I/None/None
Input Energy: default to default keV	Output Energy: default to default

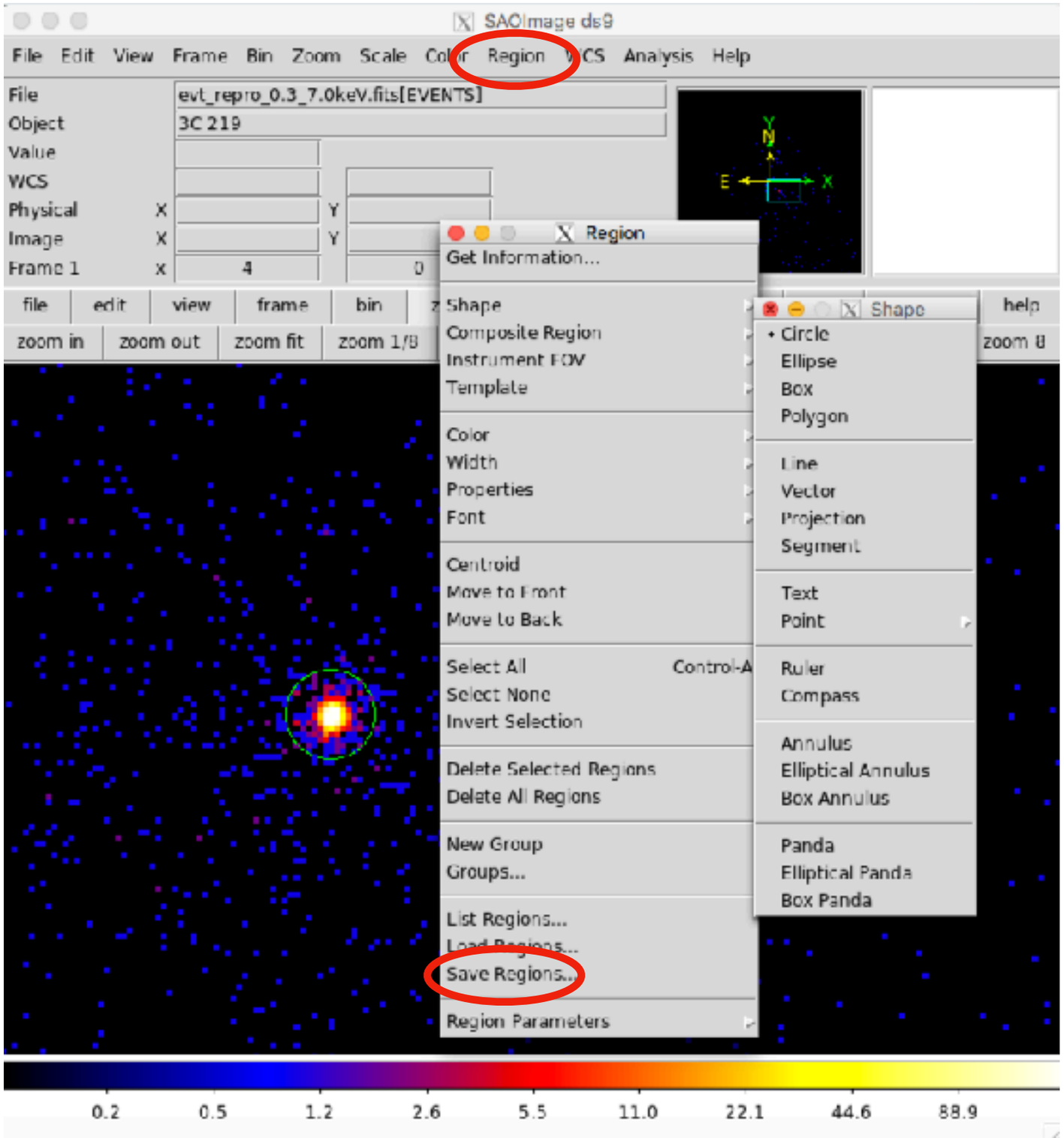
Model:	Galactic NH:	Redshift(z):	Redshifted NH:	Photon Index:	Count Rate:
Power Law	cm**-2		cm**-2	N=AE**-a	cts/s

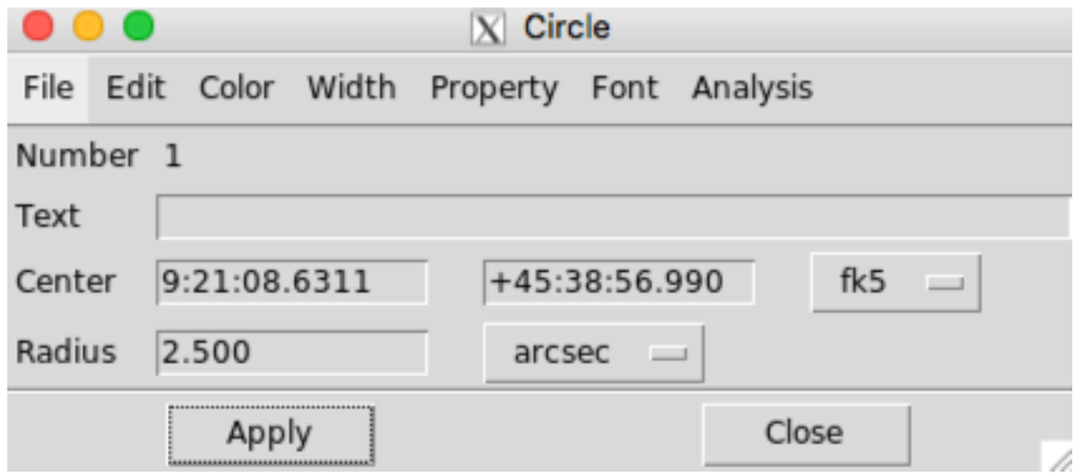
Source: point source — Frame Time: Specify 3.2 sec

CALCULATE CLEAR HELP

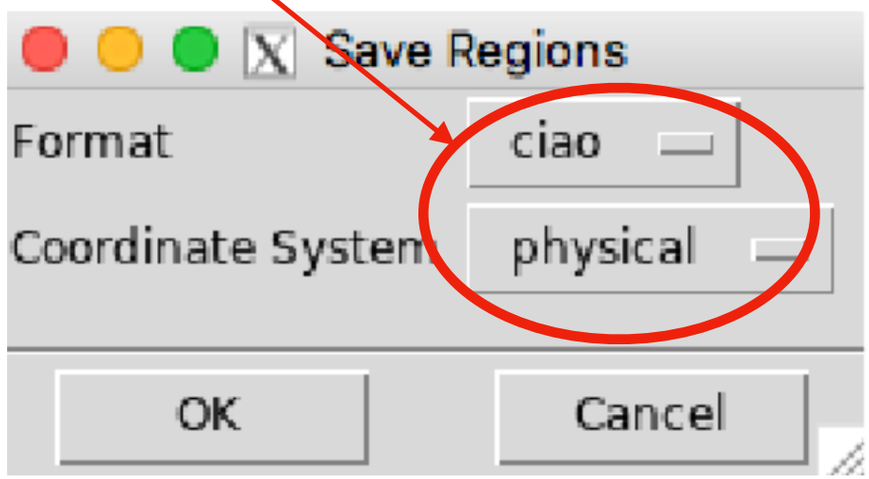
PIMMS Prediction:	Pileup:	Predicted piled count rate:		Background Count Rate:
cts/sec count rate	%	cts/frame	cts/sec	cts/sec

How to obtain the spectrum of the source (and background): source extraction region





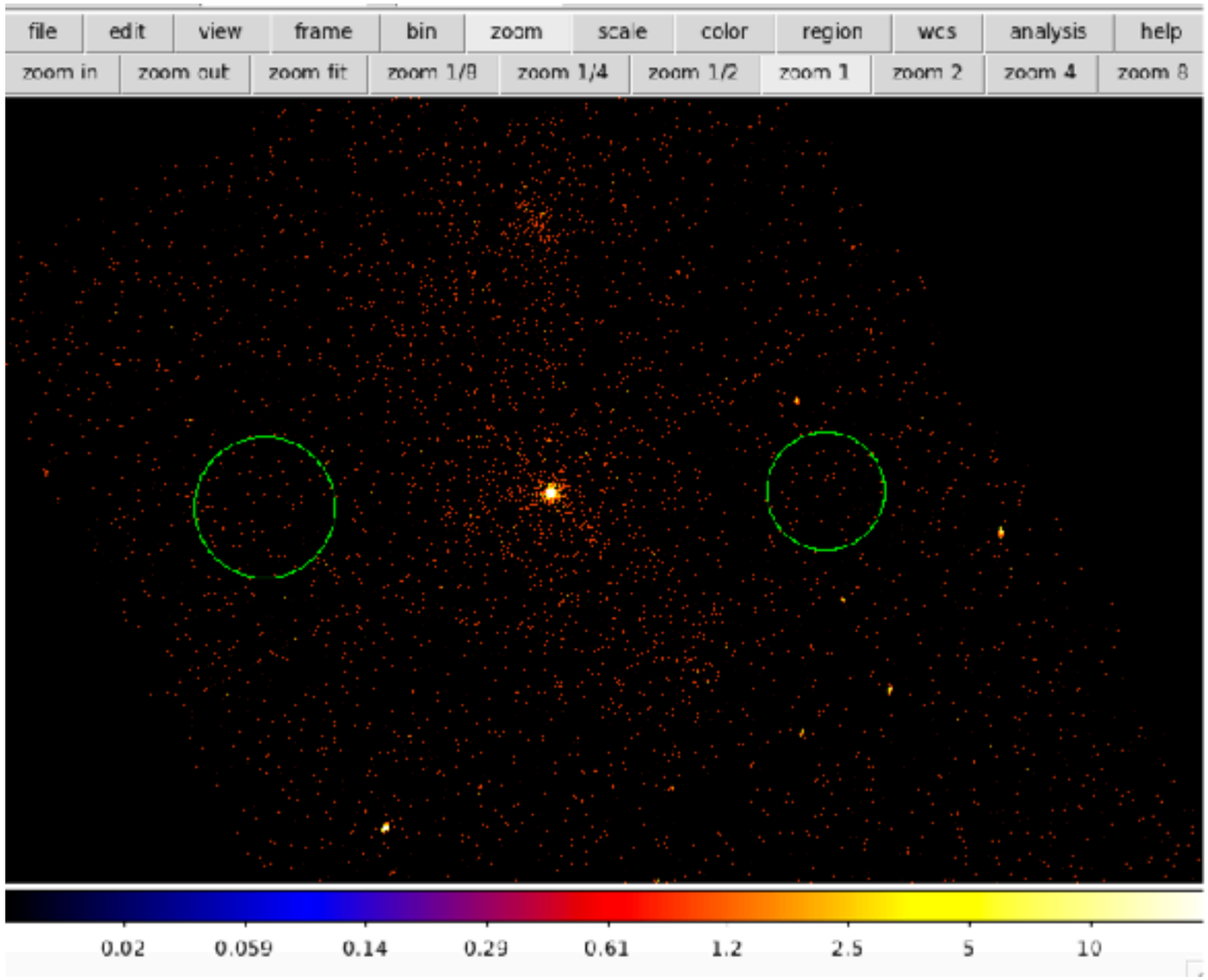
save the region as src.reg
N.B. the format & coordinate system of the .reg file



http://cxc.cfa.harvard.edu/ciao/threads/regions/

How to obtain the spectrum of the source (and background): bkg extraction region

- one or multiple region(s) in the field;
- on the same ccd;
- free from field sources;
- save it as bkg.reg (remember: format=CIAO; coord. system=physical)




```
sapmcm127:repro gmiglior$ more src.reg
circle(4142.5,4039.501,6.0975609)
sapmcm127:repro gmiglior$ more bkg.reg
circle(4310.5,4040.501,36.462573)
circle(3968,4030,43.488126)
```

How to obtain the spectrum of the source (and background): specextract for a point source

- run the script “specextract”:

```
sapmcm127:repro gmiglior$ punlearn specextract
sapmcm127:repro gmiglior$ pset specextract
infile="acisf00827_repro_evt2.fits[sky=region(src.reg)]"
sapmcm127:repro gmiglior$ pset specextract
bkgfile="acisf00827_repro_evt2.fits[sky=region(bkg.reg)]"
sapmcm127:repro gmiglior$ pset specextract weight=no
sapmcm127:repro gmiglior$ pset specextract correctpsf=yes
sapmcm127:repro gmiglior$ pset specextract asp=pcadf087648241N003_asol1.fits
sapmcm127:repro gmiglior$ specextract
```

→ **for point-like sources**

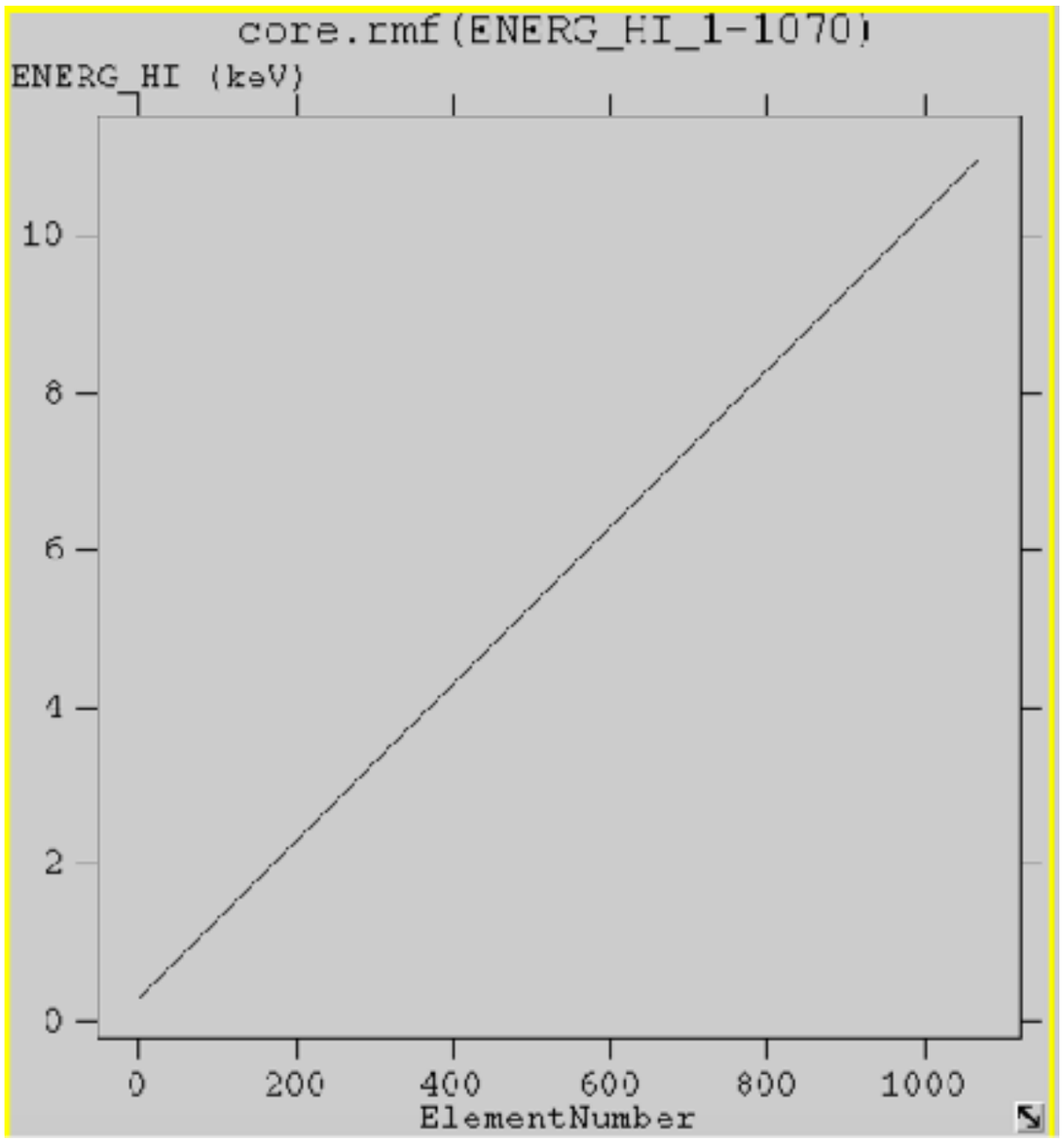
- “specextract” runs all the following steps:
  - `dmextract`: to extract source and (optionally) background spectra. This tool also creates the WMAP used as input to `mkacisrmf`.
  - `mkarf`: to create ARF(s).
  - `arfcorr`: to apply an energy-dependent point-source aperture correction to the source ARF file.
  - `mkrmf` or `mkacisrmf`: to build the RMF(s), depending on which is appropriate for the data and the calibration; see the Creating ACIS RMFs why topic for details.
  - `dmgroup`: to group the source spectrum and/or background spectrum.
  - `dmhedit`: to update the BACKFILE, RESPFILE and ANCRFILE keys in the source and background spectrum files.

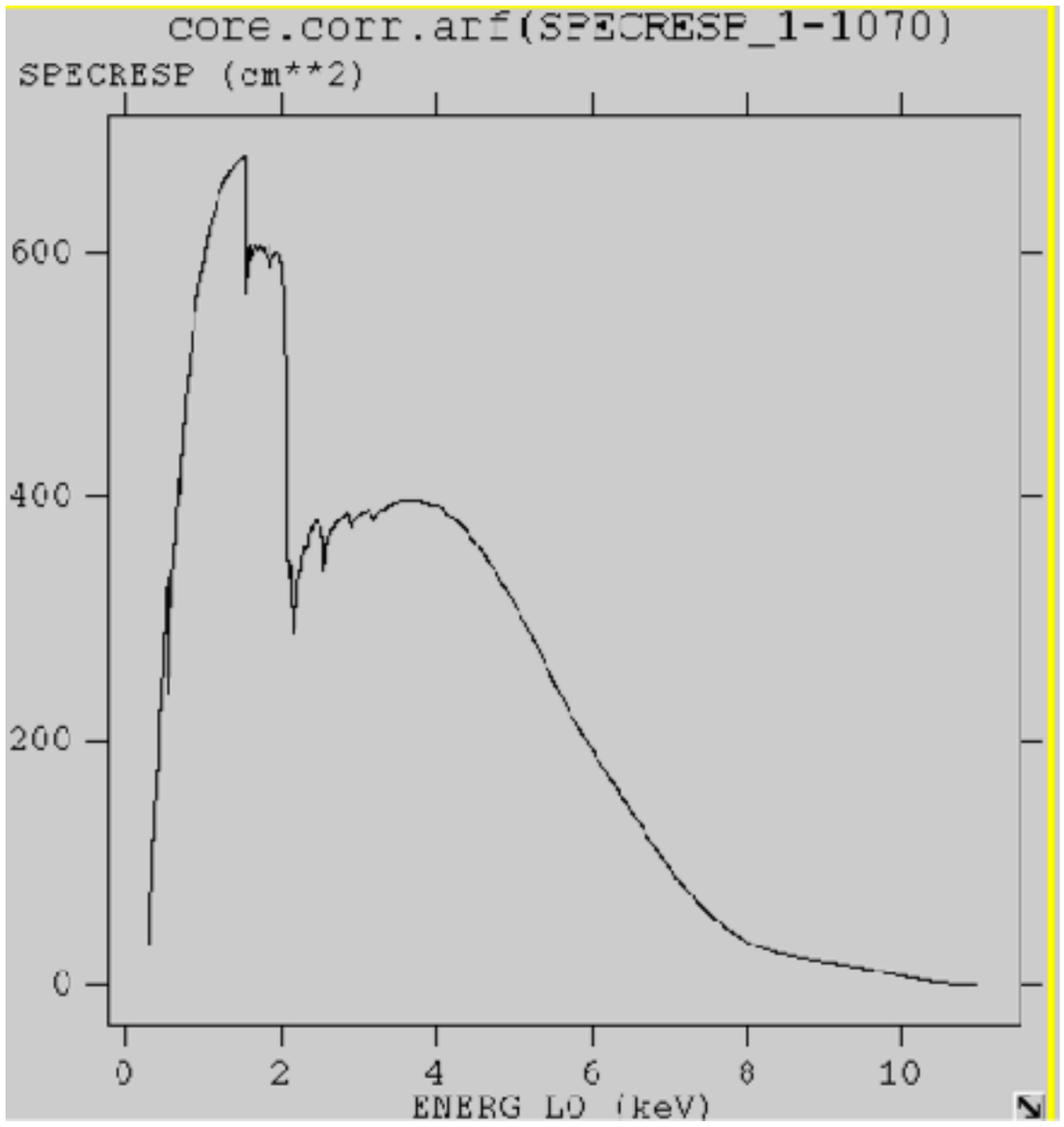
http://cxc.cfa.harvard.edu/ciao/threads/pointlike/

Response function= RMF x ARF

1. The ***Redistribution Matrix File (RMF):*** encapsulates the mapping between the physical properties of incoming photons (such as their energy) and their detected properties (such as detector pulse heights or PHA) for a given detector. For X-ray spectral analysis, the RMF encodes the probability R(E,p) that a detected photon of energy E will be assigned to a given channel value (PHA or PI) of p.

2. The ***Auxiliary Response File (ARF):*** includes information on the effective area, filter transmission and any additional energy-dependent efficiencies, i.e. **the efficiency of the instrument in revealing photons**





How to obtain the spectrum of the source (and background): specextract for a, extended source

- run the script “specextract”:

```
sapmcm127:repro gmiglior$ punlearn specextract
sapmcm127:repro gmiglior$ pset specextract
infile=“acisf00827_repro_evt2.fits[sky=region(jet.reg)]"
sapmcm127:repro gmiglior$ pset specextract
bkgfile="acisf00827_repro_evt2.fits[sky=region(bkg.reg)]"
sapmcm127:repro gmiglior$ pset specextract weight=yes
sapmcm127:repro gmiglior$ pset specextract correctpsf=no
sapmcm127:repro gmiglior$ pset specextract asp=pcadf087648241N003_asol1.fits
sapmcm127:repro gmiglior$ specextract
```

for extended sources the ARF is weighted depending on how much flux fell onto bad pixels/ columns etc

- “specextract” runs all the following steps:
  - `dmextract`: to extract source and (optionally) background spectra. This tool also creates the WMAP used as input to `mkacisrmf`.
  - `sky2tdet`: to create the WMAP input for `mkwarf`.
  - `mkwarf`: to create weighted ARF(s).
  - `mkrmf` or `mkacisrmf`: to build the RMF(s), depending on which is appropriate for the data and the calibration; see the Creating ACIS RMFs why topic for details.
  - `dmgroup`: to group the source spectrum and/or background spectrum.
  - `dmhedit`: to update the BACKFILE, RESPFILE and ANCRFILE keys in the source and background spectrum files.

http://cxc.cfa.harvard.edu/ciao/threads/extended/

How to combine multiple spectra

- if you have multiple observations of the same target, you can: 1- co-add the spectra obtained from the single observations or.. 2- simultaneously fit the spectra (in Xspec):

> punlearn combine_spectra
-> pset combine_spectra src_spectra=obs1843.pi,obs1842.pi
-> pset combine_spectra outroot=spec_combined
-> pset combine_spectra src_arfs=…
-> pset combine_spectra src_rmfs=...
-> pset combine_spectra bkg_spectra=…(optional)
-> pset combine_spectra bkg_arfs=…(optional)
-> pset combine_spectra bkg_rmfs=... (optional)
-> pset combine_spectra bscale_method=… options: asca/time/counts
-> combine_spectra verbose 2

In case of long list of files to be summed up: @namefile
Example: *pset combine_spectra src_spectra=@list_spectra*

http://cxc.cfa.harvard.edu/ciao/threads/coadding/

How to compare the X-ray and radio morphology

https://ned.ipac.caltech.edu/classic

NED

For news and featured updates, please see News on the new interface.

OBJECTS	DATA	LITERATURE	TOOLS	INFO
By Name	Images by Object Name Region	References by Object Name	Coordinate Transformation & Extinction Calculator	Introduction Latest News/Updates
Near Name	Photometry & SEDs	References by Author Name	Velocity Calculator	Features FAQ
Near Position	Spectra	Text Search	Cosmology Calculators	Brochure (pdf) Best Practices (pdf)
IAU Format	Redshifts	Knowledgebase LEVEL 5	Extinction-Law Calculators	Source Nomenclature
By Parameters	Redshift-Independent Distances	Galaxy Distance Tabulations (NED-D)	Galaxy Environment by Precomputed Parameters Radial Velocity Constraint	Web Links NED Home
By Classifications *Types, Attributes*	Classifications by Object Name	Abstracts	X/Y offset to RA/DEC	Glossary & Lexicon
By Refcode	Positions		Batch Help	Team Users Committee
Object Notes	Diameters		Build Data Table from Input List By Name Near Name/Position (Cross-Matching)	Contact Us

If your research benefits from the use of NED, we would appreciate the following acknowledgement in your paper: *This research has made use of the NASA/IPAC Extragalactic Database (NED) which is operated by the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.*

How to compare the X-ray and radio morphology

NASA/IPAC EXTRAGALACTIC DATABASE

Date and Time of the Query: 2018-11-19 T11:00:37 PST

Help | Comment | NED Home

You have selected the following parameters to search on:

Parameters for Distances and Cosmology: $H_o = 73.0$; $\Omega_{matter} = 0.27$; $\Omega_{vacuum} = 0.73$;
Derived Quantities use a Redshift corrected to a Reference Frame defined by the 3K CMB

NED results for object 3C 219

1 objects found in NED.

SOURCE LIST

Row No.	Object Name (* => Essential Note)	Equ J2000.0 RA	DEC	Object Type	Velocity/Redshift km/s	z	Qual	Mag./ Filter	Separ. arcmin	Number of Refs	Notes	Phot	Posn	Vel/z	Diam	Assoc	Images	Spectra	Row No.
1	3C 219	09h21m08.6s	+45d38m57s	QSO	>100000	0.174732		17.8g	...	352	13	167	16	14	10	1	Retrieve	Retrieve	1

Detailed information for each object

Object No. 1 - 3C 219

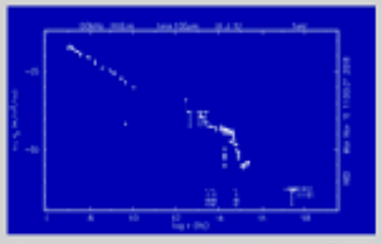
INDEX for 3C 219

Essential Data (jump to sub-section of this query report):

- Essential Note
- Cross-IDs
- Coordinates
- Basic Data
- Quantities Derived from Redshift
- Redshift-Independent Distances
- Quick-Look Photometry and Luminosities
- Quick-Look Angular and Physical Sizes
- Classifications
- Foreground Galactic Extinction
- External Services

Detailed Data (NED queries):

Images

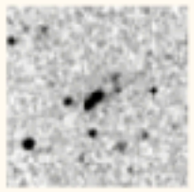
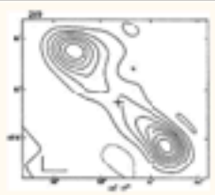
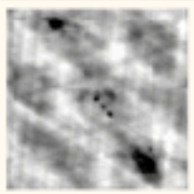
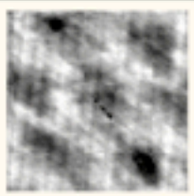
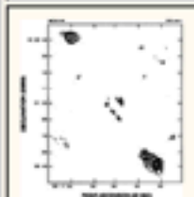
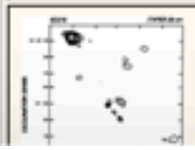


167 Photometric data point(s) and SED

- Spectra
- Redshift Independent Distances
- 352 Reference(s)
- 16 Position data point(s)
- 14 Redshift data point(s)
- 10 Diameter data point(s)
- 13 Note(s)
- 1 Association(s)

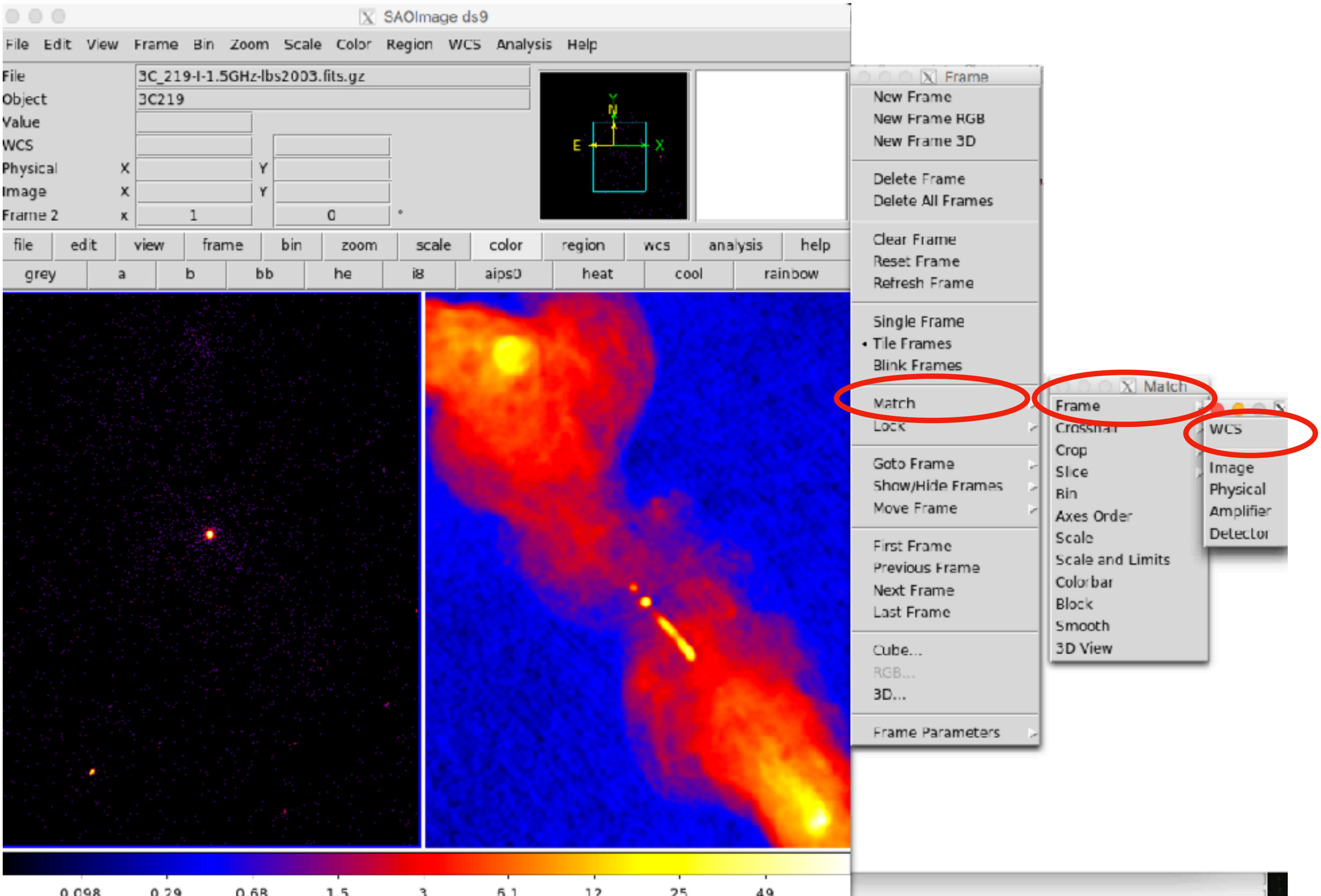
How to compare the X-ray and radio morphology

Images and maps in NED archive for object 3C 219

Preview	FITS/JPG File	More Information	View & Overlay	Band, Wavelength	Image Size (arcmin)	Res. (arcsec)	Telescope	Refcode
	20KB FITS image Retrieve	Display FITS Header		103aE , 6450A	2.0 x 2.0 ChangeSize	1.70	Palomar48-inchSchmidt	1994DSS...1...0000:
	53KB JPG image Retrieve	Display Caption	N/A	1.4GHz , 21cm	N/A	N/A	OneMile	1968MNRAS.138..259M
	1091KB FITS image Retrieve	Display FITS Header		1.5GHz , 20cm	2.6 x 2.6	3.00	VLA	1995ApJS...99..349N
	1362KB FITS image Retrieve	Display FITS Header		1.5GHz , 20cm	3.2 x 2.5	1.40	VLA	1992ApJ...385..173C
	1088KB FITS image Retrieve	Display FITS Header		1.5GHz , 20cm	2.6 x 2.6	1.40	VLA	1995ApJS...99..349N
	65KB JPG image Retrieve	Display Caption	N/A	1.5GHz , 20cm	N/A	N/A	VLA	1995ApJS...99..349N
	61KB JPG image Retrieve	Display Caption	N/A	1.5GHz , 20cm	N/A	N/A	VLA	1995ApJS...99..349N

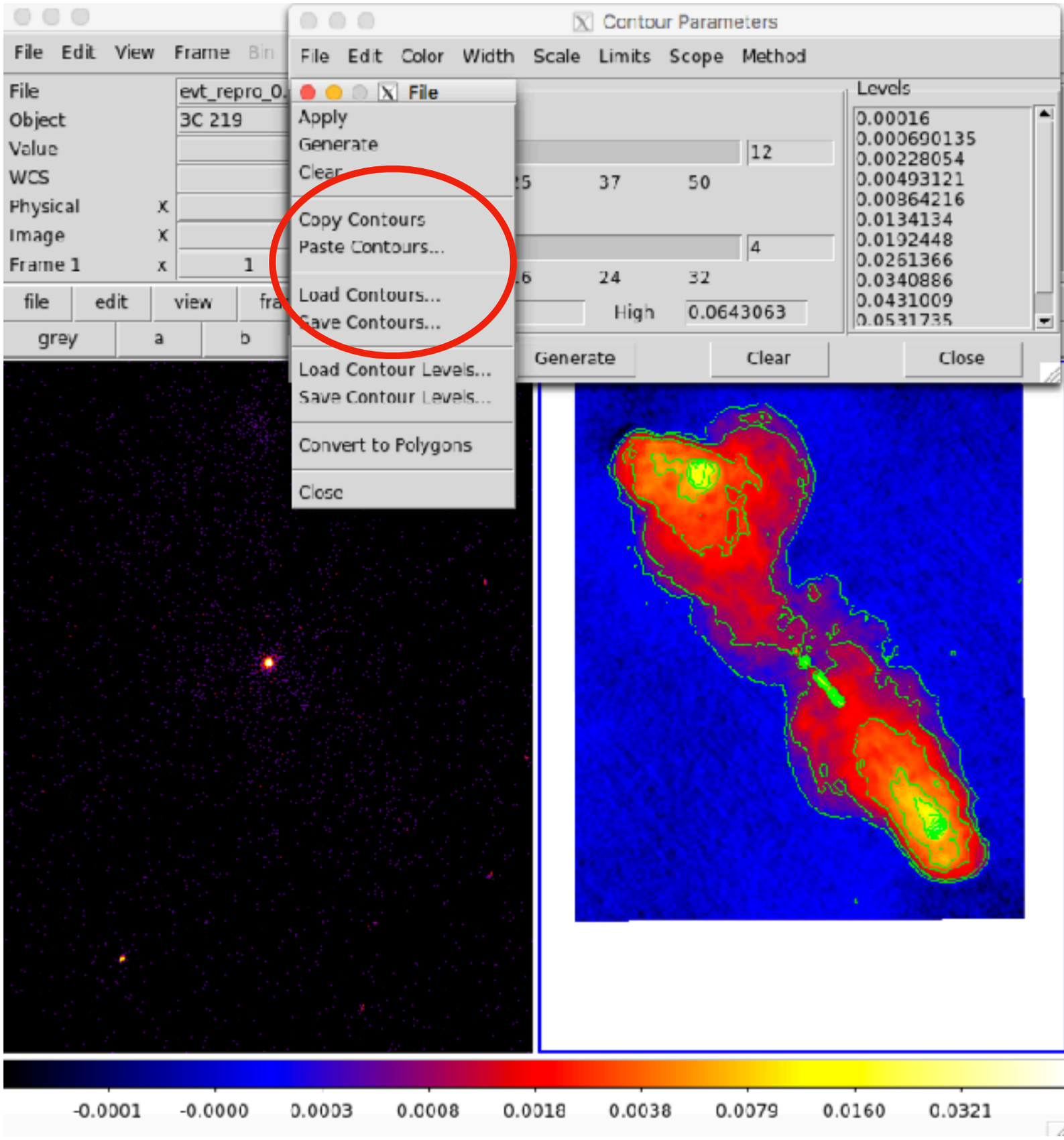
How to compare the X-ray and radio morphology

```
sapmcm127:repro gmiglior$ ds9 evt_repro_0.3_7.0keV.fits 3C_219-I-1.5GHz-lbs2003.fits.gz &
```

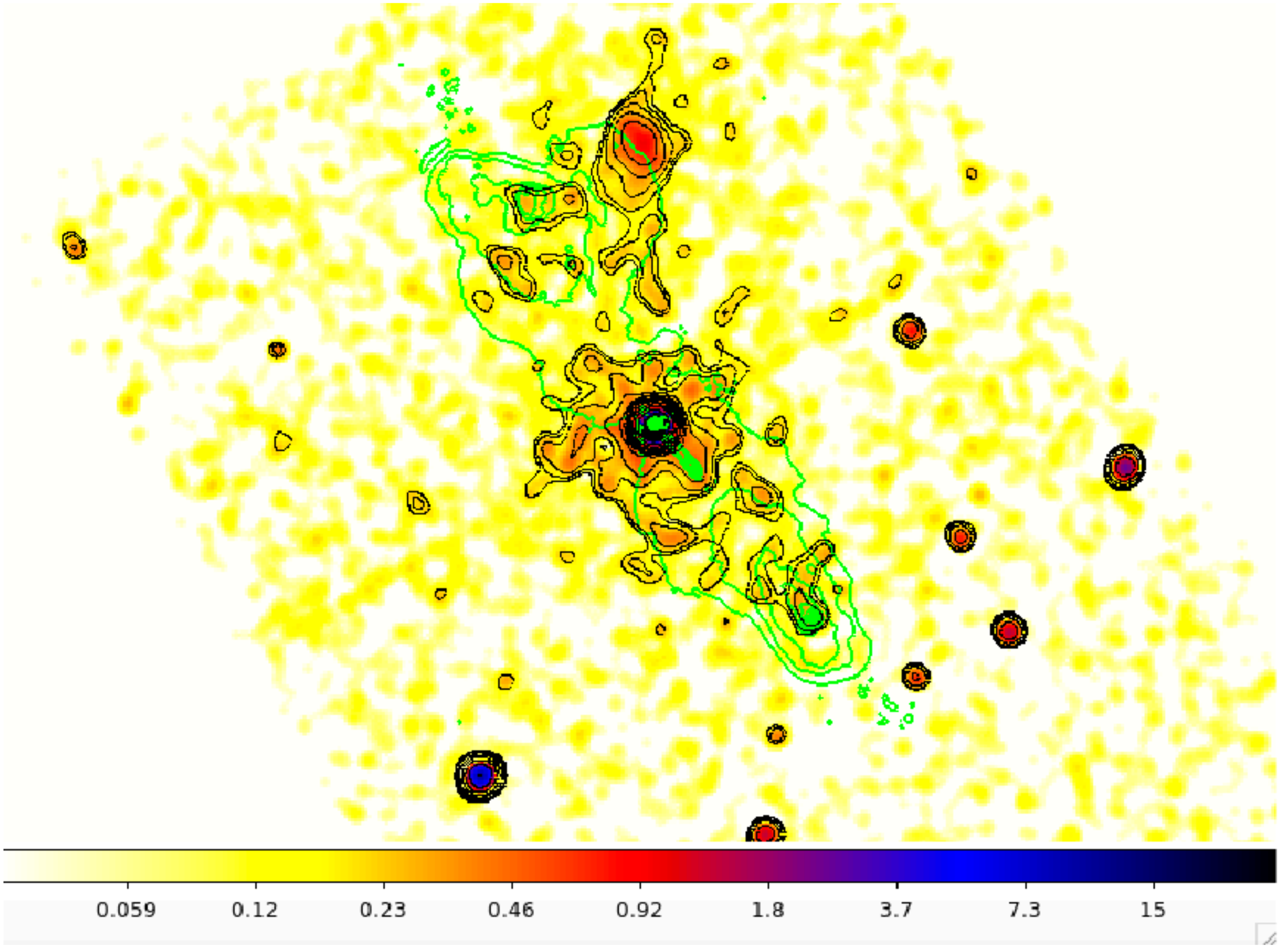


How to compare the X-ray and radio morphology

- in the radio image frame go to Analysis=>contour parameters;
- several ways of define the contours: for ex. from the peak of the emission or based on the rms;
- generate the contours and the apply them
- in File menu=> copy contours (or save them);
- change to the X-ray frame;
- in the contour parameters: File=>paste contours (or load them)



How to compare the X-ray and radio morphology



the same can be done in other wavelengths (optical, IR, mm, ...)

```
dmcopy "evt_repro_0.3_7.0keV.fits[bin x=::2,y=::2]" evt_repro_0.3_7.0keV_binsz2.img
```

How to extract a lightcurve

1) select a source and background region

2) identify the ccd

```
> punlearn dmstat
> dmstat "acisf00953N003_evt2.fits[sky=region(src1.reg)][cols ccd_id]"
```

3) extract the lightcurve (background subtracted)

```
>punlearn dmextract
>pset dmextract infile="acisf00953N003_evt2.fits
  [ccd_id=3,sky=region(src2.reg)][bin time= : : 2000]"
>pset dmextract outfile="src_sub_lc.fits"
>pset dmextract bkg="acisf00953N003_evt2.fits
  [ccd_id=3,sky=region(bkg.reg)]"
>pset dmextract opt="ltc1"
>dmextract
```

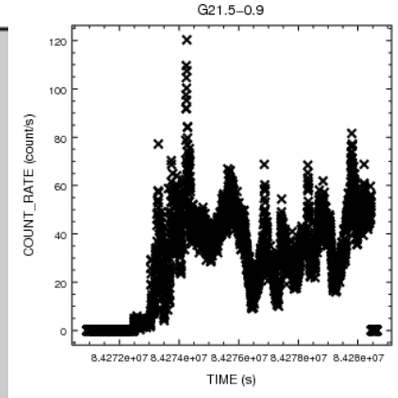
MIN:MAX:STEP

There are several ways to visualize a light curve. Here are two examples:

Chips provided by CIAO

```
unix% chips
-----------------------------------------
Welcome to ChIPS: CXC's Plotting Package
-----------------------------------------
CIAO 4.3 ChIPS version 1 Thursday, December 2, 2010

chips> make_figure("src2_sub_lc.fits[cols time,net_rate,err_rate]", "line.color=red")
```



The ftool ***lcurve***

```
eleonora:pn eleonora$ lcurve

lcurve 1.0 (xronos5.22)

Number of time series for this task[1]
Ser. 1 filename +options (or @file of filenames +options)[lcurve_sup10.lc]
 Series 1 file    1:lcurve_sup10.lc

 Selected FITS extensions: 1 - RATE TABLE;

 Source .............                    Start Time (d) .... 12931 23:33:28.493
 FITS Extension ....  1 - `RATE      `   Stop Time (d) ..... 12932 11:11:04.570
 No. of Rows .......          419        Bin Time (s) ......    100.0
 Right Ascension ...                     Internal time sys.. Converted to TJD
 Declination .......                     Experiment ........ XMM      EPN
 Filter ............. Medium
 Corrections applied: Vignetting - No ; Deadtime - No ; Bkgd - No ; Clock - Yes

 Selected Columns:  3- Time;  1- Y-axis;  2- Y-error;

 File contains binned data.

Name of the window file ('-' for default window)[-]

 Expected Start ... 12931.98157977479  (days)      23:33:28:493  (h:m:s:ms)
 Expected Stop .... 12932.46602511985  (days)      11:11: 4:570  (h:m:s:ms)

 Minimum Newbin Time    100.00000      (s)
 for Maximum Newbin No..              419

 Default Newbin Time is:   100.00000    (s) (to have 1 Intv. of     419 Newbins)
 Type INDEF to accept the default value
```