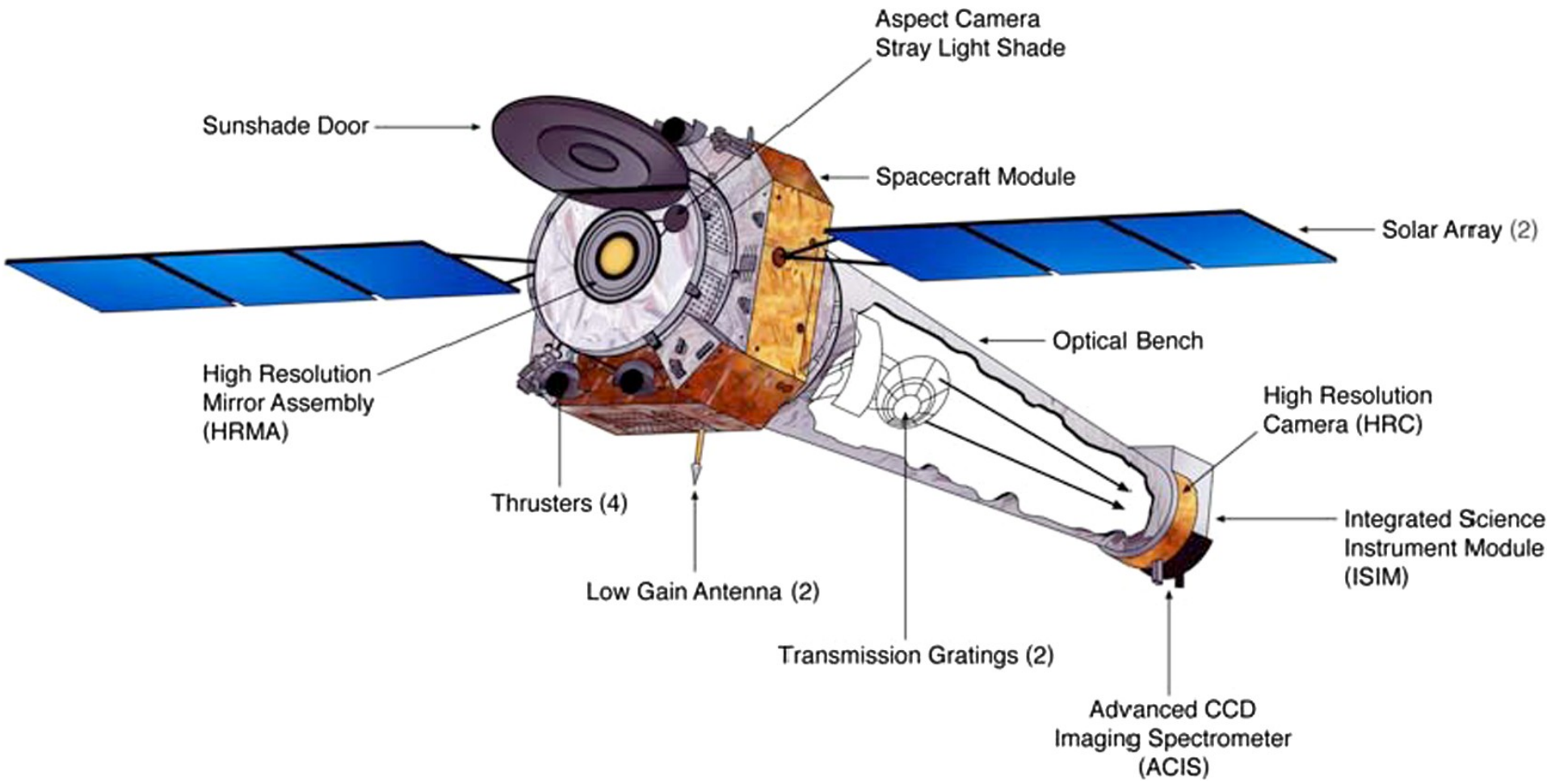
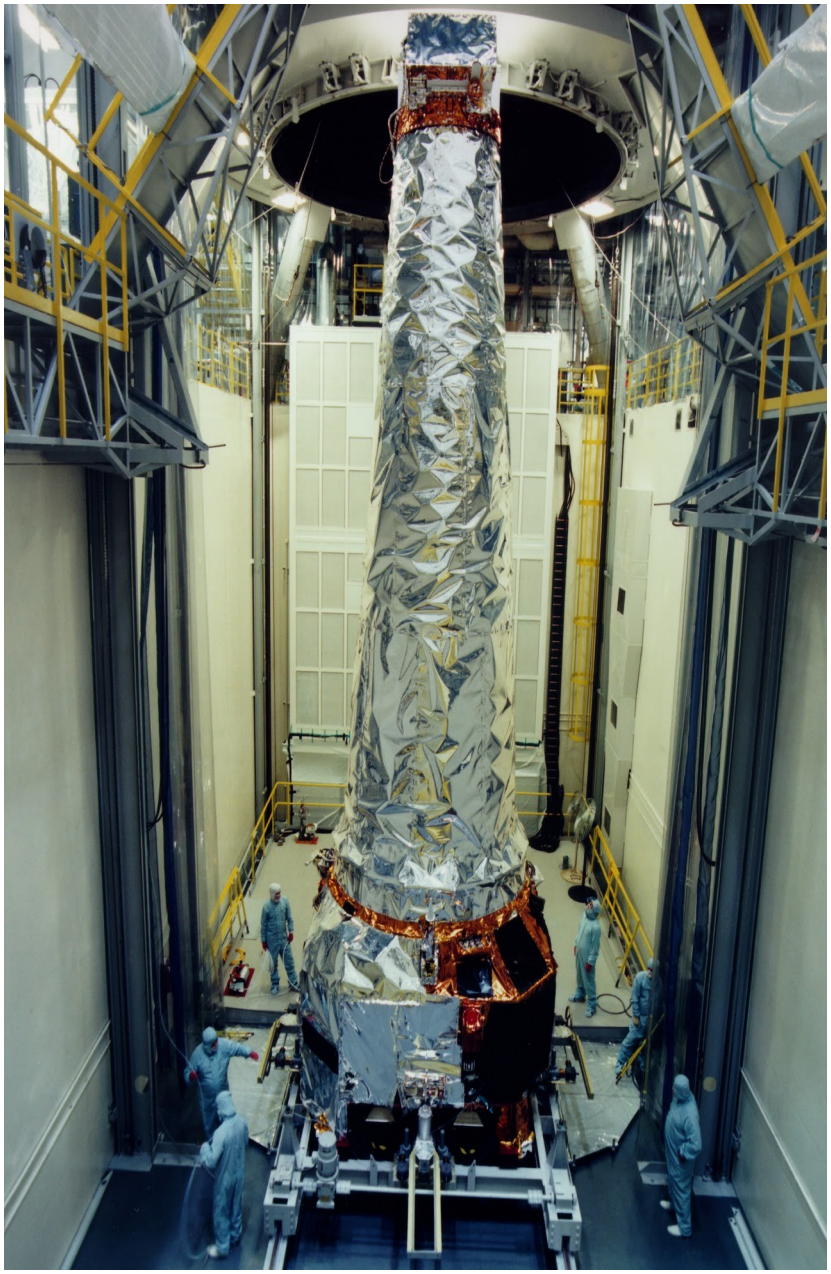
Chandra Tutorial

Laboratorio di Astrofisica 2015

The spacecraft

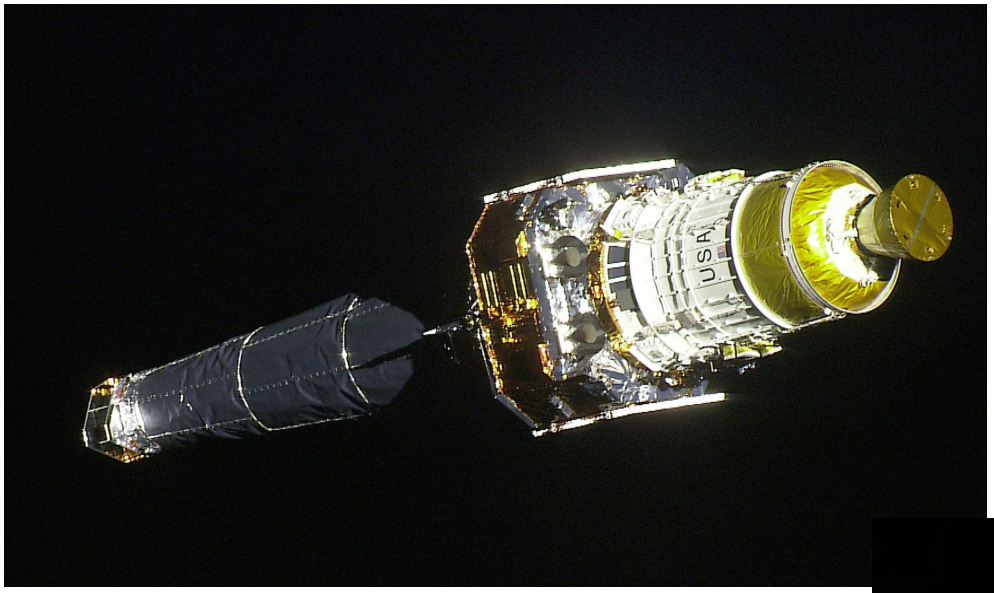


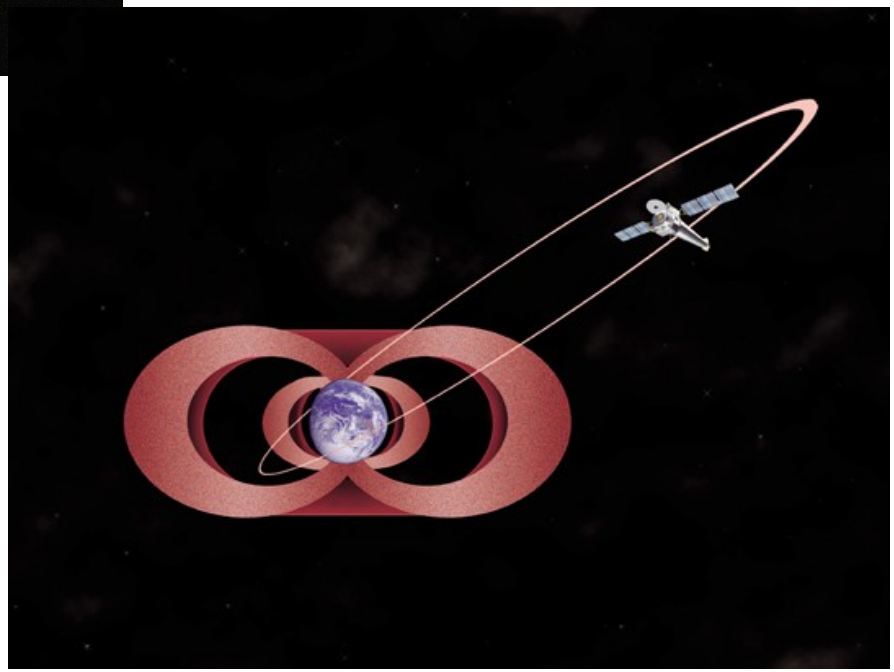
The real spacecraft



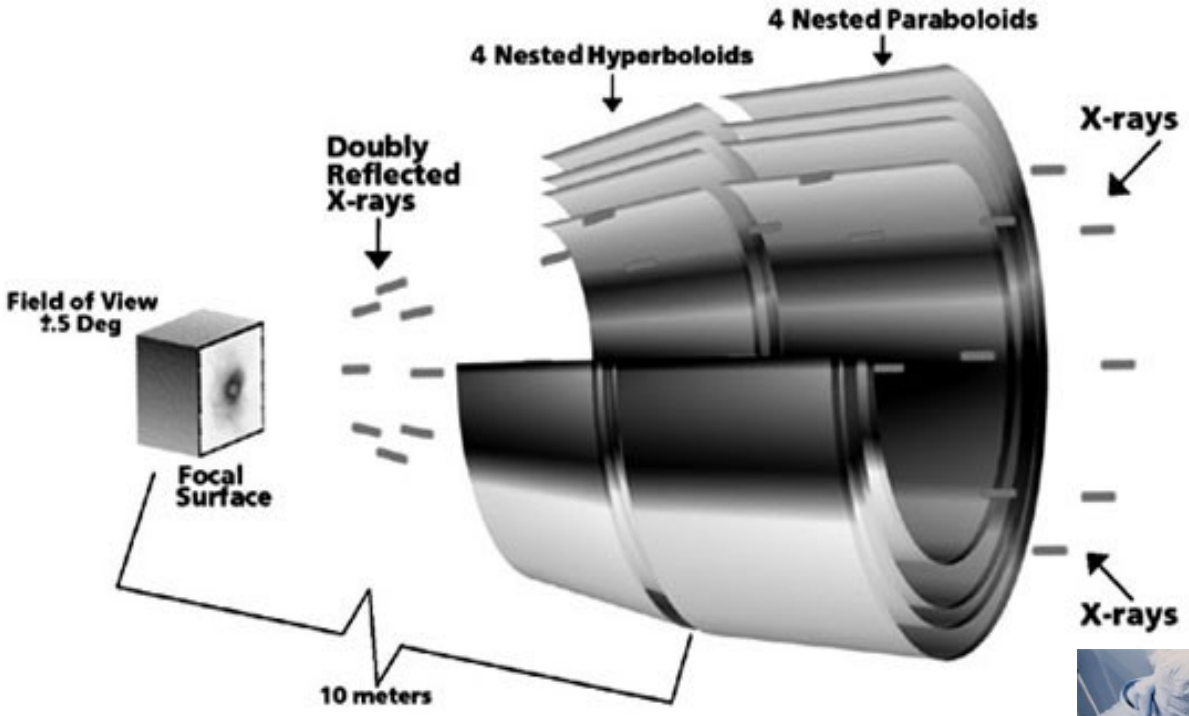
Launched:
July 23, 1999

The real spacecraft





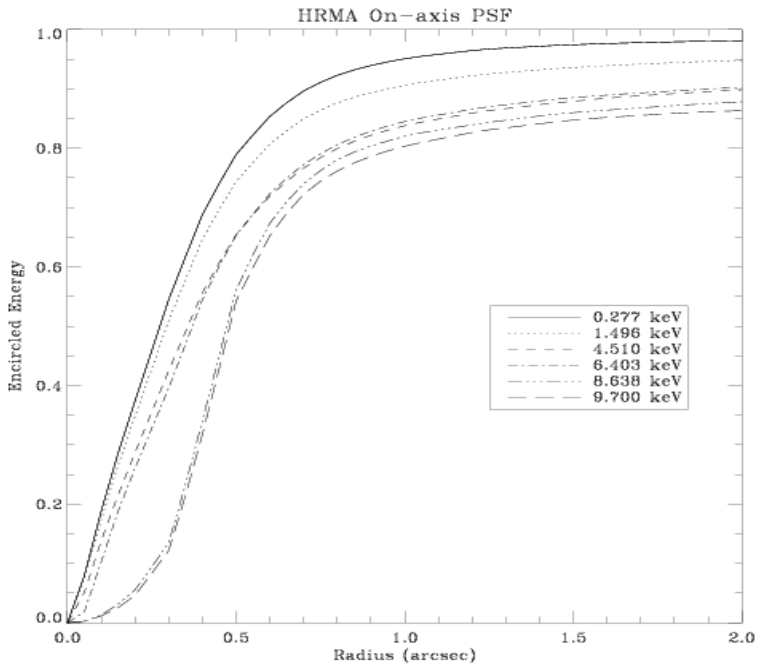
Mirrors

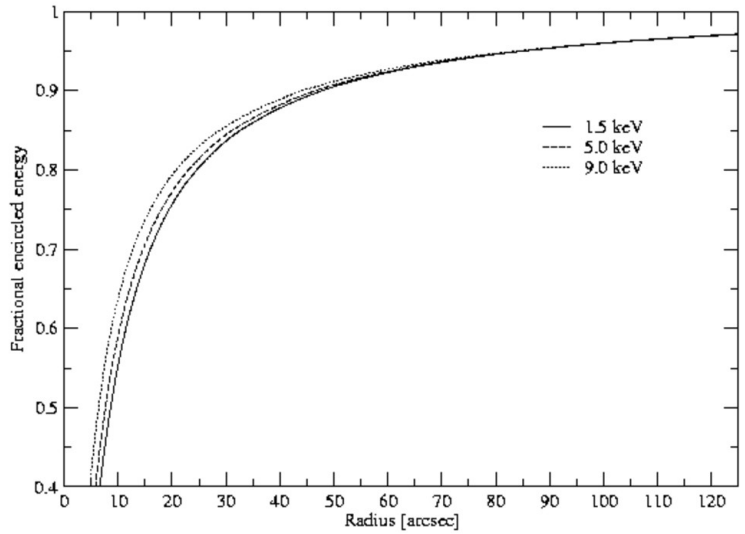


Mirror elements are 0.8 m long and from 0.6 m to 1.2 m diameter

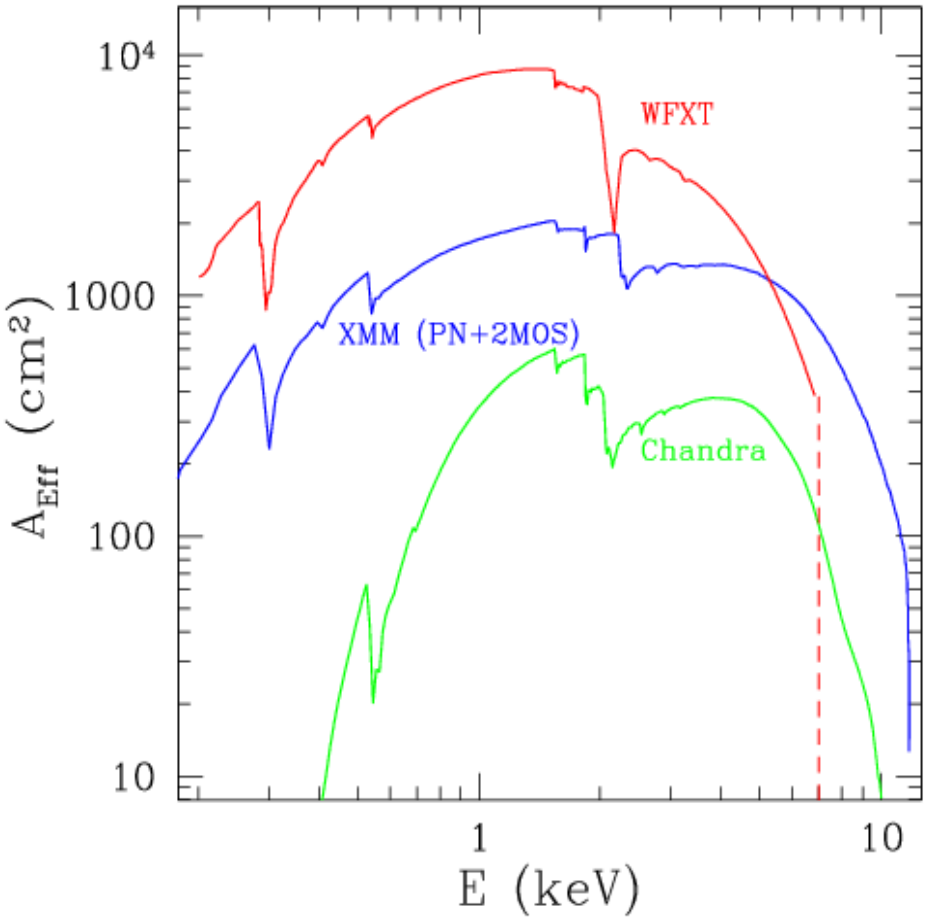
Chandra vs. XMM

PSF



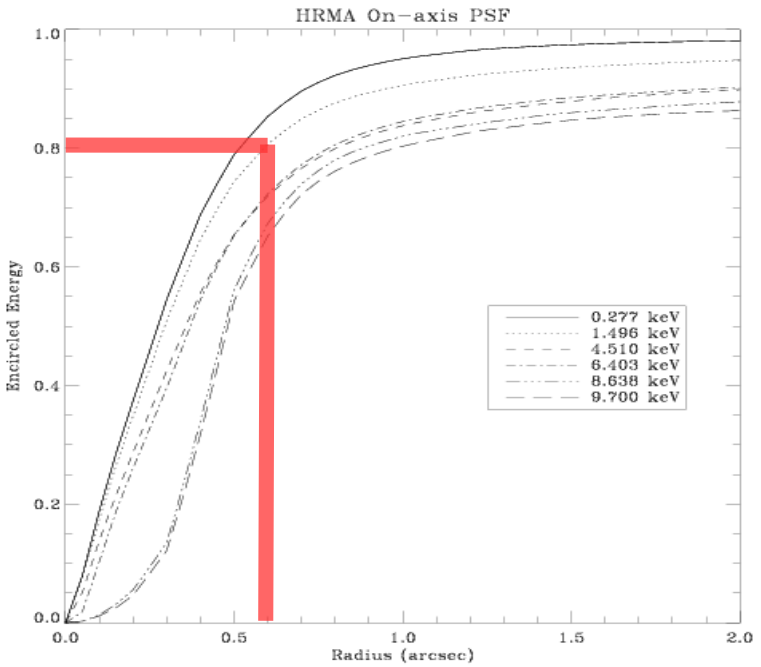


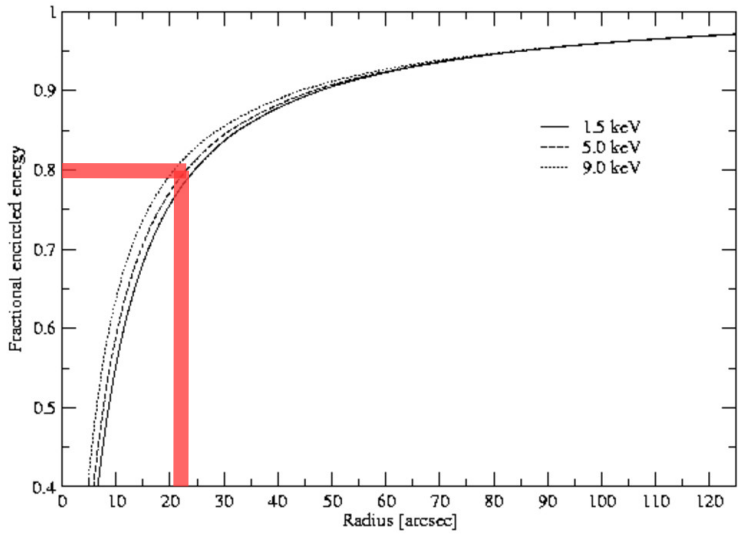
Effective Area



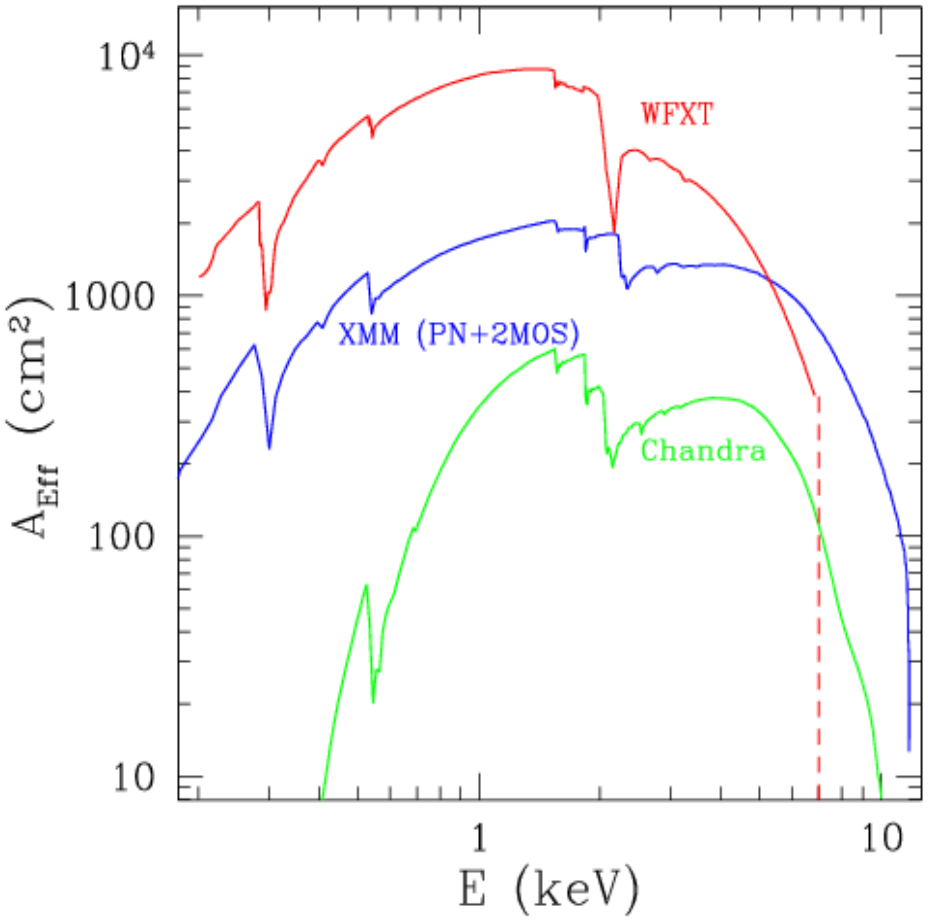
Chandra vs. XMM

PSF

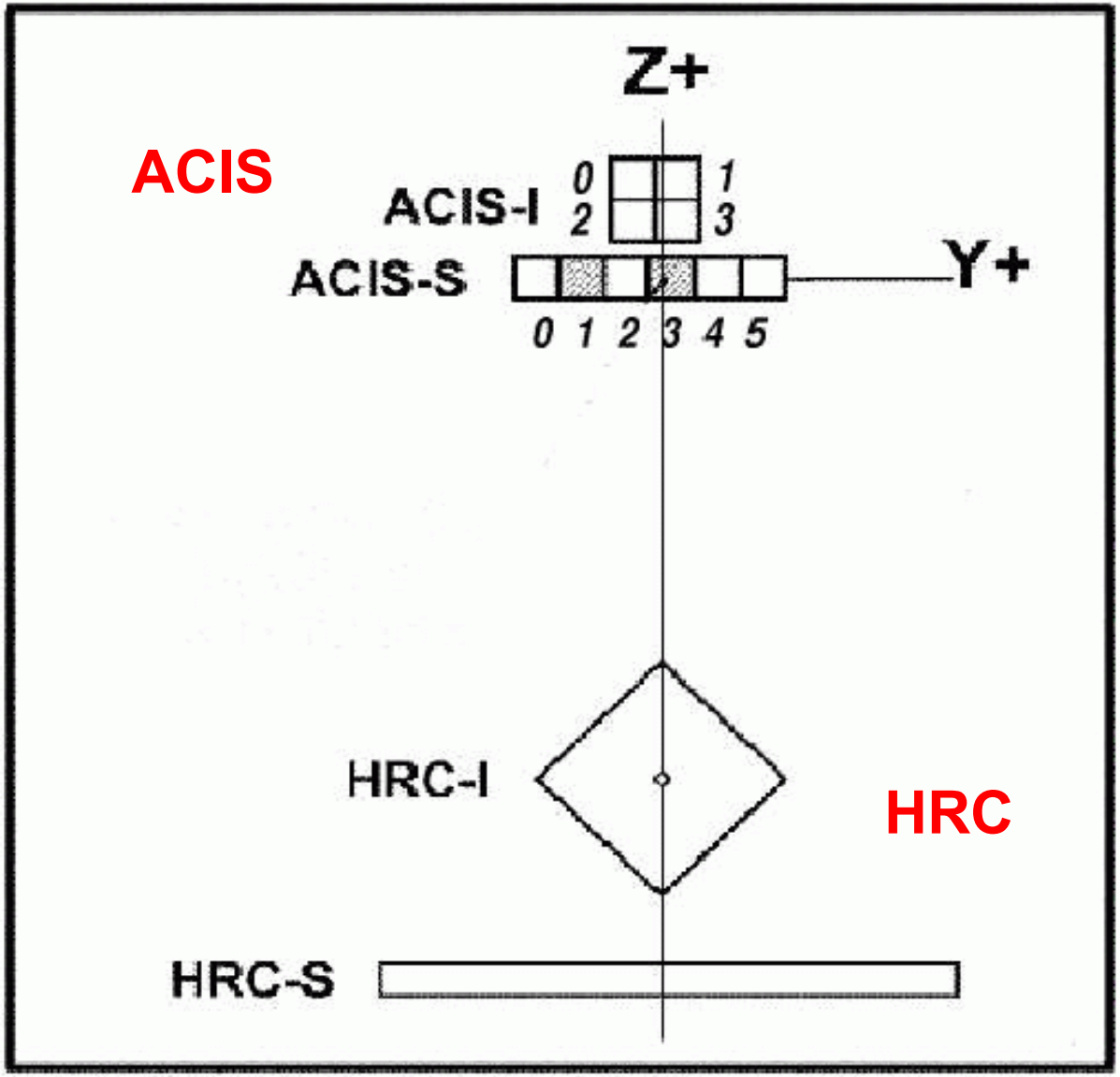




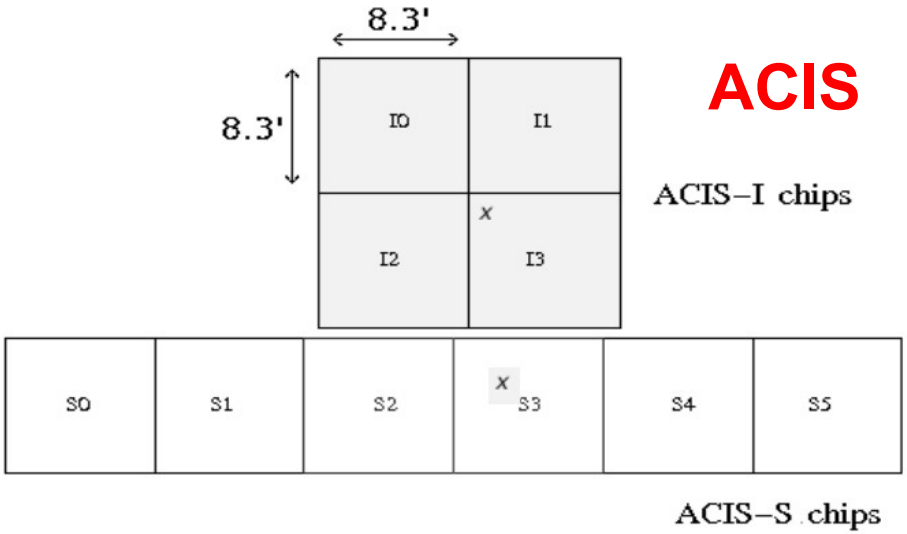
Effective Area



The detectors:

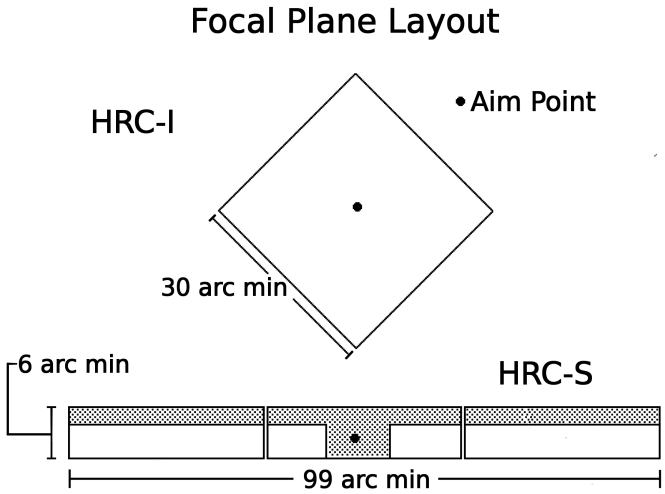


The detectors:



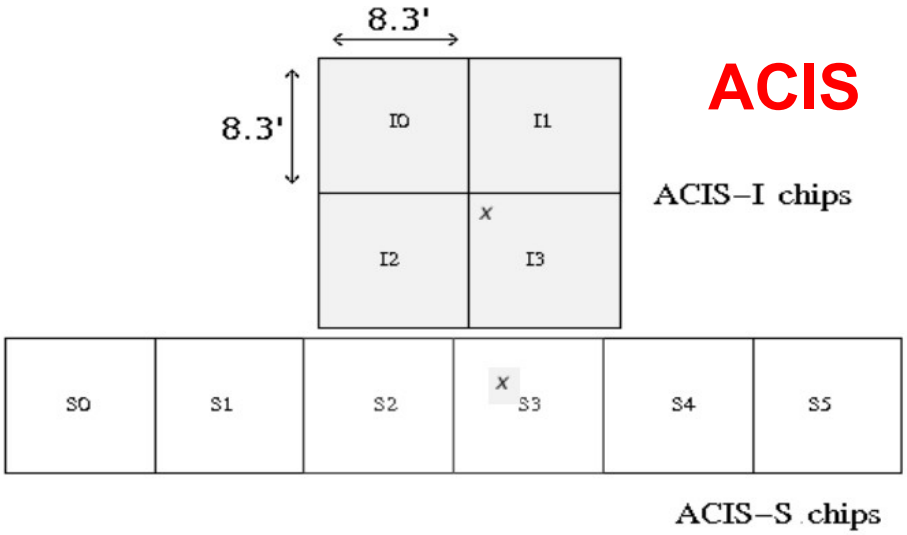
ACIS

HRC



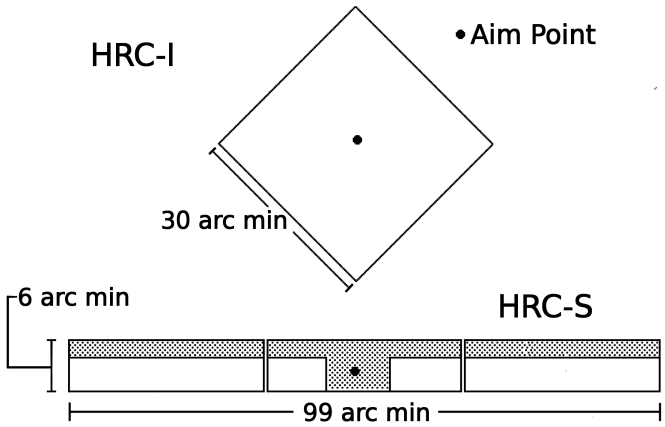
+HETG and LETG dispersive spec.

The detectors:



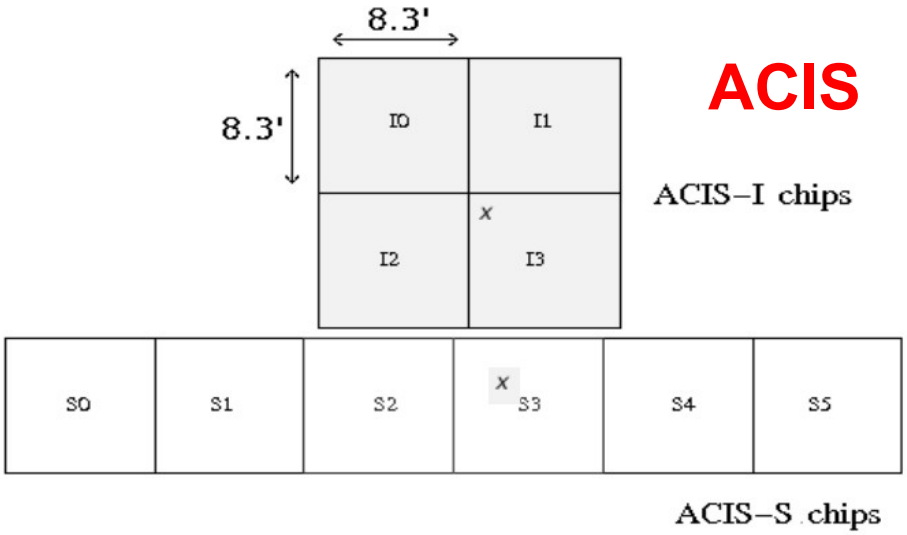
ACIS

~~**HRC**~~

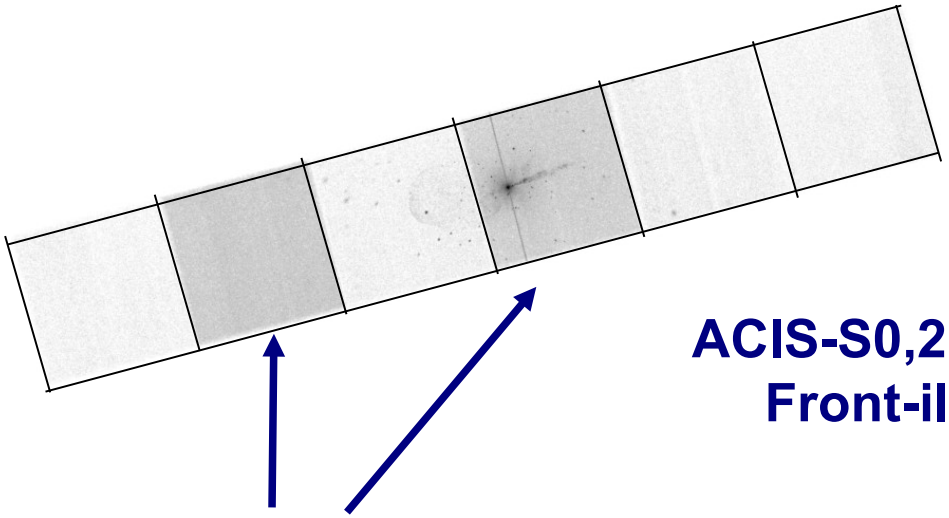


~~**+HETG and LETG dispersive spec.**~~

The detectors:

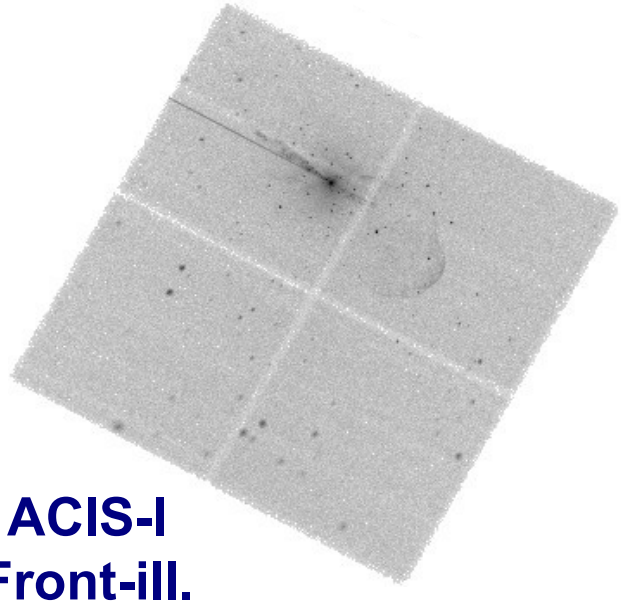


ACIS



ACIS-S1 and S3 back-ill.

ACIS-S0,2,4,5 Front-ill.



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

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Chandra ⇢ *CIAO*

XMM ⇢ *SAS*

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Chandra → *CIAO*

XMM → *SAS*

1. How to get data: proposals of observations

proprietary data for one year

archival data available to the community

→ How to download X-ray data from a public archive

→ How the downloaded files look like

→ How to reduce X-ray (*Chandra*) data

→ How to create the radio and/or X-ray contours for an extended object

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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

National Aeronautics and Space Administration
Goddard Space Flight Center
Sciences and Exploration

GO Search HEASARC website [Advanced Search]

HEASARC Quick Links
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NASA's HEASARC
High Energy Astrophysics Science Archive Research Center

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Guest Observer Facilities & Science Centers	
AGILE	ASCA
Astro-H	BeppoSAX
COBE	CGRO
Chandra	EUVE
Fermi	GALEX
HETE-2	INTEGRAL
MAXI	NICER
NuSTAR	ROSAT
RXTE	Suzaku
Swift	WMAP
XMM-Newton	
NASA Archives	
ADS	AstroGravS
EOSDIS	ExoArchive
HORIZONS	IRSA
KOA	LAMBDA
MAST	NExScI
NED	NSSDC

The High Energy Astrophysics Science Archive Research Center (HEASARC) is the primary archive for NASA's (and other space agencies') missions studying electromagnetic radiation from extremely energetic cosmic phenomena ranging from black holes to the Big Bang. Since its merger with the Legacy Archive for Microwave Background Data Analysis (LAMBDA) in 2008, the HEASARC archive contains not only data obtained by high-energy astronomy missions observing in the extreme-ultraviolet (EUV), X-ray, and gamma-ray bands, but also data from space missions, balloons, and ground-based facilities that have studied the relic cosmic microwave background (CMB).

HEASARC Picture of the Week

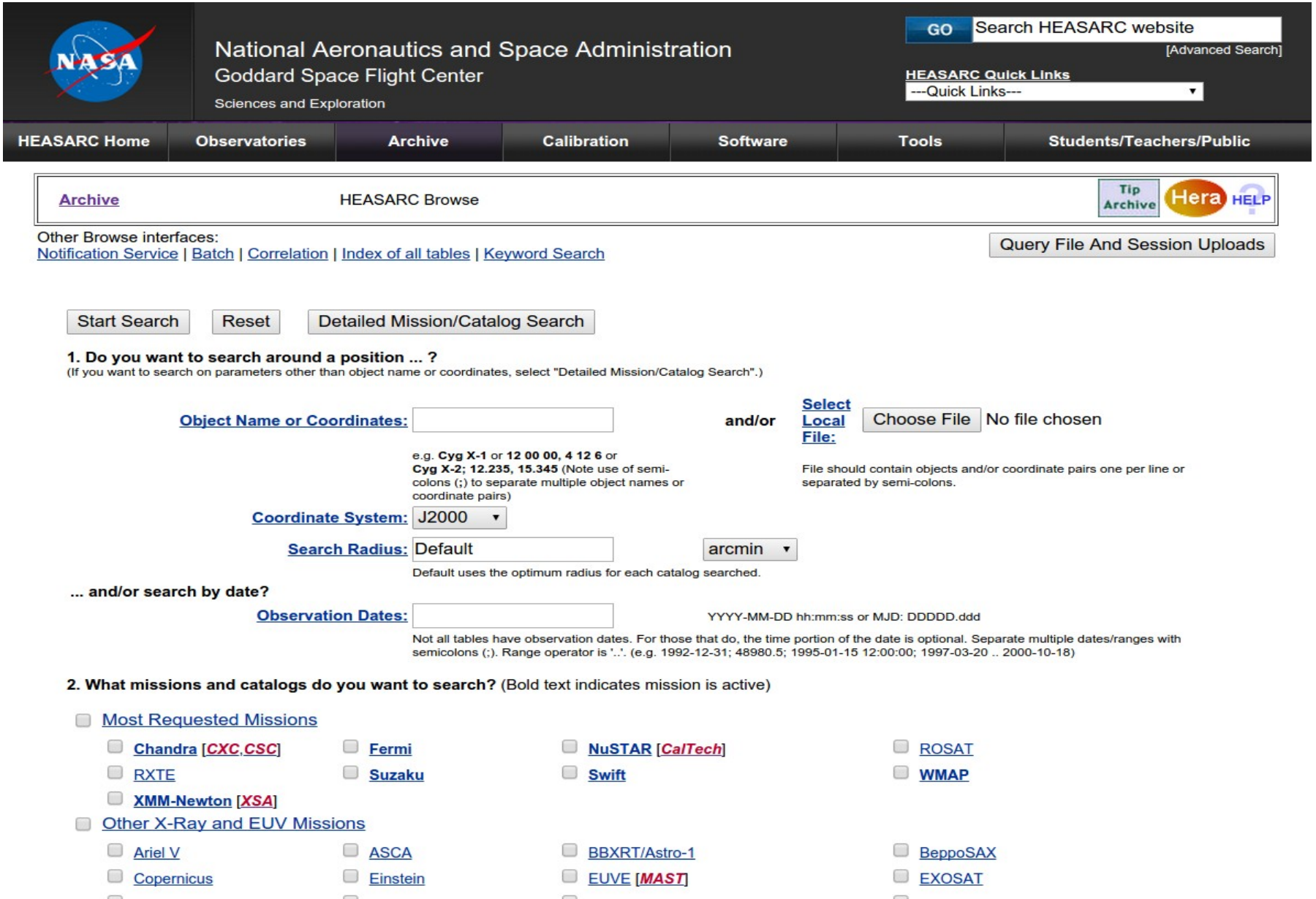
APOD: Astronomy Picture of the Day

Latest News

- **Chandra Observatory Identifies Impact of Cosmic Chaos on Star Birth** (28 Oct 2014)
  Zhuravleva et al. (2014, Nature, in press) have analyzed the Chandra data for the nearby cool-core clusters of galaxies Persesu and Virgo and conclude that turbulence may be preventing hot gas there from cooling, addressing a long-standing question of why galaxy clusters do not form large numbers of stars.
- **INTEGRAL IBIS AGN Catalog** (24 Oct 2014)
  This catalog of the classification and X-ray properties of 272 active galactic nuclei which have been detected by the INTEGRAL IBIS instrument (from **Malizia et al. 2012, MNRAS, 476, 1750**) is now available in Browse and **Xamin**.
- **5th NuSTAR Public Data Release** (23 Oct 2014)
  214 new NuSTAR data sets from the first 24 months of observations were released to the public NuSTAR archive on September 23rd. NuSTAR data are accessible via the usual HEASARC archive interfaces, i.e., Xamin and Browse, by querying the NuSTAR master table (numaster). NuSTAR data can also be accessed from the HEASARC FTP site.

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

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



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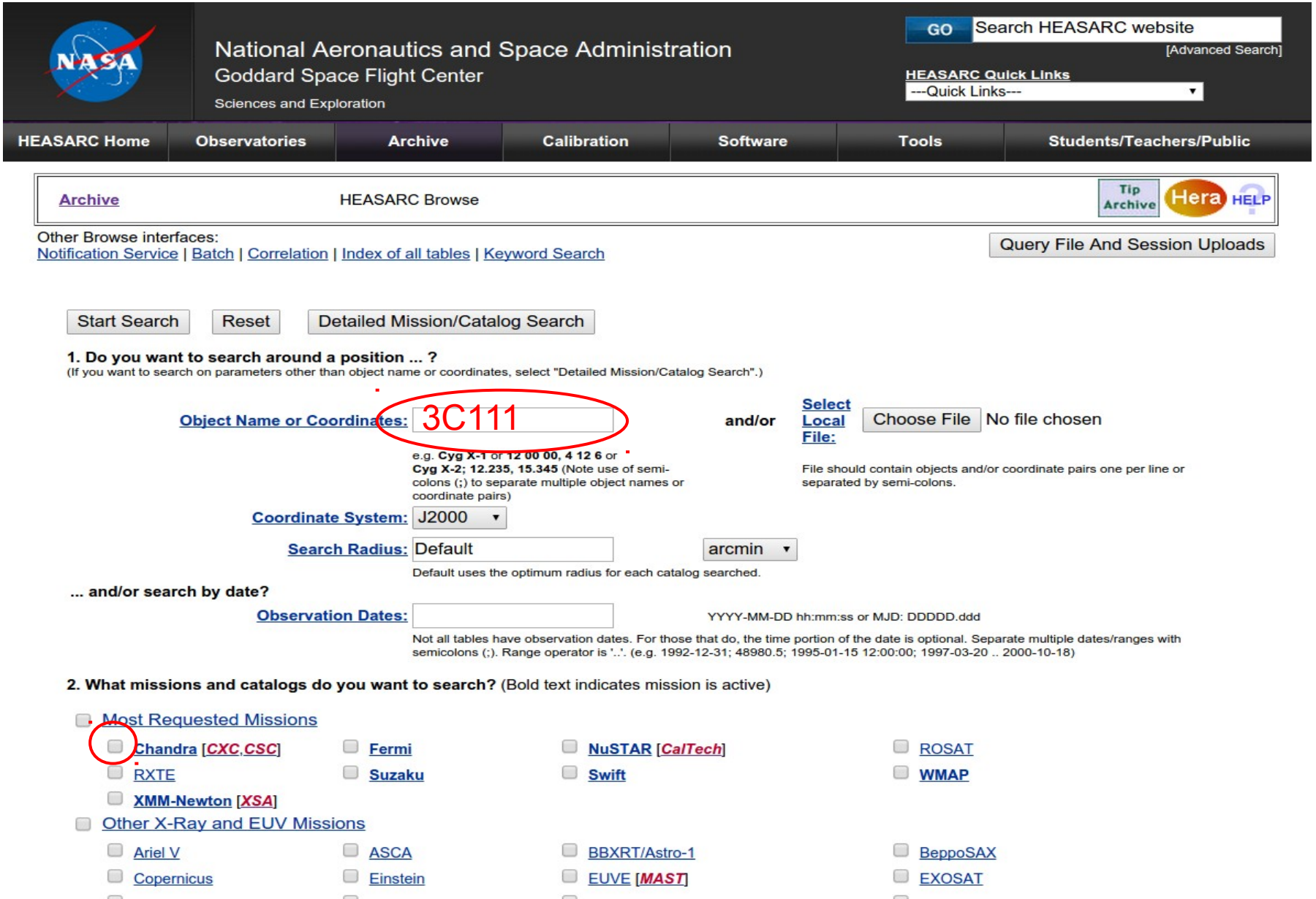


High Energy Astrophysics Science Archive Research Center (HEASARC) - NASA

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

Main Search Form — Browse Query Results — Tip Archive — Hera — HELP

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, 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 All	Related Links	Services	obsid	status	name	ra	dec	time	detector	grating	exposure [s]	type	pi	public date	Search Offset ['] from (target)
	ASCA ROSAT RXTE XMM	O R N S D	16219	unobserved	3C 111	04 18 21.30	+38 01 35.8	2014-11-12	ACIS-S	HETG	150000	GO	Tombesi		0.004 (3c111)
	ASCA ROSAT RXTE XMM	O R N S D F	14990	archived	3C 111	04 18 21.30	+38 01 36.0	2013-01-10 04:29:04	ACIS-S	NONE	122250	GO	Perlman	2014-01-15	0.006 (3c111)
	ASCA ROSAT RXTE XMM	O R N S D B F	9279	archived	0415+379	04 18 21.30	+38 01 35.8	2008-12-08 06:04:09	ACIS-S	NONE	10140	GO	Lister	2009-12-08	0.004 (3c111)

3 rows retrieved from chanmaster

Data Product Retrieval

- **Select the checkboxes for the rows of interest above,**
- **Un-check any data products below you are not interested in**
- **Select the Data Product Retrieval tab for retrieval options**

Data Products available for chanmaster
- **All**
- Chandra Proposal Abstracts (abstracts)
- Events Lists (events)
- FITS and JPEG Images (images)
- Miscellaneous Files (misc)

Further Actions:

Do you want to **plot** your chanmaster results using Java Plot (help) or Xamin (notes)?
Do you want to Cross-correlate your chanmaster results with another catalog or table? (help)

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

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

Archive Data Products for selected row in Chandra Observations

- 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

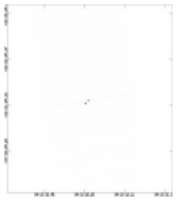
Chandra Observations (chanmaster) FTOOLS

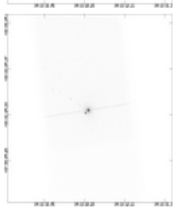
obsid	status	name	ra	dec	time	detector	grating	exposure	type	pi	public_date
14990	archived	3C 111	04 18 21.30	+38 01 36.0	2013-01-10 04:29:04	ACIS-S	NONE	122250	GO	Perlman	2014-01-15

☐ Select all products in this row

FITS and JPEG Images

☐ Center Image (acisf14990N001_e1_cntr_img2.fits.gz)	FITS	837 kB	updated: 2013/01/12 00:00:00
☐ Center Image (acisf14990N001_e2_cntr_img2.fits.gz)	FITS	945 kB	updated: 2013/01/12 00:00:00
☐ Center Image (acisf14990N001_e1_cntr_img2.jpg)	JPEG	85 kB	updated: 2013/01/12 00:00:00
☐ Center Image (acisf14990N001_e2_cntr_img2.jpg)	JPEG	223 kB	updated: 2013/01/12 00:00:00
☐ Full Image (acisf14990N001_e1_full_img2.fits.gz)	FITS	828 kB	updated: 2013/01/12 00:00:00
☐ Full Image (acisf14990N001_e2_full_img2.fits.gz)	FITS	844 kB	updated: 2013/01/12 00:00:00





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

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

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Bad Pixel List (acisf14990_000N001_e2_bpix1.fits.gz)	FITS	29 kB	updated: 2013/01/12 00:00:00
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Secondary Products (secondary)	DIRECTORY	263085 kB	updated: 2014/01/15 22:26:39

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Archive	Retrieve Data Products

Estimated size of TAR file: 314 MB

Your TAR file is being created now. When finished you may retrieve it via the following link

http://heasarc.gsfc.nasa.gov/FTP/retrieve/w3browse/w3browse-164971.tar.

Please wait until the "TAR complete" message appears below before retrieving.

Below are data products included in the TAR file: (filenames ending in '.gz' or '.Z' have been compressed for faster downloading.)

Tarred: /FTP/chandra/data/science/ao14/cat7//14990/primary/acisf14990N001_e2_full_img2.fits.gz
Tarred: /FTP/chandra/data/science/ao14/cat7//14990/primary/acisf14990N001_e2_evt2.fits.gz
Tarred: /FTP/chandra/data/science/ao14/cat7//14990/primary/acisf14990_000N001_e1_bpix1.fits.gz
Tarred: /FTP/chandra/data/science/ao14/cat7//14990/primary/acisf14990N001_e2_full_img2.jpg
Tarred: /FTP/chandra/data/science/ao14/cat7//14990/primary/acisf14990N001_e1_evt2.fits.gz
Tarred: /FTP/chandra/data/science/ao14/cat7//14990/oif.fits
Tarred: /FTP/chandra/data/science/ao14/cat7//14990/primary/acisf14990N001_e1_full_img2.jpg
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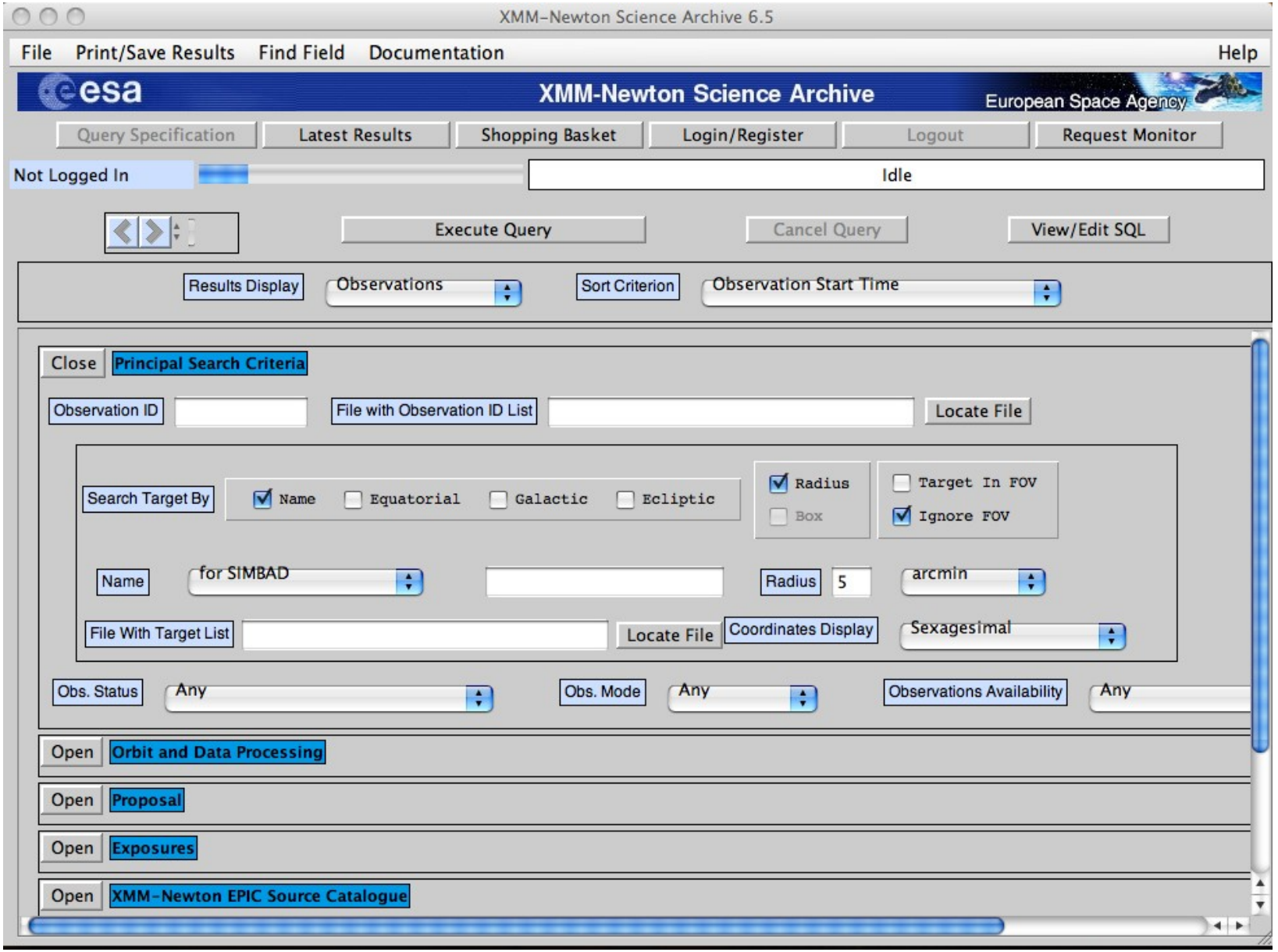
Tarred: /FTP/chandra/data/science/ao14/cat7//14990/secondary

TAR complete: Actual size: 314 MB.

Remote files are not included in the tar file. Use the **Create Download Script** option to retrieve remote files.

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

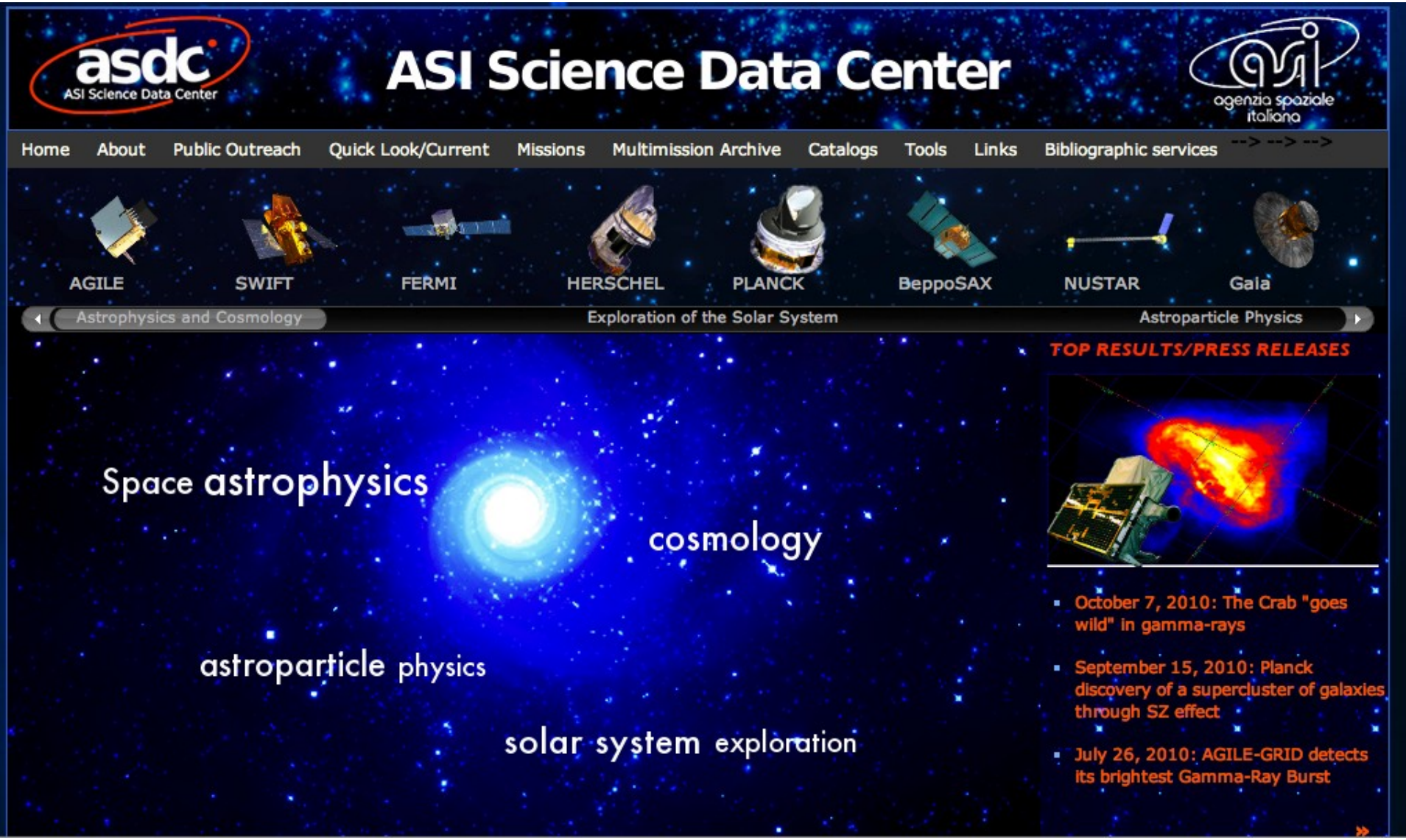
http://xmm.esac.esa.int/xsa/



see XMM tutorial...

ASI Scientific Data Center (ASDC- Frascati, Roma)

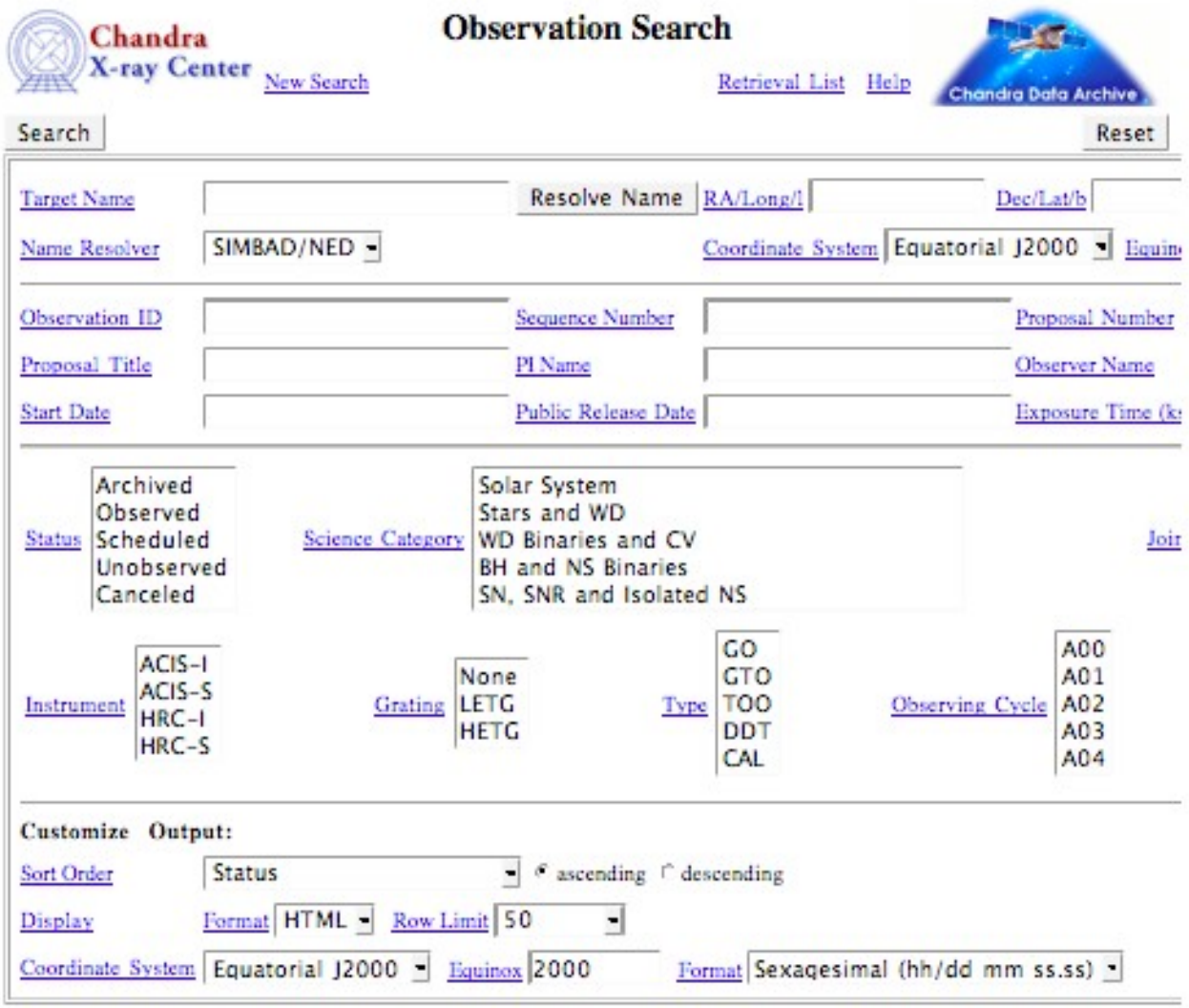
http://www.asdc.asi.it/



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

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

Chandra Data Archive: Observation Search — **webchaser** — http://cda.harvard.edu/chaser/



Search Results

New Search Retrieval List Help

View Observation Information | Add to Retrieval List

Primary products
Secondary products

Select all | Unselect all

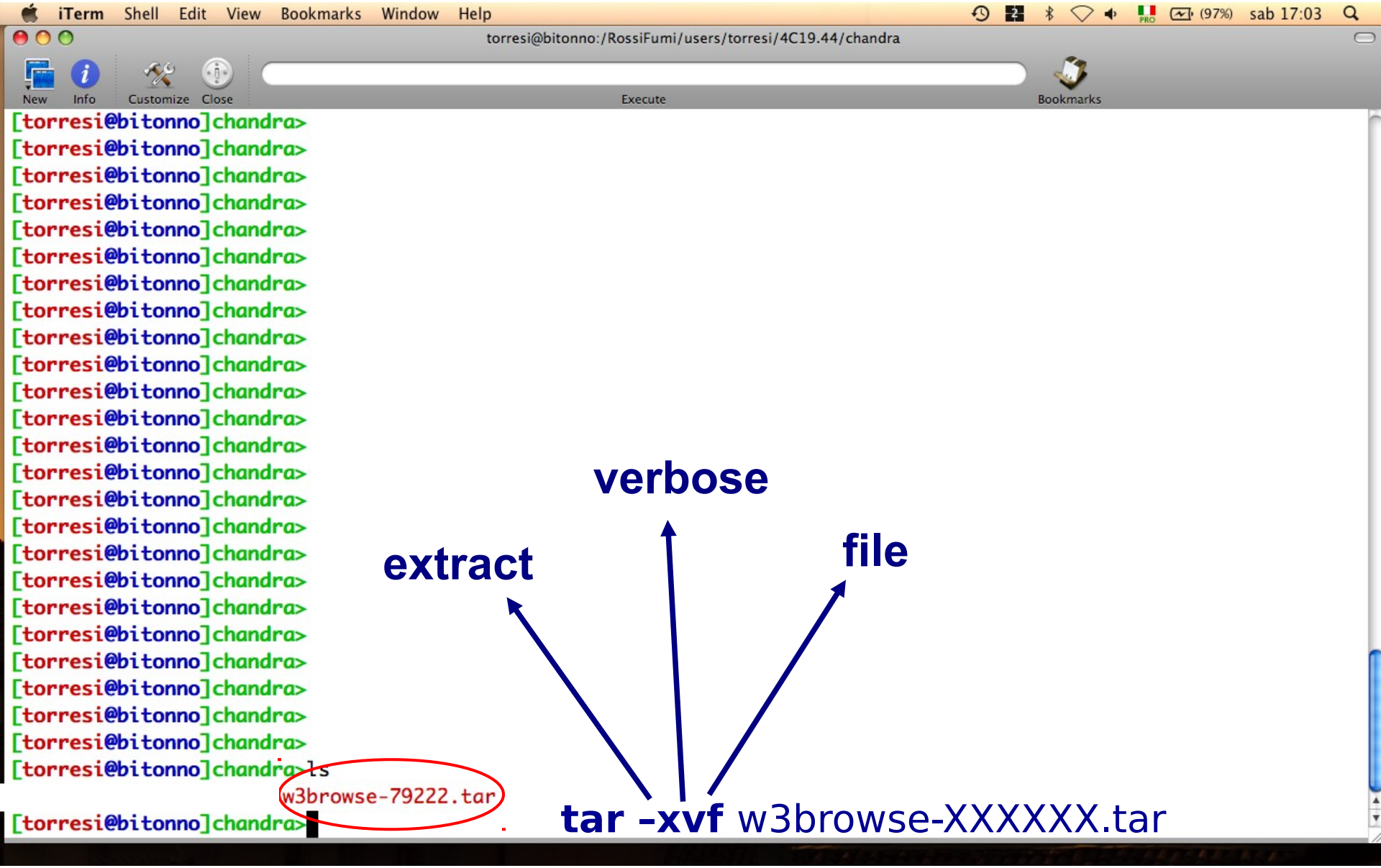
Select	Row	Seq Num	Obs ID	Instrument	Grating	Appr Exp (ks)	Exposure (ks)	Target
☐	1	700743	4064	ACIS-S	NONE	5.0	4.73	BR 0331-1622
☐	2	700744	4065	ACIS-S	NONE	4.0	4.12	BR 0353-3820
☐	3	700745	4066	ACIS-S	NONE	4.0	4.04	BR 0418-5723
☐	4	700746	4067	ACIS-S	NONE	5.0	4.73	BR 0424-2209
☐	5	700747	4068	ACIS-S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

→ How to download X-ray data from a public archive

→ How the downloaded files look like

→ How to reduce X-ray (*Chandra*) data

→ How to create the radio and/or X-ray contours for an extended object


iTerm Shell Edit View Bookmarks Window Help
(97%) sab 17:03
torresi@bitonno:/RossiFumi/users/torresi/4C19.44/chandra
New Info Customize Close
Execute
Bookmarks
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[torresi@bitonno]chandra>ls
w3browse-79222.tar
[torresi@bitonno]chandra>
verbose
extract
file
tar -xvf w3browse-XXXXXX.tar


iTerm Shell Edit View Bookmarks Window Help
(97%) sab 17:03
torresi@bitonno:/RossiFumi/users/torresi/4C19.44/chandra
New Info Customize Close
Execute
Bookmarks
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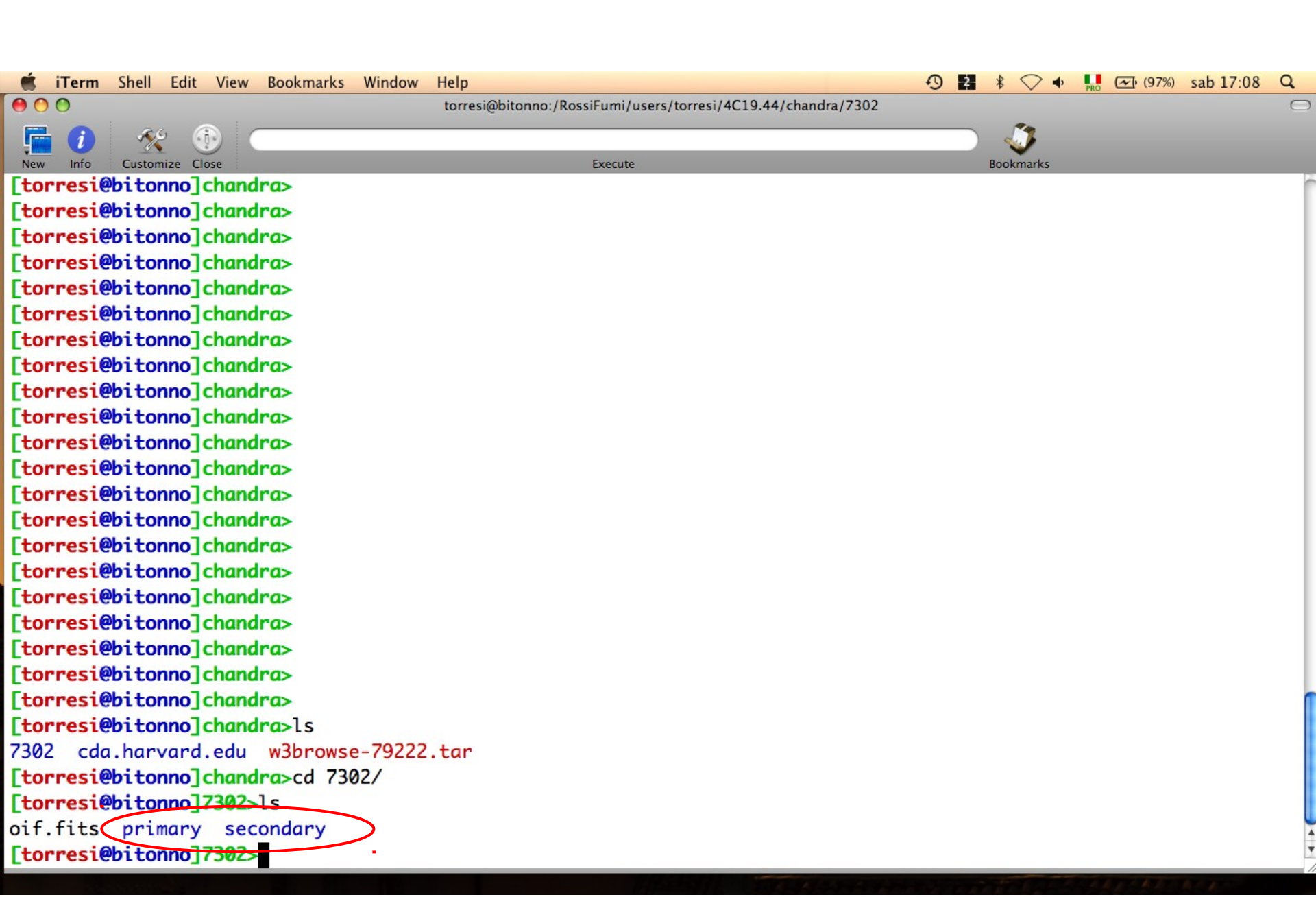
[torresi@bitonno]chandra>ls
7302
[torresi@bitonno]chandra>
cd #obsid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New Info Customize Close Execute Bookmarks
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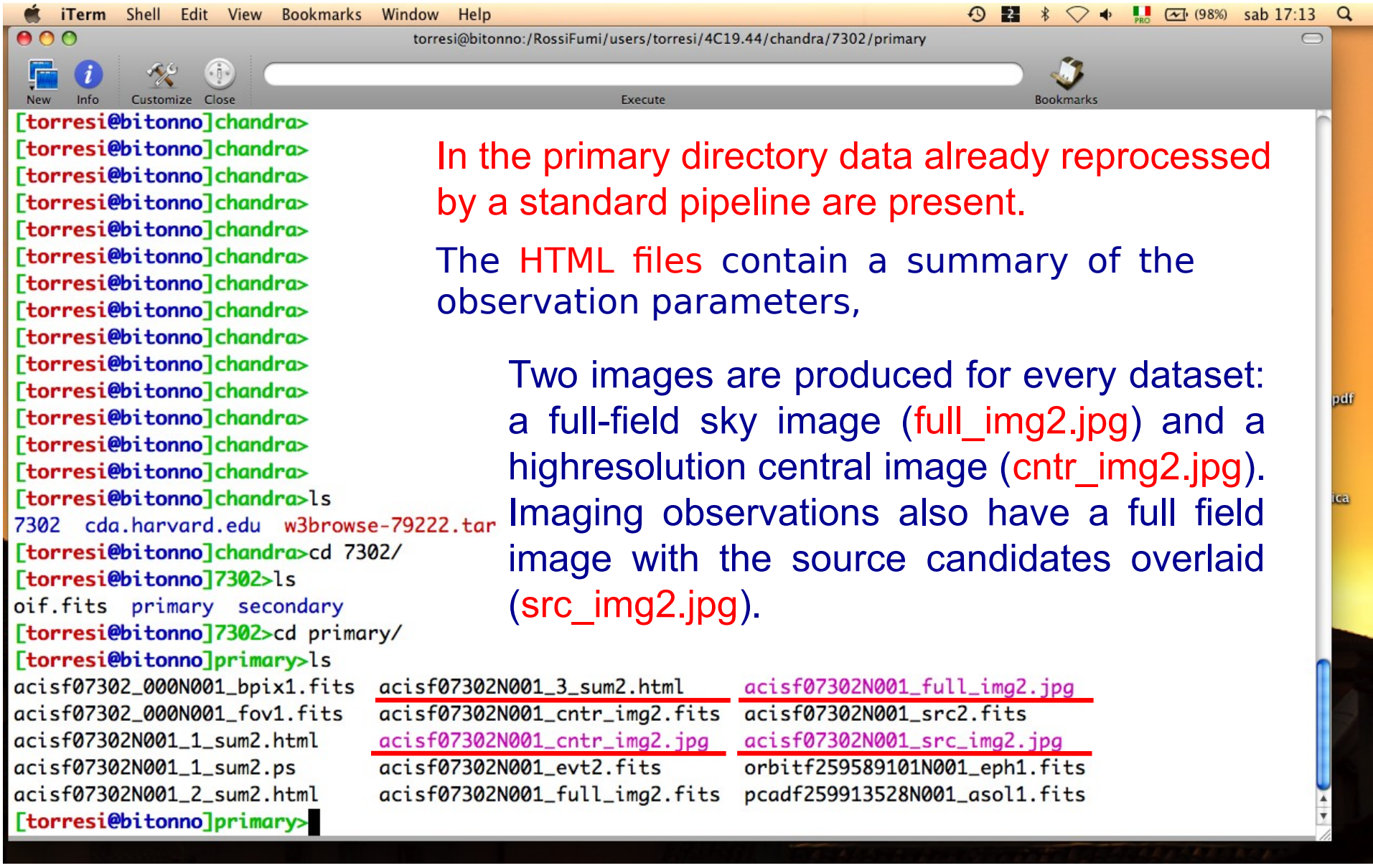
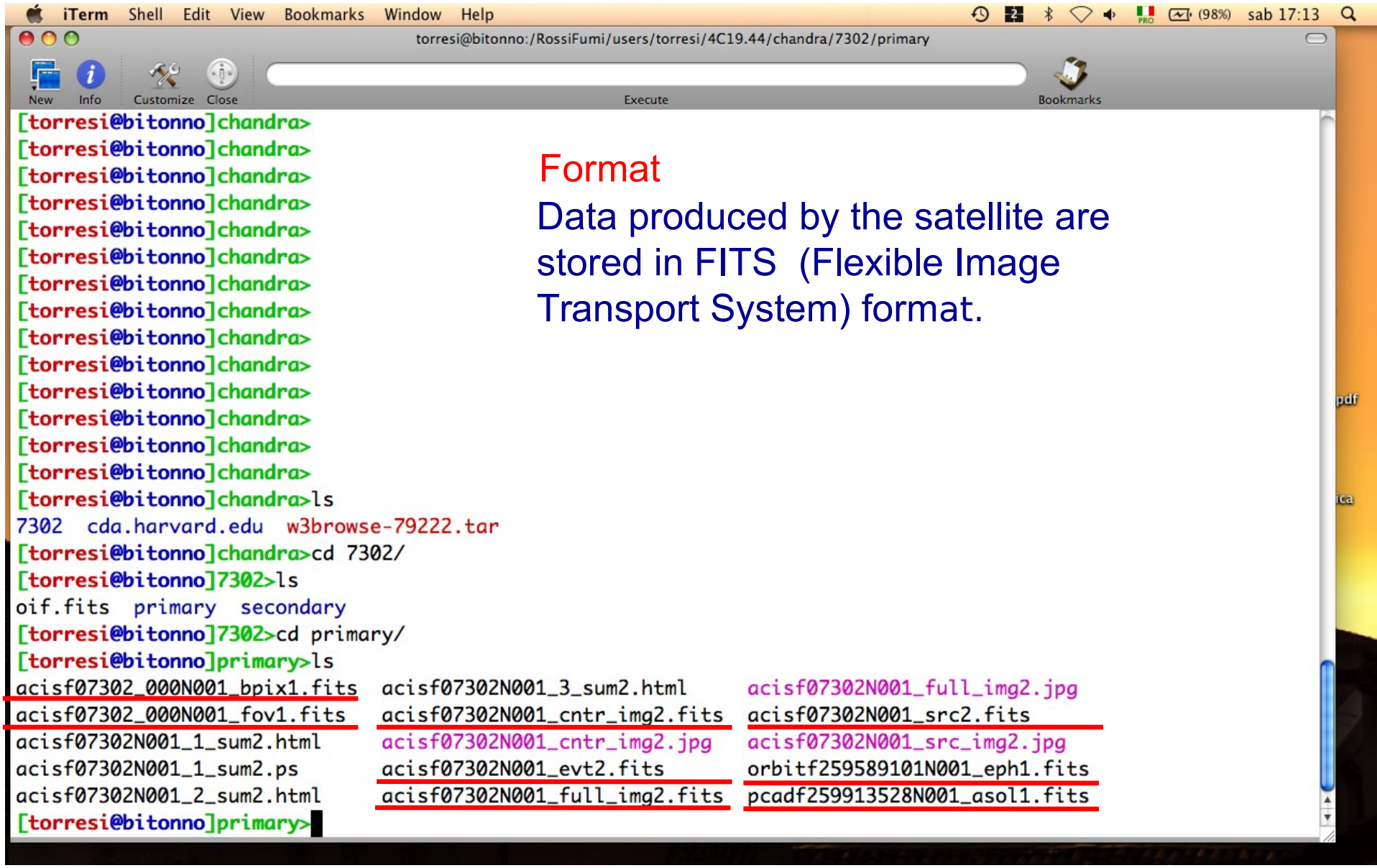
7302 cda.harvard.edu w3browse-79222.tar
[torresi@bitonno]chandra>cd 7302/
[torresi@bitonno]7302>ls
oif.fits primary secondary
[torresi@bitonno]7302>



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

The HTML files contain a summary of the observation parameters,

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


iTerm Shell Edit View Bookmarks Window Help
(98%) sab 17:13
torresi@bitonno:/RossiFumi/users/torresi/4C19.44/chandra/7302/primary
New Info Customize Close Execute Bookmarks
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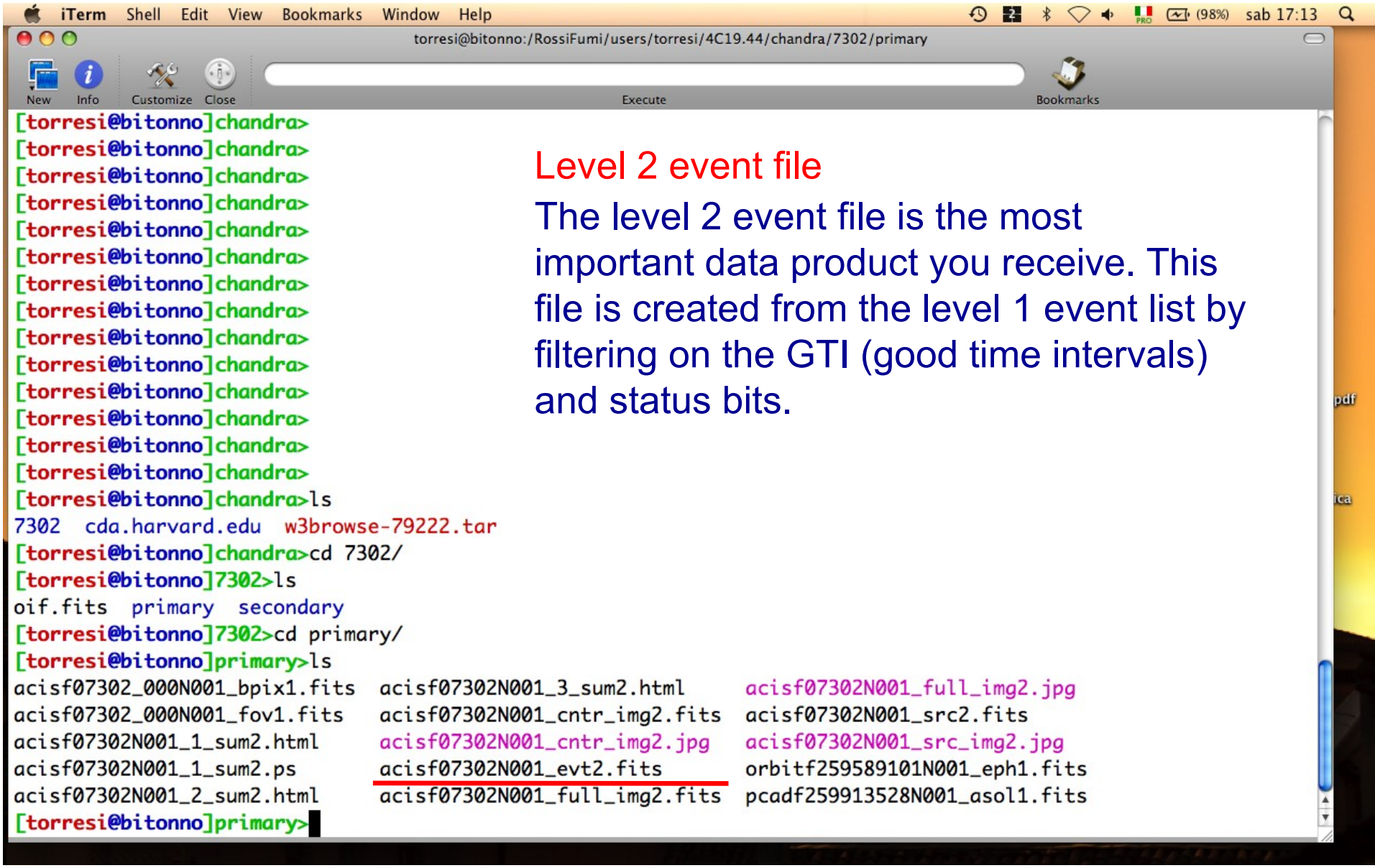
oif.fits primary secondary
[torresi@bitonno]7302>cd primary/
[torresi@bitonno]primary>ls
acisf07302_000N001_bpix1.fits
acisf07302_000N001_fov1.fits
acisf07302N001_1_sum2.html
acisf07302N001_1_sum2.ps
acisf07302N001_2_sum2.html
acisf07302N001_3_sum2.html
acisf07302N001_cntr_img2.fits
acisf07302N001_cntr_img2.jpg
acisf07302N001_evt2.fits
acisf07302N001_full_img2.fits
acisf07302N001_full_img2.jpg
acisf07302N001_src2.fits
acisf07302N001_src_img2.jpg
orbitf259589101N001_eph1.fits
pcadf259913528N001_asol1.fits
[torresi@bitonno]primary>
Format
Data produced by the satellite are stored in FITS (Flexible Image Transport System) format.


iTerm Shell Edit View Bookmarks Window Help
(98%) sab 17:13
torresi@bitonno:/RossiFumi/users/torresi/4C19.44/chandra/7302/primary
New Info Customize Close Execute Bookmarks
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oif.fits primary secondary
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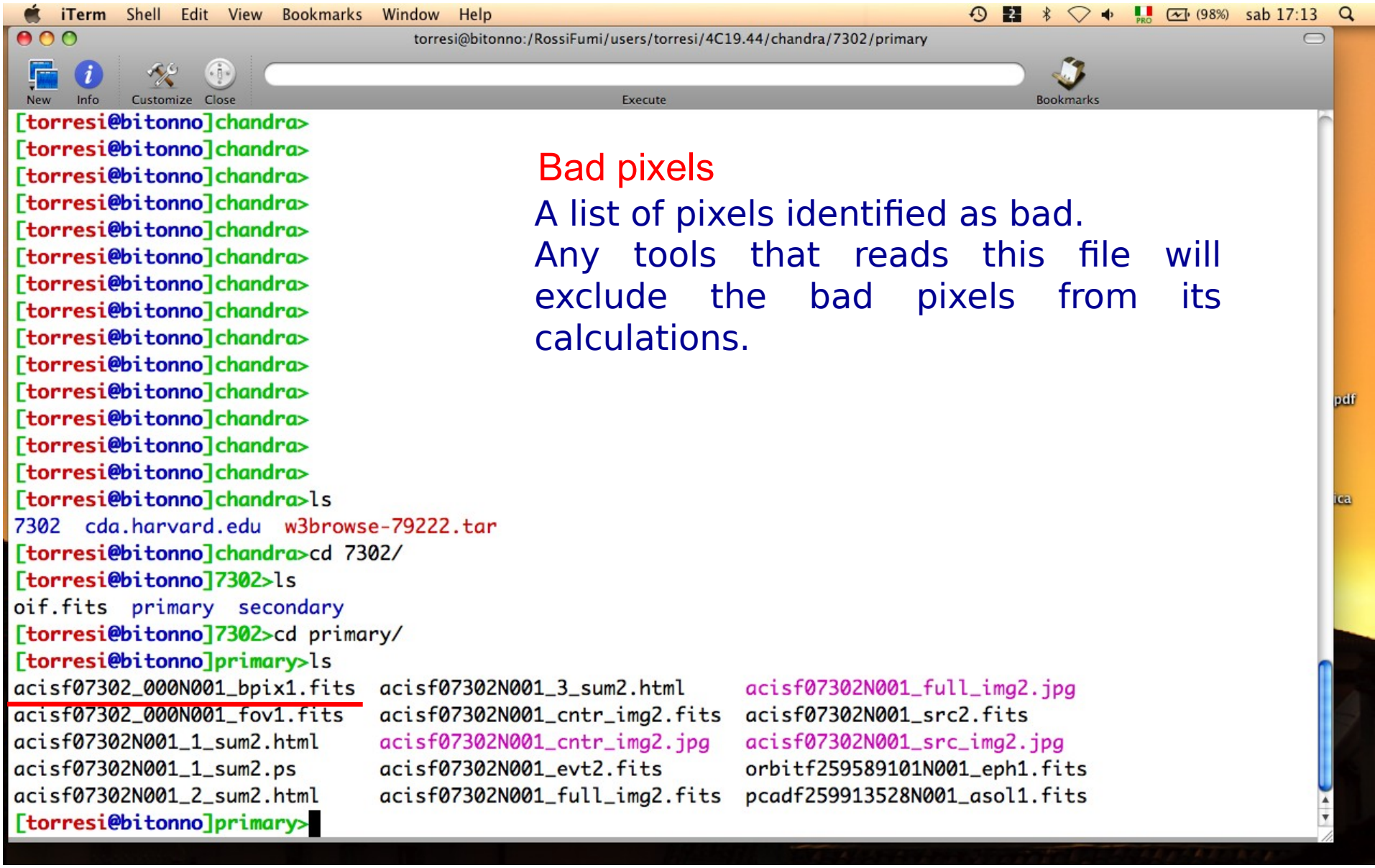
acisf07302_000N001_bpix1.fits acisf07302N001_3_sum2.html acisf07302N001_full_img2.jpg
acisf07302_000N001_fov1.fits acisf07302N001_cntr_img2.fits acisf07302N001_src2.fits
acisf07302N001_1_sum2.html acisf07302N001_cntr_img2.jpg acisf07302N001_src_img2.jpg
acisf07302N001_1_sum2.ps acisf07302N001_evt2.fits orbitf259589101N001_eph1.fits
acisf07302N001_2_sum2.html acisf07302N001_full_img2.fits pcadf259913528N001_asol1.fits
[torresi@bitonno]primary>
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.


iTerm Shell Edit View Bookmarks Window Help
(98%) sab 17:13
torresi@bitonno:/RossiFumi/users/torresi/4C19.44/chandra/7302/primary
New Info Customize Close Execute Bookmarks
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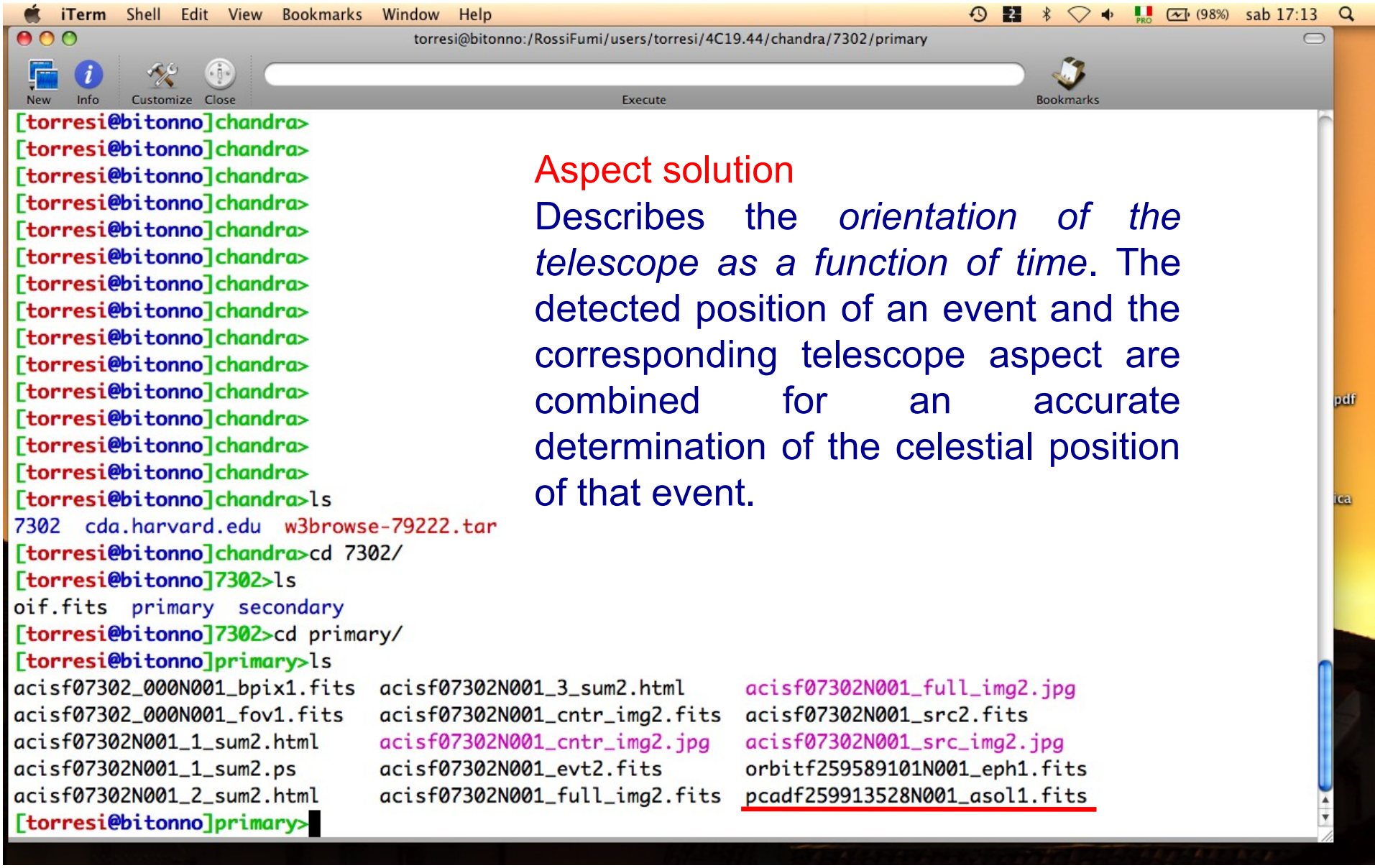
[torresi@bitonno]7302>ls
oif.fits primary secondary
[torresi@bitonno]7302>cd primary/
[torresi@bitonno]primary>ls
acisf07302_000N001_bpix1.fits acisf07302N001_3_sum2.html acisf07302N001_full_img2.jpg
acisf07302_000N001_fov1.fits acisf07302N001_cntr_img2.fits acisf07302N001_src2.fits
acisf07302N001_1_sum2.html 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 that reads this file will exclude the bad pixels from its calculations.


iTerm Shell Edit View Bookmarks Window Help
(98%) sab 17:13
torresi@bitonno:/RossiFumi/users/torresi/4C19.44/chandra/7302/primary
New Info Customize Close Execute Bookmarks
[torresi@bitonno]chandra>
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[torresi@bitonno]chandra>ls
7302 cda.harvard.edu w3browse-79222.tar
[torresi@bitonno]chandra>cd 7302/
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oif.fits primary secondary
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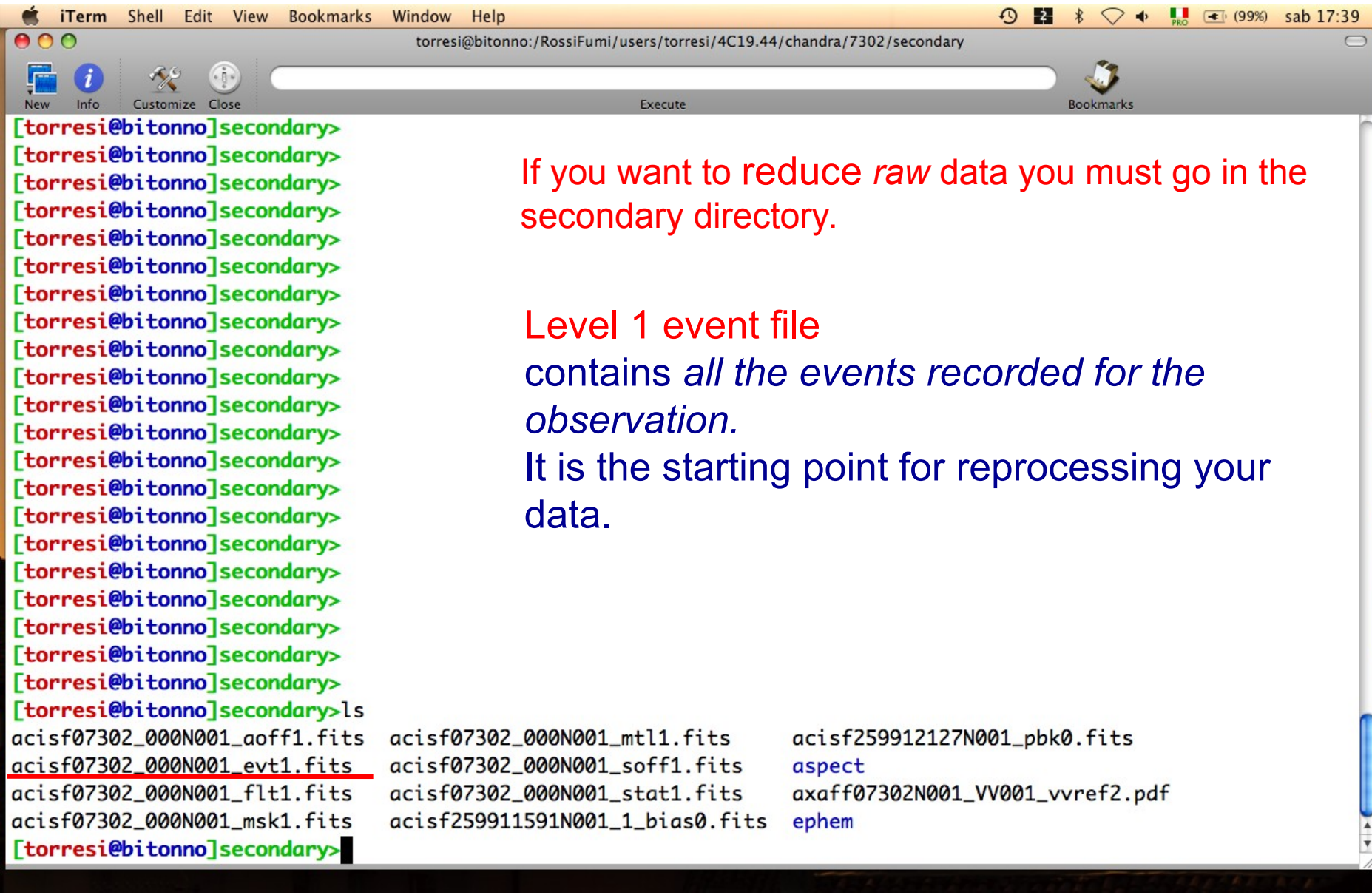
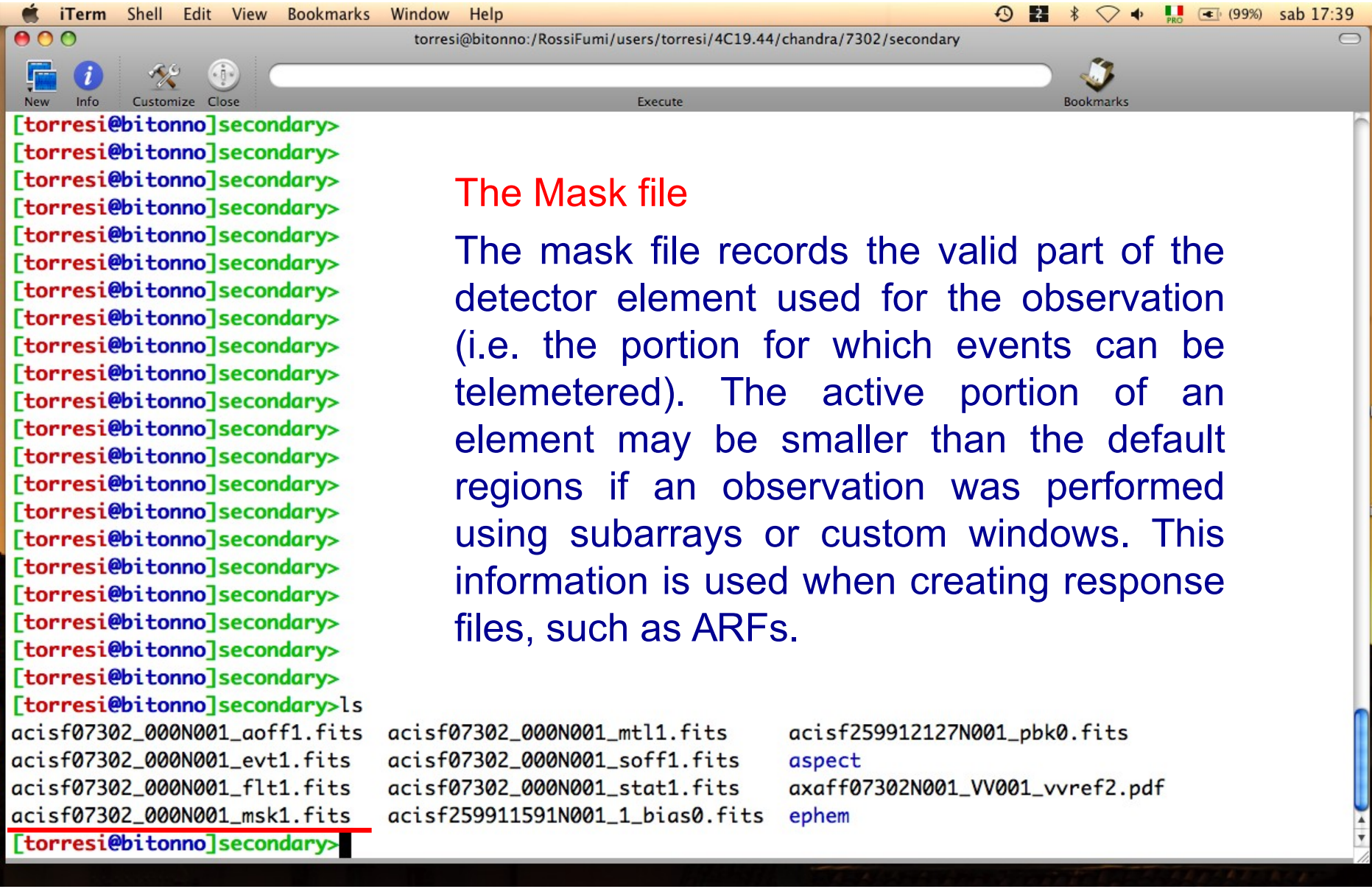
[torresi@bitonno]primary>ls
acisf07302_000N001_bpix1.fits acisf07302N001_3_sum2.html acisf07302N001_full_img2.jpg
acisf07302_000N001_fov1.fits acisf07302N001_cntr_img2.fits acisf07302N001_src2.fits
acisf07302N001_1_sum2.html acisf07302N001_cntr_img2.jpg acisf07302N001_src_img2.jpg
acisf07302N001_1_sum2.ps 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.


iTerm Shell Edit View Bookmarks Window Help
(99%) sab 17:39
torresi@bitonno:/RossiFumi/users/torresi/4C19.44/chandra/7302/secondary
New Info Customize Close
Execute
Bookmarks
[torresi@bitonno]secondary>
[torresi@bitonno]secondary>ls
acisf07302_000N001_aoff1.fits
acisf07302_000N001_evt1.fits
acisf07302_000N001_flt1.fits
acisf07302_000N001_msk1.fits
acisf07302_000N001_mtl1.fits
acisf07302_000N001_soff1.fits
acisf07302_000N001_stat1.fits
acisf259911591N001_1_bias0.fits
acisf259912127N001_pbk0.fits
aspect
axaff07302N001_VV001_vvref2.pdf
ephem
[torresi@bitonno]secondary>
If you want to reduce raw data you must go in the secondary directory.
Level 1 event file
contains all the events recorded for the observation.
It is the starting point for reprocessing your data.



The Mask file

The mask file records the valid part of the detector element used for the observation (i.e. the portion for which events can be telemetered). The active portion of an element may be smaller than the default regions if an observation was performed using subarrays or custom windows. This information is used when creating response files, such as ARFs.

iTerm Shell Edit View Bookmarks Window Help (99%) sab 17:39

torresi@bitonno:/RossiFumi/users/torresi/4C19.44/chandra/7302/secondary

New Info Customize Close Execute Bookmarks

Good Time Intervals

The GTI information for the observation, e.g. the start and stop times of all accepted time intervals over the observation. The major contributor to creating GTIs is information about when there is aspect data and when that aspect data is good. When the event file is filtered, the GTIs are stored as extensions of the data file, creating a record of the time filters applied to the data.

```
[torresi@bitonno]secondary>
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[torresi@bitonno]secondary>ls
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acisf07302_000N001_evt1.fits   acisf07302_000N001_soff1.fits    aspect
acisf07302_000N001_flt1.fits   acisf07302_000N001_stat1.fits    axaff07302N001_VV001_vvref2.pdf
acisf07302_000N001_msk1.fits   acisf259911591N001_1_bias0.fits  ephem
[torresi@bitonno]secondary>
```
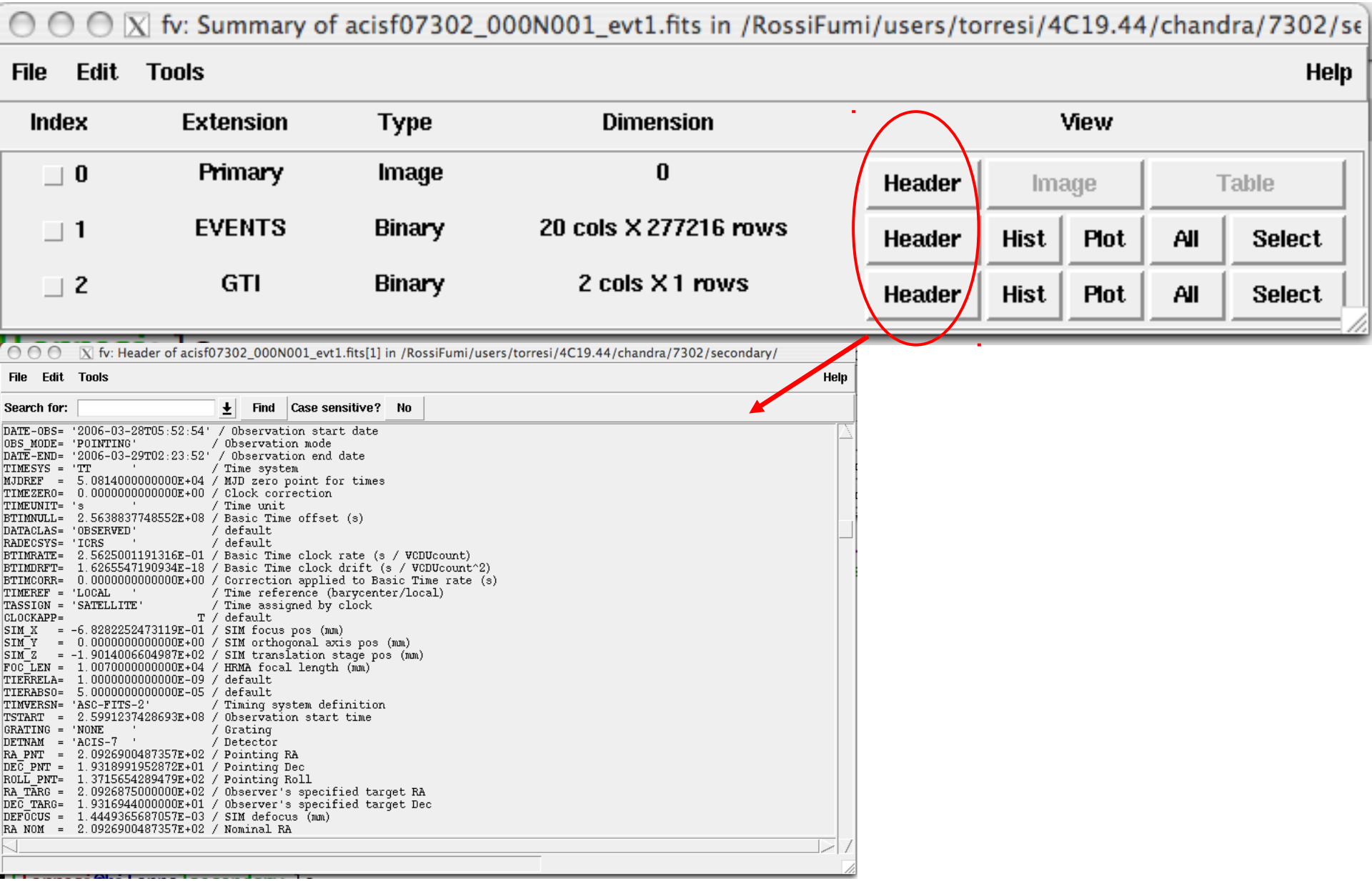

All the information of your observation are contained in the header of the fits file. You can visualize it by using the FTOOL command *fv*



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*

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
0	Primary	Image	0	Header Image Table
1	EVENTS	Binary	20 cols X 277216 rows	Header Hist Plot All Select
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 All Invert

	time 1D s Modify	ccd_id 1I Modify	node_id 1I Modify	expno 1J Modify	chipx 1I pixel Modify	chipy 1I pixel Modify	tdetx 1I pixel Modify	tdety 1I pixel Modify	detx 1E pixel Modify	dety 1E pixel Modify	x 1E pixel Modify	y 1E pixel 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	-1.428733E+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:

→ How to download X-ray data from a public archive

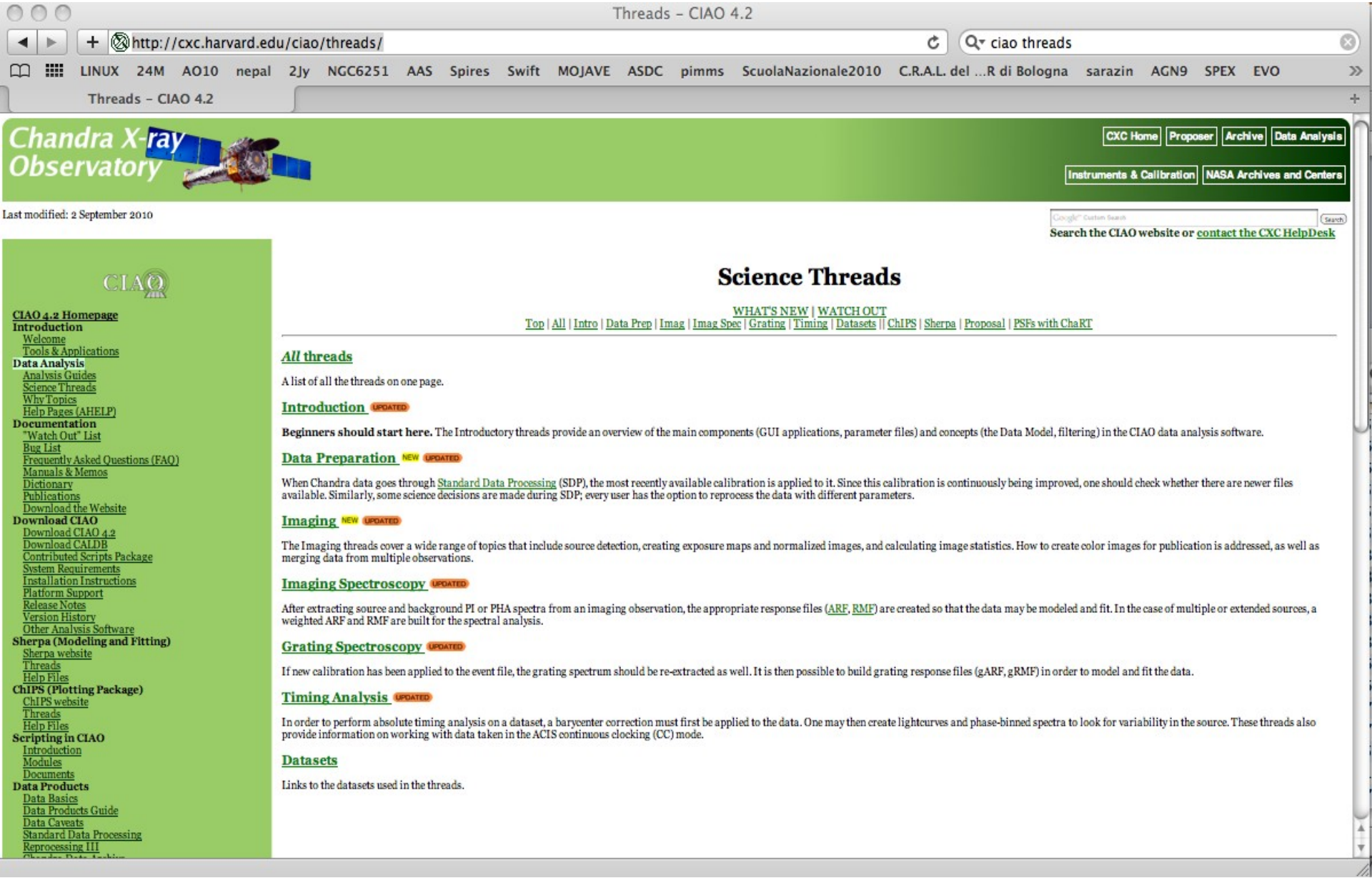
→ How the downloaded files look like

→ How to reduce X-ray (*Chandra*) data

→ How to create the radio and/or X-ray contours for an extended object

Chandra data reduction

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

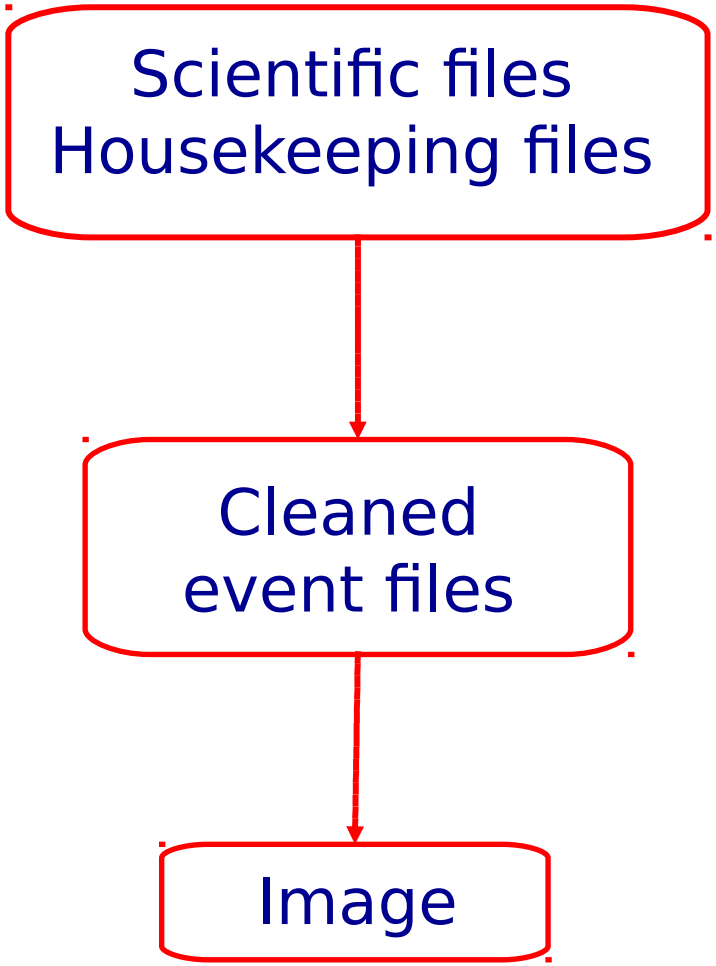


Scientific files
Housekeeping files

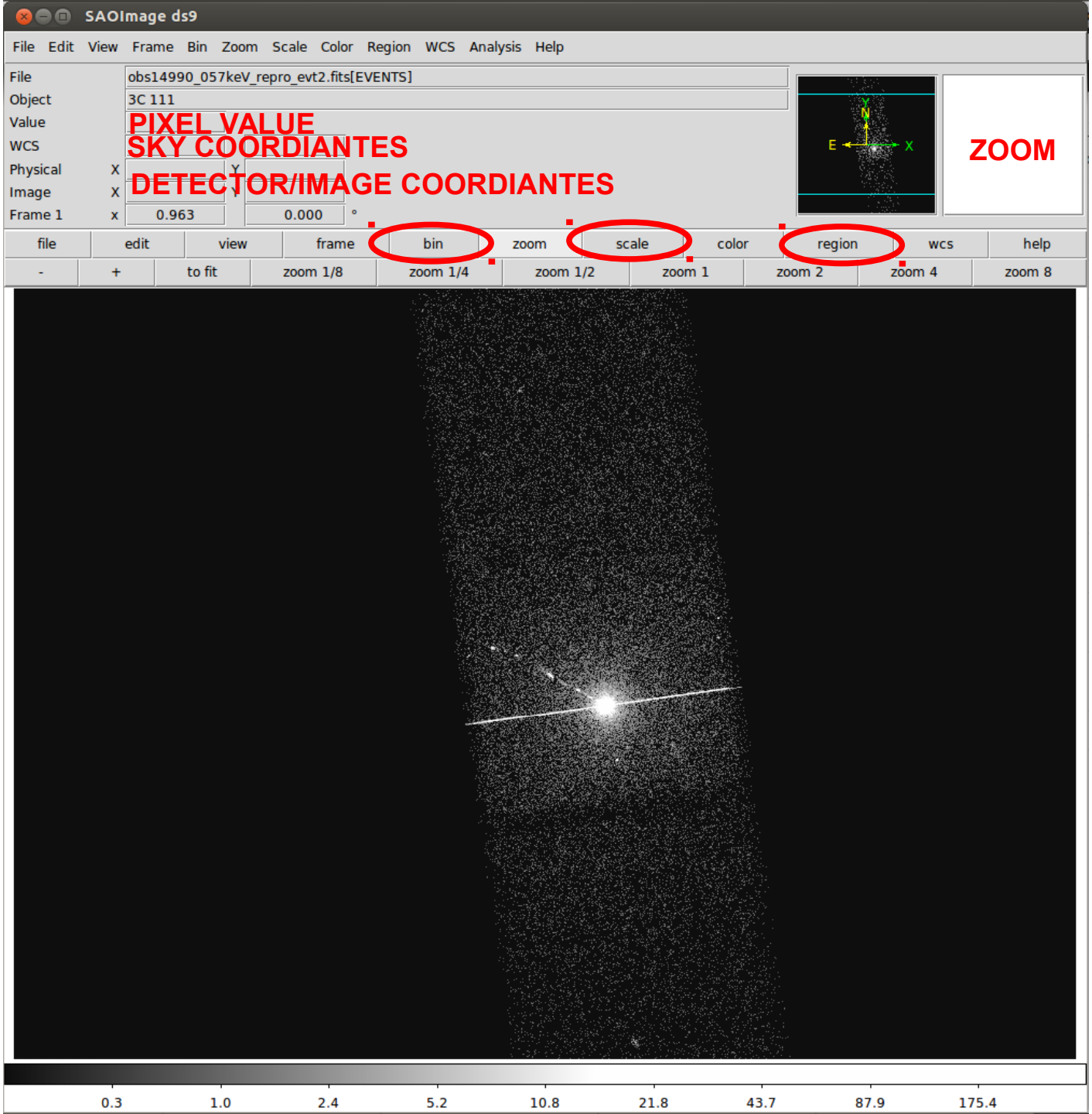
Scientific files
Housekeeping files

- 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 of the background light curve

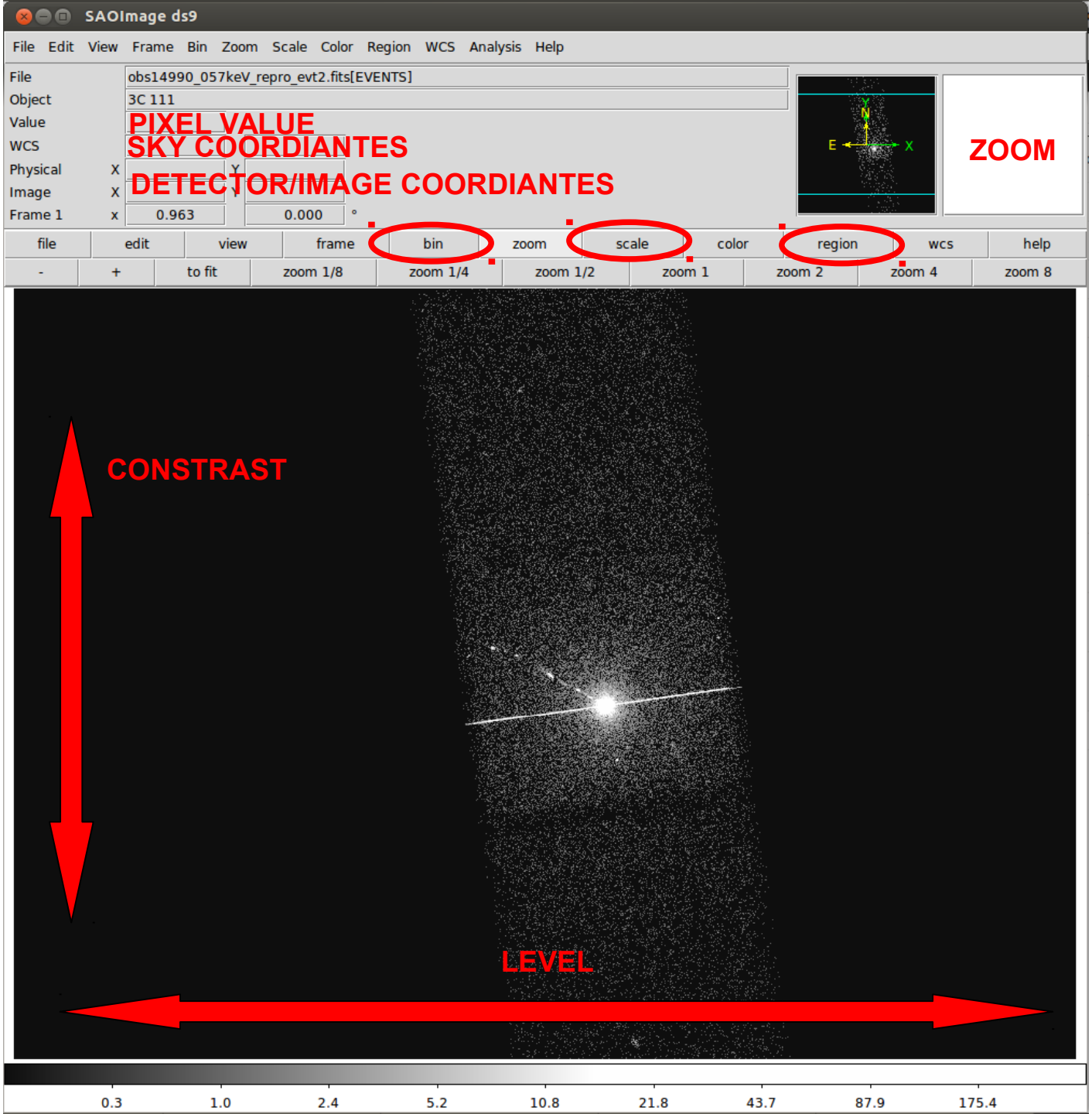
Cleaned
event files


Scientific files
Housekeeping files
Cleaned
event files
Image

DS9:


SAOImage ds9
File Edit View Frame Bin Zoom Scale Color Region WCS Analysis Help
File
obs14990_057keV_repro_evt2.fits[EVENTS]
Object
3C 111
Value
WCS
Physical X Y
Image X Y
Frame 1 x 0.963 0.000 °
PIXEL VALUE
SKY COORDIANTES
DETECTOR/IMAGE COORDIANTES
N
E
X
ZOOM
file edit view frame bin zoom scale color region wcs help
- + to fit zoom 1/8 zoom 1/4 zoom 1/2 zoom 1 zoom 2 zoom 4 zoom 8
0.3 1.0 2.4 5.2 10.8 21.8 43.7 87.9 175.4

DS9:

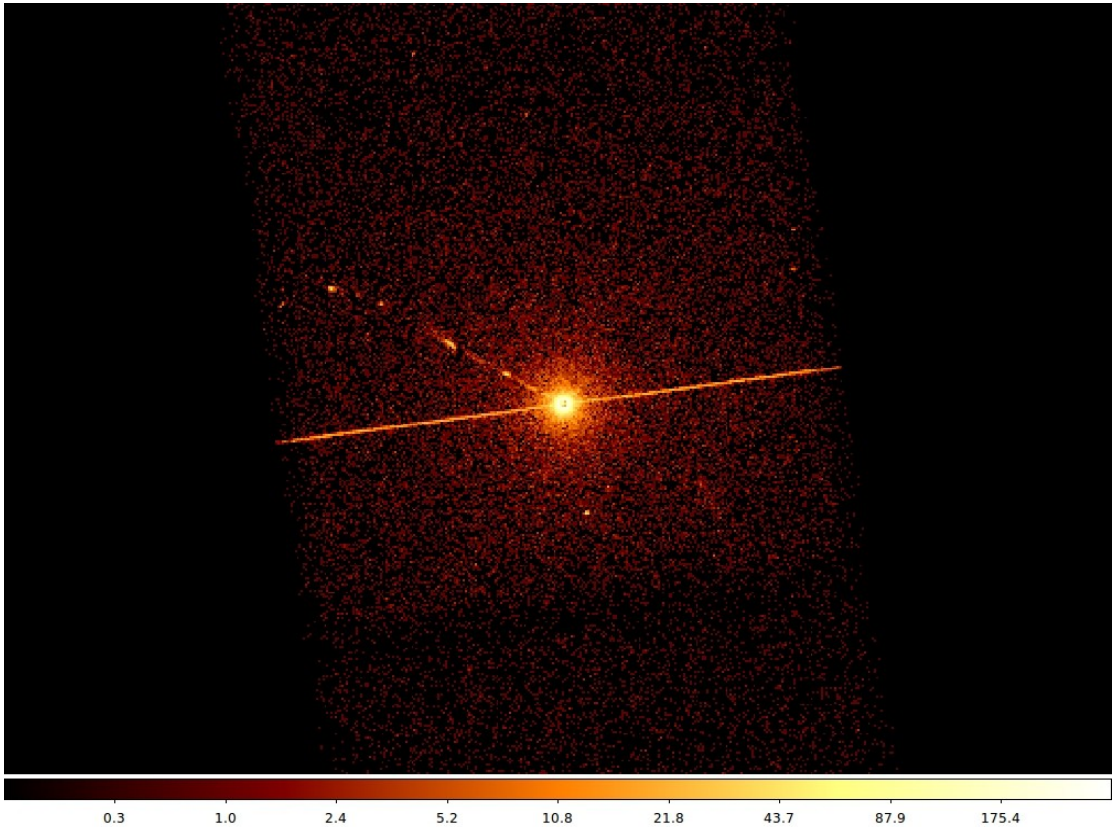

SAOImage ds9
File Edit View Frame Bin Zoom Scale Color Region WCS Analysis Help
File
Object
Value
WCS
Physical
Image
Frame 1
obs14990_057keV_repro_evt2.fits[EVENTS]
3C 111
0.963
0.000
PIXEL VALUE
SKY COORDIANTES
DETECTOR/IMAGE COORDIANTES
ZOOM
file edit view frame bin zoom scale color region wcs help
- + to fit zoom 1/8 zoom 1/4 zoom 1/2 zoom 1 zoom 2 zoom 4 zoom 8
CONSTRAST
LEVEL
0.3 1.0 2.4 5.2 10.8 21.8 43.7 87.9 175.4

Most important information deducible from an image:

- Detection (calculate the source counts and verify if the observed excess is real or due to background fluctuations)

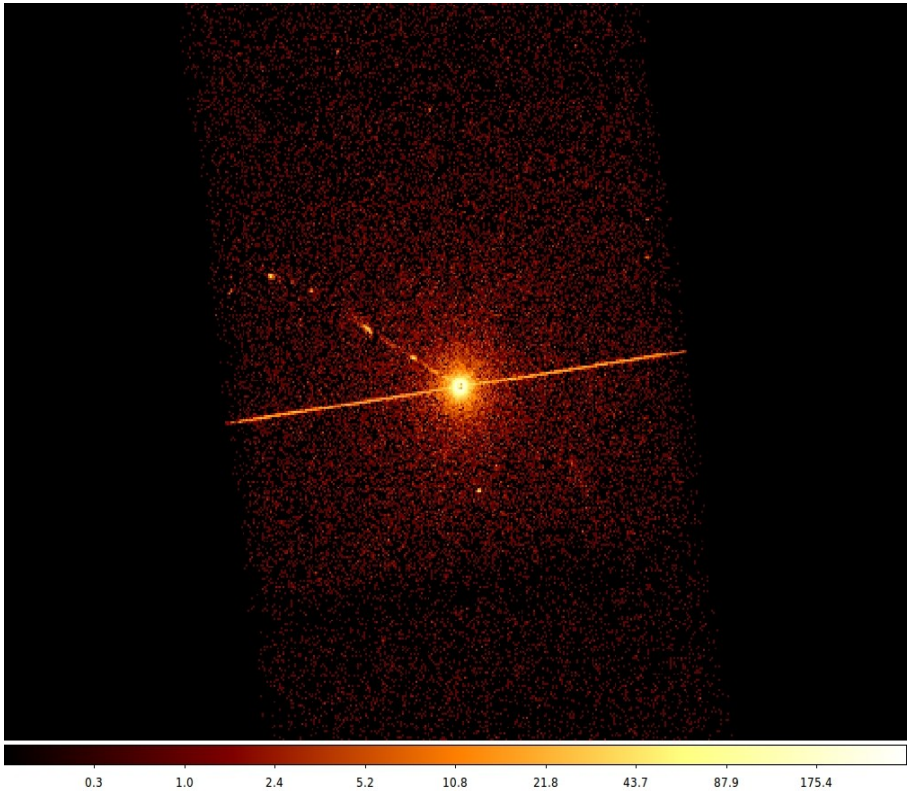
- Morphology (the source is pointlike or extended? obtain and fit a radial profile);

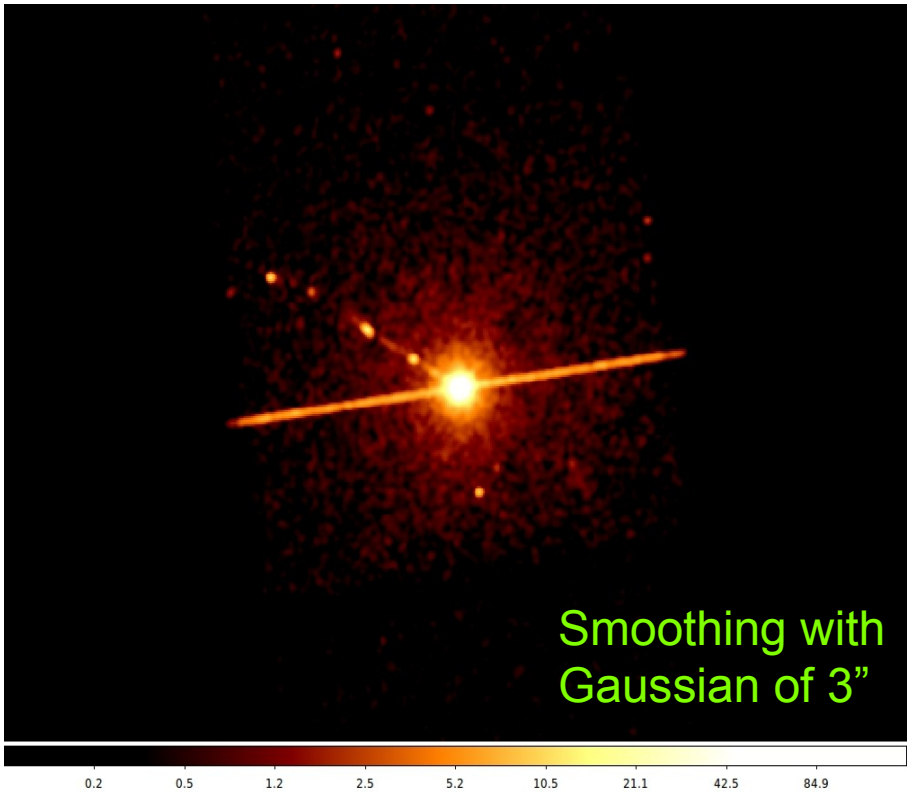
- X-ray counterparts of structures seen in other wavebands.



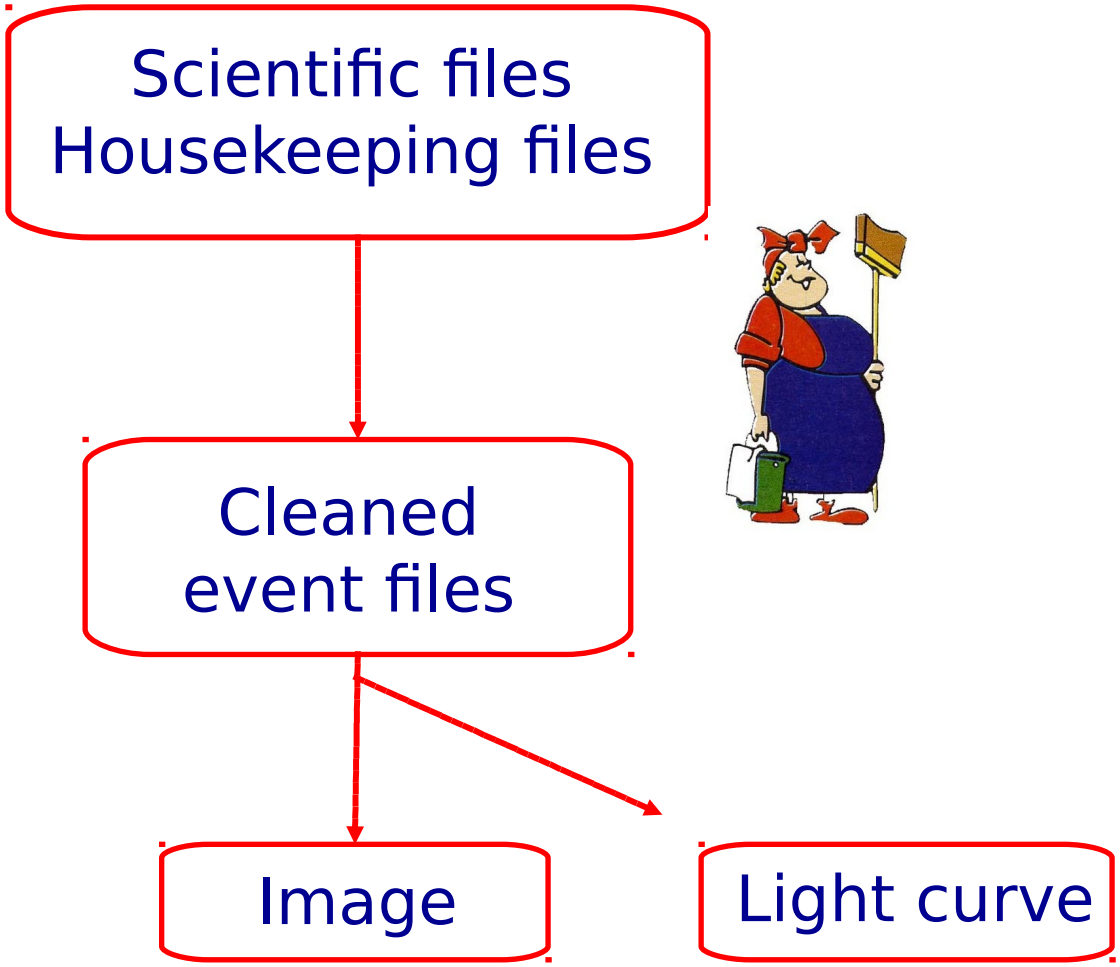
It is possible to improve the image look

smoothing



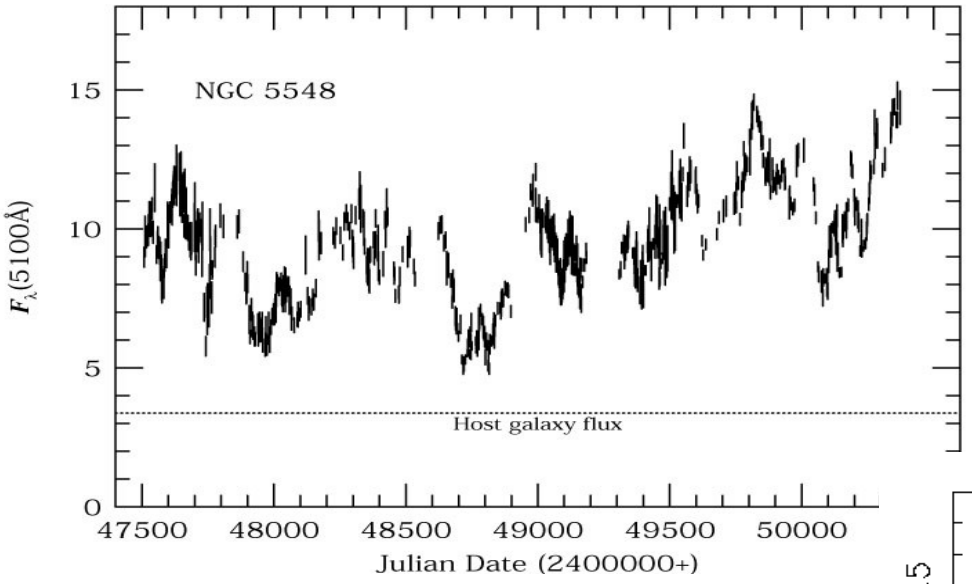


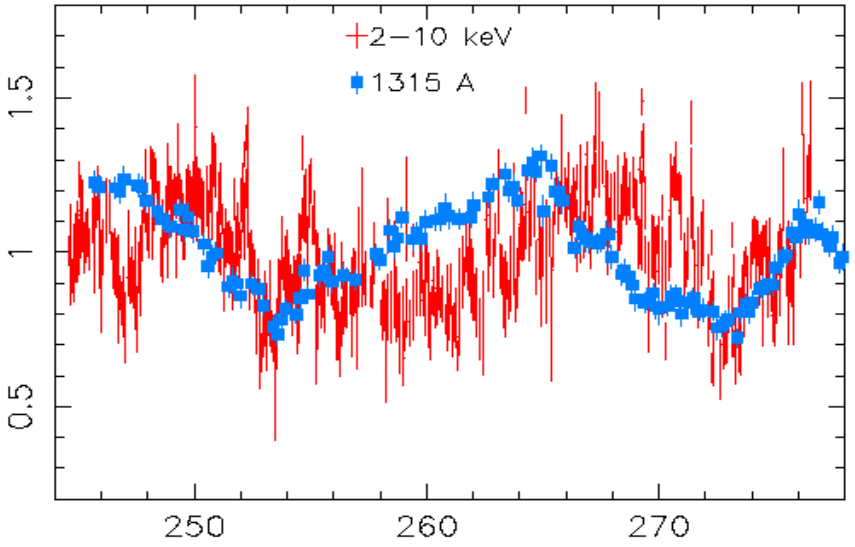
To **smooth an image** means to substitute the value of each pixel for the value obtained by weighting the pixels nearby with a certain function, that generally is a Gaussian.



see XMM tutorial…

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.





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
```

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)

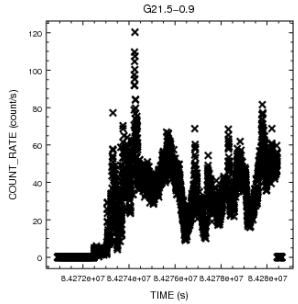
```
>punlearn dmextract
>pset dmextract infile="acisf00953N003_evt2.fits
  [ccd_id=3,sky=region(src2.reg)][bin time= : : 2000]"
>pset dmextract outfile="src_sub_lc.fits"
>pset dmextract bkg="acisf00953N003_evt2.fits
  [ccd_id=3,sky=region(bkg.reg)]"
>pset dmextract opt="ltc1"
>dmextract
```

MIN:MAX:STEP

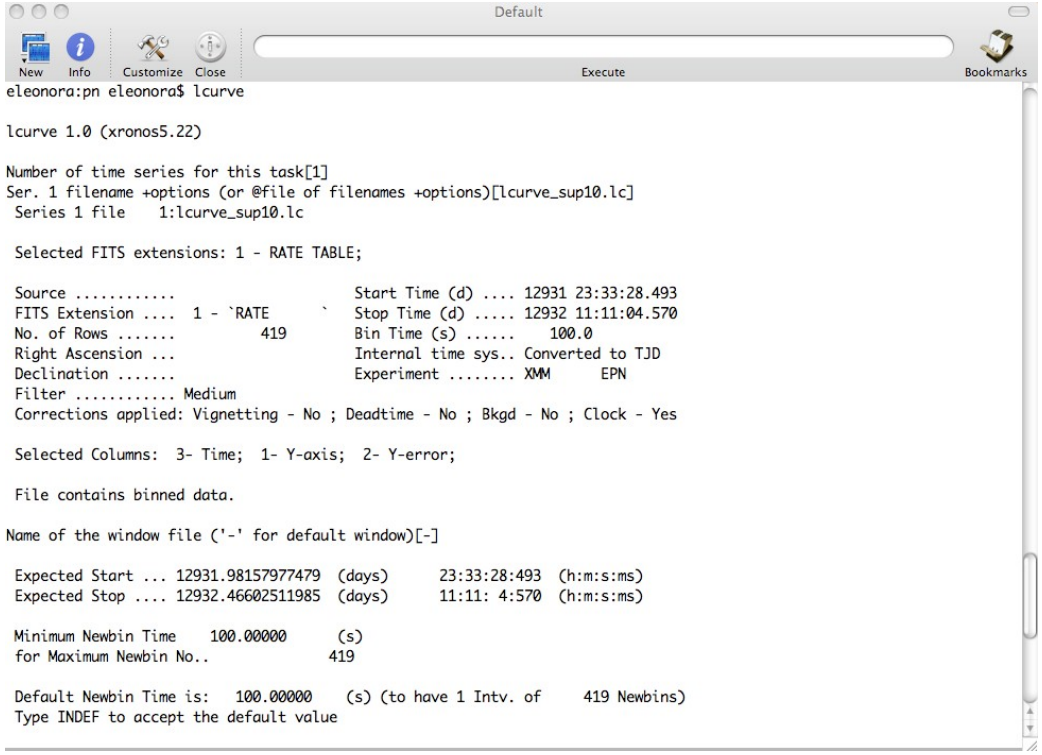
There are several ways to visualize a light curve. Here are two examples:

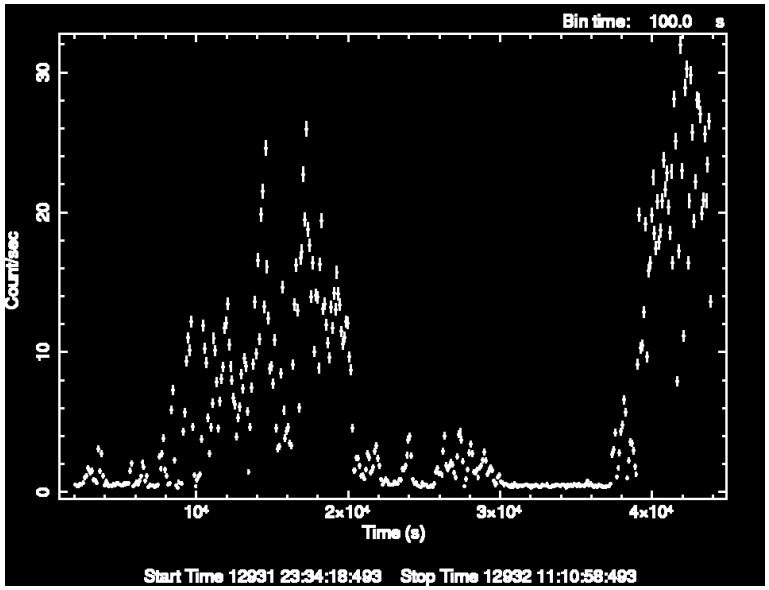
Chips provided by CIAO

```
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***





Scientific files
Housekeeping files

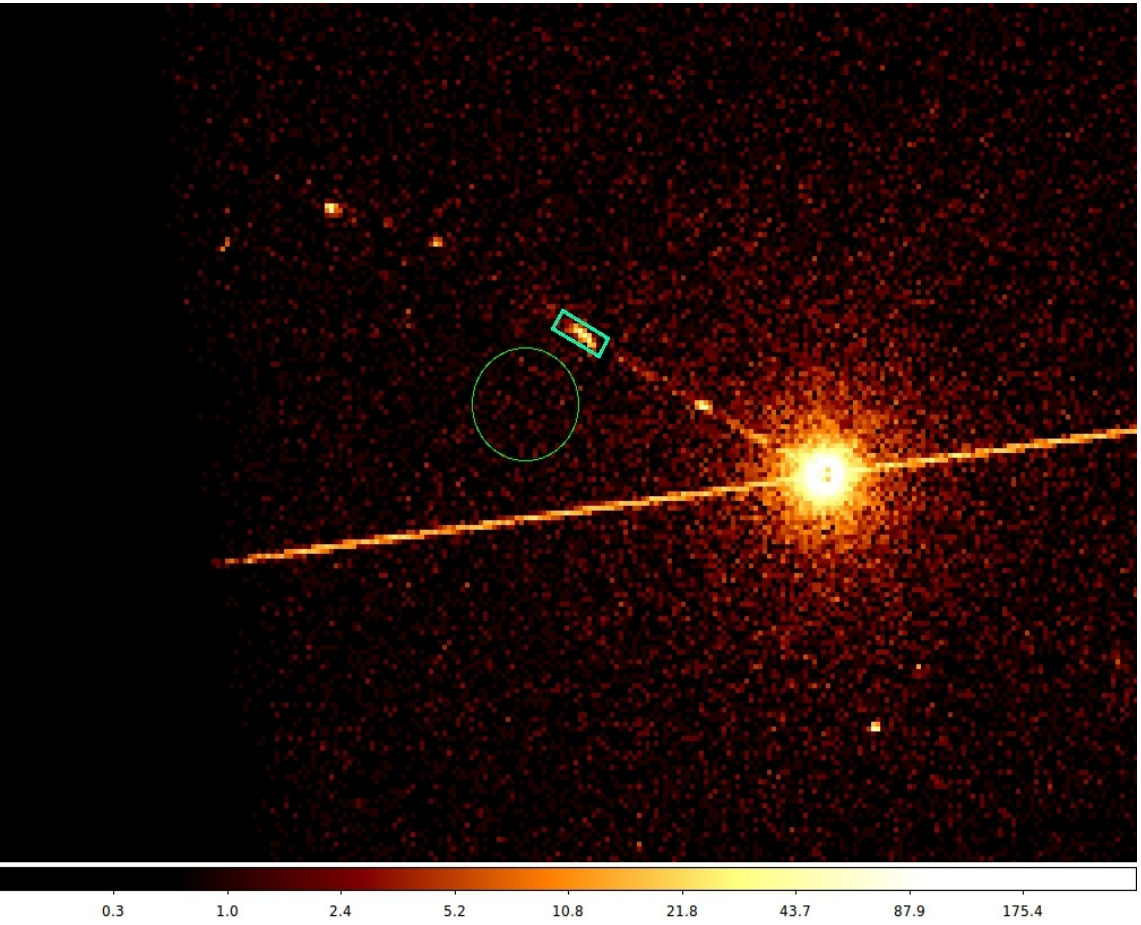
Cleaned
event files

Spectrum

Image

Light curve

Extract source and background spectra



ds9 nomefile

Region ->
File Format -> **CIAO**
-> File Coordinate system
-> Physical

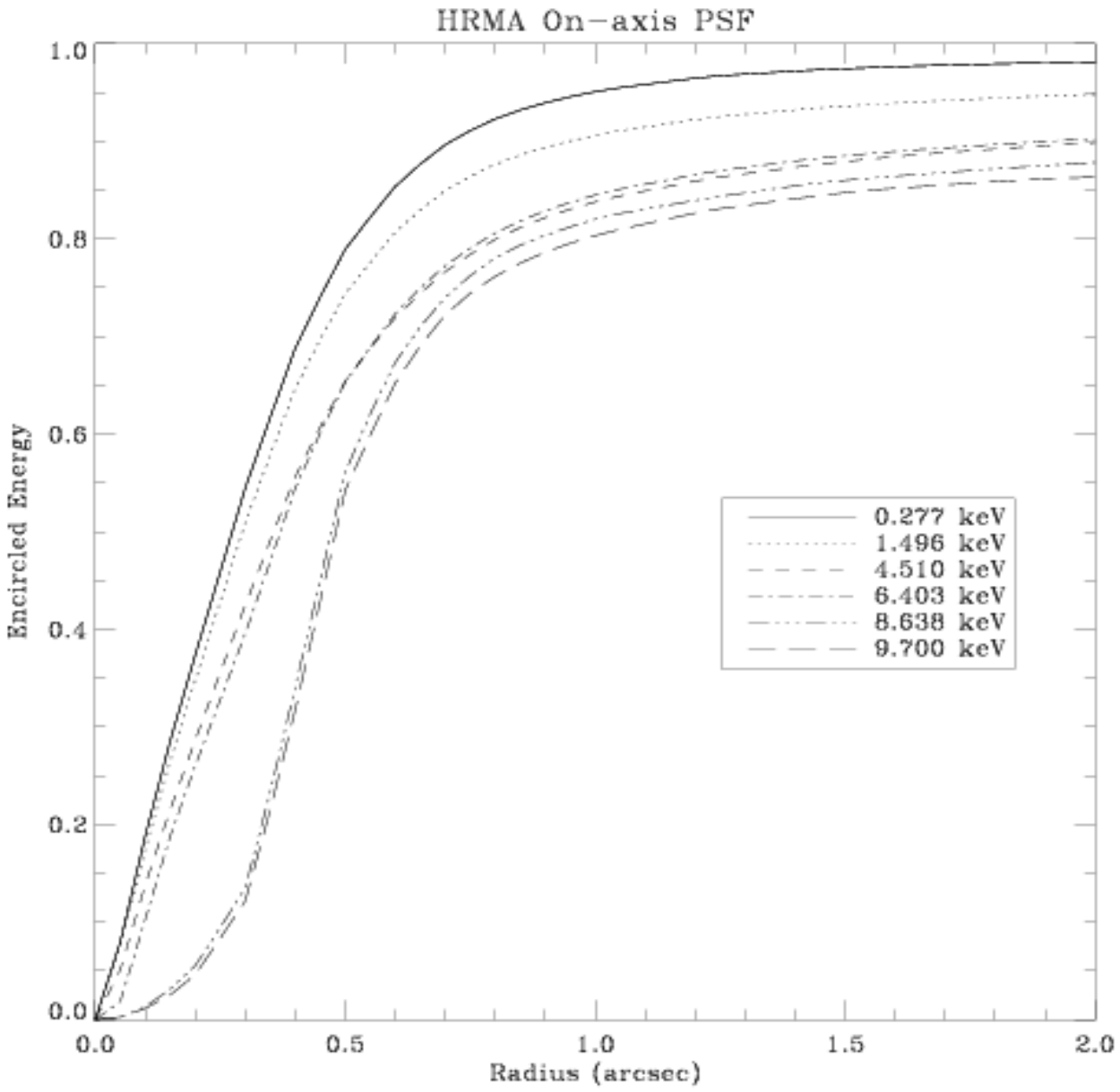
To extract the spectrum of a *pointlike* source…

```
-> punlearn specextract
-> pset specextract infile="acisf00547N002_evt2.fits[sky=region(src.reg)]"
-> pset specextract outroot=prova
-> 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 grouptype=NUM_CTS binspec=15
-> 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.

Fractional encircled energy



About 90% of photons coming from a pointlike source fall within 1”@1.5 keV

…to extract the spectrum of an *extended* source

```
-> punlearn specextract
-> pset specextract infile="acisf00547N002_evt2.fits[sky=region(src.reg)]"
-> pset specextract outroot=prova
-> 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 grouptype=NUM_CTS binspec=15
-> 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.

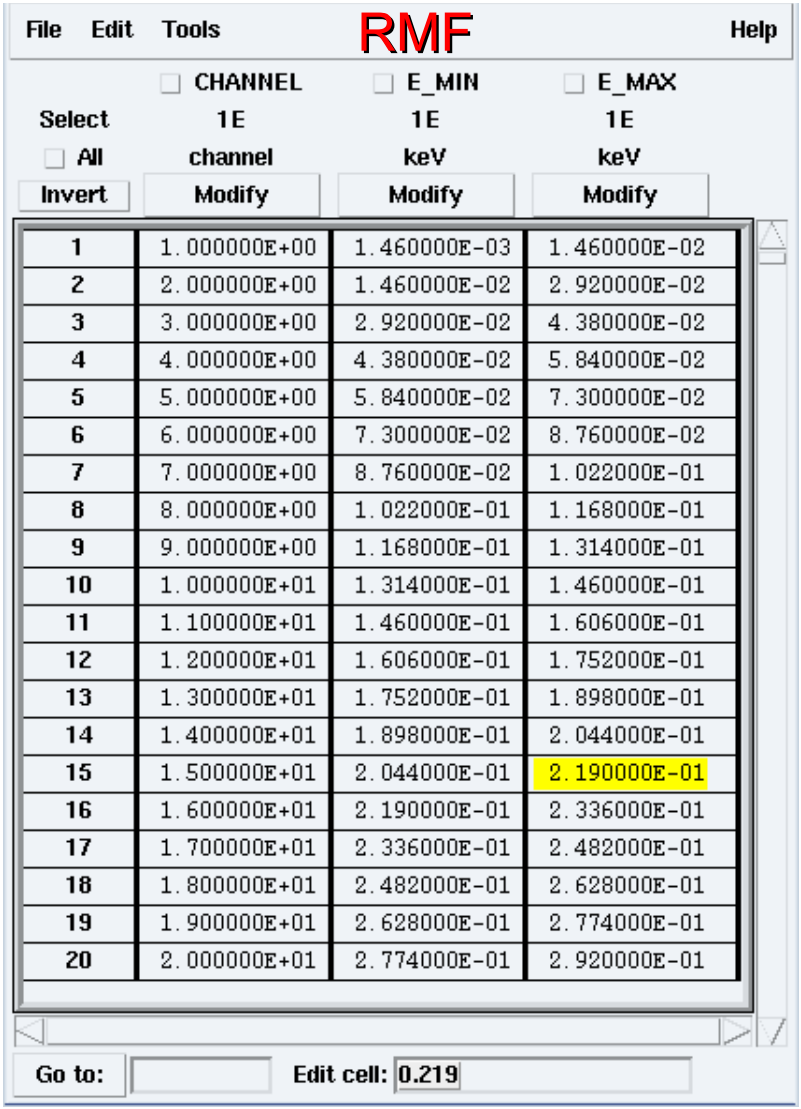
The response matrix is composed by

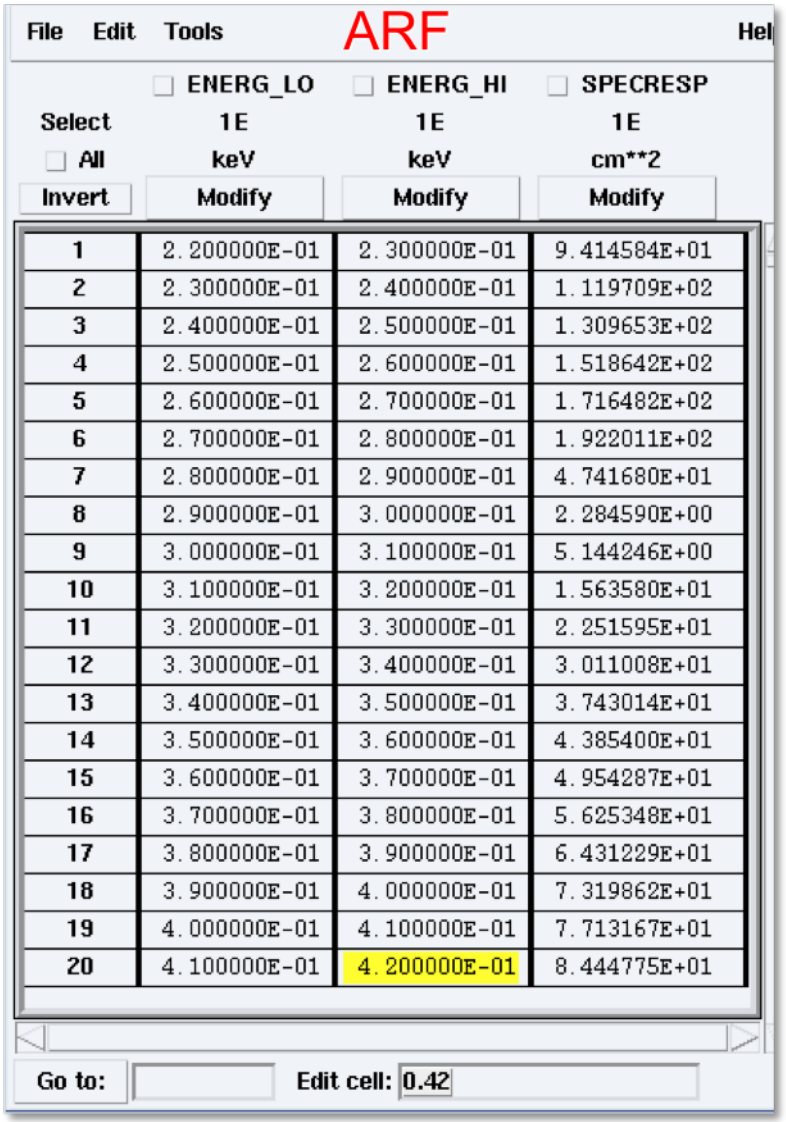
1. The ***Redistribution Matrix File (RMF):*** associates to each instrument channel (I) the appropriate photon energy (E)

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%. 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.

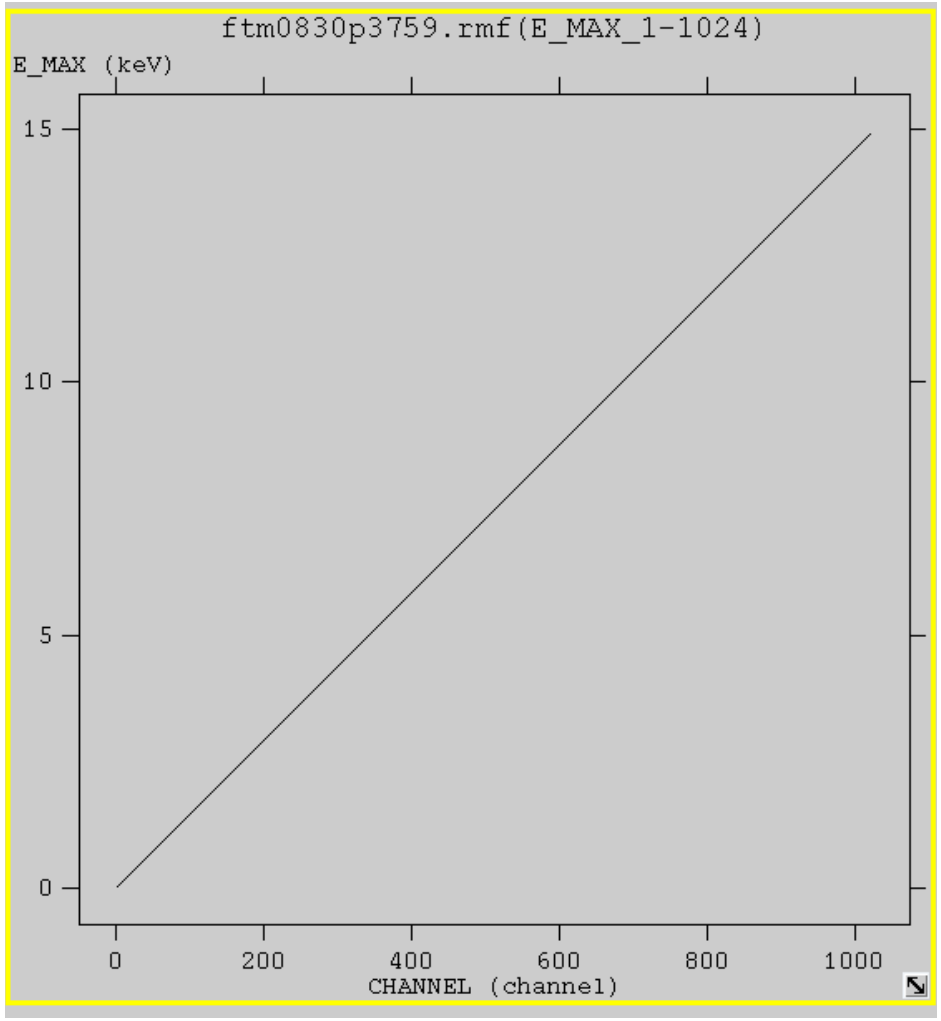
The combination of RMF and ARF produces the input spectrum, convolved with the telescope effective area and detector efficiencies versus energy.

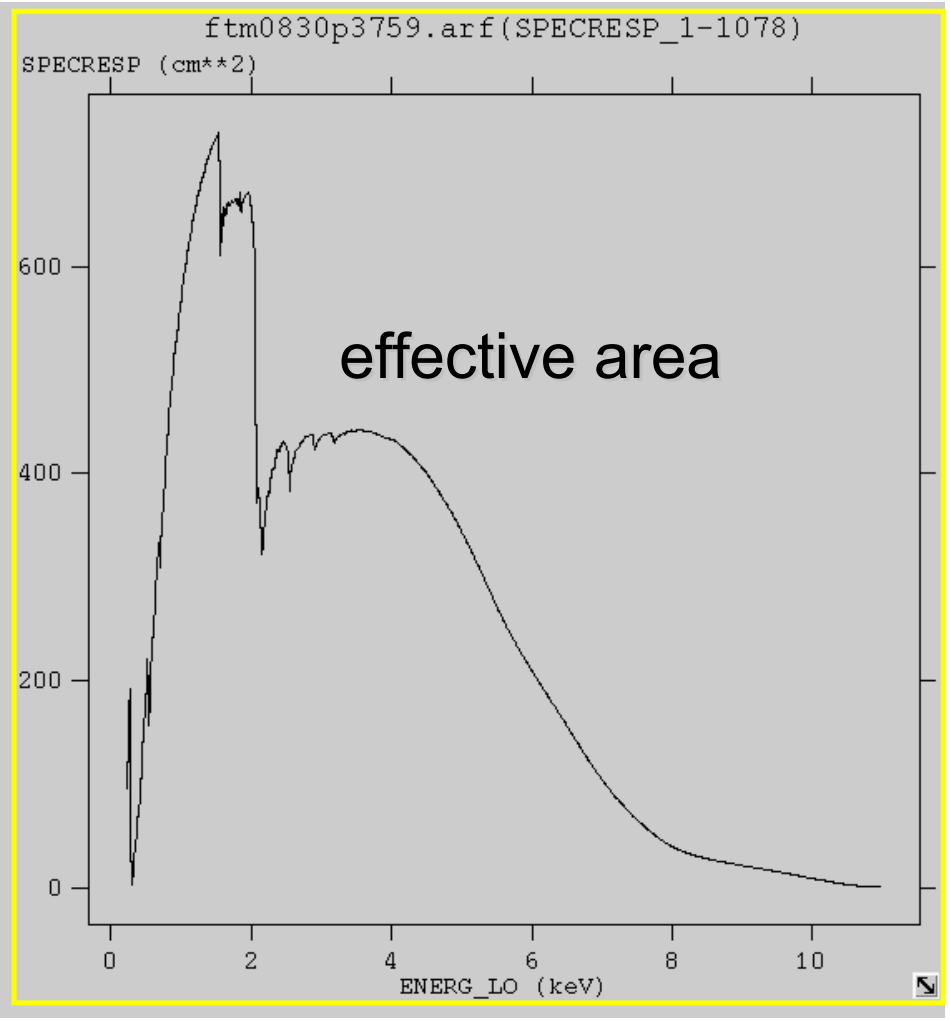

File
Edit
Tools
RMF
Help
CHANNEL
E_MIN
E_MAX
Select
1E
1E
1E
All
channel
keV
keV
Invert
Modify
Modify
Modify
1 1.000000E+00 1.460000E-03 1.460000E-02
2 2.000000E+00 1.460000E-02 2.920000E-02
3 3.000000E+00 2.920000E-02 4.380000E-02
4 4.000000E+00 4.380000E-02 5.840000E-02
5 5.000000E+00 5.840000E-02 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


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

RMF

ARF


ftm0830p3759.rmf(E_MAX_1-1024)
E_MAX (keV)
15
10
5
0
0
200
400
600
800
1000
CHANNEL (channel)


ftm0830p3759.arf(SPECRESP_1-1078)
SPECRESP (cm**2)
600
400
200
0
0
2
4
6
8
10
ENERG_LO (keV)
effective area

To combine spectra from different observations

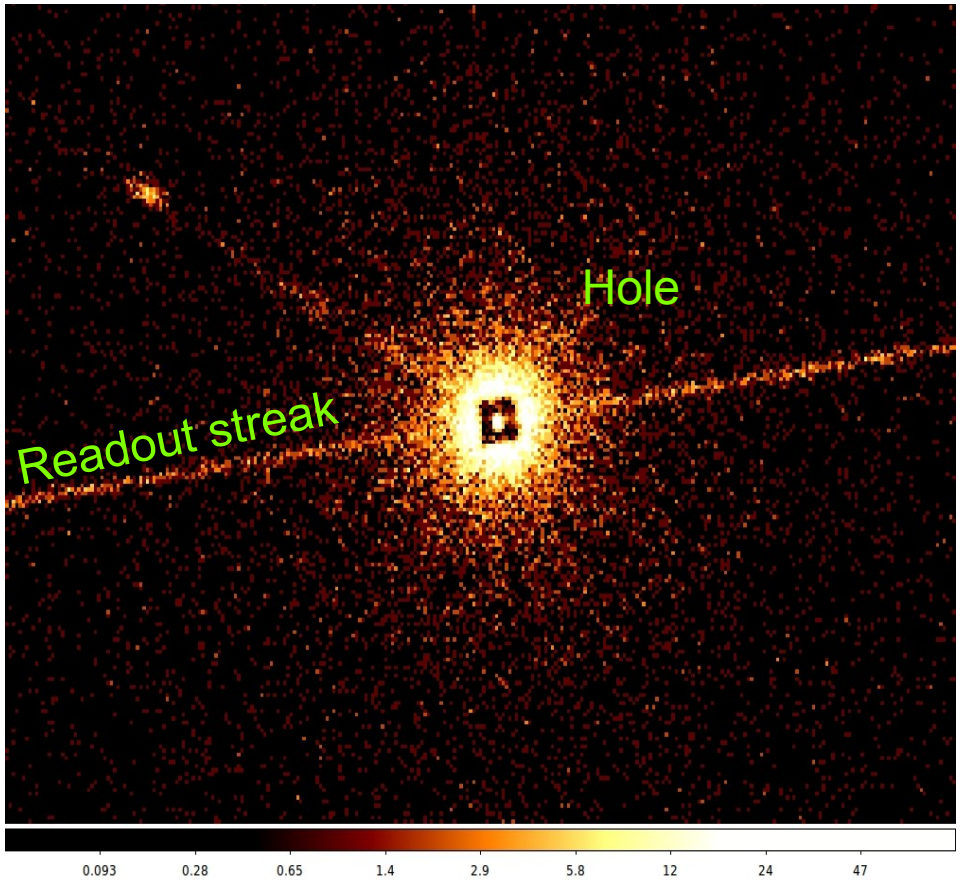
-> punlearn combine_spectra
-> pset combine_spectra src_spectra=obs1843.pi,obs1842.pi
-> pset combine_spectra outroot=combined
-> pset combine_spectra src_arfs=...
-> pset combine_spectra src_rmfs=...
-> pset combine_spectra bkg_spectra=...
-> pset combine_spectra bkg_arfs=...
-> pset combine_spectra bkg_rmfs=...
-> pset combine_spectra bscale_method=asca/time/counts
-> combine_spectra verbose 2

Pileup

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

Two or more photon are collected during the same read-out in the same pixel, and are read as a single event (with > energy)

→ loss of informatio from these events
→ distortion in the observed spectrum

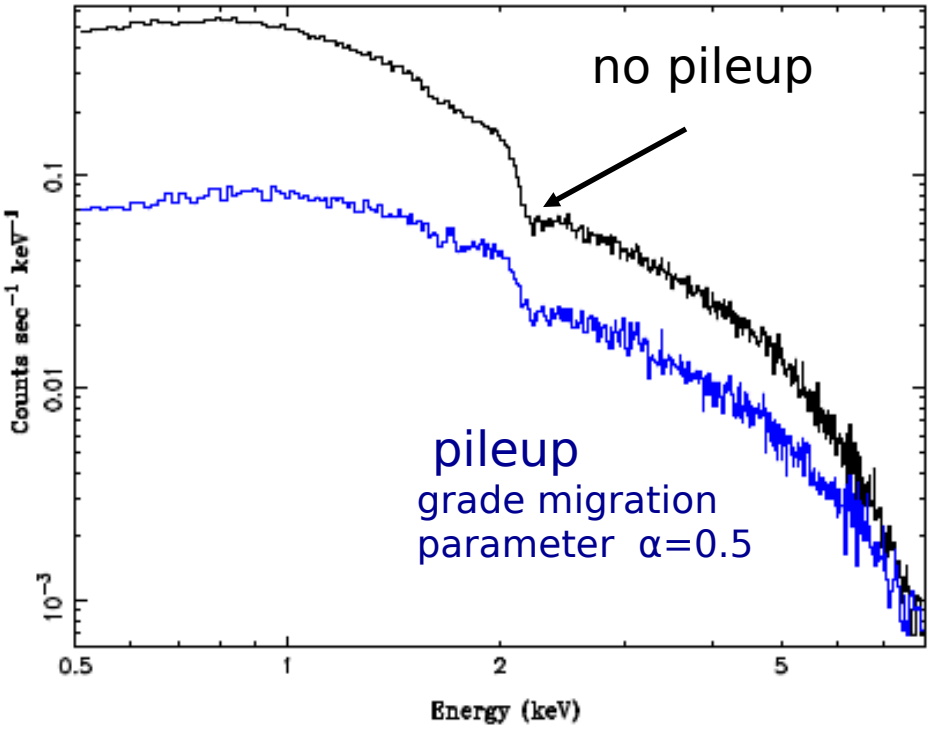


Pileup two major effects are:
ENERGY MIGRATION photon energies sum to create a detected event with higher energy;
GRADE MIGRATION event grades migrate towards values inconsistent with real photon events.

- net decrease of the observed count rate

- net decrease in the fractional rms variability of the lightcurve

spectral shape of the source distorted



Avoid pileup: reduce the counts per frame pixels (PIMMS)

Pileup mitigation: use an XSPEC – pileup model

Scientific files
Housekeeping files

Cleaned
event files

Spectrum

Image

Light curve

Scientific analysis

see Xspec
Tutorial…

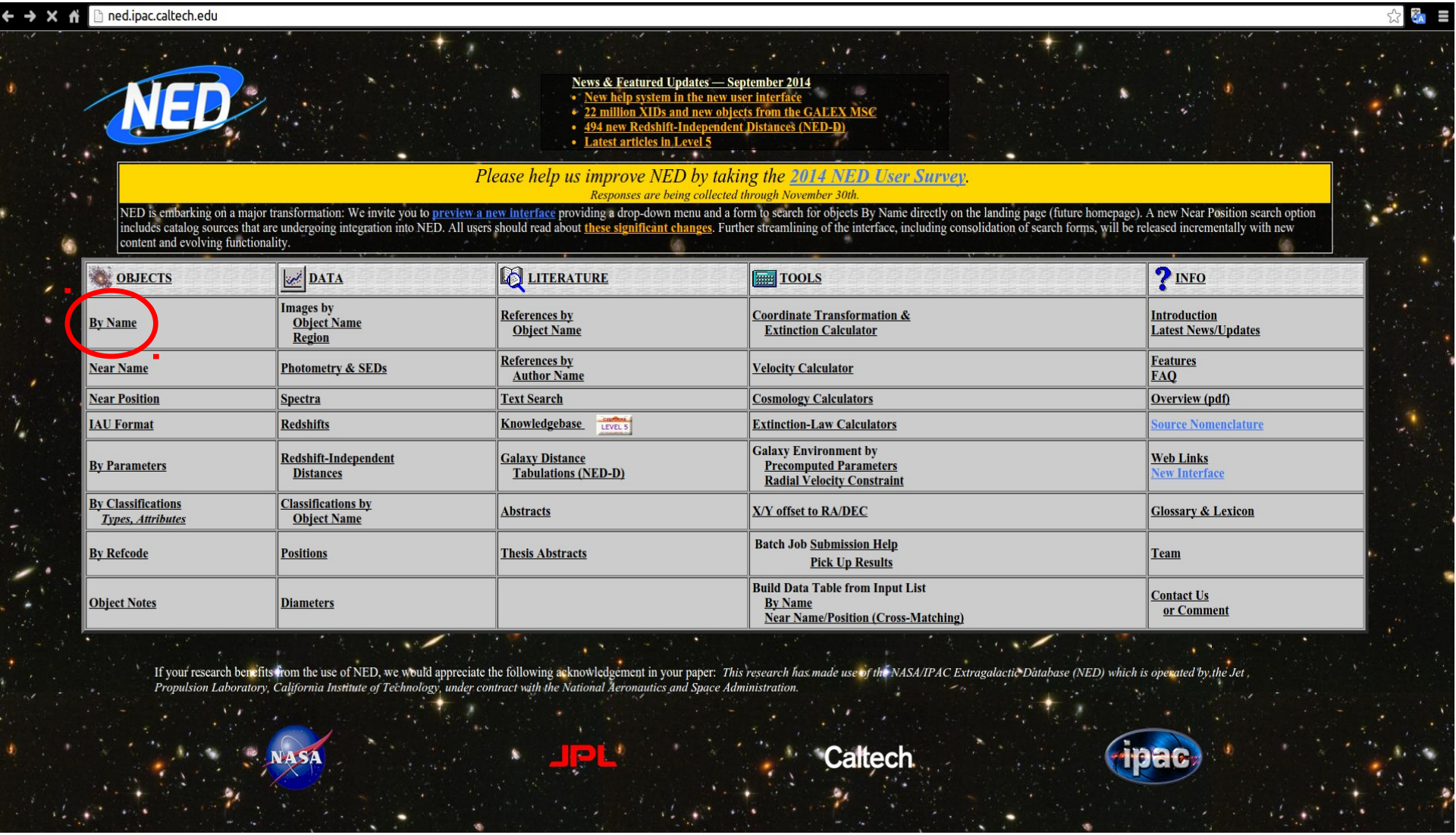
→ How to download X-ray data from a public archive

→ How the downloaded files look like

→ How to reduce X-ray (*Chandra*) data

→ How to create the radio and/or X-ray contours for an extended object

http://ned.ipac.caltech.edu/



http://ned.ipac.caltech.edu/

ned.ipac.caltech.edu/cgi-bin/objsearch?objname=3c111&extend=no&hconst=73&omegam=0.27&omegav=0.73&corr_z=1&out_csys=Equatorial&out_equinox=J2000.0&obj_sort=RA+or+Longitude&of=pre_text&zv_breaker=30000.0&li

You have selected the following parameters to search on:

Parameters for Distances and Cosmology: $H_0 = 73.0$; $\Omega_{matter} = 0.27$; $\Omega_{vacuum} = 0.73$;
Derived Quantities use a Redshift corrected to a Reference Frame defined by the 3K CMB

NED results for object 3C 111

1 objects found in NED.

SOURCE LIST

Row No.	Object Name (* => Essential Note)	EquJ2000.0 RA	EquJ2000.0 DEC	Object Type	Velocity/Redshift km/s	Velocity/Redshift z	Velocity/Redshift Qual	Mag./ Filter	Separ. arcmin	Number of Refs	Number of Notes	Number of Phot	Number of Posn	Number of Vel/z	Number of Diam	Number of Asso	Images	Spectra	Row No.
1	3C 111	04h18m21.3s	+38d01m36s	G	14540	0.048500		18.1V	...	430	9	106	6	2	3	1	Retrieve	Retrieve	1

Detailed information for each object

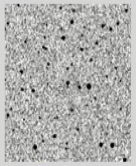
Object No. 1 - 3C 111

INDEX for 3C 111

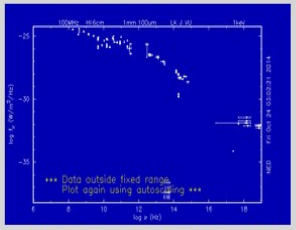
Essential Data (jump to sub-section of this query report):

- 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

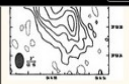
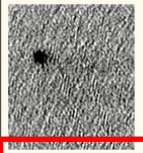
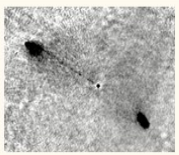
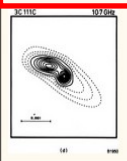
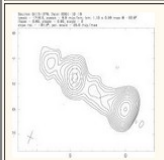
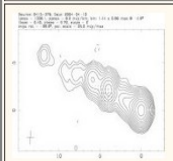


106 Photometric data point(s) and SED

- Spectra
- Redshift-Independent Distances
- 430 Reference(s)
- 6 Position data point(s)
- 2 Redshift data point(s)
- 3 Diameter data point(s)
- 9 Note(s)
- 1 Association(s)

http://ned.ipac.caltech.edu/

ned.ipac.caltech.edu/cgi-bin/imgdata?objname=3C+111&hconst=73.0&omegam=0.27&omegav=0.73&corr_z=1

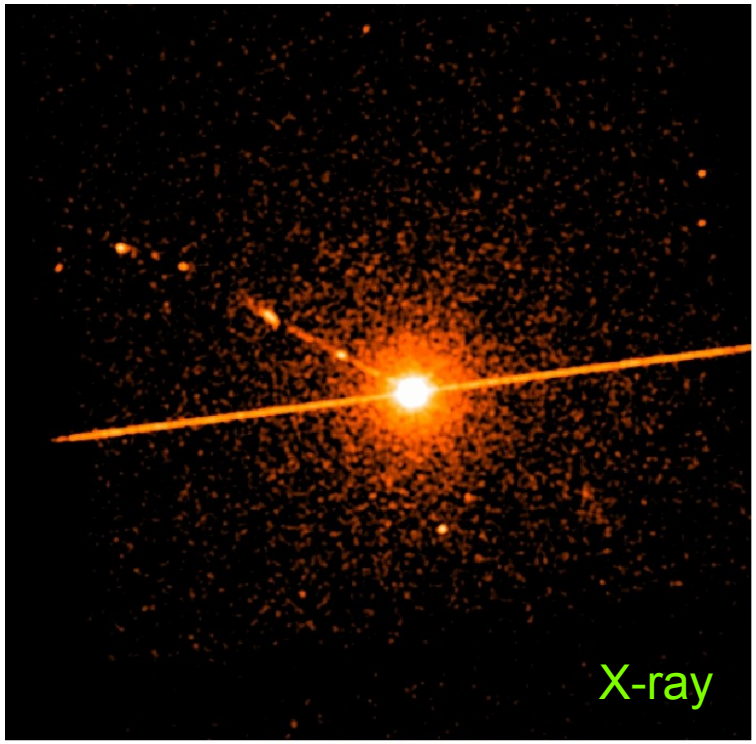
	97KB JPG image Retrieve	N/A	N/A	6cm	N/A	N/A	Cambridge_5km	1977MNRAS..84...61J
	4368KB FITS image Retrieve	Display FITS Header		8.4GHz , 3.6cm	10.2 x 10.2	2.50	VLA	1997MNRAS.291...20L
	1503KB FITS image Retrieve	Display FITS Header		8.4GHz , 3.6cm	0.6 x 0.6	0.32	VLA	1997MNRAS.291...20L
	5088KB FITS image Retrieve	Display FITS Header		8.4GHz , 3.6cm	4.3 x 3.2	1.60	VLA	1997MNRAS.291...20L
	71KB JPG image Retrieve	Display Caption	N/A	10.7GHz , 2.8cm	N/A	N/A	Cambridge_5km	1981MNRAS.195..261L
	1258KB JPG image Retrieve	N/A	N/A	15GHz , 2cm	0.001 x 0.001	0.001	VLBA	2005AJ....130.1389L
	4392KB JPG image Retrieve	N/A	N/A	15GHz , 2cm	0.002 x 0.002	0.001	VLBA	2005AJ....130.1389L

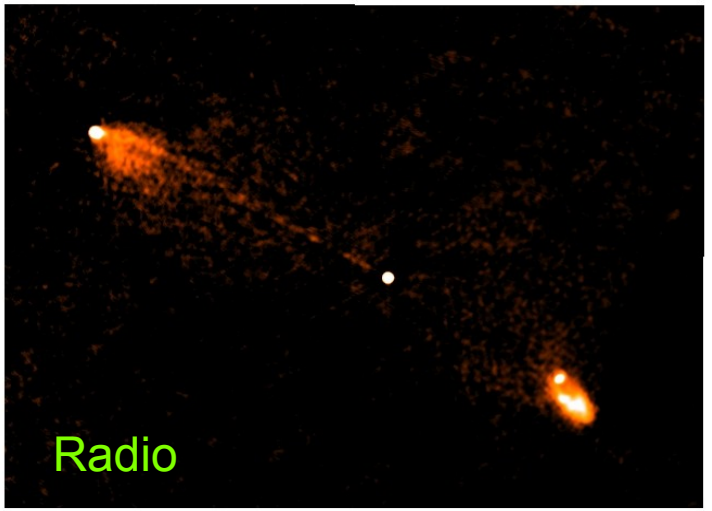
Other useful links

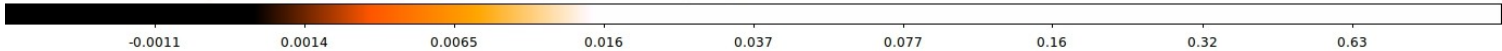
- http://www.jb.man.ac.uk/atlas/icon.html
- http://2jy.extragalactic.info/2Jy_home_page.html
- http://www.jb.man.ac.uk/atlas/dragns.html

> ds9 X-ray_image radio_image

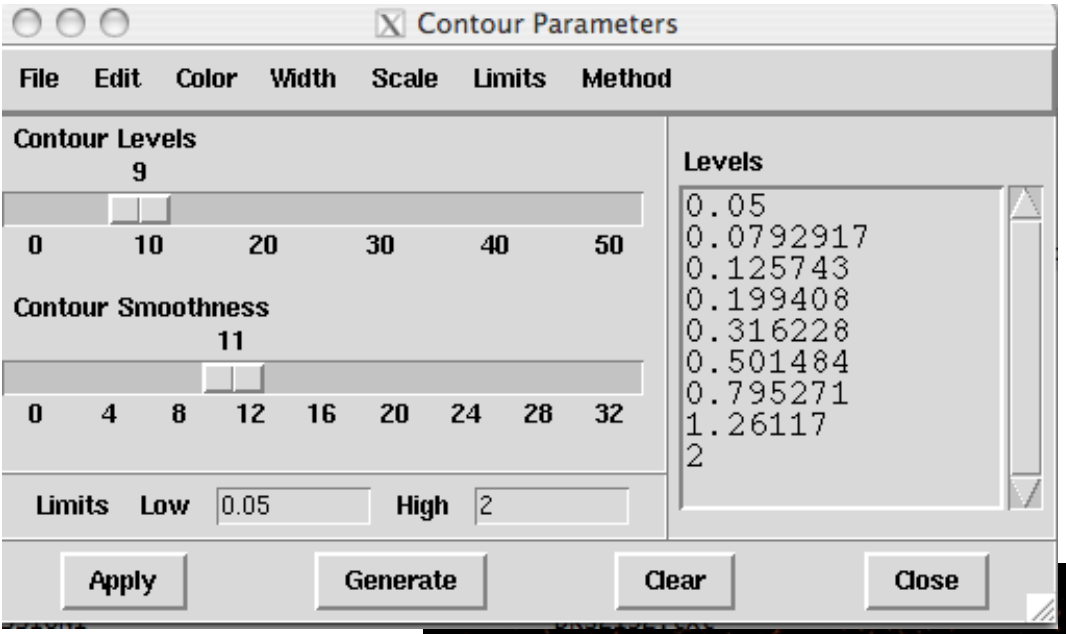
Frame → match frames
→ WCS





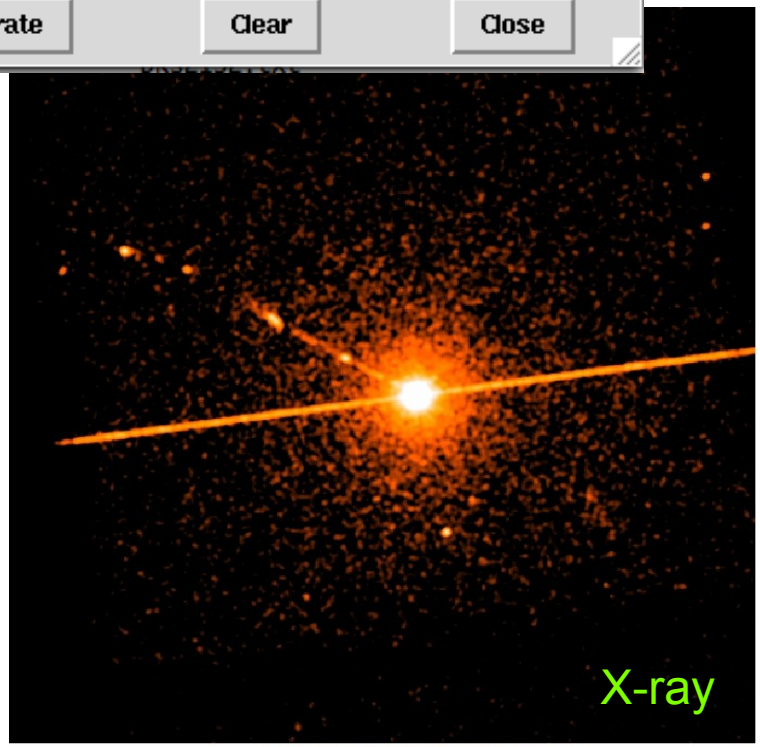


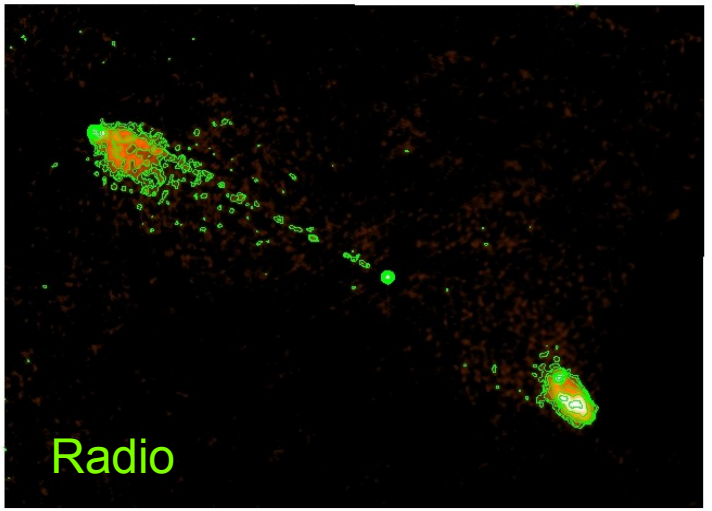
> ds9 X-ray_image radio_image

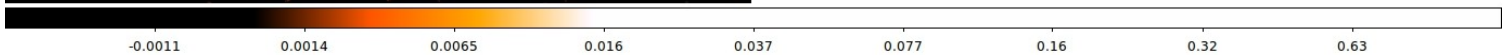


Analysis -> contours parameters

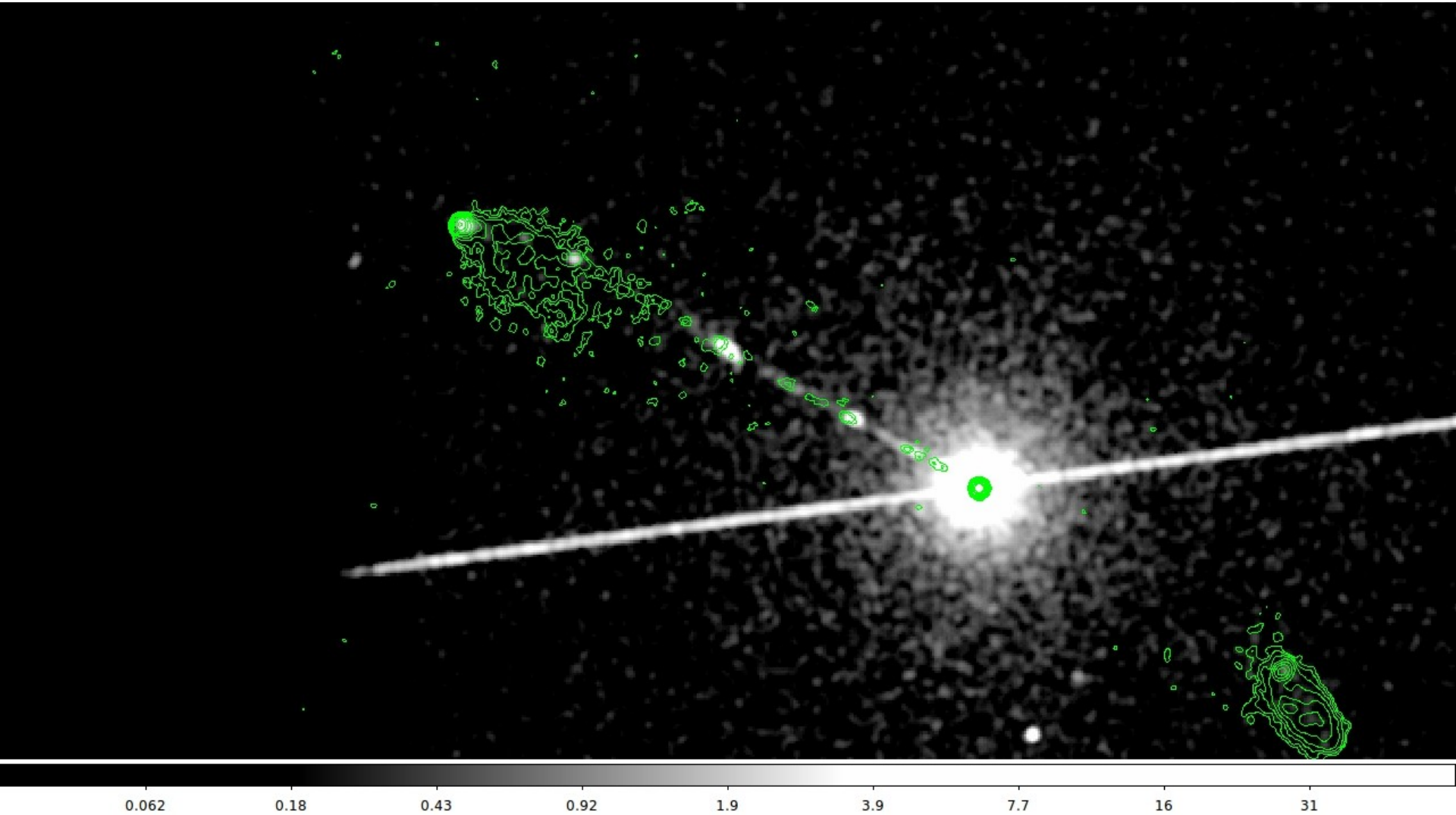
File -> save contours







Analysis → Contour parameters
→ File
→ Load contours



Not only radio/X...

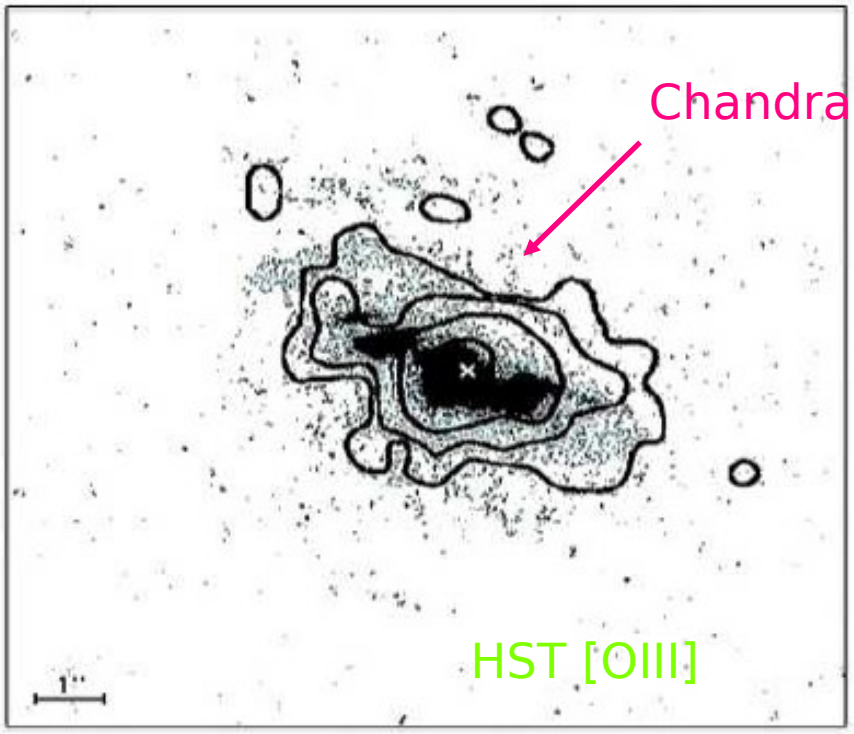


Fig. 4. Superposition of the *Chandra* soft X-ray (<2 keV) contours on an *HST* image taken through a linear ramp filter at redshifted [OIII]λ5007. The sign "x" indicates the centre of the hard X-ray source, north is up, east to the left. The X–ray image was smoothed with a Gaussian of FWHM ~ 6 pixels. The contours correspond to four logarithmic intervals in the range 1-60% of the peak flux.


THE END