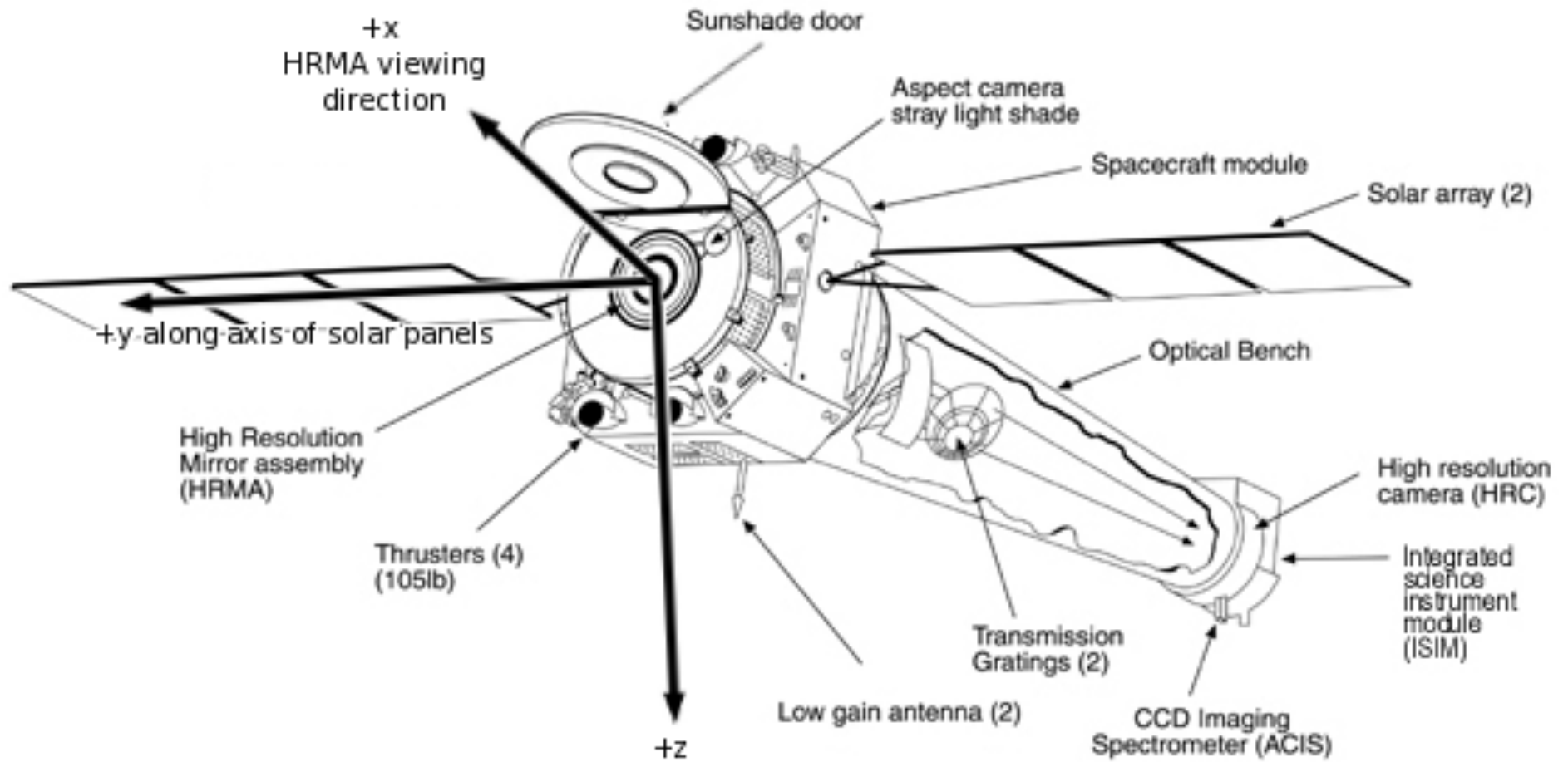


Chandra Tutorial



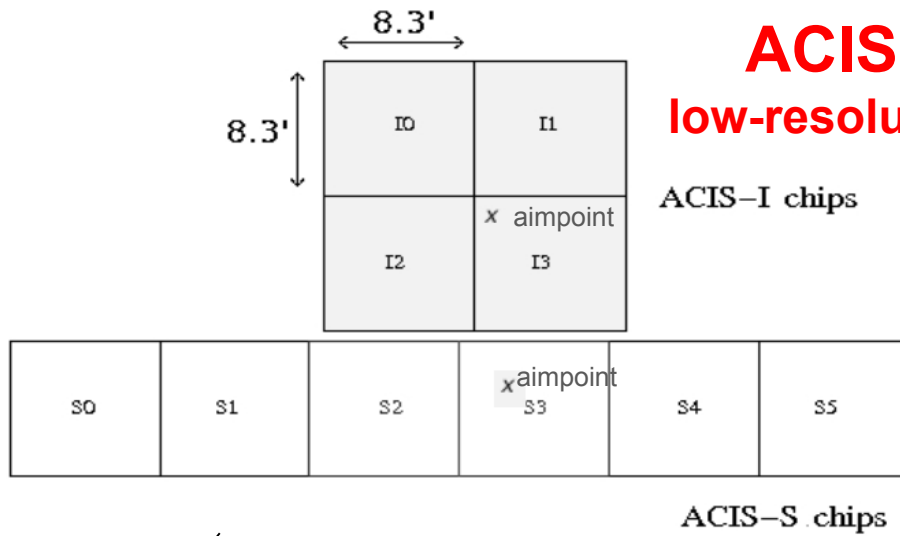
C. Vignali - Laboratorio di Astrofisica 2013

The spacecraft



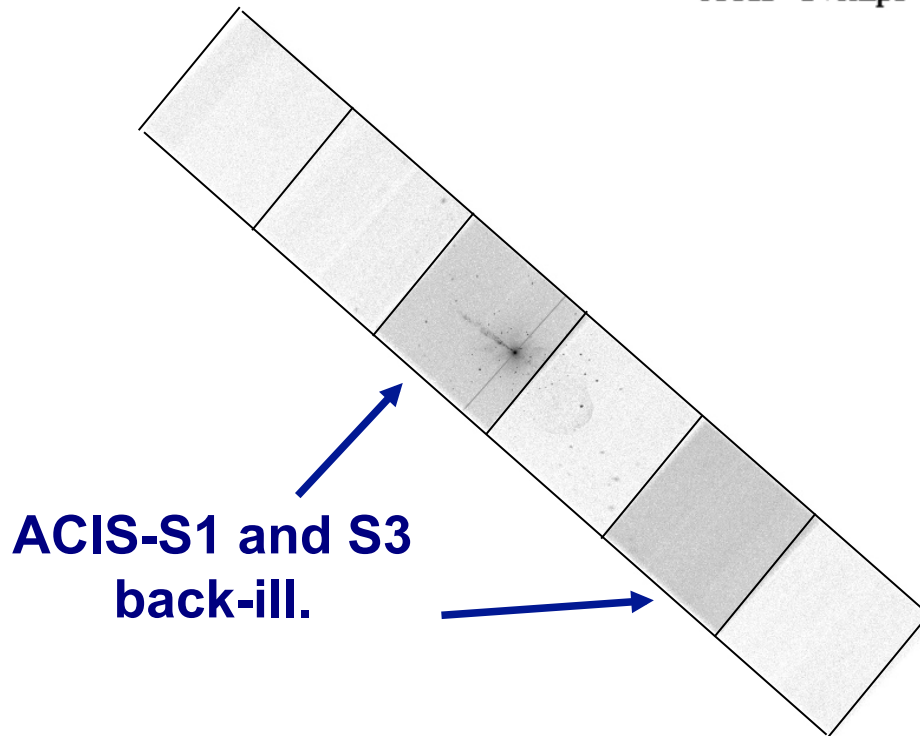
ACIS

The detectors

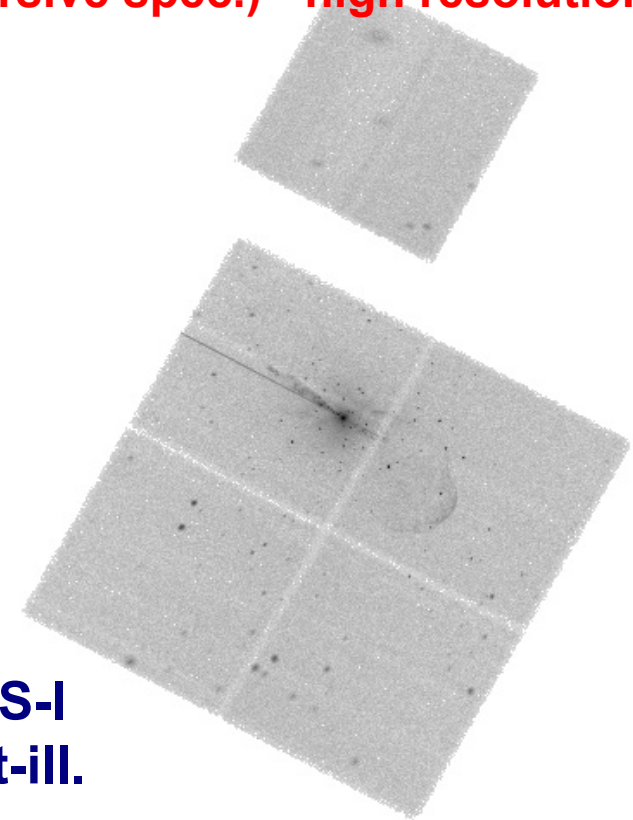


ACIS – imaging and
low-resolution spectroscopy

HRC – high-resolution camera
HETG and LETG
(dispersive spec.) - high resolution



ACIS-I
front-ill.



1. The fundamental rules to reduce X-ray data are the same in most of the cases BUT a good knowledge of the properties of X-ray satellites and their instruments is important to maximize the scientific output

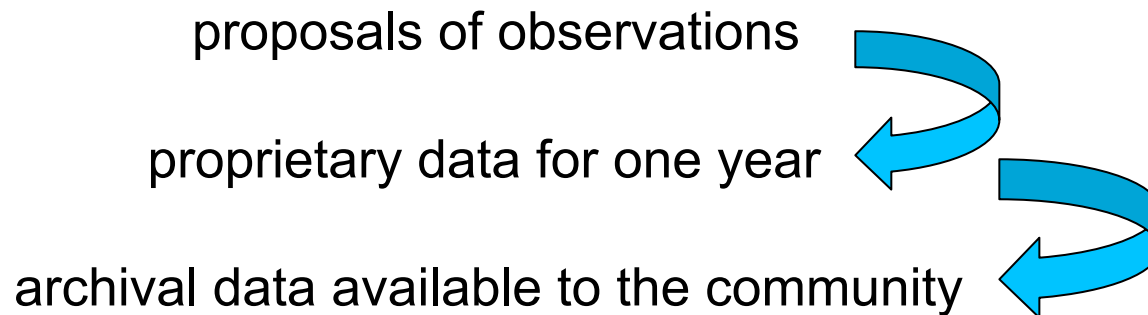
1. The fundamental rules to reduce X-ray data are the same in most of the cases BUT a good knowledge of the properties of X-ray satellites and their instruments is important to maximize the scientific output
2. X-ray data from each satellite are usually accompanied by specific software and tools to make a proper and as easy as possible data reduction and analysis, e.g.

Chandra → *CIAO*
XMM-Newton → *SAS*

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Chandra → *CIAO*
XMM-Newton → *SAS*

3. How to get X-ray data:



- ✓ Downloading of X-ray data from a public archive
- ✓ How do the downloaded files look like?
- ✓ Steps to reduce X-ray (*Chandra*) data
- ✓ Creation of radio and/or X-ray contours for an extended object
- ✓ How to create a radio/X-ray contour superposition image



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Where can I find X-ray data archives?



High Energy Astrophysics Science Archive Research Center (HEASARC) - NASA

<http://heasarc.nasa.gov/> → Archive → Browse

Archive **HEASARC Browse** Tip Archive  

Other Browse interfaces:
[Notification Service](#) | [Batch](#) | [Correlation](#) | [Index of all tables](#) | [Keyword Search](#)

Query File And Session Uploads

Main Search Form > Search Results > Choose Data Products

1. Do you want to search around a position ... ?
(If you want to search on parameters other than object name or coordinates, select "Detailed Mission/Catalog Search".)

Object Name Or Coordinates: **and/or** [Select Local File:](#) no file selected

e.g. Cyg X-1 or 12 00 00, 4 12 6 or
Cyg X-2; 12.235, 15.345 (Note use of semi-colons (;) to separate multiple object names or coordinate pairs)

Coordinate System:

Search Radius:

Default uses the optimum radius for each catalog searched.

... and/or search by date?

Observation Dates: YYYY-MM-DD hh:mm:ss or MJD: DDDDD.ddd

Not all tables have observation dates. For those that do, the time portion of the date is optional. Separate multiple dates/ranges with semicolons (;). Range operator is '..'. (e.g. 1992-12-31; 48980.5; 1995-01-15 12:00:00; 1997-03-20 .. 2000-10-18)

2. What missions and catalogs do you want to search? (Bold text indicates mission is active)

- Most Requested Missions**
- Chandra** [CXC, CSC] **Fermi** **NuSTAR** [CalTech] **ROSAT**
- RXTE** **Suzaku** **Swift** **WMAP**
- XMM-Newton** [XSA]

High Energy Astrophysics Science Archive Research Center (HEASARC) - NASA

<http://heasarc.nasa.gov/> → Archive → Browse

Archive **HEASARC Browse** [Tip Archive](#)  [HELP](#)

Other Browse interfaces:
[Notification Service](#) | [Batch](#) | [Correlation](#) | [Index of all tables](#) | [Keyword Search](#)

Query File And Session Uploads

Main Search Form > Search Results > Choose Data Products

[Start Search](#) [Reset](#) [Detailed Mission/Catalog Search](#)

1. Do you want to search around a position ... ?
(If you want to search on parameters other than object name or coordinates, select "Detailed Mission/Catalog Search".)

Object Name Or Coordinates: and/or Select Local File:

e.g. Cyg X-1 or
12 00 00, 4 12 6 or
Cyg X-2; 12.235, 15.345
(Note use of semi-colons (;)
to separate multiple object
names or coordinate pairs)

File should contain objects and/or coordinate pairs
one per line or separated by semi-colons.

Coordinate System:

Search Radius:

Default uses the optimum radius for each catalog searched.

... and/or search by date?

Observation Dates: YYYY-MM-DD hh:mm:ss or MJD: DDDDD.ddd

The time portion of the date is optional. Separate multiple dates/ranges with semicolons (;).
Range operator is '..' (e.g. 1992-12-31; 48980.5; 1995-01-15 12:00:00; 1997-03-20 .. 2000-10-18)

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Most Requested Missions

Chandra [CXC]

Fermi

ROSAT

RXTE

Suzaku

Swift

WMAP

XMM-Newton [XSA]

High Energy Astrophysics Science Archive Research Center (HEASARC) - NASA

<http://heasarc.nasa.gov/> → Archive → Browse

[Query Information](#)
[Query Results](#)
[Data Products Retrieval](#)
[Help](#)

[chandra](#)

[chanmaster](#)
[cxoxassist](#)

Click mission tabs (middle tab level) to display table tabs. Move cursor over tabs to see more information.

Table Legend:

Display all parameters for a row

Sort by a column in order: 1,2,3 Sort by column in reverse order: 3,2,1 Current table sort

Services links: O: Digitized Sky Survey image, R: ROSAT All-Sky Survey image, N: NED objects near coordinates, S: SIMBAD objects near coordinates, D: get list of data products, H: analyze data products using [Hera](#), B: ADS bibliography holdings, F: FOV plot for observation

Data Products: Click checkbox to add row to Data Product Retrieval List

[Chandra Observations \(chanmaster\)](#) [Bulletin](#) [Note](#)

Search radius used: 21.00 '

| Select | Related Links | Services | obsid | status | name | ra | dec | time | detector | grating | exposure | type | pi | public date | Search Offset |
|------------------------------|-------------------------------------|---|-----------------------|------------------------|----------------------|--------------------|---------------------|----------------------|--------------------------|-------------------------|--------------------------|----------------------|--------------------|-----------------------------|-------------------------------|
| <input type="checkbox"/> All | | | | | | | | | | | [s] | | | | |
| <input type="checkbox"/> | ASCA ROSAT RXTE XMM | O R N S D H B F | 5831 | archived | Cygnus A | 19 59 28.30 | +40 44 02.0 | 2005-02-16 13:00:09 | ACIS-I | NONE | 51770 | GO | Young | 2006-02-27 | 0.011 (cygnus a) |
| <input type="checkbox"/> | ASCA ROSAT RXTE XMM | O R N S D H B F | 360 | archived | CYGNUS A | 19 59 28.30 | +40 44 02.0 | 2000-05-21 03:12:26 | ACIS-S | NONE | 35160 | GTO | Wilson | 2001-06-06 | 0.011 (cygnus a) |
| <input type="checkbox"/> | ASCA ROSAT RXTE XMM | O R N S D H B F | 6252 | archived | Cygnus A | 19 59 28.30 | +40 44 02.0 | 2005-09-07 04:47:32 | ACIS-I | NONE | 30050 | GO | Young | 2006-02-27 | 0.011 (cygnus a) |
| <input type="checkbox"/> | ASCA ROSAT RXTE XMM | O R N S D H B F | 6225 | archived | Cygnus A | 19 59 28.30 | +40 44 02.0 | 2005-02-15 15:25:05 | ACIS-I | NONE | 24630 | GO | Young | 2006-02-27 | 0.011 (cygnus a) |
| <input type="checkbox"/> | ASCA ROSAT RXTE XMM | O R N S D H B F | 6226 | archived | Cygnus A | 19 59 28.30 | +40 44 02.0 | 2005-02-19 05:09:29 | ACIS-I | NONE | 24150 | GO | Young | 2006-02-27 | 0.011 (cygnus a) |

High Energy Astrophysics Science Archive Research Center (HEASARC) - NASA

<http://heasarc.nasa.gov/> → Archive → Browse

[Query Information](#)
[Query Results](#)
[Data Products Retrieval](#)
[Help](#)

[chandra](#)

[chanmaster](#)
[cxoxassist](#)

Click mission tabs (middle tab level) to display table tabs. Move cursor over tabs to see more information.

Table Legend:

- 🔍 Display all parameters for a row
- ⬇️ Sort by a column in order: 1,2,3 ⬆️ Sort by column in reverse order: 3,2,1 ⬇️/⬆️ Current table sort
- Services links: O: Digitized Sky Survey image, R: ROSAT All-Sky Survey image, N: NED objects near coordinates, S: SIMBAD objects near coordinates, D: get list of data products, H: analyze data products using [Hera](#), B: ADS bibliography holdings, F: FOV plot for observation

Data Products: Click checkbox to add row to Data Product Retrieval List

[Chandra Observations \(chanmaster\)](#) [Bulletin](#) [Note](#)

Search radius used: 21.00 '

| Select | Related Links | Services | obsid | status | name | ra | dec | time | detector | grating | exposure | type | pi | public date | Search Offset |
|------------------------------|---|---|-----------------------|------------------------|----------------------|--------------------|---------------------|----------------------|--------------------------|-------------------------|--------------------------|----------------------|--------------------|-----------------------------|-------------------------------|
| <input type="checkbox"/> All | | | ⬇️⬆️ | ⬇️⬆️ | ⬇️⬆️ | ⬇️⬆️ | ⬇️⬆️ | ⬇️⬆️ | ⬇️⬆️ | ⬇️⬆️ | ⬇️⬆️ [s] | ⬇️⬆️ | ⬇️⬆️ | ⬇️⬆️ | ['] from (target) |
| <input type="checkbox"/> | ASCA ROSAT RXTE XMM | O R N S D H B F | 5831 | archived | Cygnus A | 19 59 28.30 | +40 44 02.0 | 2005-02-16 13:00:09 | ACIS-I | NONE | 51770 | GO | Young | 2006-02-27 | 0.011 (cygnus a) |
| <input type="checkbox"/> | ASCA ROSAT RXTE XMM | O R N S D H B F | 360 | archived | CYGNUS A | 19 59 28.30 | +40 44 02.0 | 2000-05-21 03:12:26 | ACIS-S | NONE | 35160 | GTO | Wilson | 2001-06-06 | 0.011 (cygnus a) |
| <input type="checkbox"/> | ASCA ROSAT RXTE XMM | O R N S D H B F | 6252 | archived | Cygnus A | 19 59 28.30 | +40 44 02.0 | 2005-09-07 04:47:32 | ACIS-I | NONE | 30050 | GO | Young | 2006-02-27 | 0.011 (cygnus a) |
| <input type="checkbox"/> | ASCA ROSAT RXTE XMM | O R N S D H B F | 6225 | archived | Cygnus A | 19 59 28.30 | +40 44 02.0 | 2005-02-15 15:25:05 | ACIS-I | NONE | 24630 | GO | Young | 2006-02-27 | 0.011 (cygnus a) |
| <input type="checkbox"/> | ASCA ROSAT RXTE XMM | O R N S D H B F | 6226 | archived | Cygnus A | 19 59 28.30 | +40 44 02.0 | 2005-02-19 05:09:29 | ACIS-I | NONE | 24150 | GO | Young | 2006-02-27 | 0.011 (cygnus a) |

High Energy Astrophysics Science Archive Research Center (HEASARC) - NASA

<http://heasarc.nasa.gov/> → Archive → Browse

HEASARC Browse: Data Products for selected row in C... <http://heasarc.nasa.gov/cgi-bin/W3Browse/w3hdprods.pl?...>

Archive Data Products for selected row in Chandra Observations Tip Archive Hera HELP

[Choose Tables](#) > Choose Data Products > Retrieve Data Products

- Do you want to view a data product? Click on its hyperlinked data format.
- Do you want to retrieve data products in a tarfile? Check the boxes beside each product and click one of the buttons at the bottom of the page.

Select all products for all rows

[Chandra Observations \(chanmaster\)](#) [FTOOLS](#)

| obsid | status | name | ra | dec | time | detector | grating | exposure | type | pi |
|-------|----------|--------------------|----------------|-------------------|------------------------|----------|---------|----------|------|-------|
| 7797 | archived | Centaurus A Jet | 13 25 19.15 | -43 02 42.4 | 2007-03-22 08:59:51 | ACIS-I | NONE | 98170 | GO | Kraft |

Select all products in this row

FITS and JPEG Images

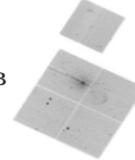
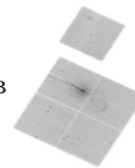
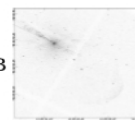
Center Image
(acisf07797N002_cntr_img2.fits.gz) [FITS](#) 210 kB updated: 2007/08/10 14:16:00

Center Image
(acisf07797N002_cntr_img2.jpg) [JPEG](#) 615 kB updated: 2007/08/10 14:16:00

Full Image
(acisf07797N002_full_img2.fits.gz) [FITS](#) 82 kB updated: 2007/08/10 14:18:00

Full Image
(acisf07797N002_full_img2.jpg) [JPEG](#) 47 kB updated: 2007/08/10 14:18:00

Source Image
(acisf07797N002_src_img2.jpg) [JPEG](#) 47 kB updated: 2007/08/10 14:18:00



High Energy Astrophysics Science Archive Research Center (HEASARC) - NASA

<http://heasarc.nasa.gov/>

→ [Archive](#) → [Browse](#)

HEASARC Browse: Data Products for selected row in C... <http://heasarc.nasa.gov/cgi-bin/W3Browse/w3hdprods.pl?..>

| | | | |
|--|----------------------|------------|------------------------------------|
| <input type="checkbox"/> Observation Summary | HTML | 4 kB | updated: 2007/08/10 14:18:00 |
| <input type="checkbox"/> Observation Summary | HTML | 3 kB | updated: 2007/08/10 14:18:00 |
| <input type="checkbox"/> Observation Summary (acisf07797N002_1_sum2.ps) | PS | 2030 kB | updated: 2007/08/10 14:18:00 |

TAR selected products

Create Download Script

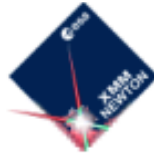
Azzera

Save to Hera

[What is Hera?](#)

Page maintainer: [Browse Feedback](#)

XMM-Newton Science Operations Centre (ESA-Vilspa, Spain) – I
<http://xmm.esac.esa.int/xsa/>



XMM-Newton Science Archive Search

Position **File**

Name
 Equatorial
 Galactic
 Ecliptic

Target in Field Of View Circle Box

Name for ▼

► **Observation and Proposal filters**

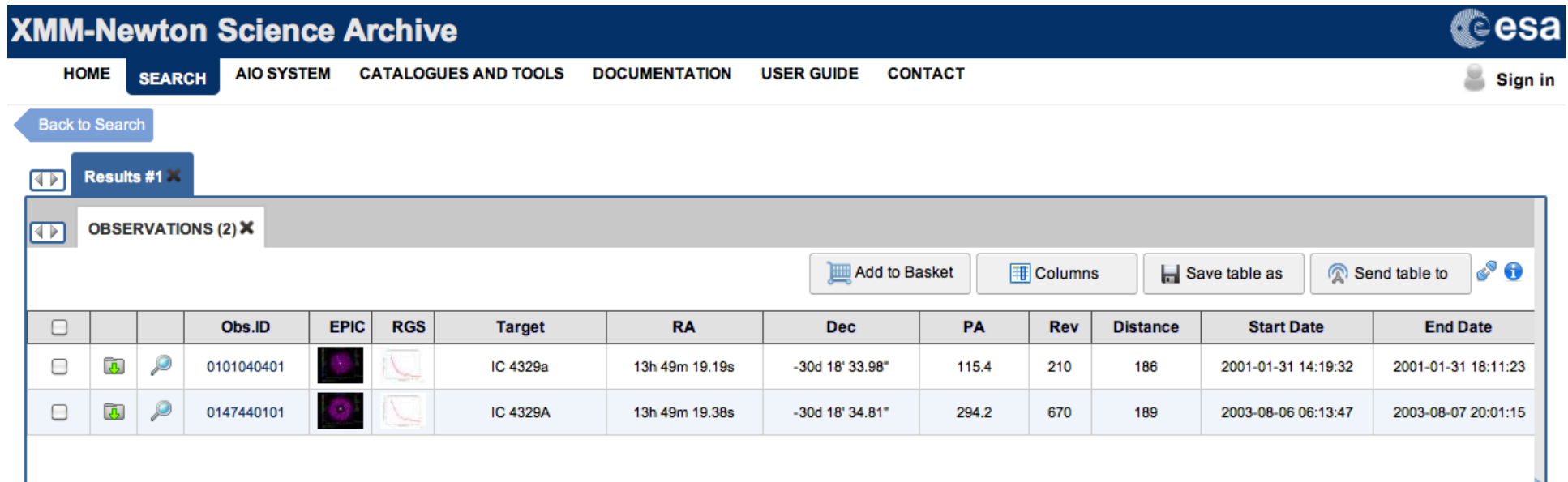
► **Display options**

[Reset Form](#)

[Catalogue Search >](#)

XMM-Newton Science Operations Centre (ESA-Vilspa, Spain) – I

<http://xmm.esac.esa.int/xsa/>



The screenshot displays the XMM-Newton Science Archive interface. At the top, there is a navigation bar with the ESA logo and links for HOME, SEARCH, AIO SYSTEM, CATALOGUES AND TOOLS, DOCUMENTATION, USER GUIDE, and CONTACT. A 'Sign in' button is also present. Below the navigation bar, a 'Back to Search' button is visible. The main content area shows 'Results #1' and a table of 'OBSERVATIONS (2)'. The table includes columns for Obs.ID, EPIC, RGS, Target, RA, Dec, PA, Rev, Distance, Start Date, and End Date. Two observations are listed, each with a small thumbnail image and a spectrum plot.

| <input type="checkbox"/> | | | Obs.ID | EPIC | RGS | Target | RA | Dec | PA | Rev | Distance | Start Date | End Date |
|--------------------------|--|--|------------|------|-----|----------|----------------|-----------------|-------|-----|----------|---------------------|---------------------|
| <input type="checkbox"/> | | | 0101040401 | | | IC 4329a | 13h 49m 19.19s | -30d 18' 33.98" | 115.4 | 210 | 186 | 2001-01-31 14:19:32 | 2001-01-31 18:11:23 |
| <input type="checkbox"/> | | | 0147440101 | | | IC 4329A | 13h 49m 19.38s | -30d 18' 34.81" | 294.2 | 670 | 189 | 2003-08-06 06:13:47 | 2003-08-07 20:01:15 |

Preview of data (images/extracted spectra) is possible as well as interactive analysis of X-ray images

More details on the XMM-Newton tutorial...

ASI Scientific Data Center (ASDC- Frascati, Roma)

<http://www.asdc.asi.it/>

asdc
ASI Science Data Center

ASI Science Data Center

agenzia spaziale italiana

Home About Public Outreach Quick Look/Current Missions Multimission Archive Catalogs Tools Links Bibliographic services

AGILE SWIFT FERMI HERSCHEL PLANCK BeppoSAX NUSTAR Gaia

Astrophysics and Cosmology Exploration of the Solar System Astroparticle Physics

Space astrophysics cosmology astroparticle physics solar system exploration

TOP RESULTS/PRESS RELEASES

- October 7, 2010: The Crab "goes wild" in gamma-rays
- September 15, 2010: Planck discovery of a supercluster of galaxies through SZ effect
- July 26, 2010: AGILE-GRID detects its brightest Gamma-Ray Burst


Chandra X-ray Center (CXC-CFA, Cambridge-Boston)


<http://cda.harvard.edu/chaser/>

Chandra Data Archive: Observation Search

webchaser

<http://cda.harvard.edu/chaser/>

 **Chandra X-ray Center** [New Search](#)

Observation Search [Retrieval List](#) [Help](#)  Chandra Data Archive

[Target Name](#) [Resolve Name](#) [RA/Long/l](#) [Dec/Lat/b](#)

[Name Resolver](#) [Coordinate System](#) [Equin](#)

[Observation ID](#) [Sequence Number](#) [Proposal Number](#)

[Proposal Title](#) [PI Name](#) [Observer Name](#)

[Start Date](#) [Public Release Date](#) [Exposure Time \(k](#)

[Status](#)

[Science Category](#)

[Instrument](#)

[Grating](#)

[Type](#)

[Observing Cycle](#)

[Join](#)

Customize Output:

[Sort Order](#) ascending descending

[Display](#) [Format](#) [Row Limit](#)

[Coordinate System](#) [Equinox](#) [Format](#)



View Observation Information | Add to Retrieval List

[Primary products](#)
 [Secondary products](#)

[Select all](#) | [Unselect all](#)

| Select | Row | Seq Num | Obs ID | Instrument | Grating | Appr Exp (ks) | Exposure (ks) | Target |
|--------------------------|-----|---------|--------|------------|---------|---------------|---------------|---------------|
| <input type="checkbox"/> | 1 | 700743 | 4064 | ACIS-S | NONE | 5.0 | 4.73 | BR 0331-1622 |
| <input type="checkbox"/> | 2 | 700744 | 4065 | ACIS-S | NONE | 4.0 | 4.12 | BR 0353-3820 |
| <input type="checkbox"/> | 3 | 700745 | 4066 | ACIS-S | NONE | 4.0 | 4.04 | BR 0418-5723 |
| <input type="checkbox"/> | 4 | 700746 | 4067 | ACIS-S | NONE | 5.0 | 4.73 | BR 0424-2209 |
| <input type="checkbox"/> | 5 | 700747 | 4068 | ACIS-S | NONE | 5.0 | 4.59 | PSS 0747+4434 |
| <input type="checkbox"/> | 6 | 700748 | 4069 | ACIS-S | NONE | 5.0 | 5.12 | PSS 1058+1245 |
| <input type="checkbox"/> | 7 | 700749 | 4070 | ACIS-S | NONE | 5.0 | 4.76 | BRI 1117-1330 |
| <input type="checkbox"/> | 8 | 700750 | 4071 | ACIS-S | NONE | 5.0 | 4.92 | PSS 1506+5220 |
| <input type="checkbox"/> | 9 | 700751 | 4072 | ACIS-S | NONE | 5.0 | 4.91 | PSS 1646+5514 |
| <input type="checkbox"/> | 10 | 700752 | 4073 | ACIS-S | NONE | 5.0 | 4.96 | BR 2213-6729 |

Now all in one command:
download_chandra_obsid Obs_ID

- ✓ Downloading of X-ray data from a public archive
- ✓ How do the downloaded files look like?
- ✓ Steps to reduce X-ray (*Chandra*) data
- ✓ Creation of radio and/or X-ray contours for an extended object
- ✓ How to create a radio/X-ray contour superposition image



`cd 7302 → obs id`


```
iTerm Shell Edit View Bookmarks Window Help
torresi@bitonno: /RossiFumi/users/torresi/4C19.44/chandra/7302/primary
New Info Customize Close Execute Bookmarks
[torresi@bitonno]chandra>
[torresi@bitonno]chandra>
[torresi@bitonno]chandra>
[torresi@bitonno]chandra>
[torresi@bitonno]chandra>
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[torresi@bitonno]chandra>
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[torresi@bitonno]chandra>
[torresi@bitonno]chandra>
[torresi@bitonno]chandra>
[torresi@bitonno]chandra>
[torresi@bitonno]chandra>
[torresi@bitonno]chandra>
[torresi@bitonno]chandra>ls
7302 cda.harvard.edu w3browse-79222.tar
[torresi@bitonno]chandra>cd 7302/
[torresi@bitonno]7302>ls
oif.fits primary secondary
[torresi@bitonno]7302>cd primary/
[torresi@bitonno]primary>ls
acisf07302_000N001_bpix1.fits  acisf07302N001_3_sum2.html  acisf07302N001_full_img2.jpg
acisf07302_000N001_fov1.fits  acisf07302N001_cntr_img2.fits acisf07302N001_src2.fits
acisf07302N001_1_sum2.html   acisf07302N001_cntr_img2.jpg acisf07302N001_src_img2.jpg
acisf07302N001_1_sum2.ps     acisf07302N001_evt2.fits     orbitf259589101N001_eph1.fits
acisf07302N001_2_sum2.html   acisf07302N001_full_img2.fits pcadf259913528N001_asol1.fits
[torresi@bitonno]primary>
```

In the **primary** directory data already reprocessed by a standard pipeline are present

The **HTML** files contain a summary of the observation parameters, such as the instrument, detector, and grating that were used

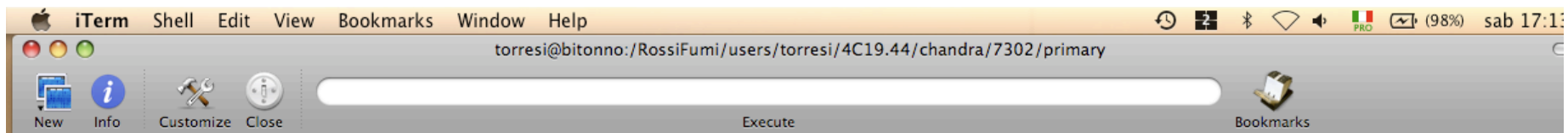
Two images are produced for every dataset: a full-field sky image (**full_img2.jpg**) and a high-resolution image of the center of the field (**cntr_img2.jpg**). Imaging observations also have a full field image with the source candidates overlaid (**src_img2.jpg**)

Data produced by the satellite are stored in
FITS (Flexible Image Transport System) format

```
[torresi@bitonno] chandra>  
[torresi@bitonno] chandra>  
[torresi@bitonno] chandra>  
[torresi@bitonno] chandra>  
[torresi@bitonno] chandra>  
[torresi@bitonno] chandra>  
[torresi@bitonno] chandra>  
[torresi@bitonno] chandra>  
[torresi@bitonno] chandra>  
[torresi@bitonno] chandra>  
[torresi@bitonno] chandra>  
[torresi@bitonno] chandra>  
[torresi@bitonno] chandra>  
[torresi@bitonno] chandra>  
[torresi@bitonno] chandra>ls  
7302 cda.harvard.edu w3browse-79222.tar  
[torresi@bitonno] chandra>cd 7302/  
[torresi@bitonno] 7302>ls  
oif.fits primary secondary  
[torresi@bitonno] 7302>cd primary/  
[torresi@bitonno] primary>ls
```

| | | |
|---|---|---|
| acisf07302_000N001_bpix1.fits | acisf07302N001_3_sum2.html | acisf07302N001_full_img2.jpg |
| acisf07302_000N001_fov1.fits | acisf07302N001_cntr_img2.fits | acisf07302N001_src2.fits |
| acisf07302N001_1_sum2.html | acisf07302N001_cntr_img2.jpg | acisf07302N001_src_img2.jpg |
| acisf07302N001_1_sum2.ps | acisf07302N001_evt2.fits | orbitf259589101N001_eph1.fits |
| acisf07302N001_2_sum2.html | acisf07302N001_full_img2.fits | pcadf259913528N001_asol1.fits |

```
[torresi@bitonno] primary>
```



```
[torresi@bitonno] chandra>
[torresi@bitonno] chandra>
[torresi@bitonno] chandra>
[torresi@bitonno] chandra>
[torresi@bitonno] chandra>
[torresi@bitonno] chandra>
[torresi@bitonno] chandra>
[torresi@bitonno] chandra>
[torresi@bitonno] chandra>
[torresi@bitonno] chandra>
[torresi@bitonno] chandra>
[torresi@bitonno] chandra>
[torresi@bitonno] chandra>
[torresi@bitonno] chandra>
[torresi@bitonno] chandra>
[torresi@bitonno] chandra>
[torresi@bitonno] chandra>
[torresi@bitonno] chandra>ls
7302 cda.harvard.edu w3browse-79222.tar
[torresi@bitonno] chandra>cd 7302/
[torresi@bitonno] 7302>ls
oif.fits primary secondary
[torresi@bitonno] 7302>cd primary/
[torresi@bitonno] primary>ls
acisf07302_000N001_bpix1.fits acisf07302N001_3_sum2.html acisf07302N001_full_img2.jpg
acisf07302_000N001_fov1.fits acisf07302N001_cntr_img2.fits acisf07302N001_src2.fits
acisf07302N001_1_sum2.html acisf07302N001_cntr_img2.jpg acisf07302N001_src_img2.jpg
acisf07302N001_1_sum2.ps acisf07302N001_evt2.fits orbitf259589101N001_eph1.fits
acisf07302N001_2_sum2.html acisf07302N001_full_img2.fits pcardf259913528N001_asol1.fits
[torresi@bitonno] primary>
```

Level 2 event file

The **level 2** event file is the most important data product you receive. This file is created from the level 1 event list by filtering on the GTI (good time intervals) and status bits

| | | |
|-------------------------------|---------------------------------|--------------------------------|
| acisf07302_000N001_bpix1.fits | acisf07302N001_3_sum2.html | acisf07302N001_full_img2.jpg |
| acisf07302_000N001_fov1.fits | acisf07302N001_cntr_img2.fits | acisf07302N001_src2.fits |
| acisf07302N001_1_sum2.html | acisf07302N001_cntr_img2.jpg | acisf07302N001_src_img2.jpg |
| acisf07302N001_1_sum2.ps | <u>acisf07302N001_evt2.fits</u> | orbitf259589101N001_eph1.fits |
| acisf07302N001_2_sum2.html | acisf07302N001_full_img2.fits | pcardf259913528N001_asol1.fits |

```
iTerm Shell Edit View Bookmarks Window Help
torresi@bitonno:/RossiFumi/users/torresi/4C19.44/chandra/7302/primary
New Info Customize Close Execute Bookmarks

[torresi@bitonno]chandra>
[torresi@bitonno]chandra>
[torresi@bitonno]chandra>
[torresi@bitonno]chandra>
[torresi@bitonno]chandra>
[torresi@bitonno]chandra>
[torresi@bitonno]chandra>
[torresi@bitonno]chandra>
[torresi@bitonno]chandra>
[torresi@bitonno]chandra>
[torresi@bitonno]chandra>
[torresi@bitonno]chandra>
[torresi@bitonno]chandra>
[torresi@bitonno]chandra>
[torresi@bitonno]chandra>
[torresi@bitonno]chandra>
[torresi@bitonno]chandra>
[torresi@bitonno]chandra>ls
7302 cda.harvard.edu w3browse-79222.tar
[torresi@bitonno]chandra>cd 7302/
[torresi@bitonno]7302>ls
oif.fits primary secondary
[torresi@bitonno]7302>cd primary/
[torresi@bitonno]primary>ls
acisf07302_000N001_bpix1.fits acisf07302N001_3_sum2.html acisf07302N001_full_img2.jpg
acisf07302_000N001_fov1.fits acisf07302N001_cntr_img2.fits acisf07302N001_src2.fits
acisf07302N001_1_sum2.html acisf07302N001_cntr_img2.jpg acisf07302N001_src_img2.jpg
acisf07302N001_1_sum2.ps acisf07302N001_evt2.fits orbitf259589101N001_eph1.fits
acisf07302N001_2_sum2.html acisf07302N001_full_img2.fits pcadf259913528N001_asol1.fits
[torresi@bitonno]primary>
```

Bad pixels

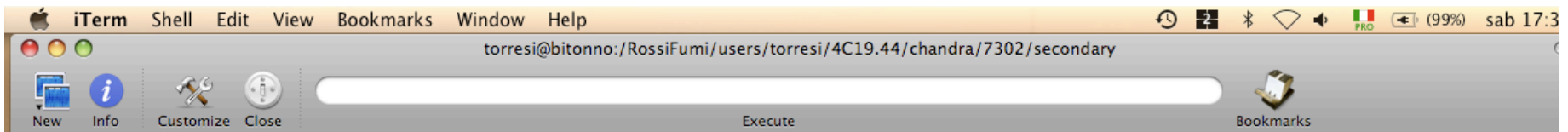
A list of pixels identified as bad
Any tools reading this file will exclude
the bad pixels from calculations

```
iTerm Shell Edit View Bookmarks Window Help
torresi@bitonno:~/RossiFumi/users/torresi/4C19.44/chandra/7302/primary

[torresi@bitonno]chandra>
[torresi@bitonno]chandra>
[torresi@bitonno]chandra>
[torresi@bitonno]chandra>
[torresi@bitonno]chandra>
[torresi@bitonno]chandra>
[torresi@bitonno]chandra>
[torresi@bitonno]chandra>
[torresi@bitonno]chandra>
[torresi@bitonno]chandra>
[torresi@bitonno]chandra>
[torresi@bitonno]chandra>
[torresi@bitonno]chandra>
[torresi@bitonno]chandra>
[torresi@bitonno]chandra>
[torresi@bitonno]chandra>ls
7302 cda.harvard.edu w3browse-79222.tar
[torresi@bitonno]chandra>cd 7302/
[torresi@bitonno]7302>ls
oif.fits primary secondary
[torresi@bitonno]7302>cd primary/
[torresi@bitonno]primary>ls
acisf07302_000N001_bpix1.fits   acisf07302N001_3_sum2.html   acisf07302N001_full_img2.jpg
acisf07302_000N001_fov1.fits   acisf07302N001_cntr_img2.fits  acisf07302N001_src2.fits
acisf07302N001_1_sum2.html     acisf07302N001_cntr_img2.jpg  acisf07302N001_src_img2.jpg
acisf07302N001_1_sum2.ps      acisf07302N001_evt2.fits     orbitf259589101N001_eph1.fits
acisf07302N001_2_sum2.html     acisf07302N001_full_img2.fits  pcadf259913528N001_asol1.fits
[torresi@bitonno]primary>
```

Aspect solution

Describes the *orientation of the telescope as a function of time*. The detected position of an event and the corresponding telescope aspect are combined for an accurate determination of the celestial position of that event



The Bias map(s)

When the bad pixel list (bpix1.fits) is created, each bias map is searched for pixels whose bias values are either too low or too high. There is one bias map for each ACIS chip that was used for the observation

```
acisf07302_000N001_aoff1.fits  acisf07302_000N001_mtl1.fits  acisf259912127N001_pbk0.fits
acisf07302_000N001_evt1.fits  acisf07302_000N001_soff1.fits  aspect
acisf07302_000N001flt1.fits  acisf07302_000N001_stat1.fits  axaff07302N001_VV001_vvref2.pdf
acisf07302_000N001_msk1.fits  acisf259911591N001_1_bias0.fits  ephem
[torresi@bitonno]secondary>
```


All the information of your observation are contained in the header of the fits file. You can visualize it by using the FTOOL command *fv*

| Index | Extension | Type | Dimension | View |
|----------------------------|-----------|--------|-----------------------|-----------------------------|
| <input type="checkbox"/> 0 | Primary | Image | 0 | Header Image Table |
| <input type="checkbox"/> 1 | EVENTS | Binary | 20 cols X 277216 rows | Header Hist Plot All Select |
| <input type="checkbox"/> 2 | GTI | Binary | 2 cols X 1 rows | Header Hist Plot All Select |

fv: Header of acisf07302_000N001_evt1.fits[1] in /RossiFumi/users/torresi/4C19.44/chandra/7302/secondary/

File Edit Tools Help

Search for: [] Find Case sensitive? No

```
DATE-OBS= '2006-03-28T05:52:54' / Observation start date
OBS_MODE= 'POINTING' / Observation mode
DATE-END= '2006-03-29T02:23:52' / Observation end date
TIMESYS = 'TT' / Time system
MJDREF = 5.081400000000000E+04 / MJD zero point for times
TIMEZERO= 0.000000000000000E+00 / Clock correction
TIMEUNIT= 's' / Time unit
BTIMNULL= 2.5638837748552E+08 / Basic Time offset (s)
DATACLASS= 'OBSERVED' / default
RADECSYS= 'ICRS' / default
BTIMRATE= 2.5625001191316E-01 / Basic Time clock rate (s / VCDUcount)
BTIMDRFT= 1.6265547190934E-18 / Basic Time clock drift (s / VCDUcount^2)
BTIMCORR= 0.000000000000000E+00 / Correction applied to Basic Time rate (s)
TIMEREF = 'LOCAL' / Time reference (barycenter/local)
TASSIGN = 'SATELLITE' / Time assigned by clock
CLOCKAPP= 'T' / default
SIM_X = -6.8282252473119E-01 / SIM focus pos (mm)
SIM_Y = 0.000000000000000E+00 / SIM orthogonal axis pos (mm)
SIM_Z = -1.9014006604987E+02 / SIM translation stage pos (mm)
FOC_LEN = 1.007000000000000E+04 / HRMA focal length (mm)
TIERRELA= 1.000000000000000E-09 / default
TIERRABSO= 5.000000000000000E-05 / default
TIMVERSN= 'ASC-FITS-2' / Timing system definition
TSTART = 2.5991237428693E+08 / Observation start time
GRATING = 'NONE' / Grating
DETNAM = 'ACIS-7' / Detector
RA_PNT = 2.0926900487357E+02 / Pointing RA
DEC_PNT = 1.9318991952872E+01 / Pointing Dec
ROLL_PNT= 1.3715654289479E+02 / Pointing Roll
RA_TARG = 2.092687500000000E+02 / Observer's specified target RA
DEC_TARG= 1.931694400000000E+01 / Observer's specified target Dec
DEFOCUS = 1.4449365687057E-03 / SIM defocus (mm)
RA_NOM = 2.0926900487357E+02 / Nominal RA
```

All the information of your obs are contained in the header of the fits file. You can visualize it by using the FTOOL command *fv*

fv: Summary of acisf07302_000N001_evt1.fits in /RossiFumi/users/torresi/4C19.44/chandra/7302/se

File Edit Tools Help

| Index | Extension | Type | Dimension | View |
|----------------------------|-----------|--------|-----------------------|-----------------------------|
| <input type="checkbox"/> 0 | Primary | Image | 0 | Header Image Table |
| <input type="checkbox"/> 1 | EVENTS | Binary | 20 cols X 277216 rows | Header Hist Plot All Select |
| <input type="checkbox"/> 2 | GTI | Binary | 2 cols X 1 rows | Header Hist Plot All Select |

fv: Binary Table of acisf07302_000N001_evt1.fits[1] in /RossiFumi/users/torresi/4C19.44/chandra/7302/secondary/

File Edit Tools

| Select | time | ccd_id | node_id | expno | chipx | chipy | tdetx | tdety | detx | dety | x | y |
|--------|--------------------|--------|---------|--------|--------|--------|--------|--------|--------------|--------------|--------------|---------------|
| 1D | 1I | 1I | 1J | 1I | 1I | 1I | 1I | 1I | 1E | 1E | 1E | 1E |
| s | Modify | Modify | Modify | Modify | pixel | pixel | pixel | pixel | pixel | pixel | pixel | pixel |
| Invert | Modify | Modify | Modify | Modify | Modify | Modify | Modify | Modify | Modify | Modify | Modify | Modify |
| 1 | 2.599123745351E+08 | 7 | 3 | 293 | 984 | 391 | 4901 | 2093 | 4.858813E+03 | 4.237318E+03 | 2.541800E+05 | -1.430559E+05 |
| 2 | 2.599123745351E+08 | 7 | 2 | 293 | 591 | 474 | 4508 | 2176 | 4.466738E+03 | 4.154643E+03 | 2.536133E+05 | -1.429493E+05 |
| 3 | 2.599123745351E+08 | 7 | 3 | 293 | 1008 | 552 | 4925 | 2254 | 4.882676E+03 | 4.076576E+03 | 2.541747E+05 | -1.428487E+05 |
| 4 | 2.599123745351E+08 | 7 | 1 | 293 | 387 | 607 | 4304 | 2309 | 4.262277E+03 | 4.021737E+03 | 2.532966E+05 | -1.427781E+05 |
| 5 | 2.599123753762E+08 | 7 | 0 | 294 | 95 | 431 | 4012 | 2133 | 3.971257E+03 | 4.197373E+03 | 2.529332E+05 | -1.430042E+05 |
| 6 | 2.599123762172E+08 | 7 | 2 | 295 | 520 | 557 | 4437 | 2259 | 4.395667E+03 | 4.071814E+03 | 2.534944E+05 | -1.428426E+05 |
| 7 | 2.599123770582E+08 | 7 | 2 | 296 | 541 | 441 | 4458 | 2143 | 4.416224E+03 | 4.186880E+03 | 2.535506E+05 | -1.429908E+05 |
| 8 | 2.599123770582E+08 | 7 | 2 | 296 | 531 | 474 | 4448 | 2176 | 4.406479E+03 | 4.154062E+03 | 2.535292E+05 | -1.429485E+05 |
| 9 | 2.599123770582E+08 | 7 | 3 | 296 | 989 | 511 | 4906 | 2213 | 4.864095E+03 | 4.116981E+03 | 2.541585E+05 | -1.429008E+05 |
| 10 | 2.599123770582E+08 | 7 | 1 | 296 | 471 | 555 | 4388 | 2257 | 4.346301E+03 | 4.073634E+03 | 2.534261E+05 | -1.428449E+05 |
| 11 | 2.599123778992E+08 | 7 | 0 | 297 | 117 | 493 | 4034 | 2195 | 3.992845E+03 | 4.135629E+03 | 2.529486E+05 | -1.429248E+05 |
| 12 | 2.599123795813E+08 | 7 | 2 | 299 | 725 | 594 | 4642 | 2296 | 4.599758E+03 | 4.033951E+03 | 2.537699E+05 | -1.427938E+05 |
| 13 | 2.599123795813E+08 | 7 | 3 | 299 | 858 | 628 | 4775 | 2330 | 4.733125E+03 | 4.000127E+03 | 2.539477E+05 | -1.427502E+05 |
| 14 | 2.599123795813E+08 | 7 | 0 | 299 | 14 | 639 | 3931 | 2341 | 3.889811E+03 | 3.989590E+03 | 2.527703E+05 | -1.427368E+05 |
| 15 | 2.599123804223E+08 | 7 | 1 | 300 | 458 | 468 | 4375 | 2170 | 4.333020E+03 | 4.159923E+03 | 2.534282E+05 | -1.429560E+05 |
| 16 | 2.599123804223E+08 | 7 | 1 | 300 | 461 | 469 | 4378 | 2171 | 4.336413E+03 | 4.158963E+03 | 2.534327E+05 | -1.429548E+05 |
| 17 | 2.599123804223E+08 | 7 | 2 | 300 | 611 | 604 | 4528 | 2306 | 4.486265E+03 | 4.024730E+03 | 2.536094E+05 | -1.427820E+05 |
| 18 | 2.599123804223E+08 | 7 | 1 | 300 | 281 | 634 | 4198 | 2336 | 4.156607E+03 | 3.994792E+03 | 2.531430E+05 | -1.427435E+05 |
| 19 | 2.599123804223E+08 | 7 | 0 | 300 | 169 | 635 | 4086 | 2337 | 4.044641E+03 | 3.993877E+03 | 2.529869E+05 | -1.427423E+05 |
| 20 | 2.599123804223E+08 | 7 | 0 | 300 | 161 | 636 | 4078 | 2338 | 4.036815E+03 | 3.992568E+03 | 2.529757E+05 | -1.427406E+05 |
| 21 | 2.599123812634E+08 | 7 | 2 | 301 | 667 | 502 | 4584 | 2204 | 4.542446E+03 | 4.126568E+03 | 2.537121E+05 | -1.429131E+05 |
| 22 | 2.599123812634E+08 | 7 | 1 | 301 | 439 | 533 | 4356 | 2235 | 4.314266E+03 | 4.095672E+03 | 2.533867E+05 | -1.427733E+05 |
| 23 | 2.599123812634E+08 | 7 | 1 | 301 | 326 | 633 | 4243 | 2335 | 4.201720E+03 | 3.995774E+03 | 2.532060E+05 | -1.427447E+05 |
| 24 | 2.599123821044E+08 | 7 | 0 | 302 | 70 | 517 | 3987 | 2219 | 3.946417E+03 | 4.111916E+03 | 2.528783E+05 | -1.428942E+05 |
| 25 | 2.599123821044E+08 | 7 | 0 | 302 | 102 | 579 | 4019 | 2281 | 3.978182E+03 | 4.049786E+03 | 2.529077E+05 | -1.428143E+05 |
| 26 | 2.599123829454E+08 | 7 | 0 | 303 | 78 | 434 | 3995 | 2136 | 3.953673E+03 | 4.194752E+03 | 2.529081E+05 | -1.430008E+05 |
| 27 | 2.599123829454E+08 | 7 | 3 | 303 | 769 | 593 | 4686 | 2295 | 4.644235E+03 | 4.035675E+03 | 2.538323E+05 | -1.427960E+05 |
| 28 | 2.599123829454E+08 | 7 | 1 | 303 | 476 | 598 | 4393 | 2300 | 4.351685E+03 | 4.030826E+03 | 2.534233E+05 | -1.427898E+05 |

Go to: Edit cell:

- ✓ Downloading of X-ray data from a public archive
- ✓ How do the downloaded files look like?
- ✓ Steps to reduce X-ray (*Chandra*) data
- ✓ Creation of radio and/or X-ray contours for an extended object
- ✓ How to create a radio/X-ray contour superposition image

Chandra data reduction

<http://cxc.harvard.edu> → Data Analysis → Threads



CIAO 4.5 Homepage

Introduction

[Welcome](#)

[Tools & Applications](#)

[CIAO News](#)

*Updated: 19 November
2013*

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](#)

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[Download CIAO 4.5](#)

[Download CALDB](#)

[Scripts & Modules](#)

[Package](#)

[System Requirements](#)

[Installation Instructions](#)

[Platform Support](#)

Science Threads

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

[Top](#) | [All](#) | [Intro](#) | [Data Prep](#) | [Imag](#) | [Imag Spec](#) | [Grating](#) | [Timing](#) | [TTT](#) | [ChIPS](#) | [Sherpa](#) | [Proposal](#) | [PSFs with ChaRT](#)

All threads

A list of all the threads on one page.

[Introduction](#) **NEW** **UPDATED**

Beginners should start here. The Introductory threads provide an overview of the main components (GUI applications, parameter files) and concepts (the Data Model, filtering) in the CIAO data analysis software.

[Data Preparation](#) **UPDATED**

When Chandra data goes through [Standard Data Processing](#) (SDP), the most recently available calibration is applied to it. Since this calibration is continuously being improved, one should check whether there are newer files available. Similarly, some science decisions are made during SDP; every user has the option to reprocess the data with different parameters.

[Imaging](#) **NEW** **UPDATED**

The Imaging threads cover a wide range of topics that include source detection, creating exposure maps and normalized images, and calculating image statistics. How to create color images for publication is addressed, as well as merging data from multiple observations.

[Imaging Spectroscopy](#) **NEW** **UPDATED**

After extracting source and background PI or PHA spectra from an imaging observation, the appropriate

Scientific files Housekeeping files

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



Now all in one command:
chandra_repro

Cleaned
event files

Scientific files
Housekeeping files

Cleaned
event files

Image

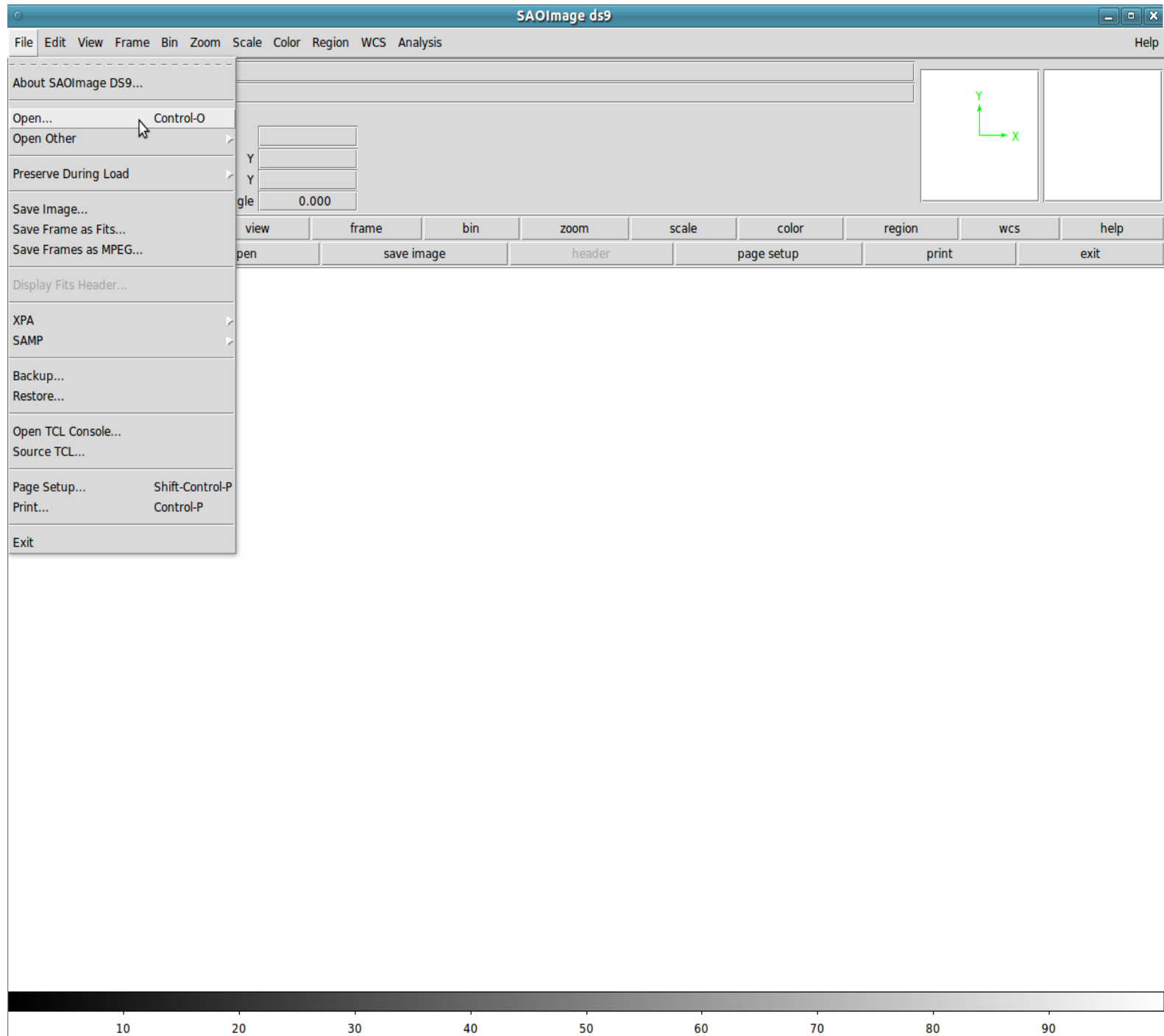


DS9:

File



Open

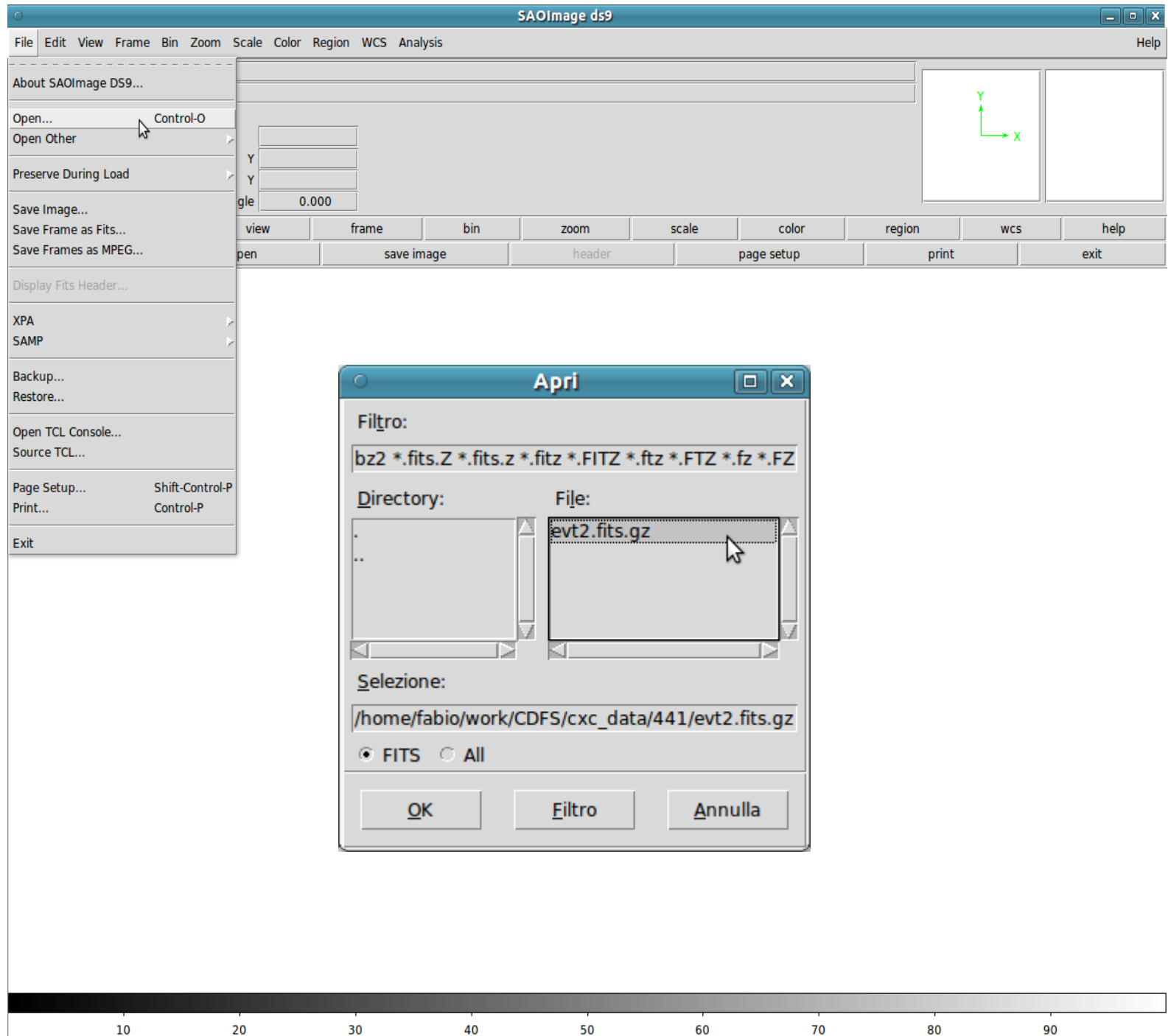


DS9:

File

Open

Evt2 file

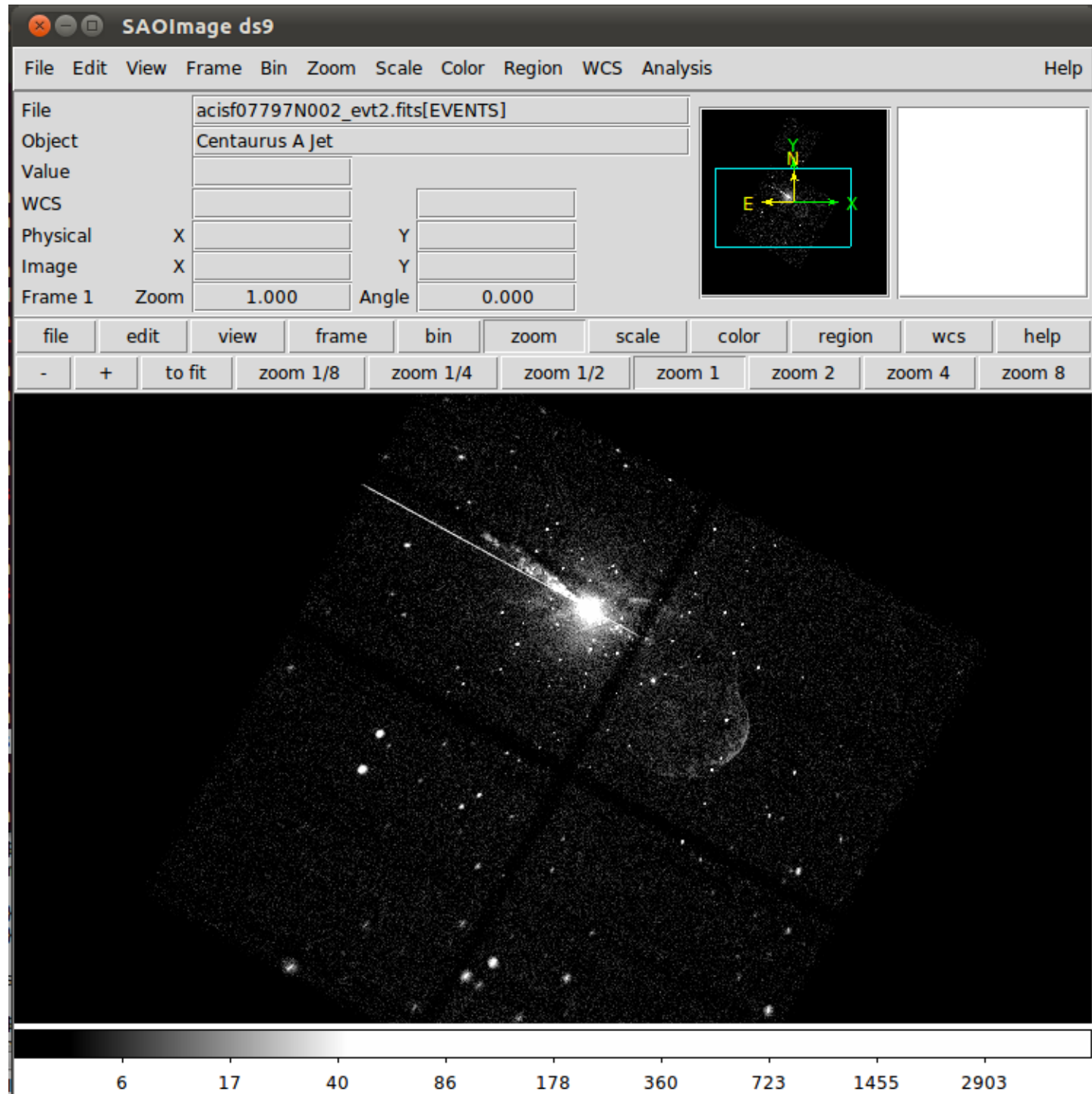


DS9:

Scale



Log



DS9:

The screenshot displays the SAOImage ds9 software interface. At the top, the title bar reads "SAOImage ds9". Below it is a menu bar with options: File, Edit, View, Frame, Bin, Zoom, Scale, Color, Region, WCS, Analysis, and Help.

The main control panel on the left contains the following fields:

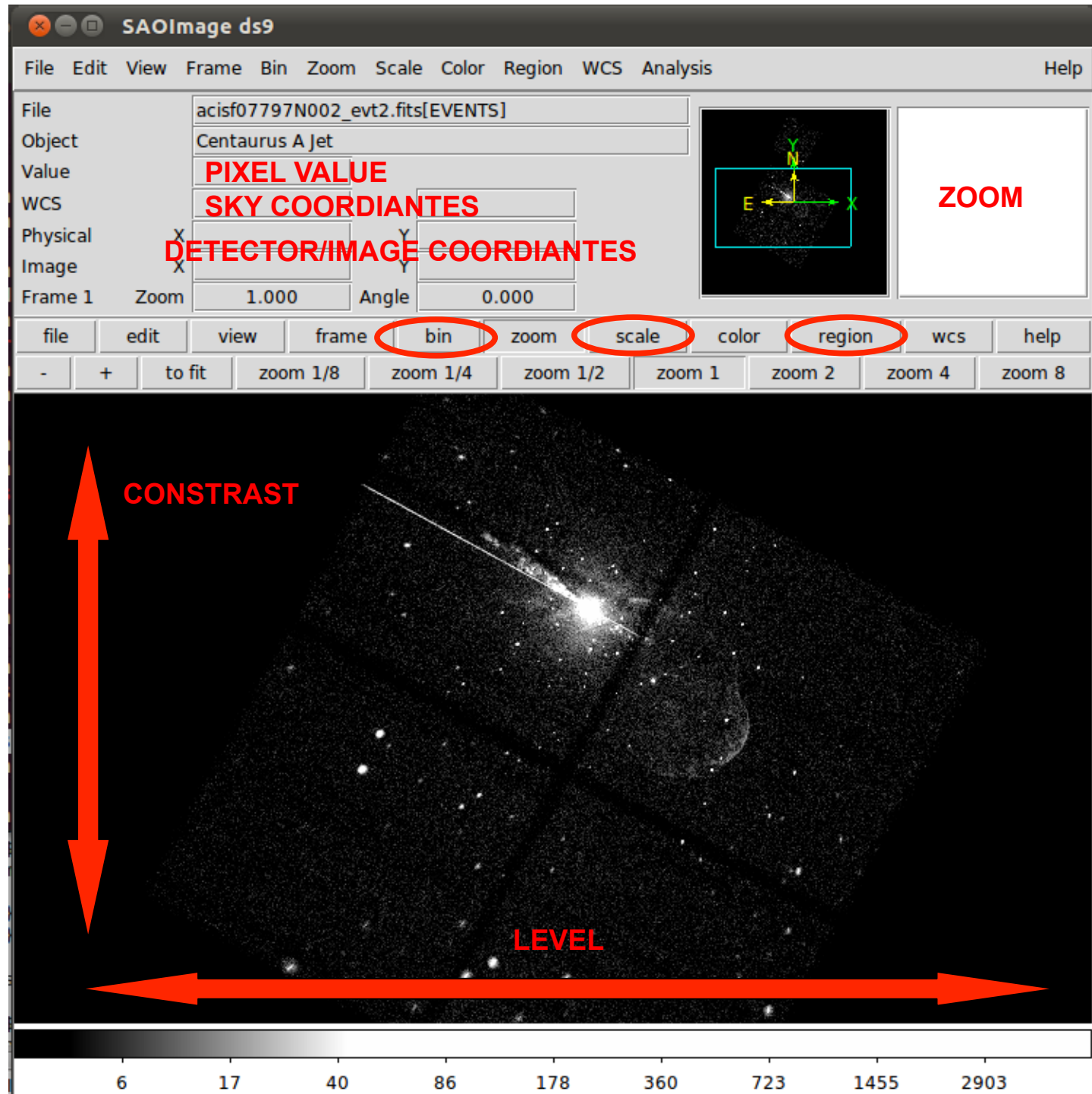
- File: acisf07797N002_evt2.fits[EVENTS]
- Object: Centaurus A Jet
- Value: **PIXEL VALUE**
- WCS: **SKY COORDIANTES**
- Physical: **DETECTOR/IMAGE COORDINATES**
- Image X: [] Y: []
- Frame 1 Zoom: 1.000 Angle: 0.000

To the right of these fields is a small preview window showing a zoomed-in view of the jet with a cyan box and yellow axes labeled N, E, and X. Further right is a "ZOOM" control panel.

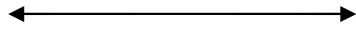
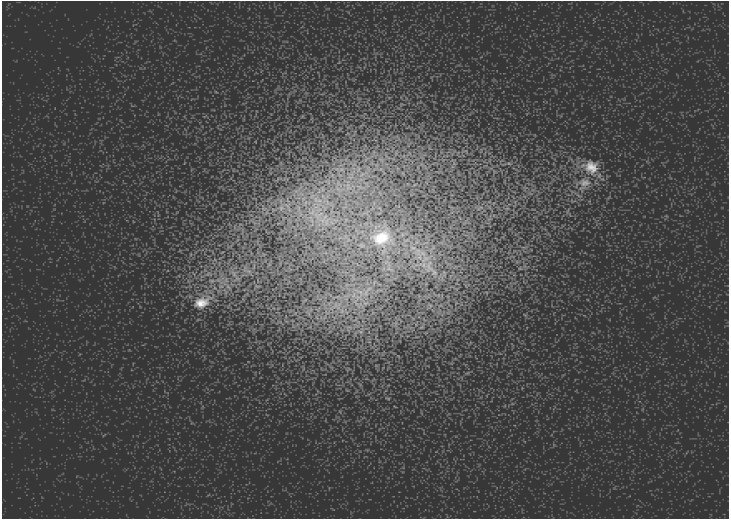
Below the control panel is a toolbar with buttons for file, edit, view, frame, **bin**, zoom, scale, color, **region**, wcs, and help. The "bin" and "region" buttons are circled in red. Below the toolbar are zoom level buttons: -, +, to fit, zoom 1/8, zoom 1/4, zoom 1/2, zoom 1, zoom 2, zoom 4, and zoom 8.

The main window shows a large image of the Centaurus A Jet, a bright, elongated structure of gas and dust. At the bottom of the window is a grayscale calibration bar with numerical values: 6, 17, 40, 86, 178, 360, 723, 1455, and 2903.

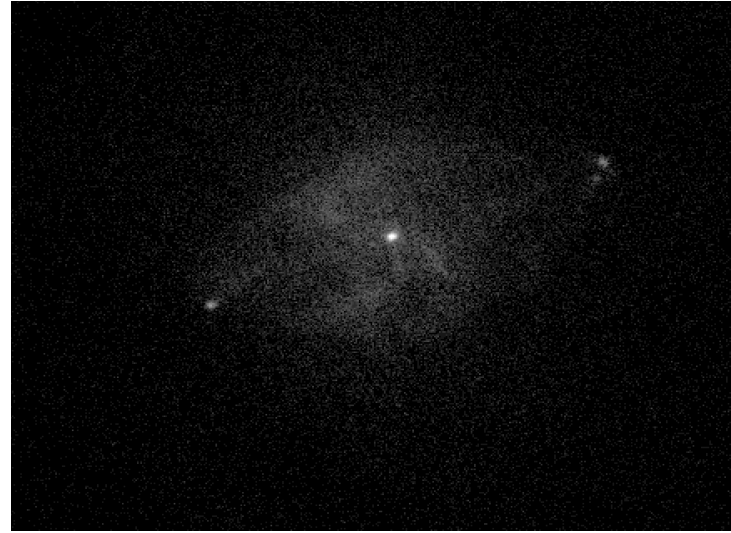
DS9:



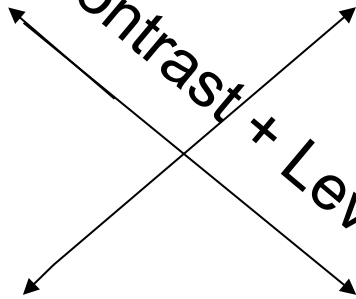
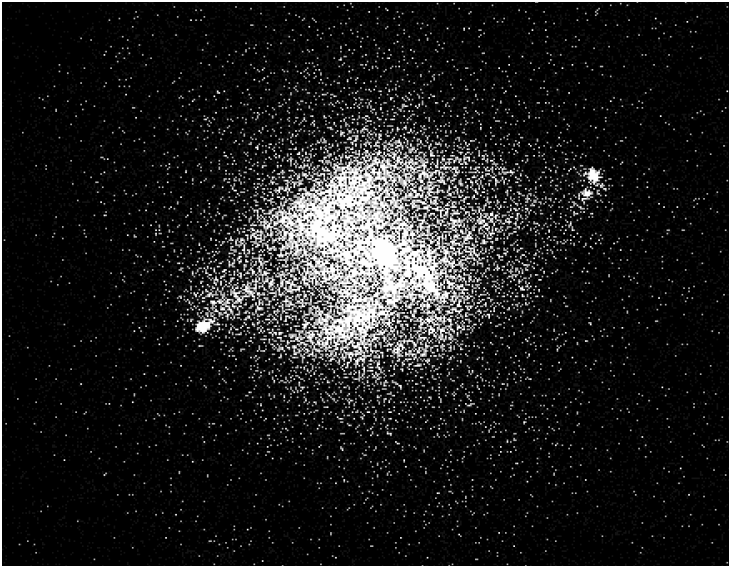
Hold right button down and move left/right and/or up/down



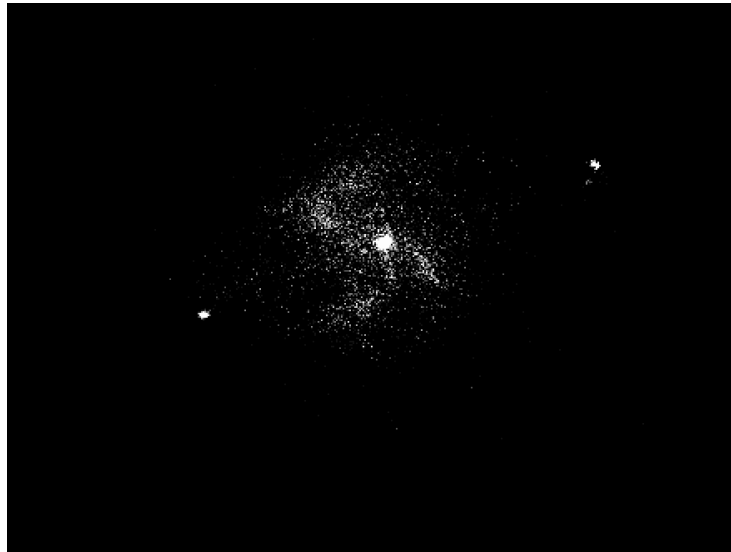
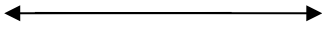
Level



Contrast

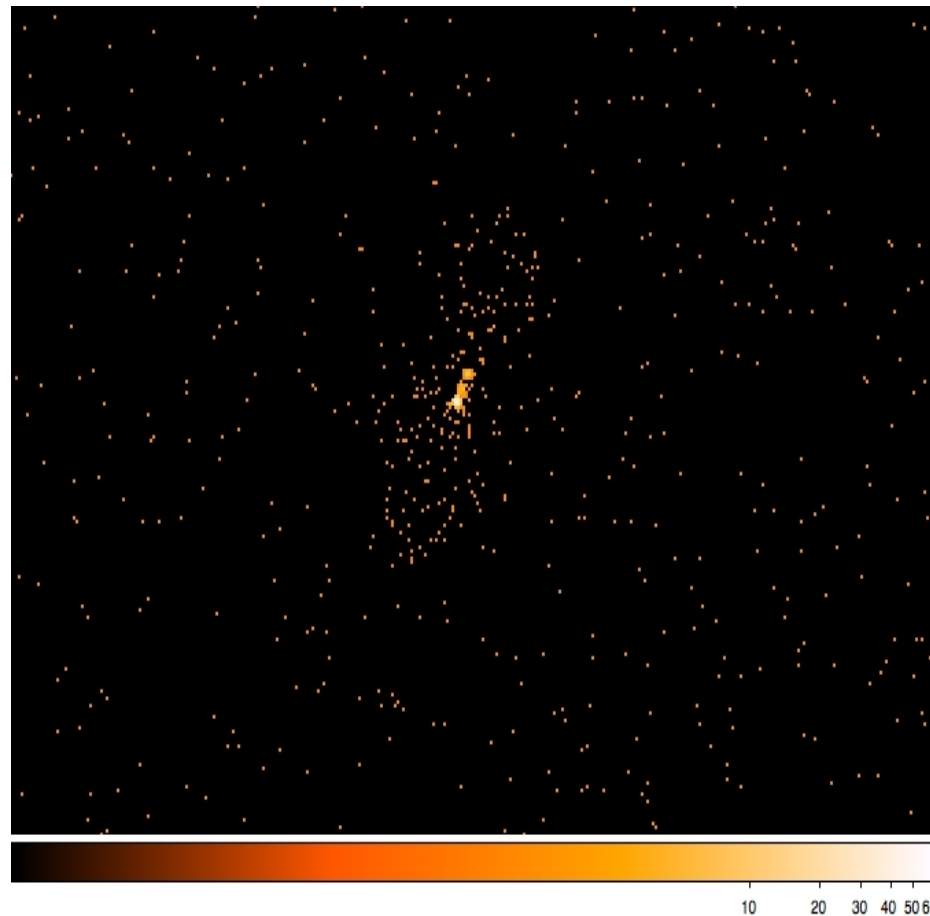


Contrast + Level



Most important information deducible from an image:

- the source is pointlike or extended;
- obtain and fit a radial profile;
- calculate the source counts and verify if the observed excess is real or due to background fluctuations;
- X-ray counterparts of structures seen in other wavebands.

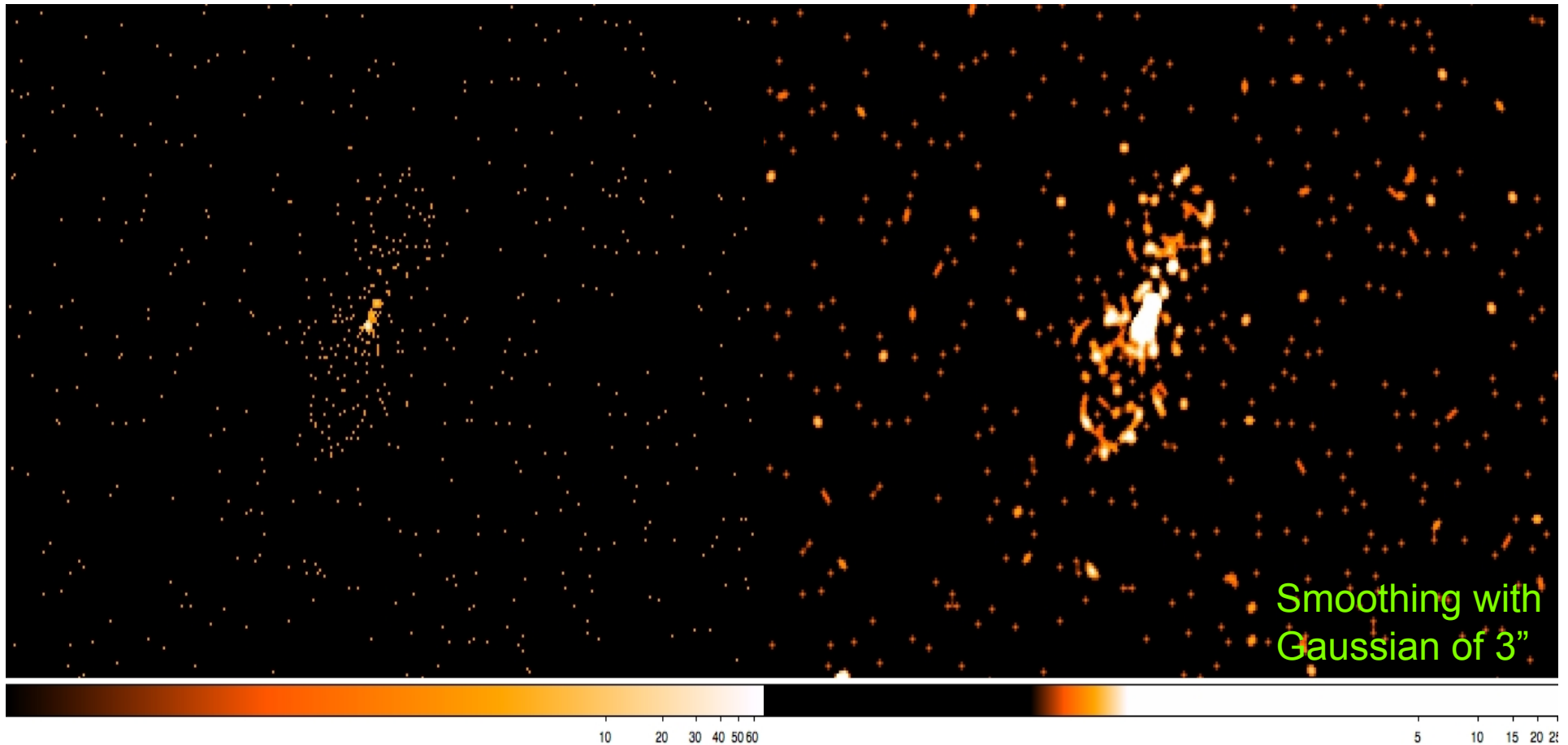


It is possible to improve the image look

$$Y(t) = \int K(t,s) X(s) ds$$

smoothing

X=input; Y=output; K=kernel



To **smooth an image** means to substitute the value of each pixel for the value obtained by weighting the pixels nearby with a certain function (e.g., a Gaussian)

Scientific files
Housekeeping files

Cleaned
event files

Image

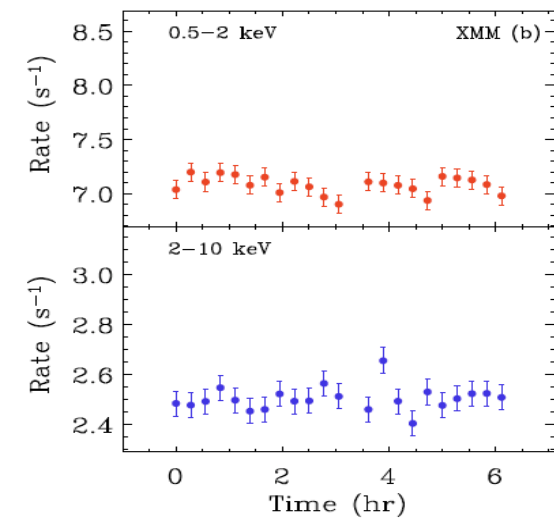
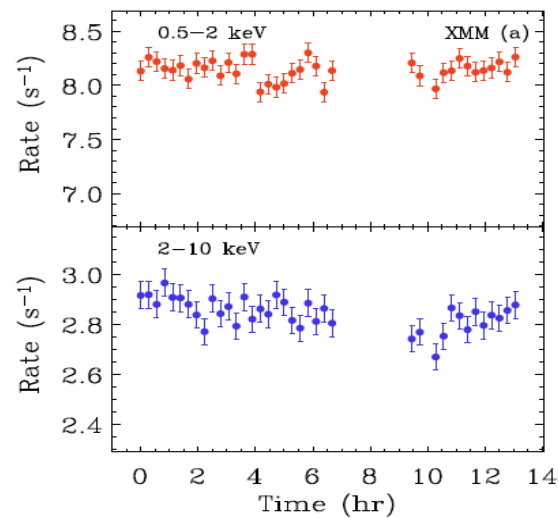
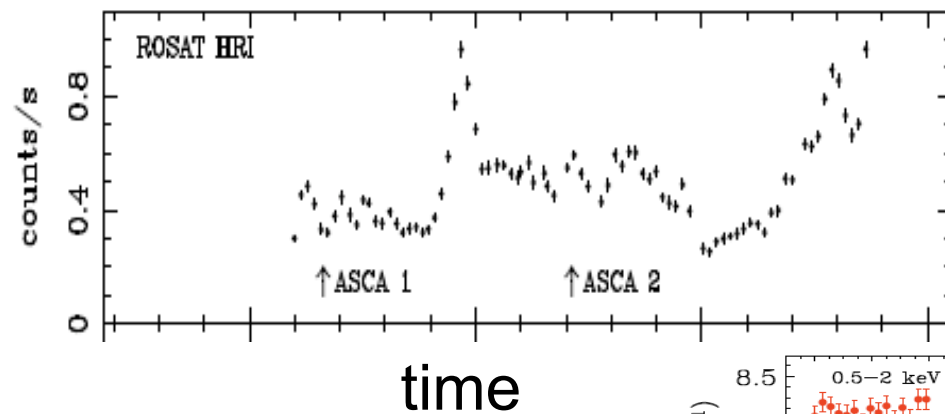
Light curve



A light curve is the plot of the flux of a source versus time. It shows if and how the flux of the source varies during a certain time.

The variability of a source can manifest on different time scales.

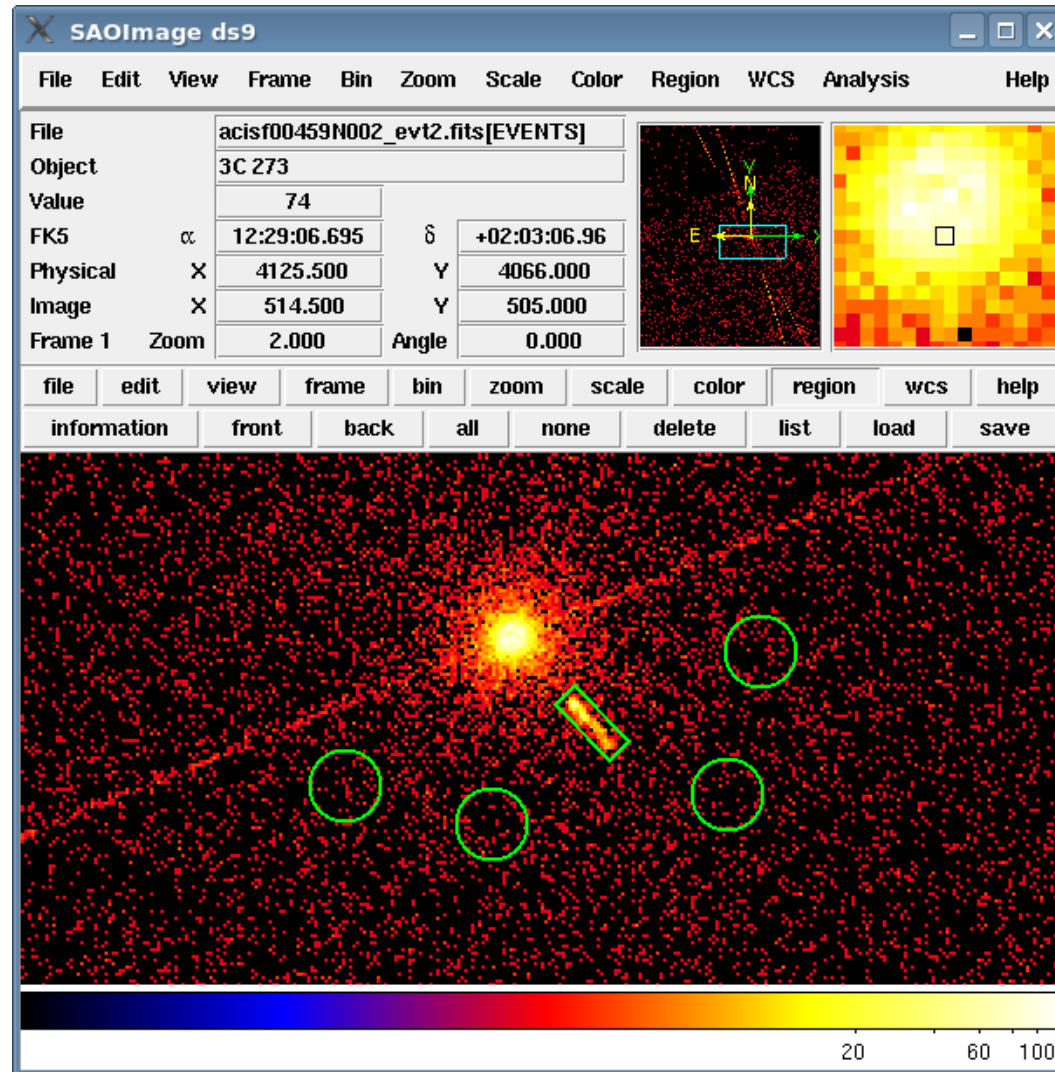
The light curve of a source is the sum of all the events at every time t , independently from the energy of a single event, that fall within a fixed spatial region.



How to extract a lightcurve

1) select a source and background region

see later



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]"

dmstat → compute statistics for images and columns in tables

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

ahelp dmstat

Notes: punlearn dmstat (or other tools) → to restore default parameter values

plist dmstat (or other tools) → to verify the parameter values for a tool

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="lrc1"
```

```
> dmextract
```

How to extract a lightcurve

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="lrc1"  
>dmextract
```



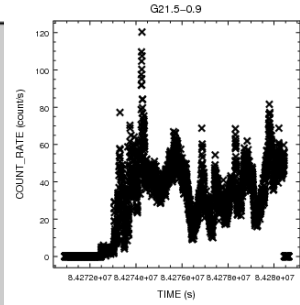
MIN:MAX:STEP

pset → Set parameter values on the command line

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

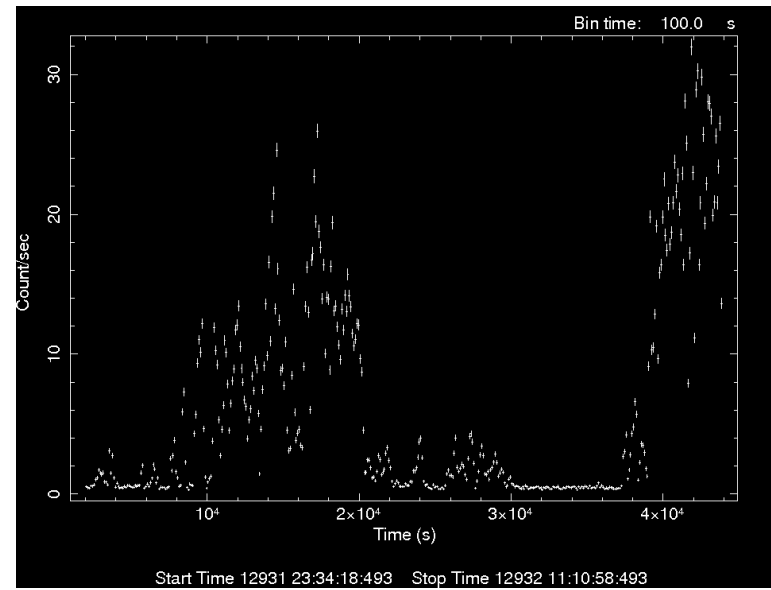
Chips provided by CIAO

```
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 fool 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
```



A light curve can be build in different temporal bins, e.g. if the observation is 1000 s long it is possible to extract light curves of 10 s and 100 s. The longer is the temporal bin the lower is the resolution but the higher is the S/N.

To establish if a source varied during the observation we can apply the χ^2 **test**: considering the light curve constant we calculate

$$\chi_v^2 = \frac{1}{v} \sum_{i=1}^n \frac{(c_i - \langle c \rangle)^2}{\sigma_i^2}$$

c_i observed counts in every temporal bin i ;

σ_i Poissonian error;

$\langle c \rangle$ average count during the observation;

$v = n - 1$ degrees of freedom;

Compute the null hypothesis probability $P(\chi^2, v)$ i.e. P that the source is not varied; this test should be repeated for several temporal bins.

see the Statistics Tutorial

Scientific files
Housekeeping files



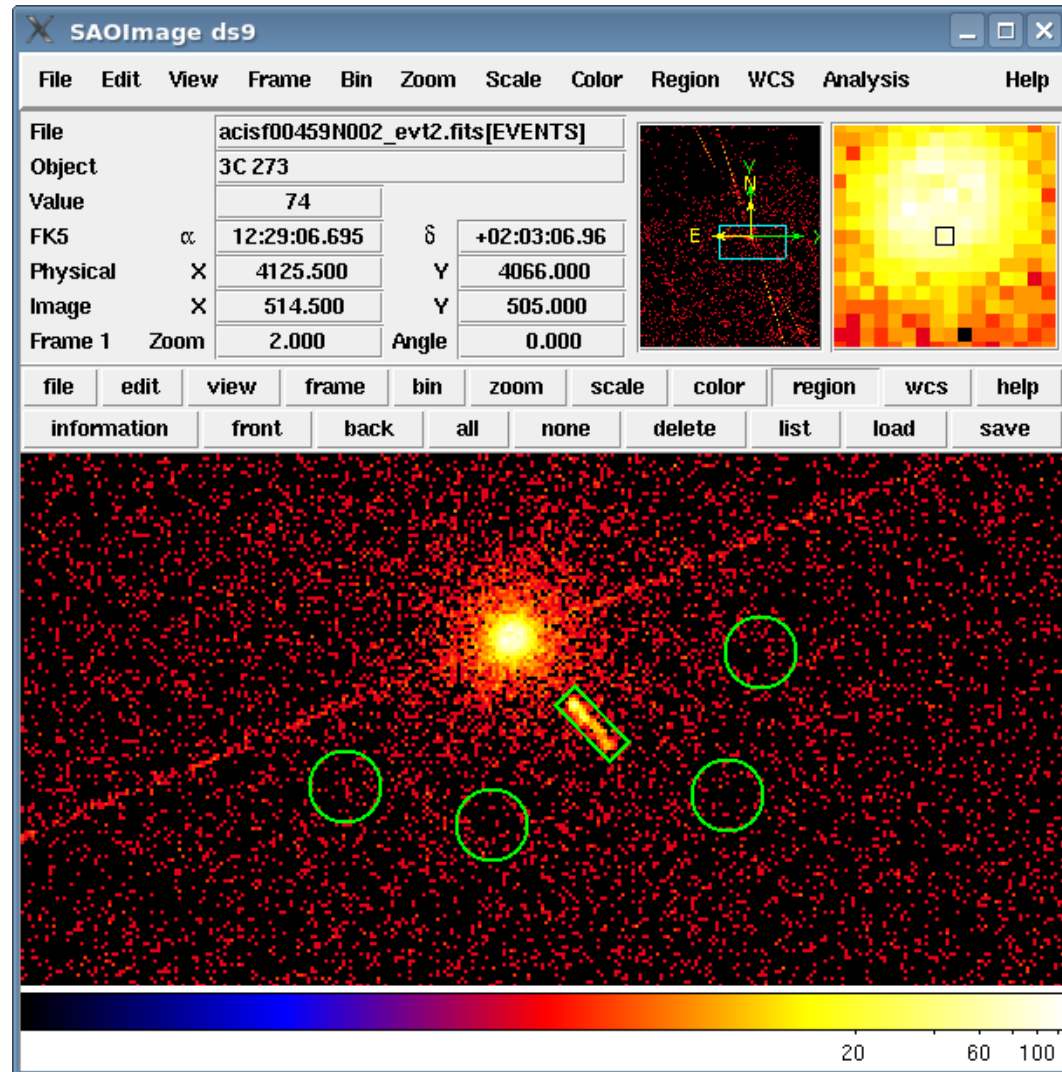
Cleaned
event files

Spectrum

Image

Light curve

Extract source and background regions



ds9 nomefile

Region ->

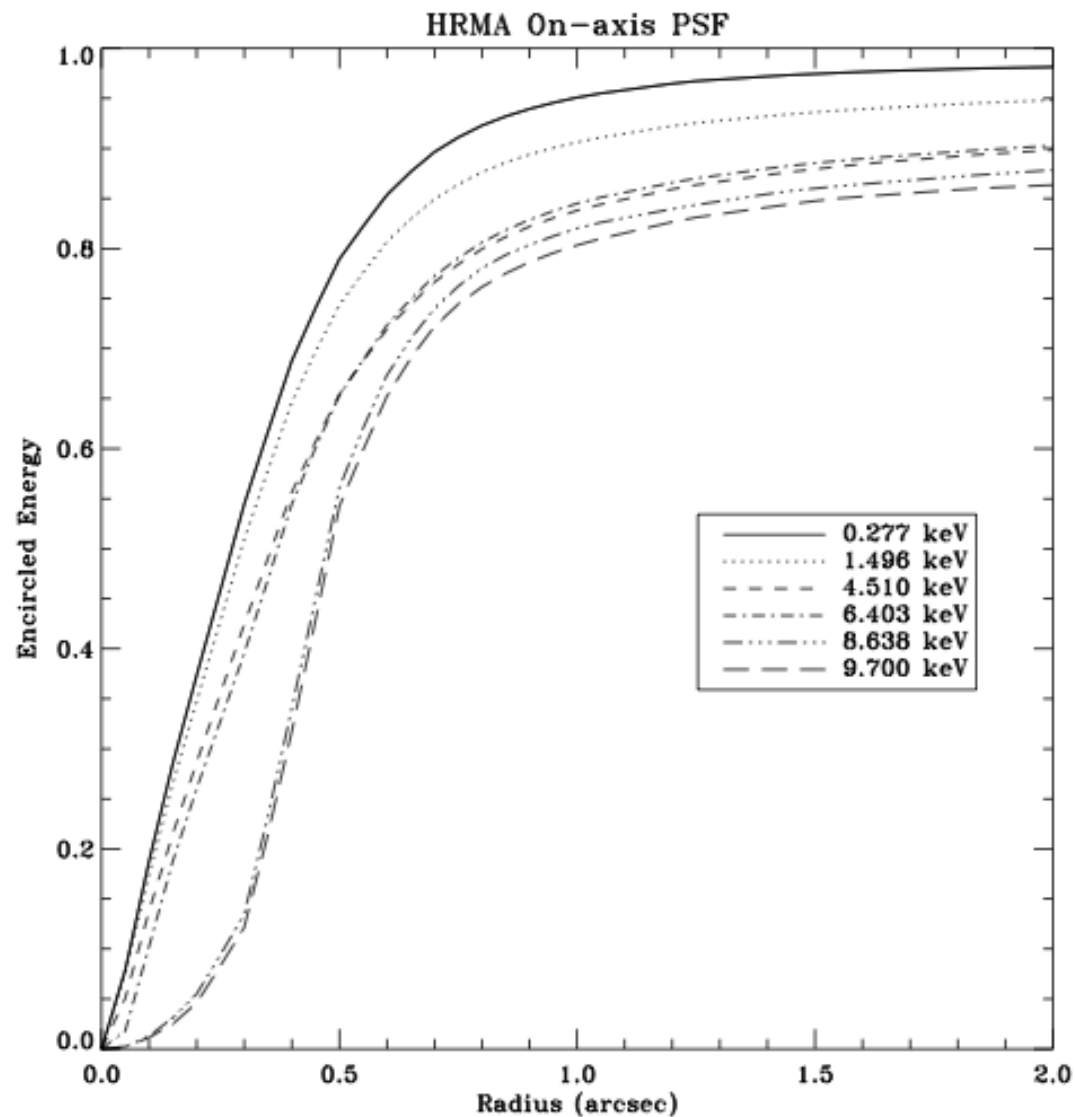
File Format ->

CIAO ->

File Coordinate

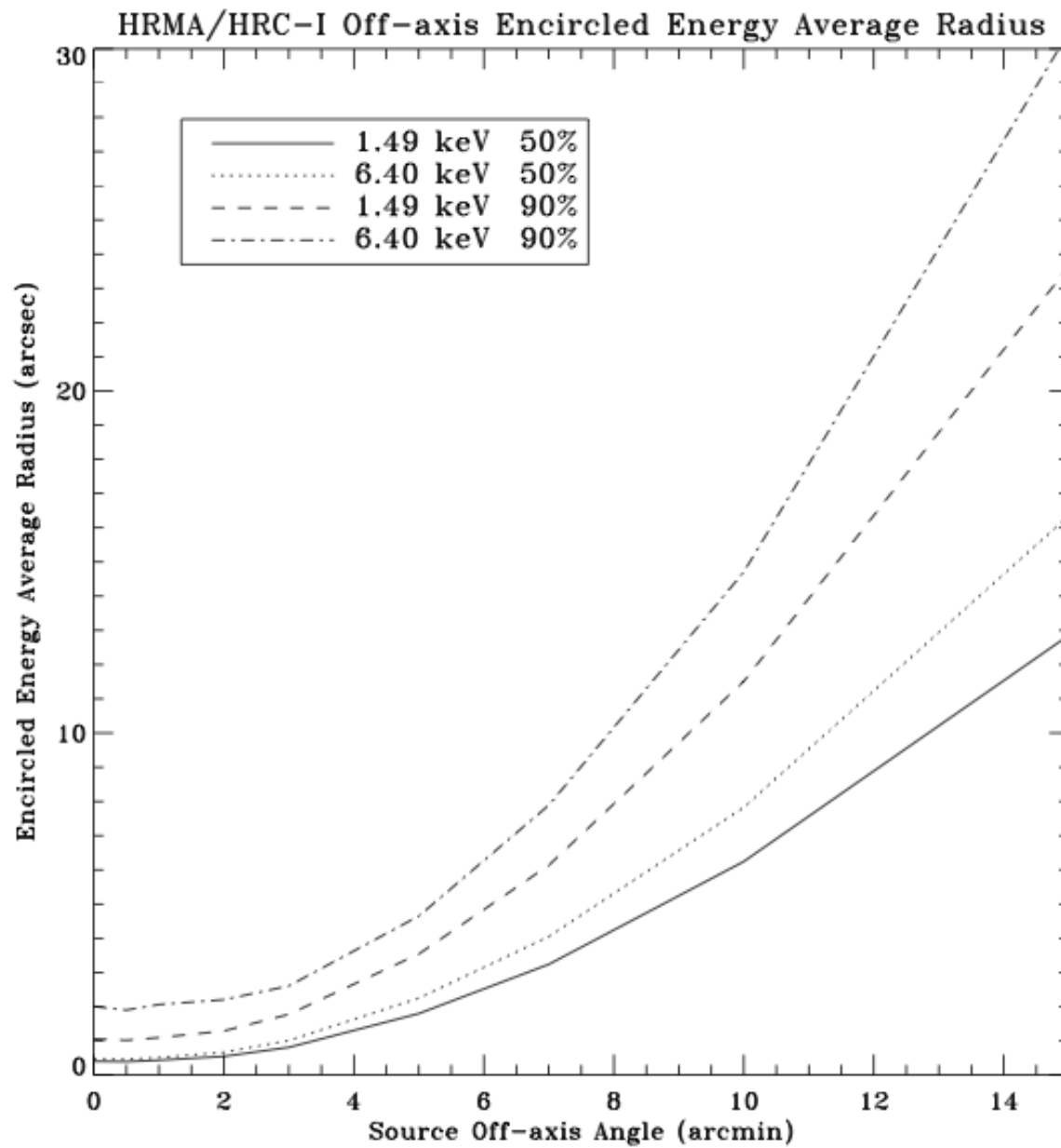
system -> Physical

Fractional encircled energy



About 90% of photons coming from a pointlike source fall within 4 pixel $\approx 2''$ @ 1.5 keV

Encircled Energy Fraction vs Off-Axis Angle



To extract the spectrum of a *pointlike source*...

```
-> punlearn specextract
-> pset specextract infile="acisf00547N002_evt2.fits[sky=region
(src.reg)]"
-> pset specextract outroot=spectrum
-> pset specextract bkgfile="acisf00547N002_evt2.fits[sky=region
(bkg.reg)]"
-> pset specextract weight=no
-> pset specextract correct=yes
-> pset specextract asp=pcadf089424455N002_asol1.fits
-> pset specextract mskfile=acisf00547_000N002_msk1.fits
-> pset specextract badpixfile=acisf00547_000N002_bpix1.fits
-> pset specextract pbkfile=acisf089424366N002_pbk0.fits
-> specextract verbose 2
```

specextract runs the following tools

- [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.

...to extract the spectrum of an *extended* source

```
-> punlearn specextract
-> pset specextract infile="acisf00547N002_evt2.fits[sky=region
(src.reg)]"
-> pset specextract outroot=spectrum
-> pset specextract bkgfile="acisf00547N002_evt2.fits[sky=region
(bkg.reg)]"
-> pset specextract weight=yes
-> pset specextract correct=no
-> pset specextract asp=pcadf089424455N002_asol1.fits
-> pset specextract mskfile=acisf00547_000N002_msk1.fits
-> pset specextract badpixfile=acisf00547_000N002_bpix1.fits
-> pset specextract pbkfile=acisf089424366N002_pbk0.fits
-> specextract verbose 2
```

specextract runs the following tools

- [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.

Grouping spectra with *grppha*

To have a given number of counts per bin, i.e., enough counts per bin to apply X^2 statistics

```
punlearn grppha
pset grppha infile=spectrum.pha
pset grppha outfile=spectrum_gr25.pha
pset grppha comm="chkey BACKFILE spectrum_bkg.pha &
chkey ANCRFILE spectrum.arf & chkey RESPFILE
spectrum.rmf & group min 15 & exit"
```

See Statistics/Fitting/xspec Tutorials

The response matrix is composed by

1. The *Redistribution Matrix File (RMF)*: associates to each instrument channel (I) the appropriate photon energy (E)

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.**

The quantum efficiency (QE) is the *fraction of incident photons registered by a detector*. For an ideal detector, this is 100% (every incoming photon results in a single count). In reality, however, no detector is 100% efficient. If, for instance, the detector is 70% efficient, then every 100 photons would result in 70 counts.

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 is then needed to produce the final observed spectrum.

File Edit Tools **RMF** Help

CHANNEL E_MIN E_MAX

Select 1E 1E 1E

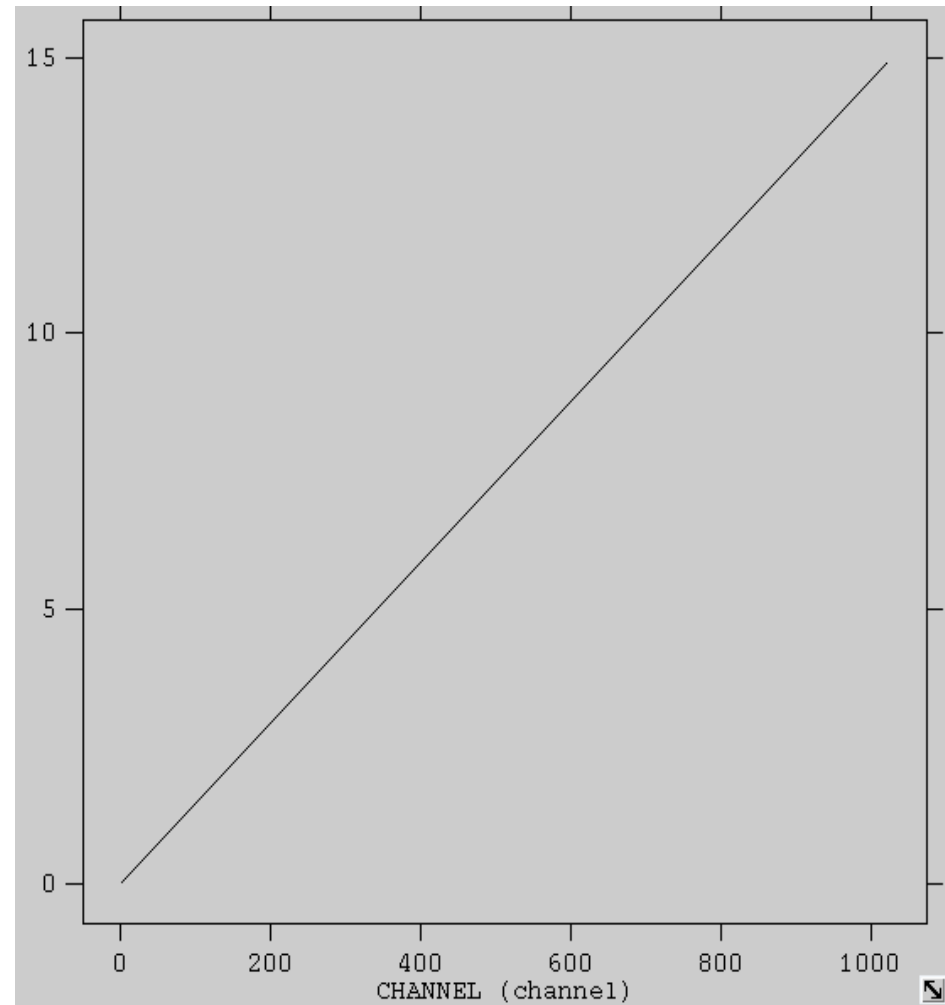
All channel keV keV

Invert Modify Modify Modify

| | | | |
|----|--------------|--------------|--------------|
| 1 | 1.000000E+00 | 1.460000E-03 | 1.460000E-02 |
| 2 | 2.000000E+00 | 1.460000E-02 | 2.920000E-02 |
| 3 | 3.000000E+00 | 2.920000E-02 | 4.380000E-02 |
| 4 | 4.000000E+00 | 4.380000E-02 | 5.840000E-02 |
| 5 | 5.000000E+00 | 5.840000E-02 | 7.300000E-02 |
| 6 | 6.000000E+00 | 7.300000E-02 | 8.760000E-02 |
| 7 | 7.000000E+00 | 8.760000E-02 | 1.022000E-01 |
| 8 | 8.000000E+00 | 1.022000E-01 | 1.168000E-01 |
| 9 | 9.000000E+00 | 1.168000E-01 | 1.314000E-01 |
| 10 | 1.000000E+01 | 1.314000E-01 | 1.460000E-01 |
| 11 | 1.100000E+01 | 1.460000E-01 | 1.606000E-01 |
| 12 | 1.200000E+01 | 1.606000E-01 | 1.752000E-01 |
| 13 | 1.300000E+01 | 1.752000E-01 | 1.898000E-01 |
| 14 | 1.400000E+01 | 1.898000E-01 | 2.044000E-01 |
| 15 | 1.500000E+01 | 2.044000E-01 | 2.190000E-01 |
| 16 | 1.600000E+01 | 2.190000E-01 | 2.336000E-01 |
| 17 | 1.700000E+01 | 2.336000E-01 | 2.482000E-01 |
| 18 | 1.800000E+01 | 2.482000E-01 | 2.628000E-01 |
| 19 | 1.900000E+01 | 2.628000E-01 | 2.774000E-01 |
| 20 | 2.000000E+01 | 2.774000E-01 | 2.920000E-01 |

Go to: Edit cell: 0.219

RMF



File Edit Tools **ARF** Hel

ENERG_LO ENERG_HI SPECRESP

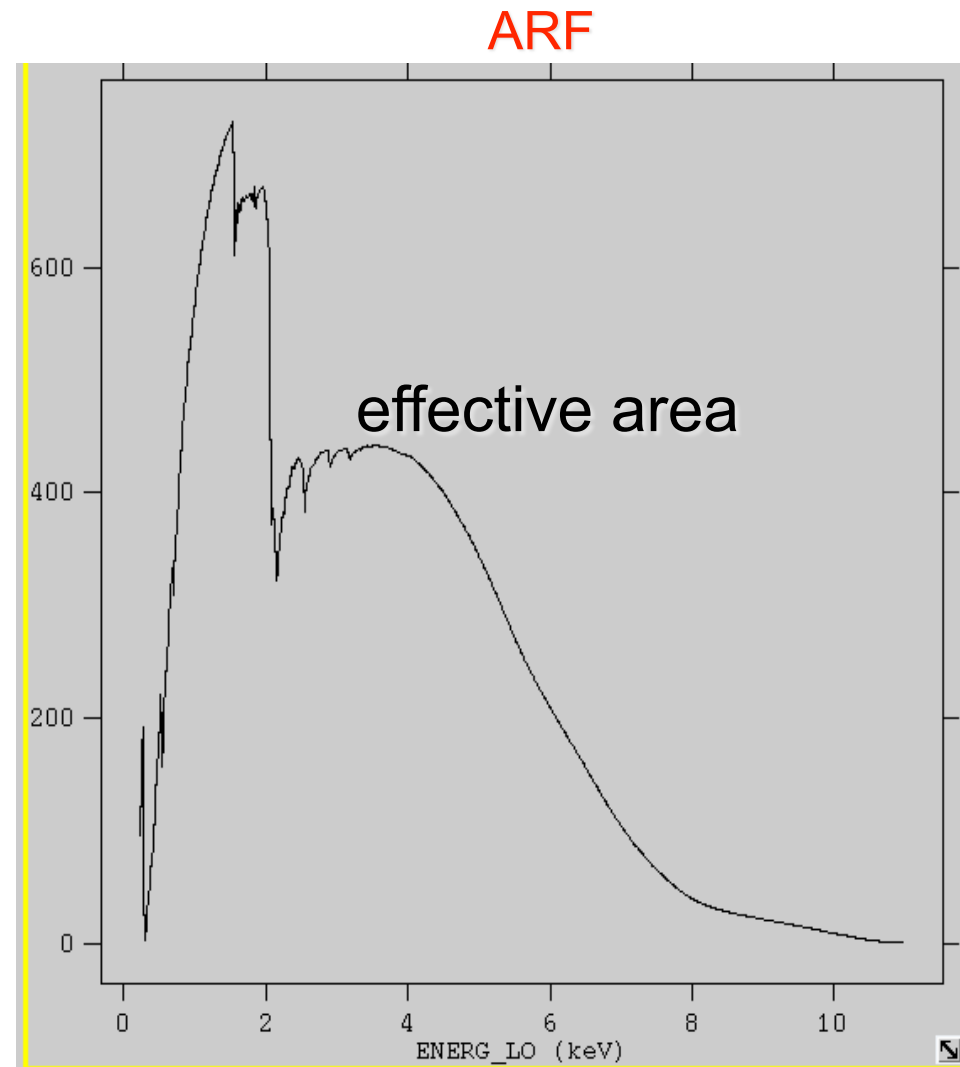
Select 1E 1E 1E

All keV keV cm**2

Invert Modify Modify Modify

| | | | |
|----|--------------|--------------|--------------|
| 1 | 2.200000E-01 | 2.300000E-01 | 9.414584E+01 |
| 2 | 2.300000E-01 | 2.400000E-01 | 1.119709E+02 |
| 3 | 2.400000E-01 | 2.500000E-01 | 1.309653E+02 |
| 4 | 2.500000E-01 | 2.600000E-01 | 1.518642E+02 |
| 5 | 2.600000E-01 | 2.700000E-01 | 1.716482E+02 |
| 6 | 2.700000E-01 | 2.800000E-01 | 1.922011E+02 |
| 7 | 2.800000E-01 | 2.900000E-01 | 4.741680E+01 |
| 8 | 2.900000E-01 | 3.000000E-01 | 2.284590E+00 |
| 9 | 3.000000E-01 | 3.100000E-01 | 5.144246E+00 |
| 10 | 3.100000E-01 | 3.200000E-01 | 1.563580E+01 |
| 11 | 3.200000E-01 | 3.300000E-01 | 2.251595E+01 |
| 12 | 3.300000E-01 | 3.400000E-01 | 3.011008E+01 |
| 13 | 3.400000E-01 | 3.500000E-01 | 3.743014E+01 |
| 14 | 3.500000E-01 | 3.600000E-01 | 4.385400E+01 |
| 15 | 3.600000E-01 | 3.700000E-01 | 4.954287E+01 |
| 16 | 3.700000E-01 | 3.800000E-01 | 5.625348E+01 |
| 17 | 3.800000E-01 | 3.900000E-01 | 6.431229E+01 |
| 18 | 3.900000E-01 | 4.000000E-01 | 7.319862E+01 |
| 19 | 4.000000E-01 | 4.100000E-01 | 7.713167E+01 |
| 20 | 4.100000E-01 | 4.200000E-01 | 8.444775E+01 |

Go to: Edit cell: 0.42

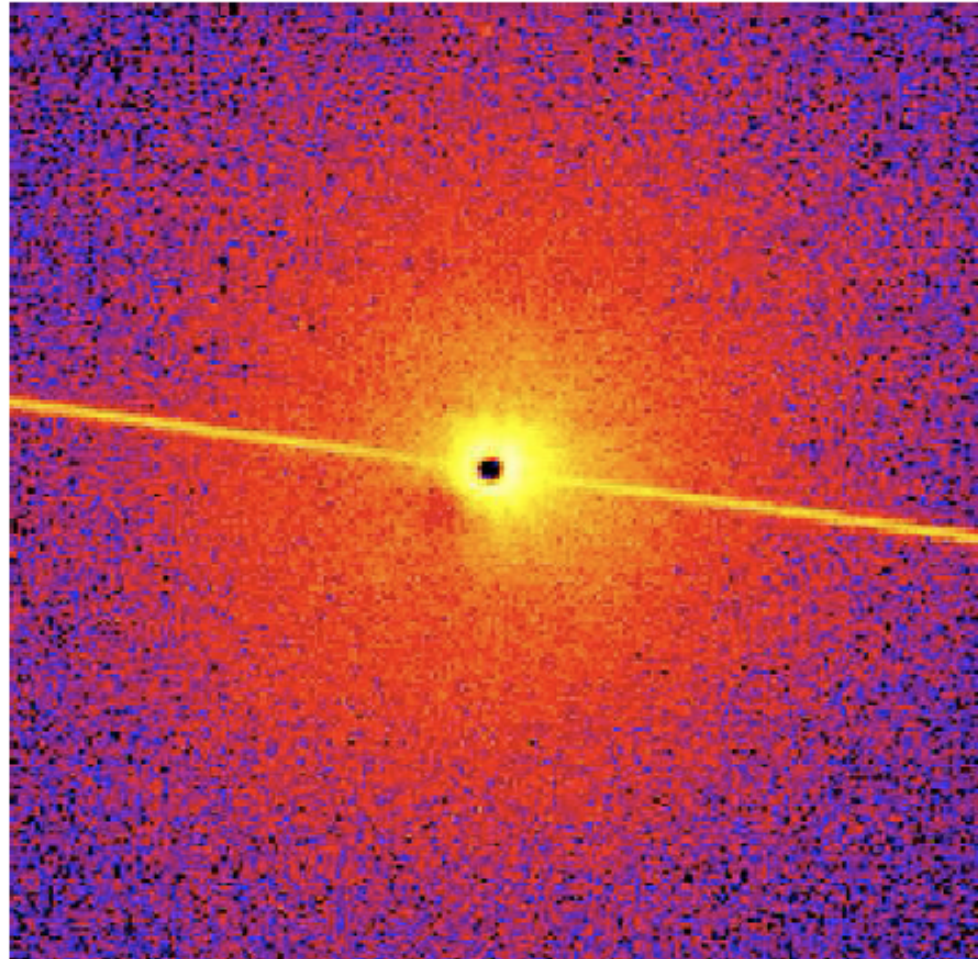


Pileup

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

Two or more photon events overlapping in a single detector frame and being read as a single event

→ loss of information from these events, and hardening of the X-ray spectrum

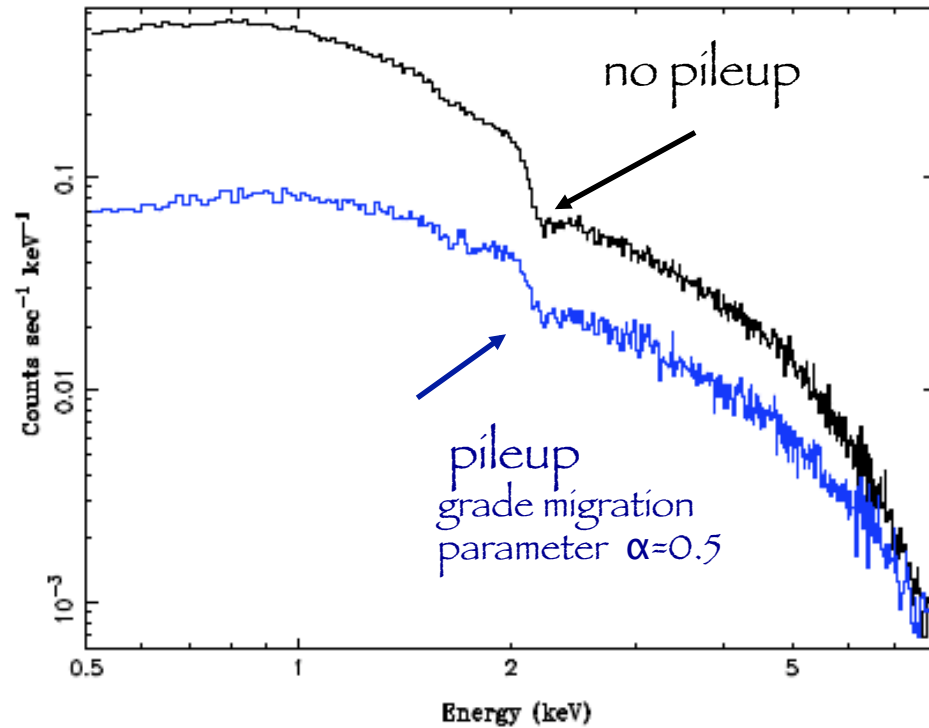


Pileup' s two major effects are:

- **ENERGY MIGRATION** photon energies sum to create a detected event with higher energy;
- **GRADE MIGRATION** event grades migrate towards values inconsistent with real photon events.

- net decrease of the total observed count rate
- net decrease in the fractional rms (root mean square) variability of the lightcurve

➡ **detected spectral shape of the source distorted**



How to avoid pileup → reduce the counts per frame per pixels (...)

How to avoid pileup → by reducing the counts per frame per pixels (...)

Pileup estimation → several ways. One is PIMMS

heasarc → tools → webpimms



Proposal Planning Toolkit

[PIMMS](#) [Colden](#) [Process](#) [Dates](#)

PIMMS v3.9k: with ACIS Pile up and Background Count Estimation

| | |
|--|---|
| Input: <input checked="" type="radio"/> Count Rate <input type="radio"/> Flux <input type="radio"/> Flux Density | Output: <input checked="" type="radio"/> Count Rate <input type="radio"/> Flux <input type="radio"/> Flux Density |
| Mission: CHANDRA-Cycle 12 | Detector/Grating/Filter: ACIS-I/None/None |
| Input Energy: 0.2 to 10.0 keV <input type="button" value="Default"/> | Output Energy: 0.2 to 10.0 <input type="button" value="Default"/> |

Model:
cm**⁻² cm**⁻² N=AE**^{-a} cts/s

Source: **Frame Time:** sec

PIMMS Prediction: cts/sec **Pileup:** % cts/frame **Background Count Rate:** cts/sec

How to avoid pileup → by reducing the counts per frame per pixels (...)

Pileup estimation → several ways. One is PIMMS

heasarc → tools → webpimms



Proposal Planning Toolkit

[PIMMS](#) [Colden](#) [Process](#) [Dates](#)

PIMMS v3.9k: with ACIS Pile up and Background Count Estimation

| | |
|--|---|
| Input: <input checked="" type="radio"/> Count Rate <input type="radio"/> Flux <input type="radio"/> Flux Density | Output: <input checked="" type="radio"/> Count Rate <input type="radio"/> Flux <input type="radio"/> Flux Density |
| Mission: CHANDRA-Cycle 12 | Detector/Grating/Filter: ACIS-I/None/None |
| Input Energy: 0.2 to 10.0 keV | Output Energy: 0.2 to 10.0 |

Model: Galactic NH: Redshift(z): Redshifted NH: Photon Index: Count Rate:

cm**2 cm**2 N=AE**a cts/s

Source: Frame Time: sec

point source Specify 3.2

PIMMS Prediction: cts/sec % cts/frame cts/sec cts/sec

Background Count Rate: cts/sec

Pileup migration → application to spectral data (pileup model in XSPEC)

The pileup model

```
=====
Model wabs<1>*pileup<2>*powerlaw<3> Source No.: 1 Active/Off
Model Model Component Parameter Unit Value
par comp
 1 1 wabs nH 10^22 3.59000E-02 +/- 0.0
 2 2 pileup fr_time s 3.20000 frozen
 3 2 pileup max_ph 5.00000 frozen
 4 2 pileup g0 1.00000 frozen
 5 2 pileup alpha 1.00000 +/- 0.0
 6 2 pileup psfrac 0.950000 frozen
 7 2 pileup nregions (scale) 1.00000
 8 3 powerlaw PhoIndex 1.70000 +/- 0.0
 9 3 powerlaw norm 2.00000E-03 +/- 0.0
=====
XSPEC12>
```

fr_time -> parameter equal to the good exposure time per frame divided by the fractional exposure. Default value 3.2 s.

max_ph -> this is the maximum number of photons considered for pileup in a single frame.

g0 -> grade correction for single photon detection. I.e., a fraction g_0 of single photon events will be retained as good grades. Default value $g_0=1$.

alpha -> the grade migration parameter, such that the probability of n events piled together in a single frame being retained as a 'good grade' is α^{n-1} . This parameter can range from 0 to 1.

psfrac -> the fraction of the spectrum that is within the central piled portion of the PSF is 95%. This value is appropriate for an extraction radius of 2" (≈ 4 pixels).

nregions -> divide the model counts among n_{regions} regions, to which the pileup model will be applied independently. For point sources =1. It should remain frozen.

Scientific files
Housekeeping files



Cleaned
event files

Spectrum

Image

Light curve



Scientific analysis

see XMM
Tutorial...

- ✓ Downloading of X-ray data from a public archive
- ✓ How do the downloaded files look like?
- ✓ Steps to reduce X-ray (*Chandra*) data
- ✓ **Creation of radio and/or X-ray contours for an extended object**
- ✓ How to create a radio/X-ray contour superposition image

NED results for object NGC 6251

NED Database

1 objects found in NED. [Skyplot\(first 100\)](#)

SOURCE LIST

| Row No. | Object Name (* => Essential Note) | EquJ2000.0 RA | DEC | Object Type | Velocity/Redshift km/s | z | Mag./ Filter | Separ. arcmin | Refs | Notes | Phot | Posn | Vel/z | Diam | Assoc | Images Retrieve | Spectra Retrieve |
|-------------------|--------------------------------------|------------------|------------|-------------|---------------------------|----------|-----------------|------------------|---------------------|-------------------|--------------------|-------------------|-------------------|-------------------|-------|------------------------------------|-------------------------------------|
| 1 | NGC 6251 | 16h32m32.0s | +82d32m16s | G | 7408 | 0.024710 | 13.64 | ... | 306 | 8 | 45 | 5 | 7 | 6 | | | |

Detailed information for each object

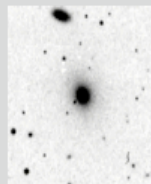
Object No. 1 - NGC 6251

INDEX for NGC 6251

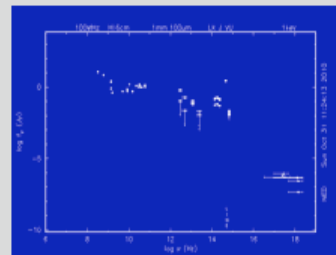
Essential Data (jump to sub-section of this query report):

- [Essential Note](#)
- [Cross-IDs](#)
- [Coordinates](#)
- [Basic Data](#)
- [Quantities Derived from Redshift](#)
- [Redshift-Independent Distances](#) NEW
- [Classifications](#) NEW
- [Foreground Galactic Extinction](#)
- [External Services](#)

Detailed Data (NED queries):

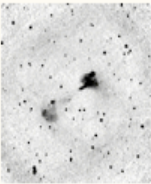

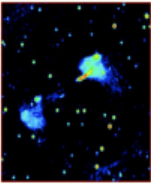
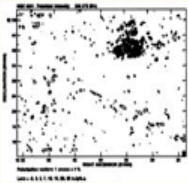
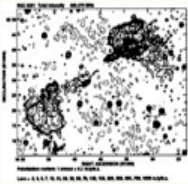
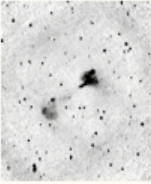

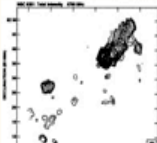


[Images](#)



[45 Photometric data point\(s\) and SED](#)

- [Spectra](#)
- [Redshift-Independent Distances](#)
- [306 Reference\(s\)](#)
- [5 Position data point\(s\)](#)
- [7 Redshift data point\(s\)](#)
- [6 diameter data point\(s\)](#)
- [8 Note\(s\)](#)
- [UGC data](#)
- [RC3 data](#)

| | | | | | | | | |
|---|--|-------------------------------------|--|----------------|---------------|--------|------------|---|
|  | 1062KB FITS image Retrieve | Display FITS Header |  | 0.3GHz , 100cm | 85.0 x 85.0 | 55.00 | WSRT | 1997A&AS..123..423M |
|  | 15KB JPG image Retrieve | N/A | N/A | 327MHz , 92cm | 85.0 x 85.0 | 55.00 | WSRT | 2003DRAGN.C.....: |
|  | 104KB JPG image Retrieve | Display Caption | N/A | 326MHz , 92cm | N/A | 55.00 | WSRT | 1997A&AS..123..423M |
|  | 202KB JPG image Retrieve | Display Caption | N/A | 326MHz , 92cm | N/A | 55.00 | WSRT | 1997A&AS..123..423M |
|  | 3162KB FITS image Retrieve | Display FITS Header |  | 326MHz , 92cm | 128.0 x 128.0 | 55.00 | WSRT | 1997A&AS..123..423M |
|  | 99KB JPG image Retrieve | Display Caption | N/A | 4.8GHz , 6.3cm | N/A | 150.00 | Effelsberg | 1997A&AS..123..423M |

Other useful links

- <http://www.jb.man.ac.uk/atlas/icon.html>
- http://2jy.extragalactic.info/2Jy_home_page.html
- <http://www.jb.man.ac.uk/atlas/dragons.html>

ds9 X-ray image radio image

The screenshot displays the SAOImage ds9 interface. The main window shows two panels: 'X-ray' on the left and 'Radio 6 cm' on the right. The X-ray panel shows a sparse field of orange and white points. The Radio 6 cm panel shows a dense, elongated structure with green and yellow contours overlaid on a color map. A 'Contour Parameters' dialog box is open in the foreground, showing settings for 'Contour Levels' (9), 'Contour Smoothness' (11), and 'Limits' (Low: 0.05, High: 2). The 'Levels' list contains values from 0.05 to 2. The 'SAOImage ds9' window has a menu bar with 'File', 'Zoom', 'Scale', 'Color', 'Region', 'WCS', 'Analysis', and 'Help'. Below the menu bar, there are controls for 'bin', 'zoom', 'scale', 'color', 'region', 'wcs', and 'help'. The 'zoom' section includes buttons for '1/8', 'zoom 1/4', 'zoom 1/2', 'zoom 1', 'zoom 2', 'zoom 4', and 'zoom 8'. A color scale bar at the bottom right ranges from 0.02 to 0.1.

Contour Parameters

File Edit Color Width Scale Limits Method

Contour Levels
9

0 10 20 30 40 50

Contour Smoothness
11

0 4 8 12 16 20 24 28 32

Limits Low 0.05 High 2

Apply Generate Clear Close

SAOImage ds9

bin Zoom Scale Color Region WCS Analysis Help

3-2_bkgflt.fits[EVENTS]

Y
Y
Angle 0.000

frame bin zoom scale color region wcs help

1/8 zoom 1/4 zoom 1/2 zoom 1 zoom 2 zoom 4 zoom 8

X-ray

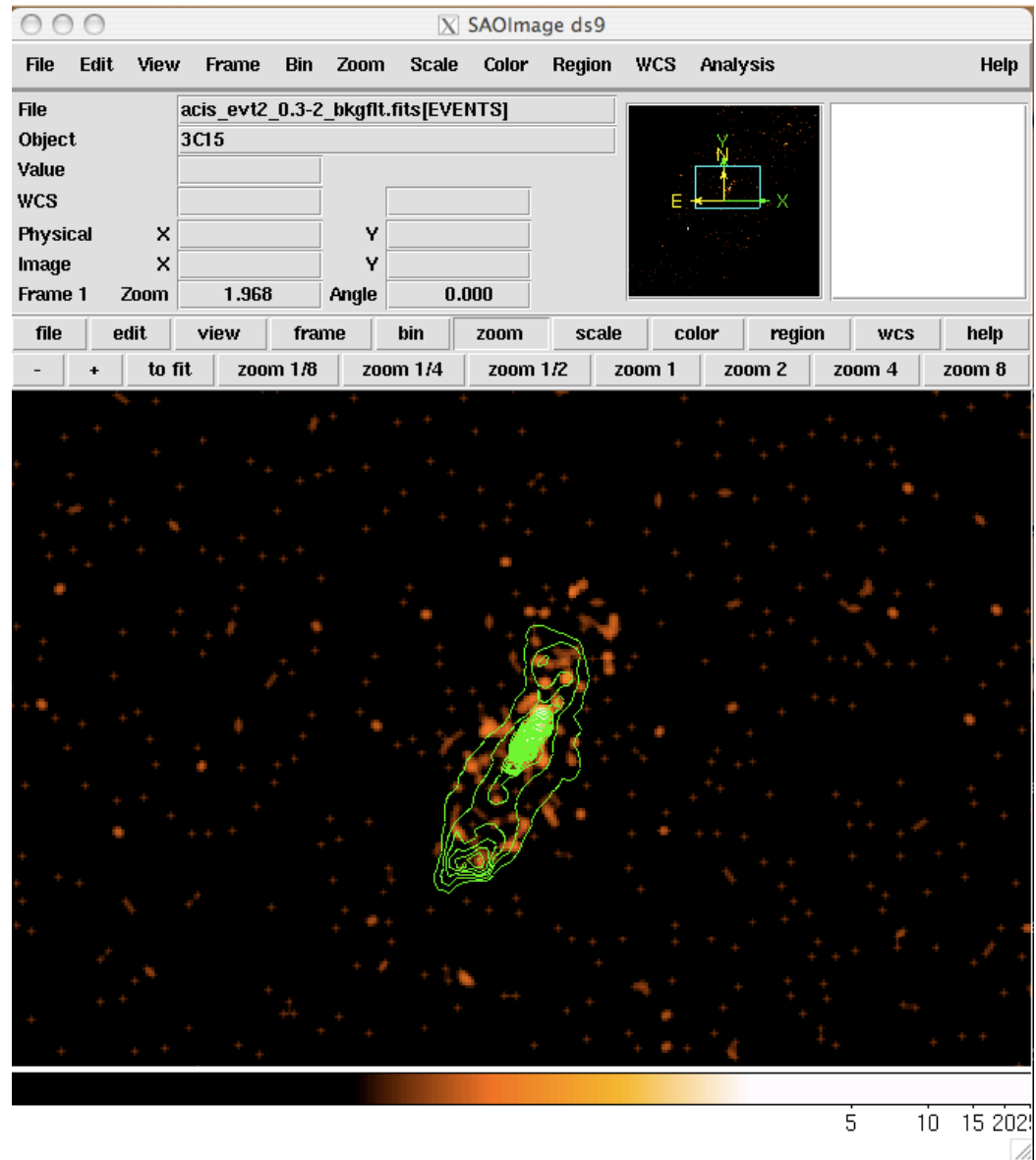
Radio 6 cm

0.02 0.06 0.1

- scale -> log
- color -> heat or b or...
- frame -> match frames
- > WCS
- Analysis -> contours
parameters
- File -> save contours

- ✓ Downloading of X-ray data from a public archive
- ✓ How do the downloaded files look like?
- ✓ Steps to reduce X-ray (*Chandra*) data
- ✓ Creation of radio and/or X-ray contours for an extended object
- ✓ How to create a radio/X-ray contour superposition image

Analysis ->
Contours parameters ->
File ->
Load contours



From the terminal (command-line):
ds9 IMAGE -scale log -contour load FILE_CONTOURS &

Not only radio/X...

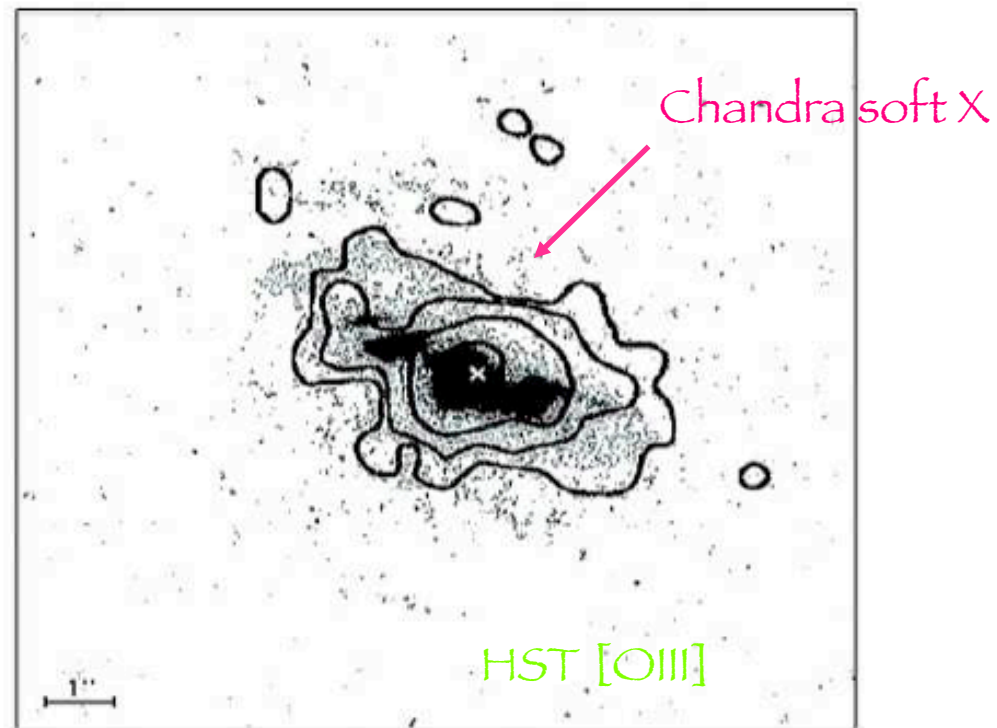
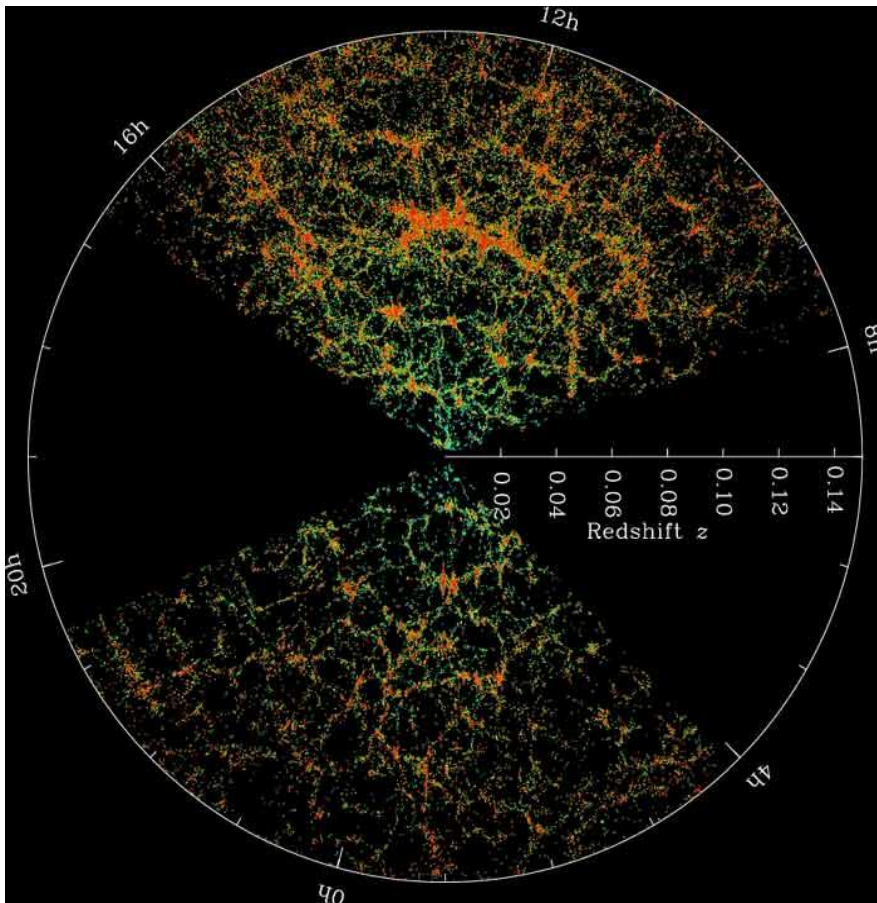


Fig.4. Superposition of the *Chandra* soft X-ray (<2 keV) contours on an *HST* image taken through a linear ramp filter at redshifted [OIII] λ 5007. The sign "x" indicates the centre of the hard X-ray source, north is up, east to the left. The X-ray image was smoothed with a Gaussian of FWHM \sim 6 pixels. The contours correspond to four logarithmic intervals in the range 1-60% of the peak flux.

Surveys

Sloan Digital Sky Survey
8,400 square degrees
>1 Million object up to $z=0.15$

Hubble Ultra Deep Field
11 square arcmin
10000 galaxies up to $z=10$

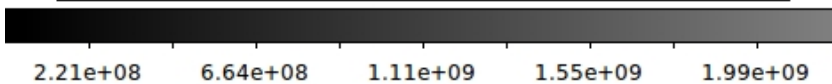
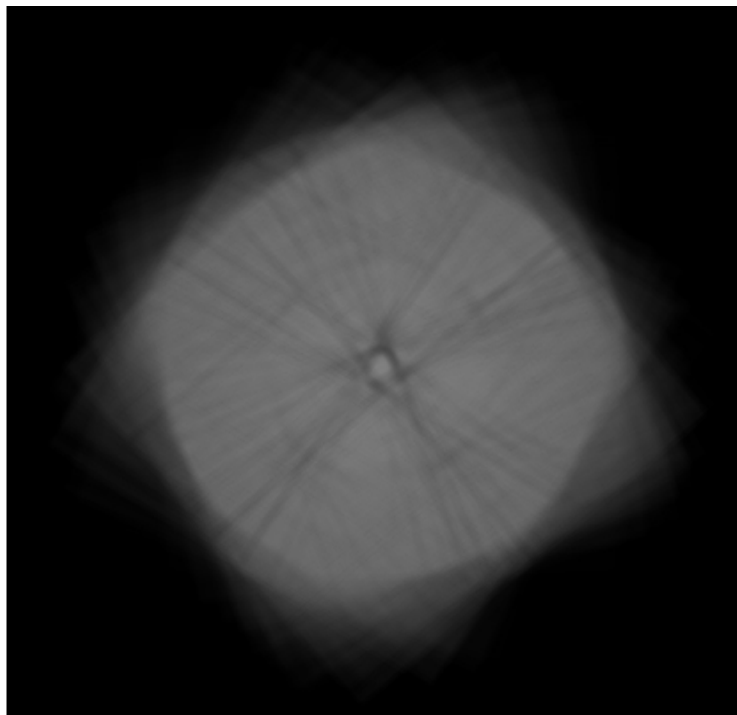


X-ray Surveys

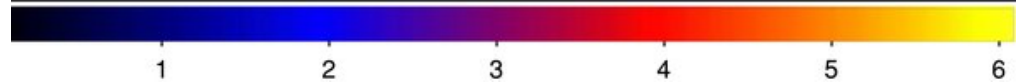
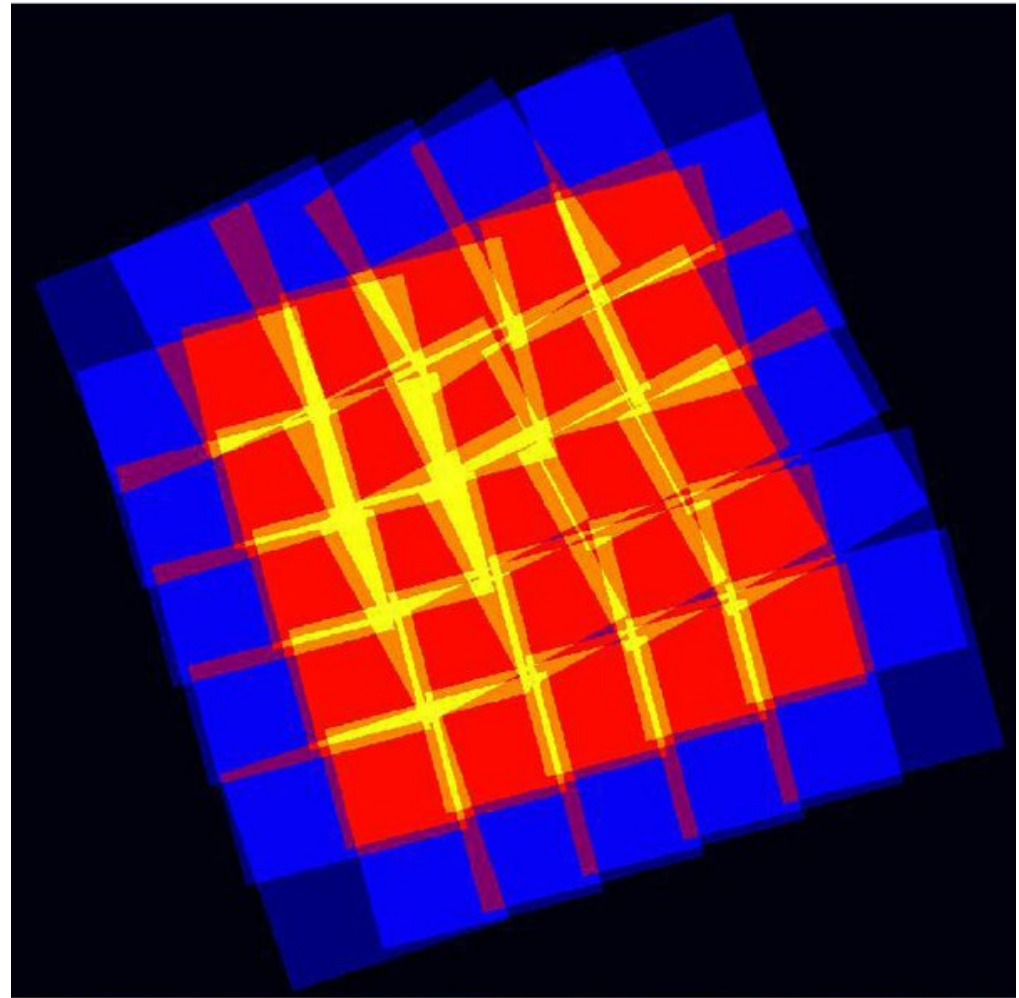
Chandra Deep Field South
0.11 square degree

52 observations
taken in 2000, 2007, 2010

Tot 4 Msec



Chandra COSMOS ~1 square degree
36 pointings

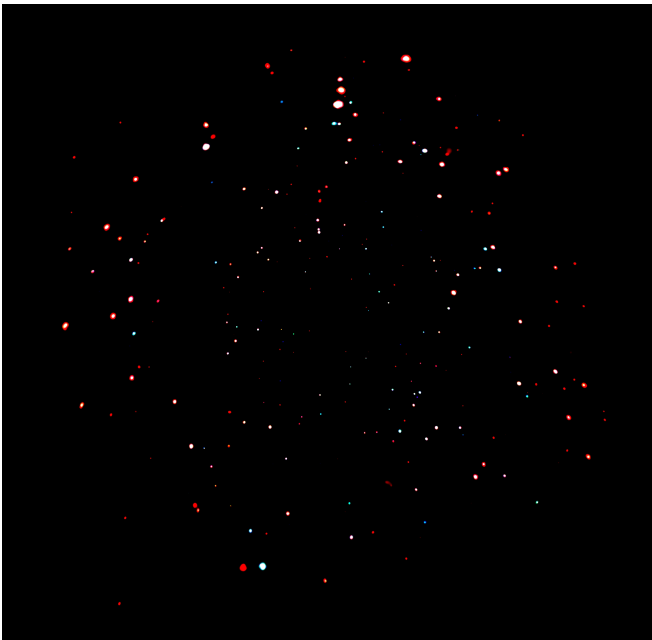


X-ray Surveys

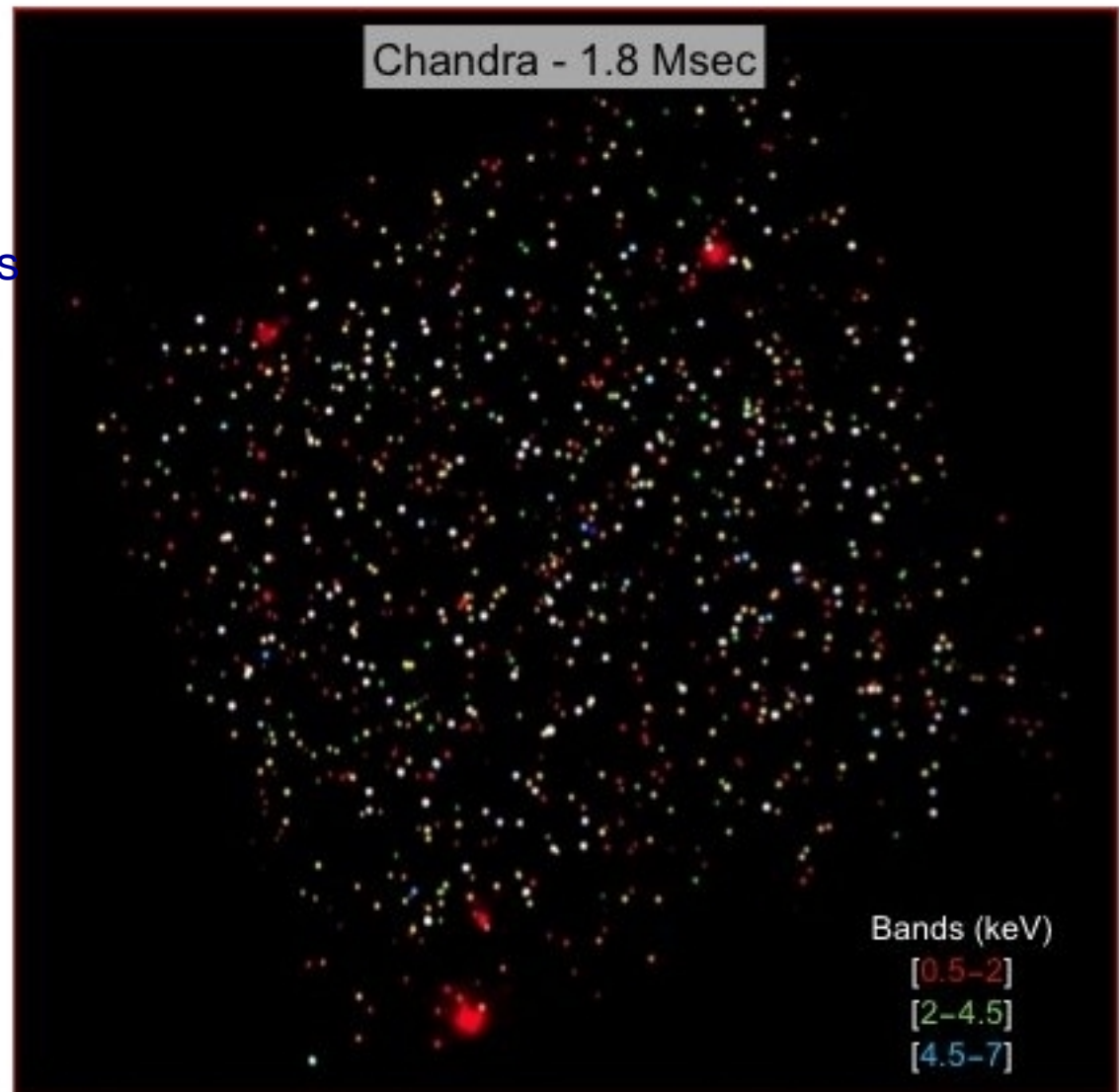
Chandra Deep Field South
0.11 square degree

53 observations
taken in 2000, 2007, 2010

Tot 4 Ms (to be extended to 7Ms
in 2014)



Chandra COSMOS ~1 square degree
36 pointings (to be extended to 2 deg²)





THE END