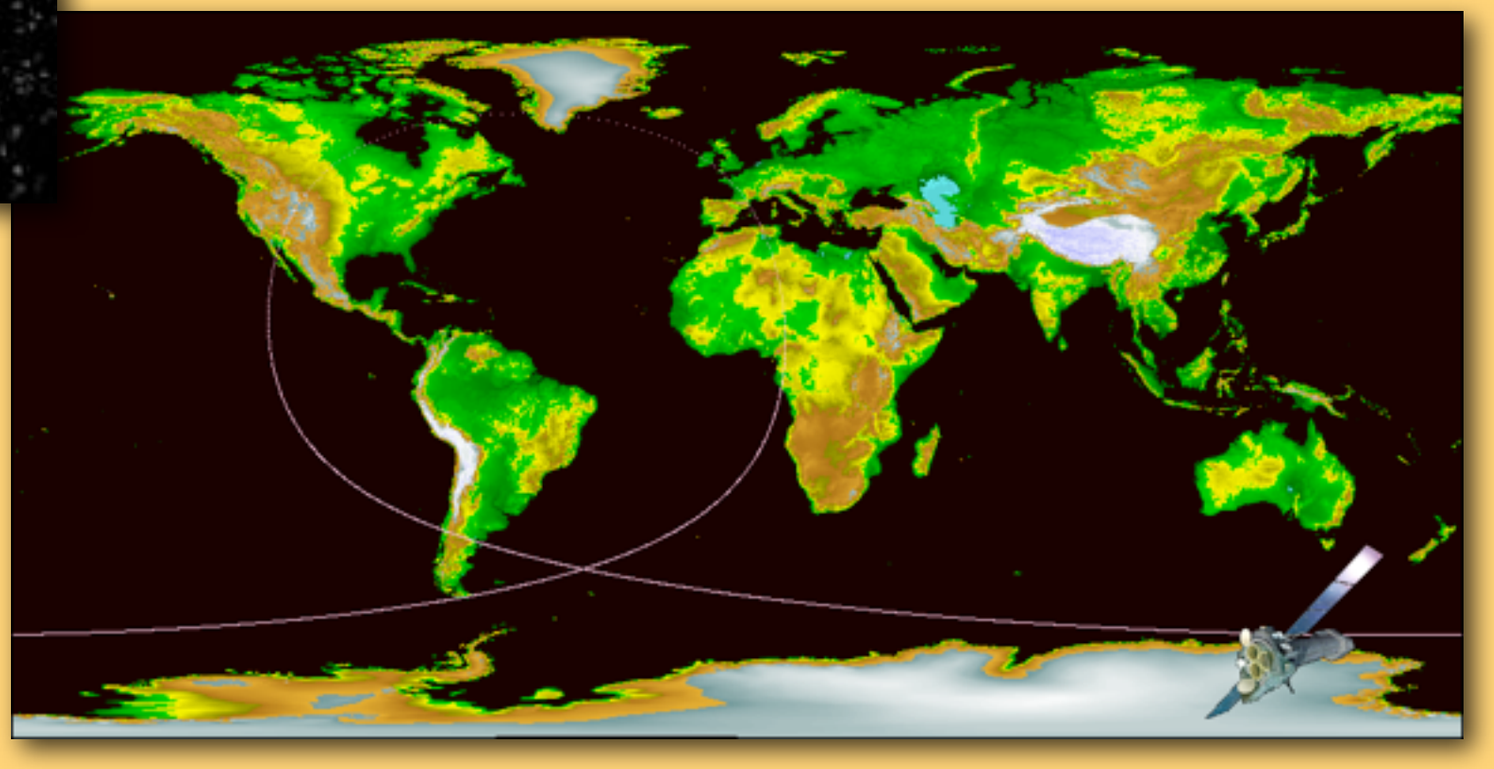
XMM-Newton Tutorial

Lab X 2013



Eleonora Torresi

INAF/IASF Bologna

previously from Barbara De Marco

27.11.2013

OUTLINE

- How to download XMM-Newton data from the public archive

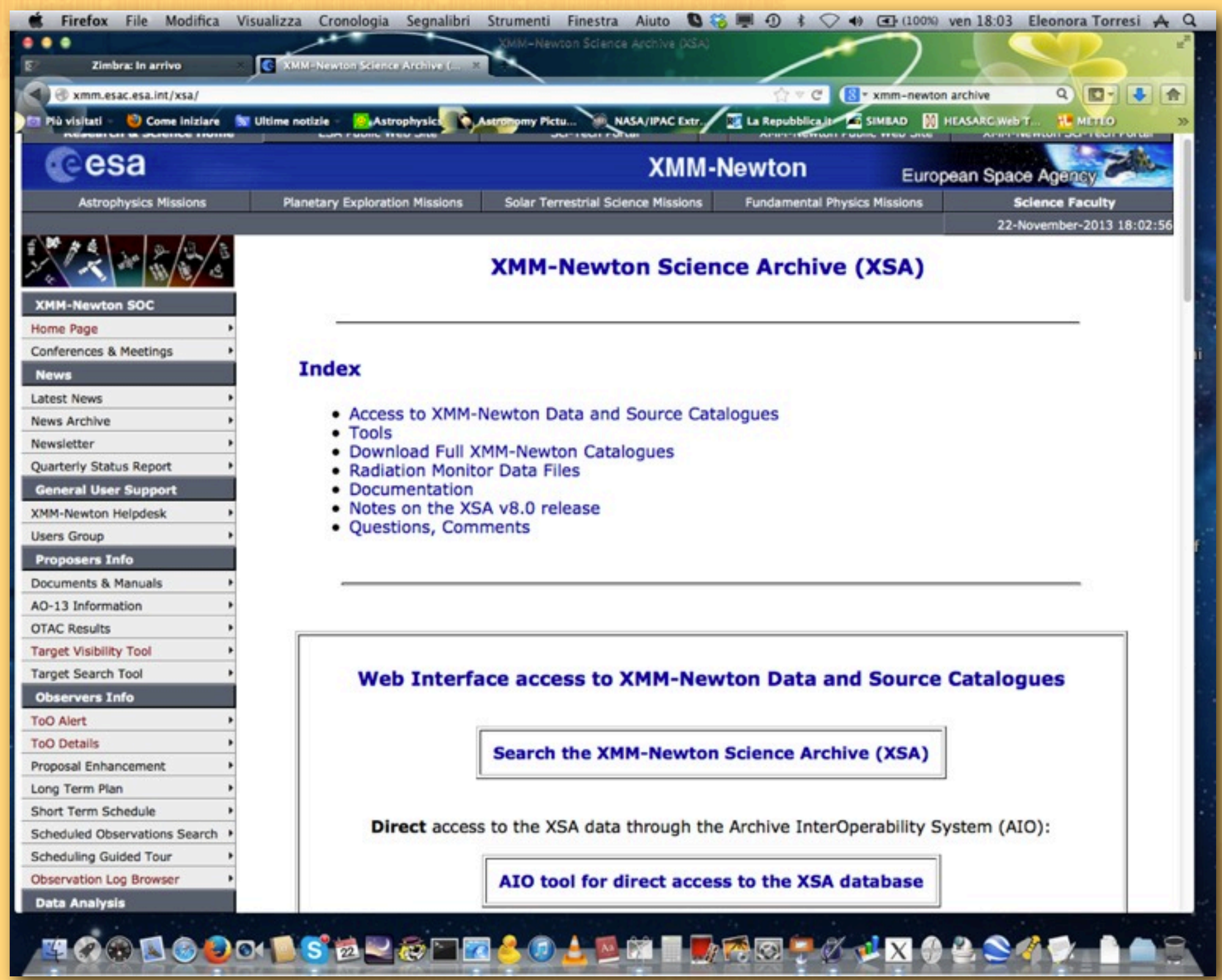
- PN, MOS1 and MOS2 data reduction:

  - selection of Good Time Intervals (GTI)
  - generation of the cleaned event file
  - source and background regions selection
  - check for the presence of pile-up
  - spectrum extraction (of both source and background)
  - creation of the Response Matrix Function (RMF)
  - creation of the Ancillary Response Function (ARF)
  - grouping of the spectra

1. How to download XMM-Newton data from the public archive

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

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



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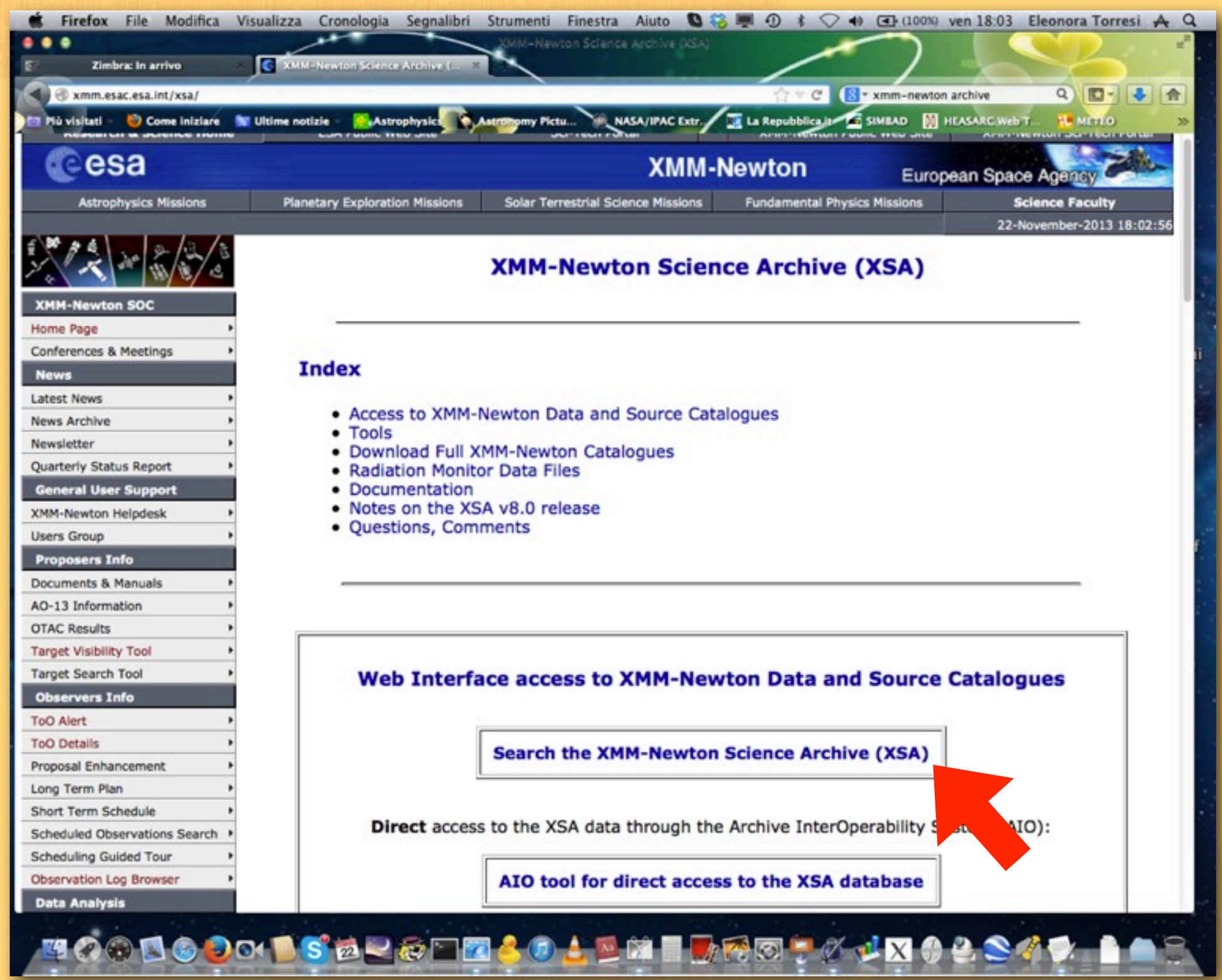

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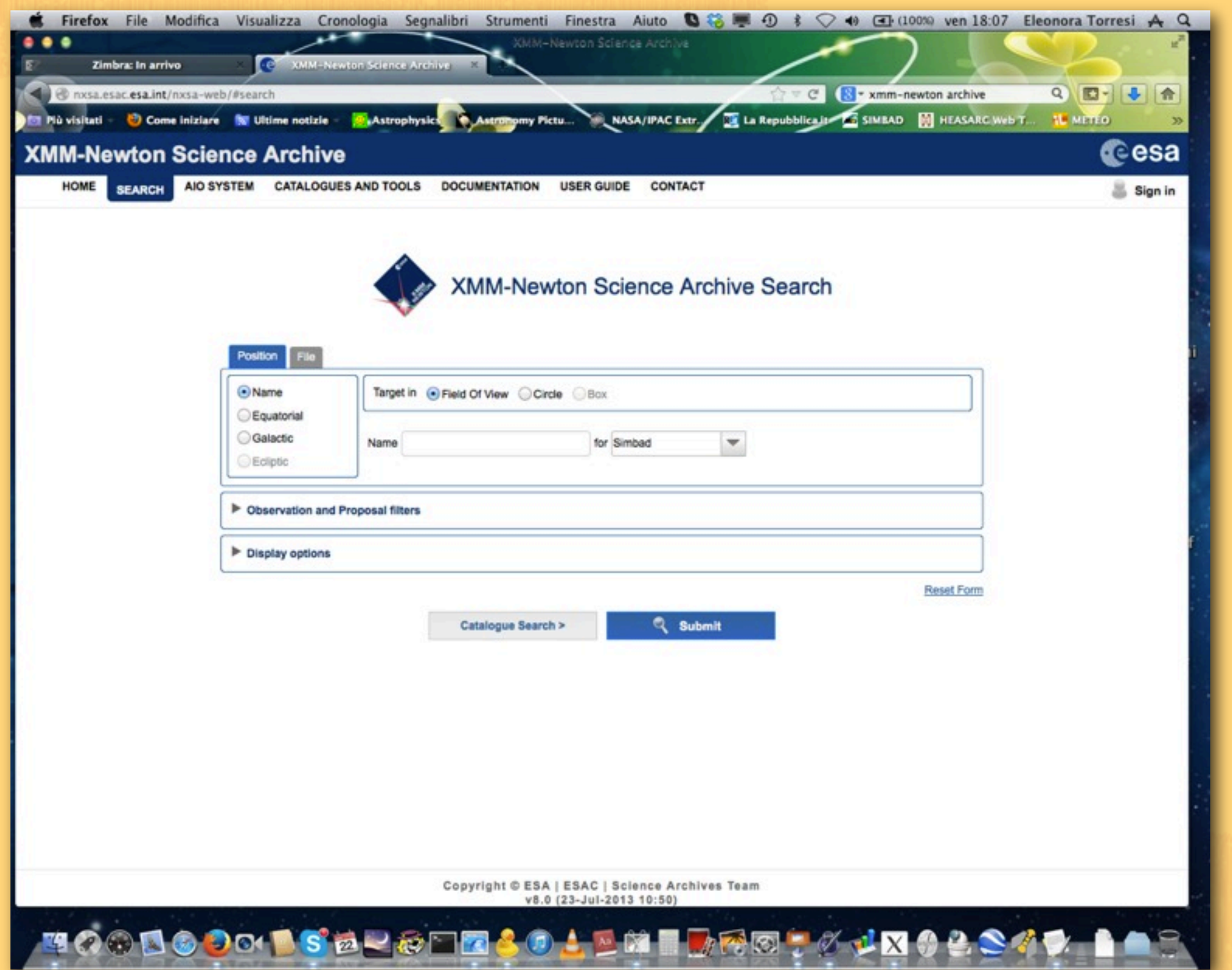

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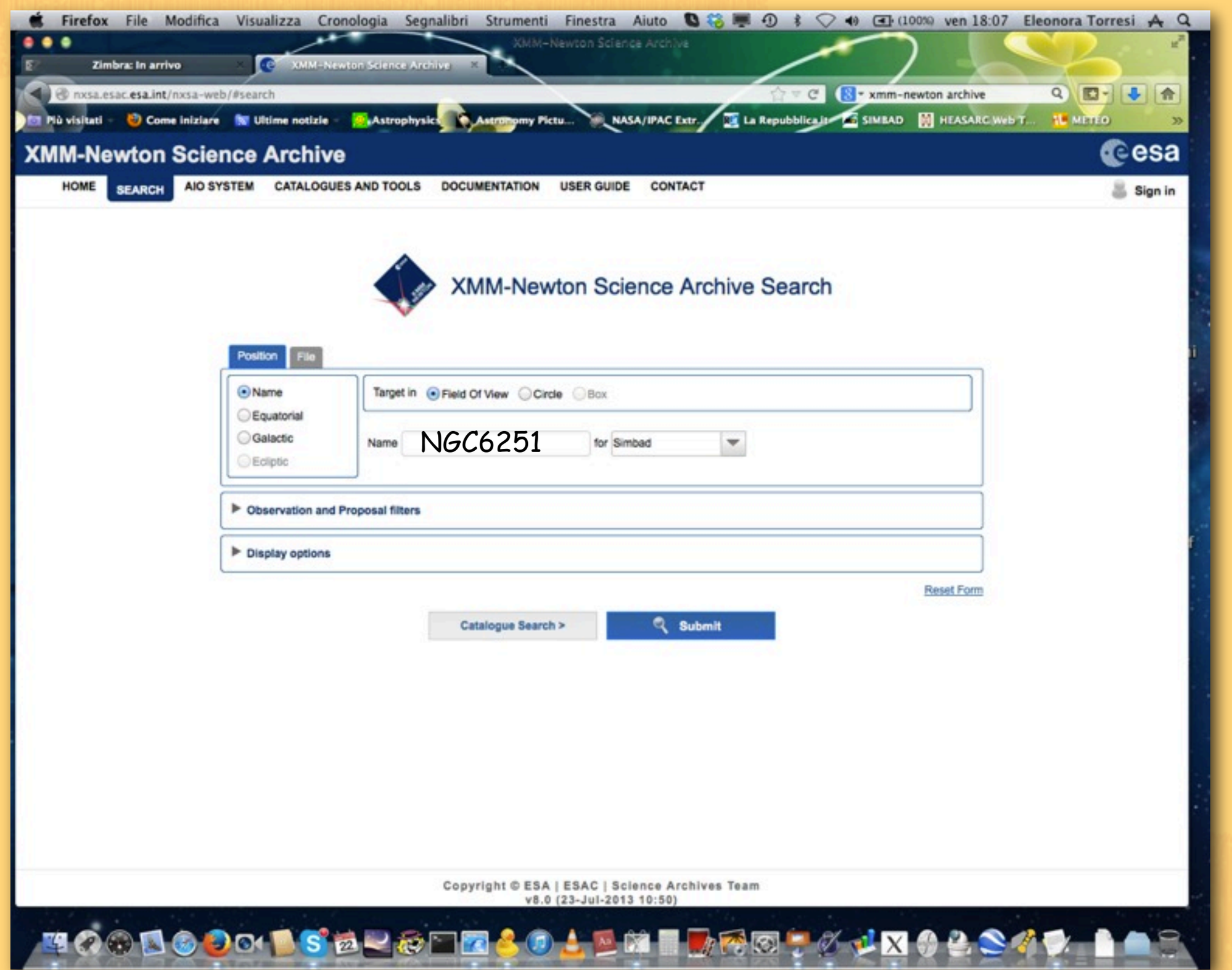

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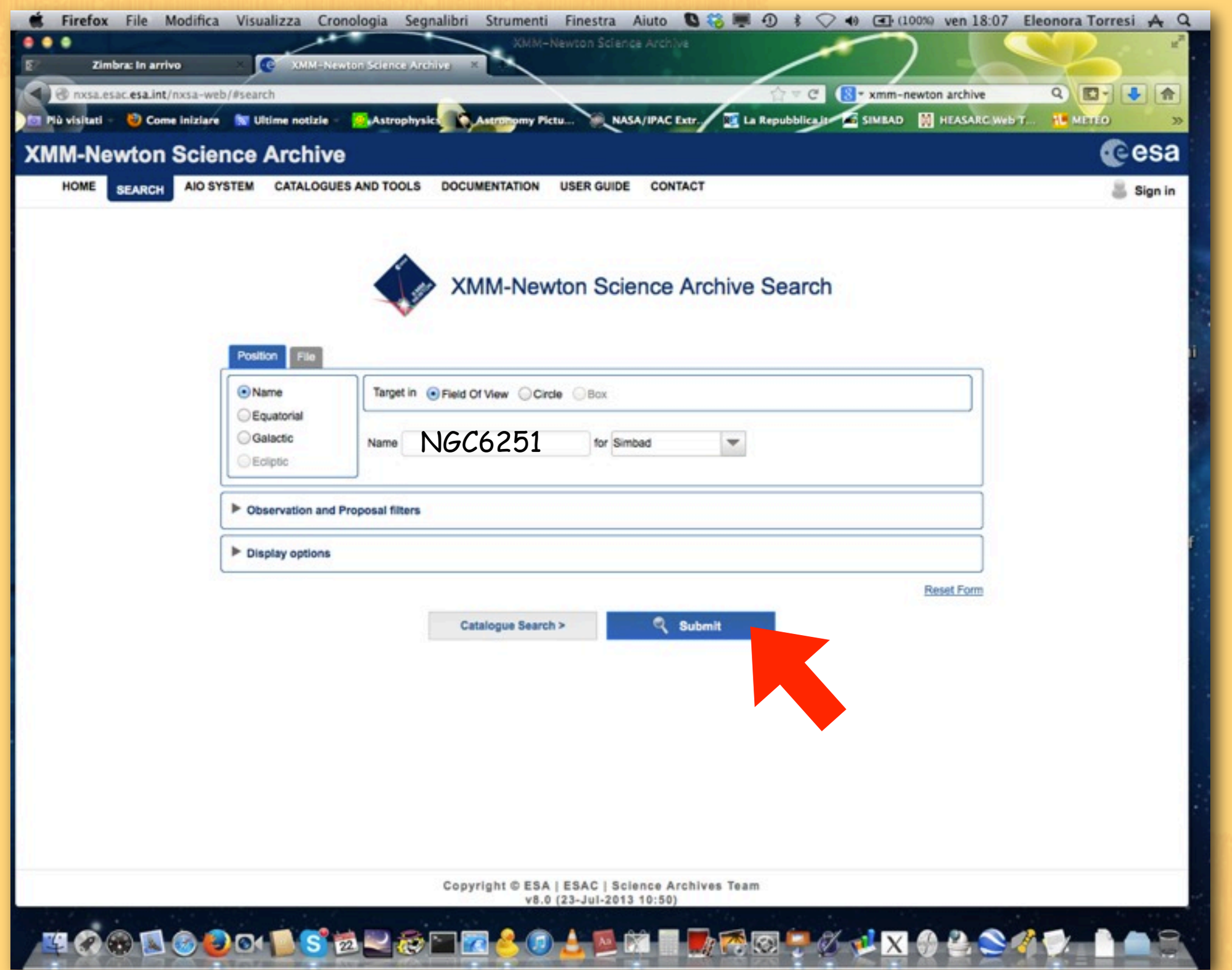

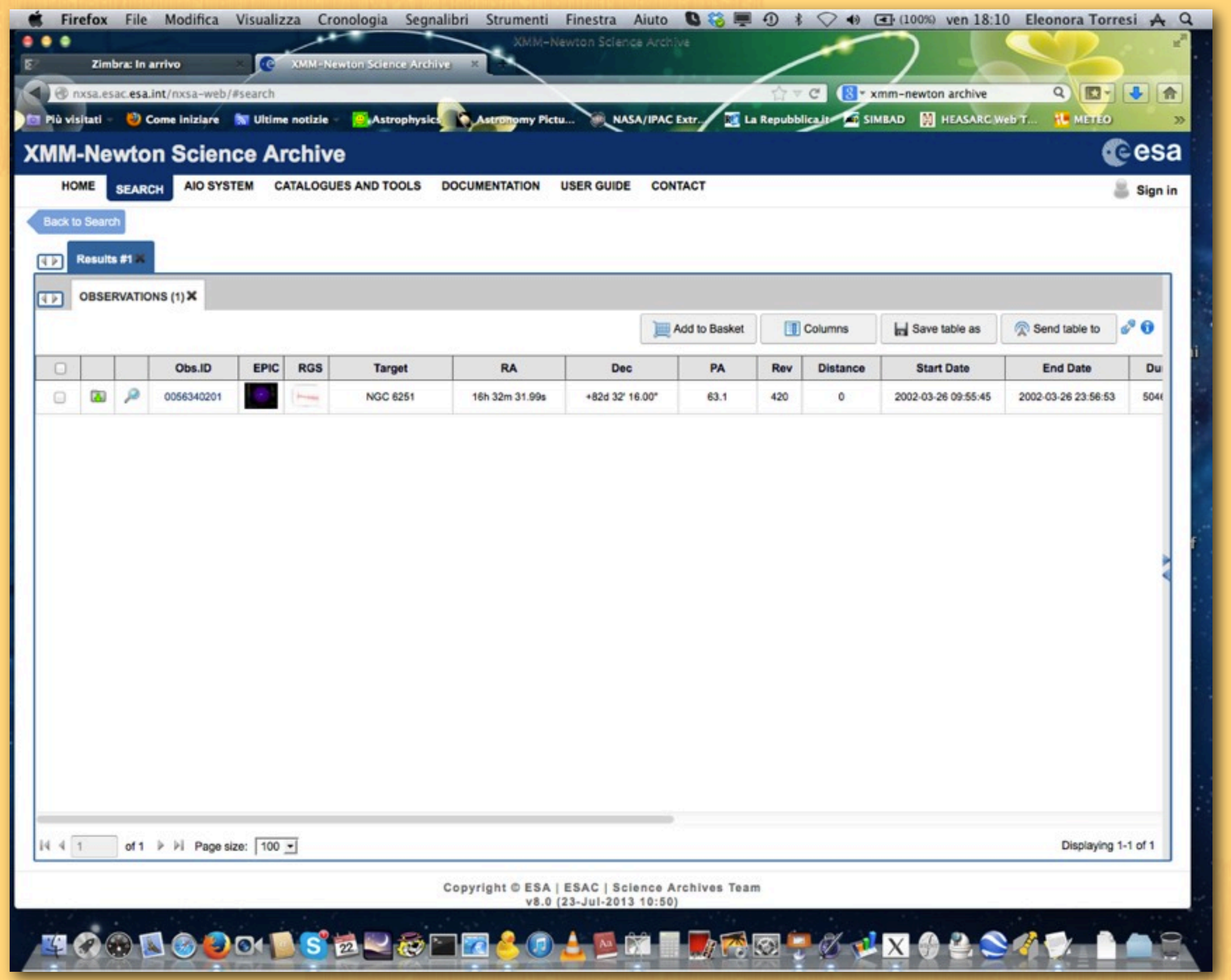
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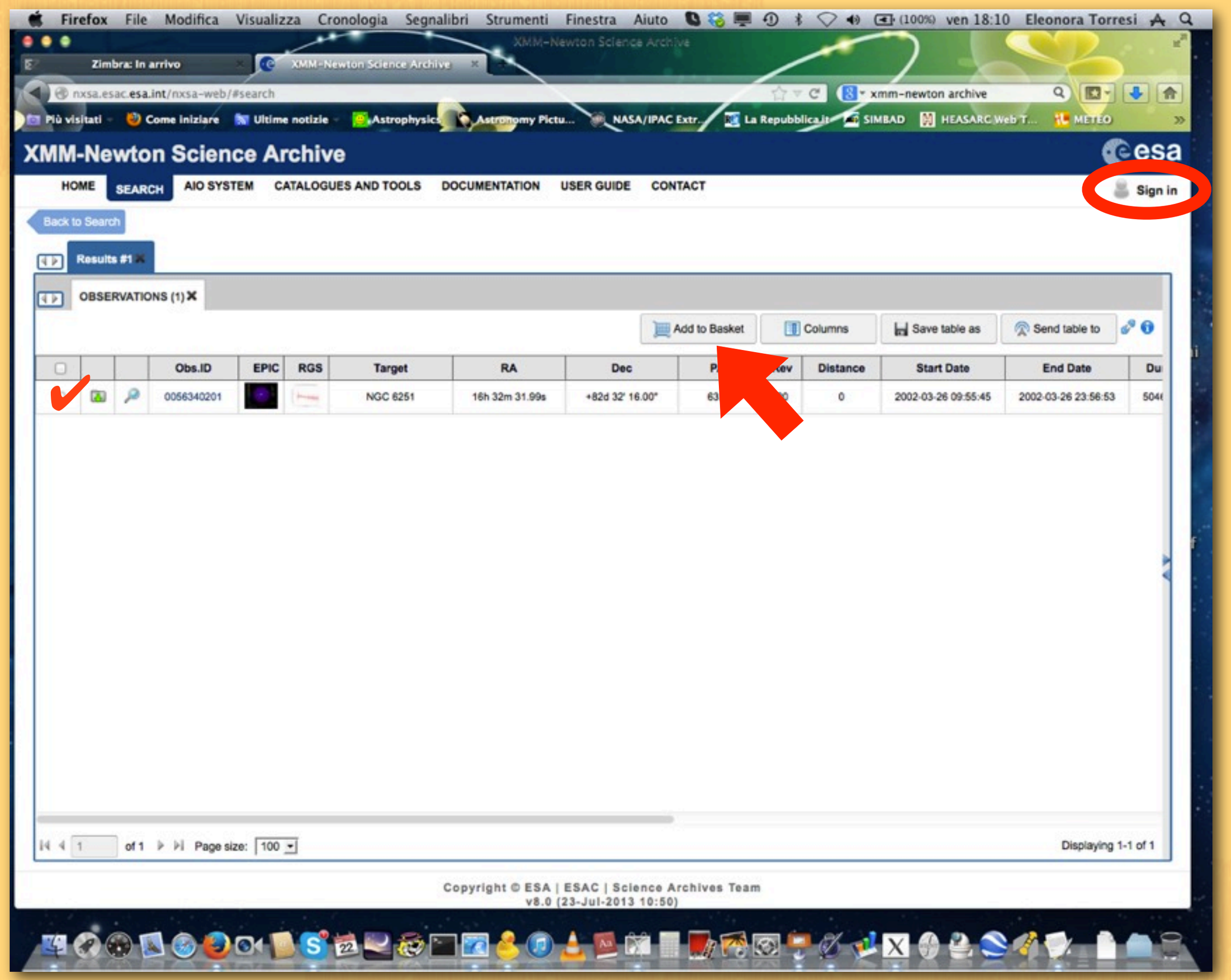
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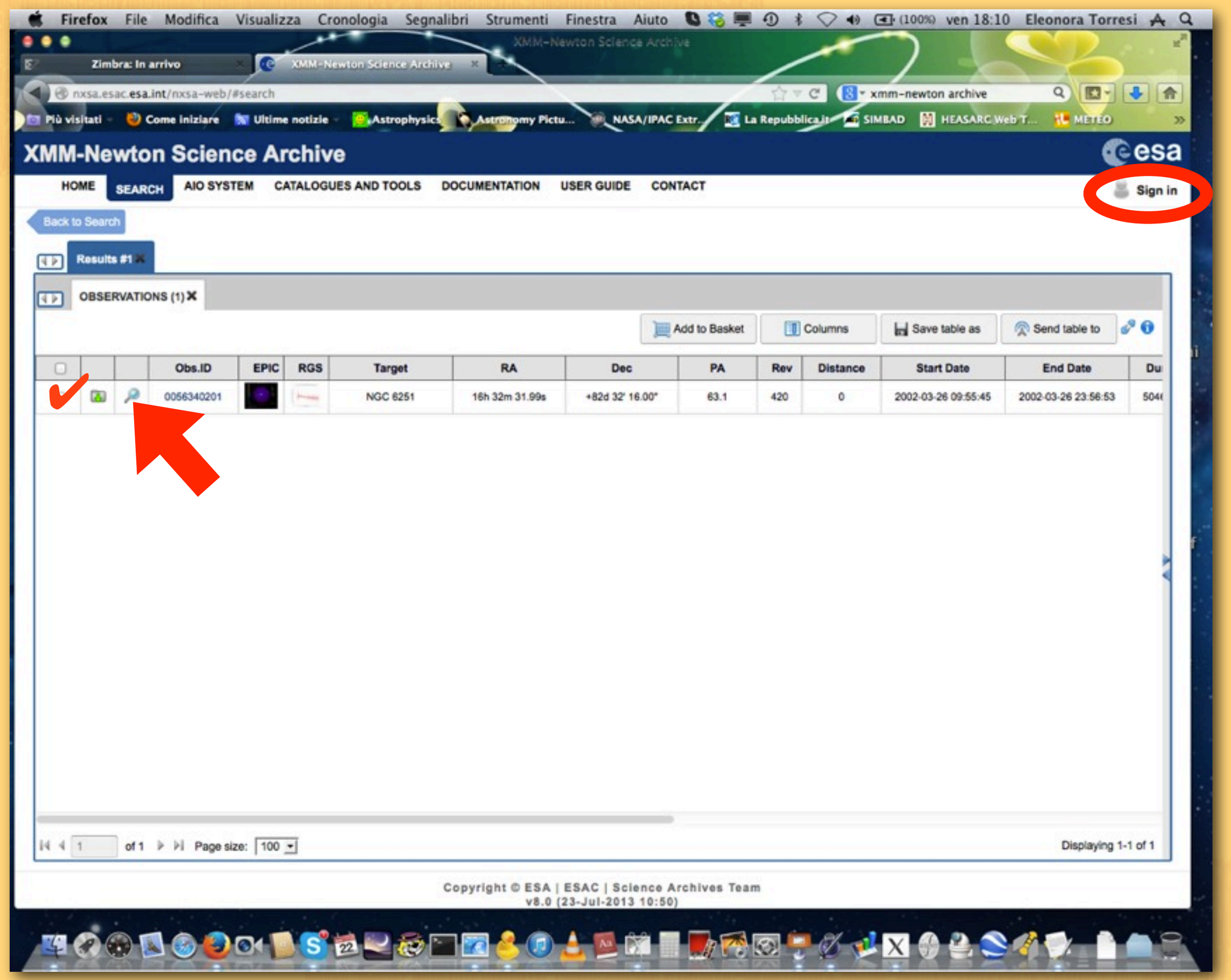
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NGC 6251
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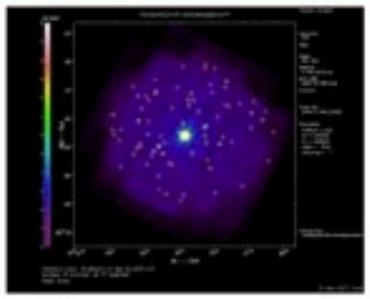

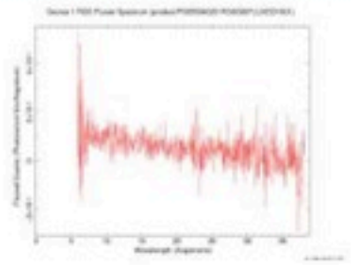

Summary | Exposures | Publications

Obs. ID	0056340201
Revolution	420
Target	NGC 6251
Exposures	3 EPIC, 40 OM, 2 RGS

Proposal Abstract

Most nearby galaxies host supermassive black holes, accreting at low rates in advection-dominated flows, or ADAFs. Depending on accretion rate and mass loss, hard X-ray continua and emission lines at soft and hard X-rays are expected in these systems. We propose XMM observations of the nearby low-power radio galaxies NGC 4261 and NGC 6251, the only radio-loud AGN, along with M87, hosting a supermassive black hole of known mass and where an ADAF may be occurring. Our proposed XMM observations will allow a detailed study of the hard X-ray continua and Fe lines detected in the ASCA data of NGC 4261 and NGC 6251, constraining the ADAF's dynamical and physical properties as a function of black hole mass and luminosity.

Show Quality Report

XMM-Newton payload

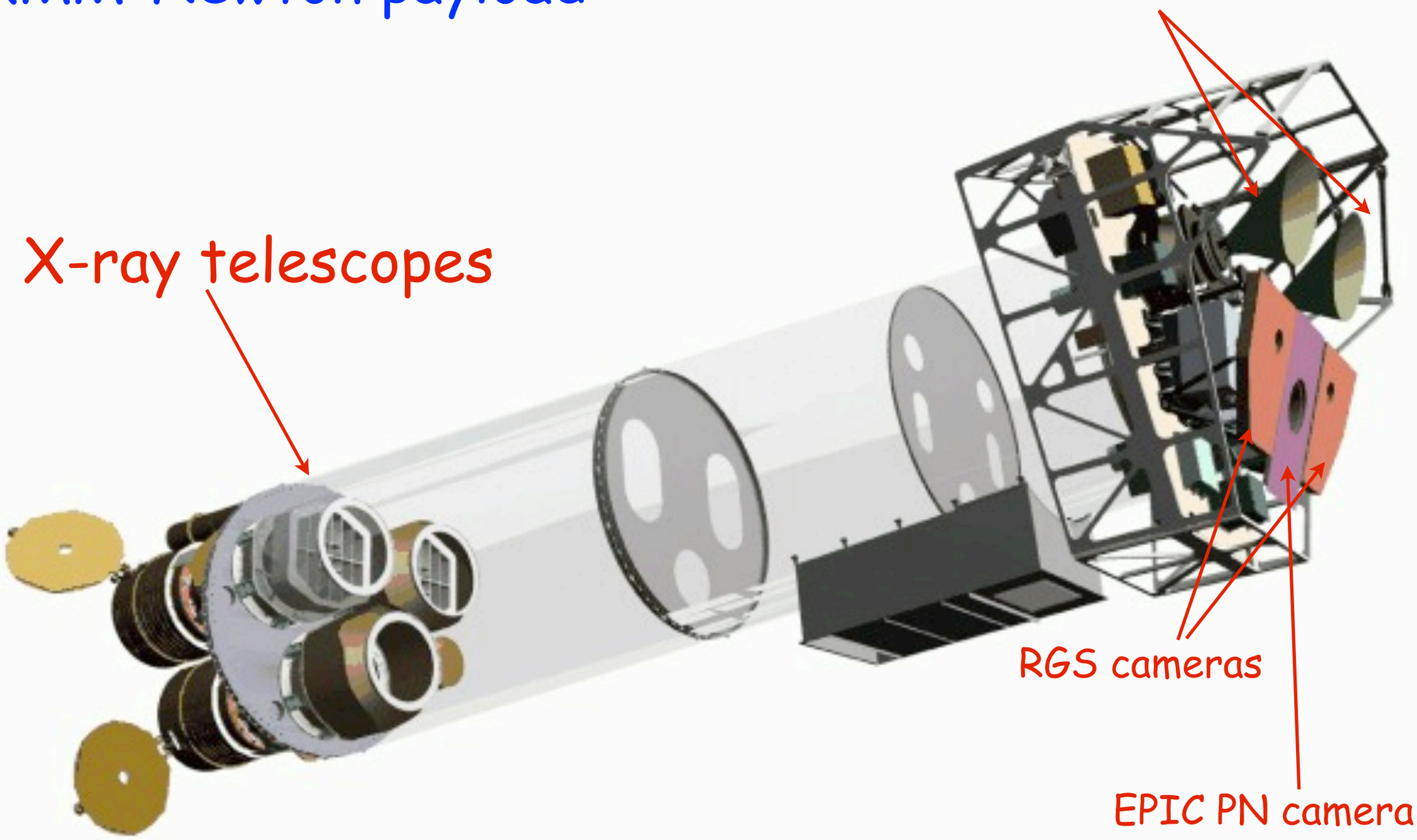

Image courtesy of Dornier Satellitensysteme GmbH and ESA

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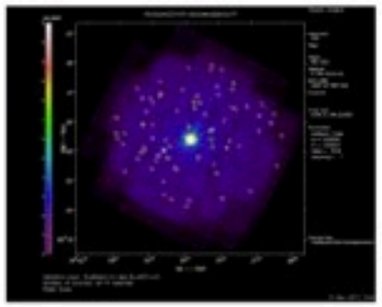

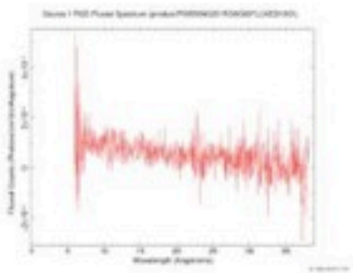

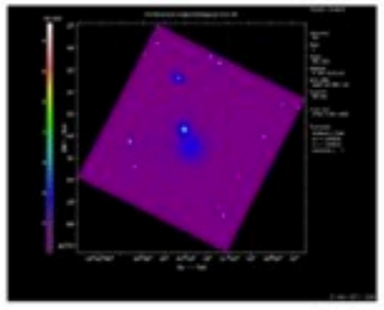

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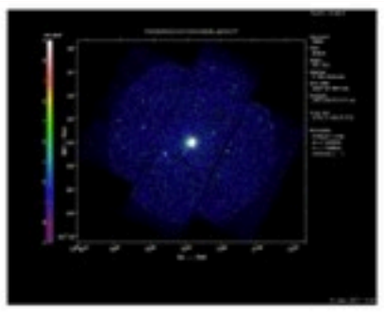
Filter	U



ExposureID	S001
Instrument	EMOS1
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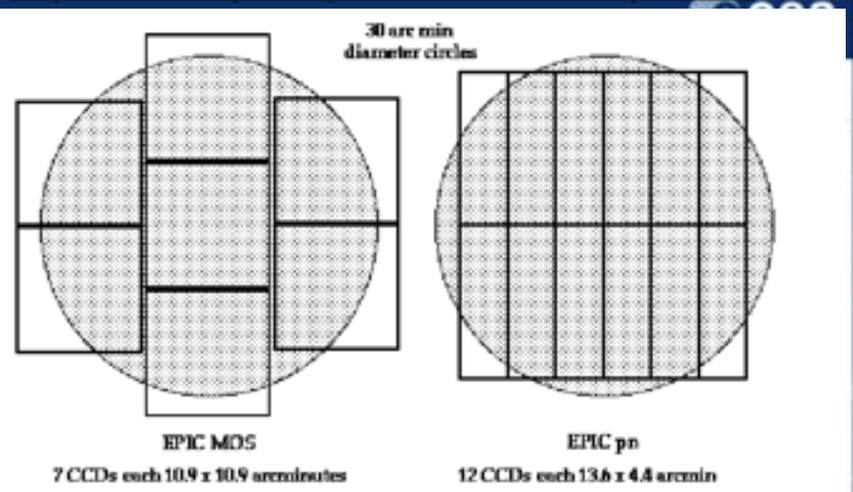
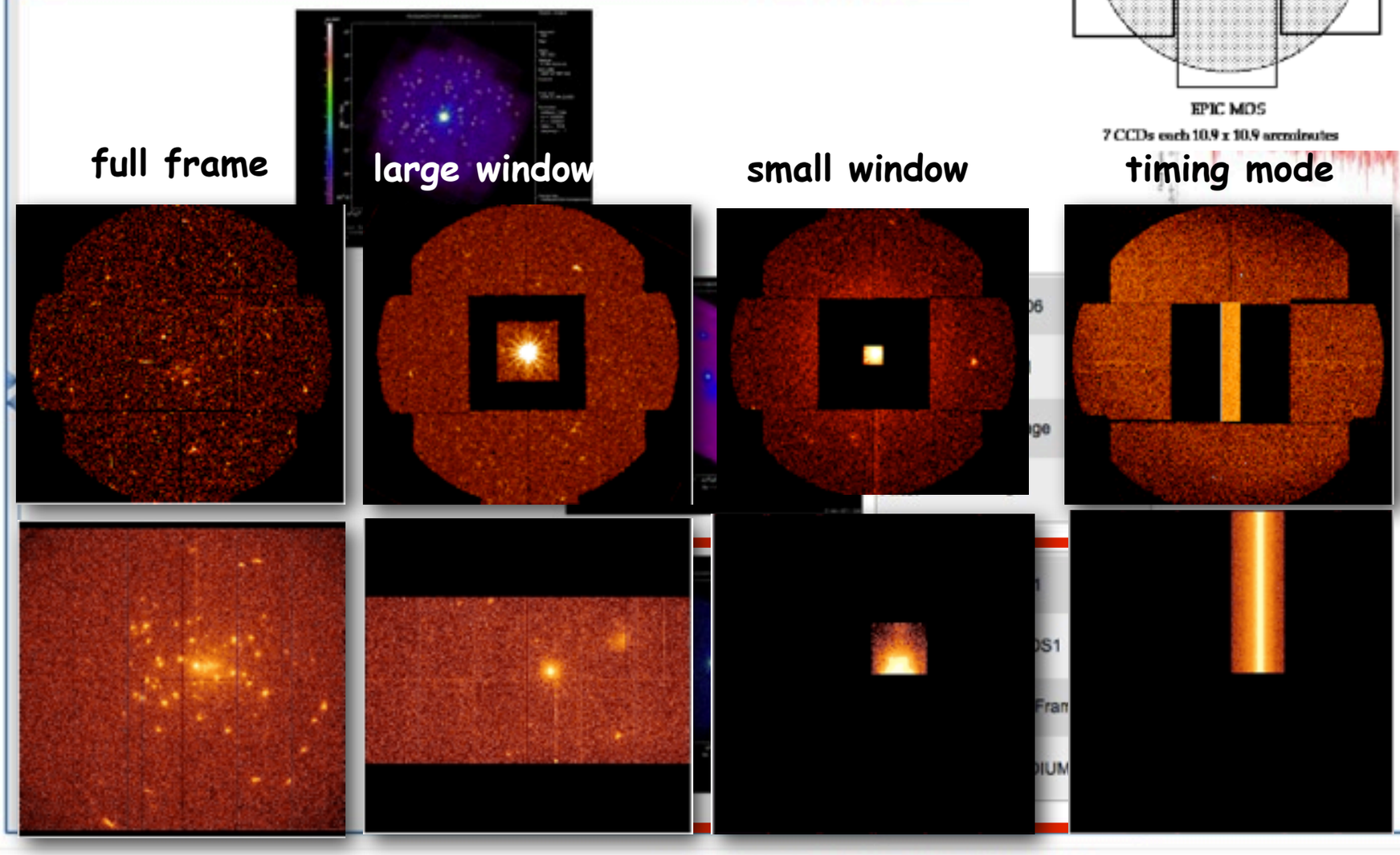
Details for Observation

Comparison of focal plane organisation of EPIC MOS and pn cameras



full frame | large window | small window | timing mode



MOS

pn

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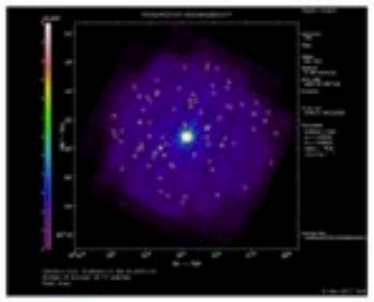
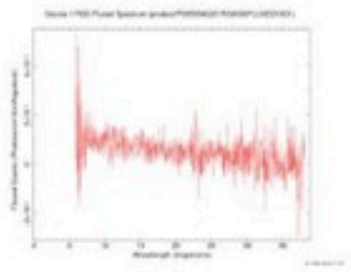
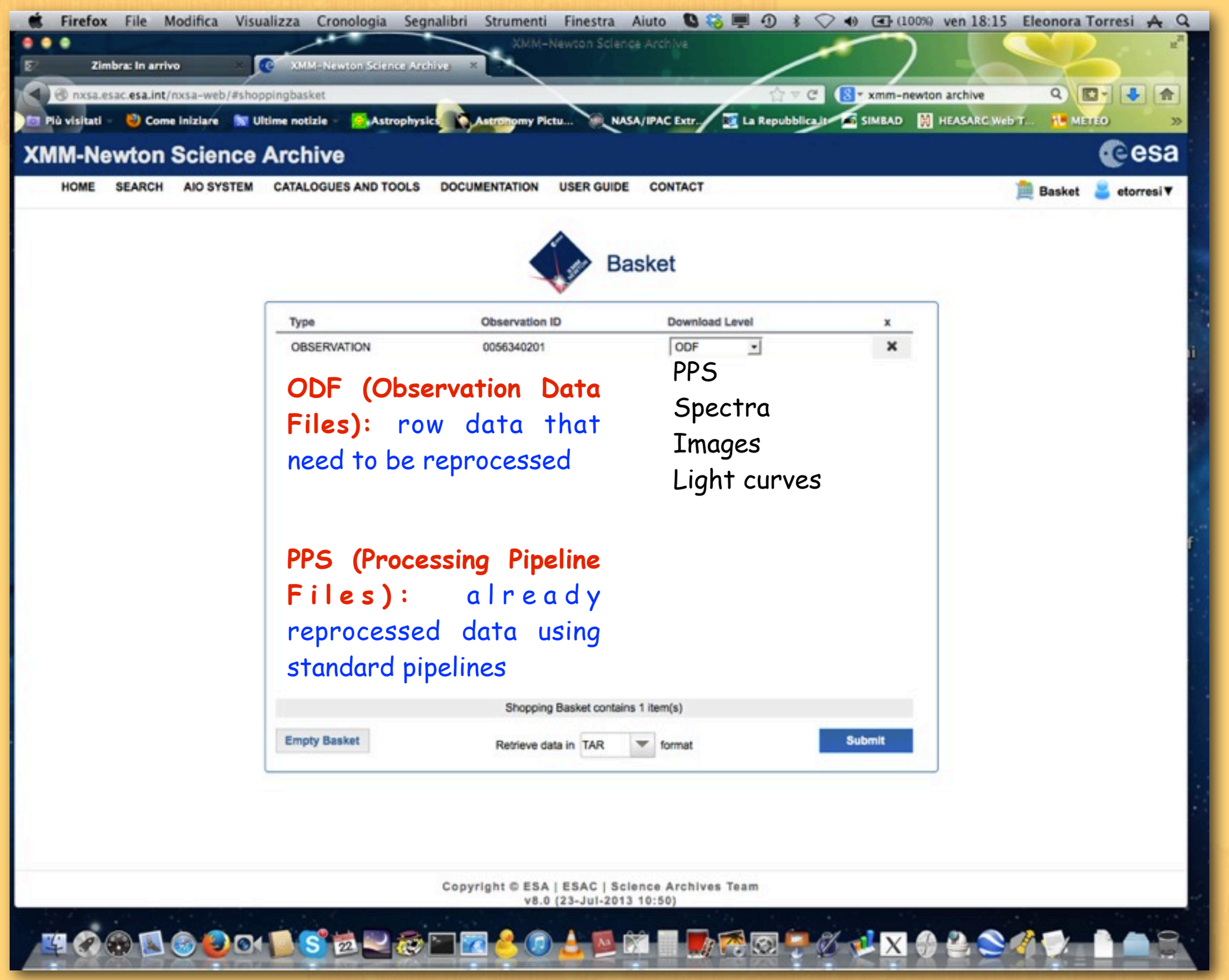




Summary | Exposures | Publications

Title	BibCode
Long-Term X-Ray Monitoring of NGC 6251: Evidence for a Jet-dominated Radio Galaxy	2008ApJ...678...78G
An XMM-Newton study of the environments, particle content and impact of low-power radio galaxies	2008MNRAS.386.1709C
The XMM-Newton view of the X-ray halo and jet of NGC 6251	2004A&A...414..885S
The XMM-Newton view of NGC 6251	2004A&A...413..139G
XMM-Newton observations of a sample of gamma-ray loud active galactic nuclei	2006A&A...453..829F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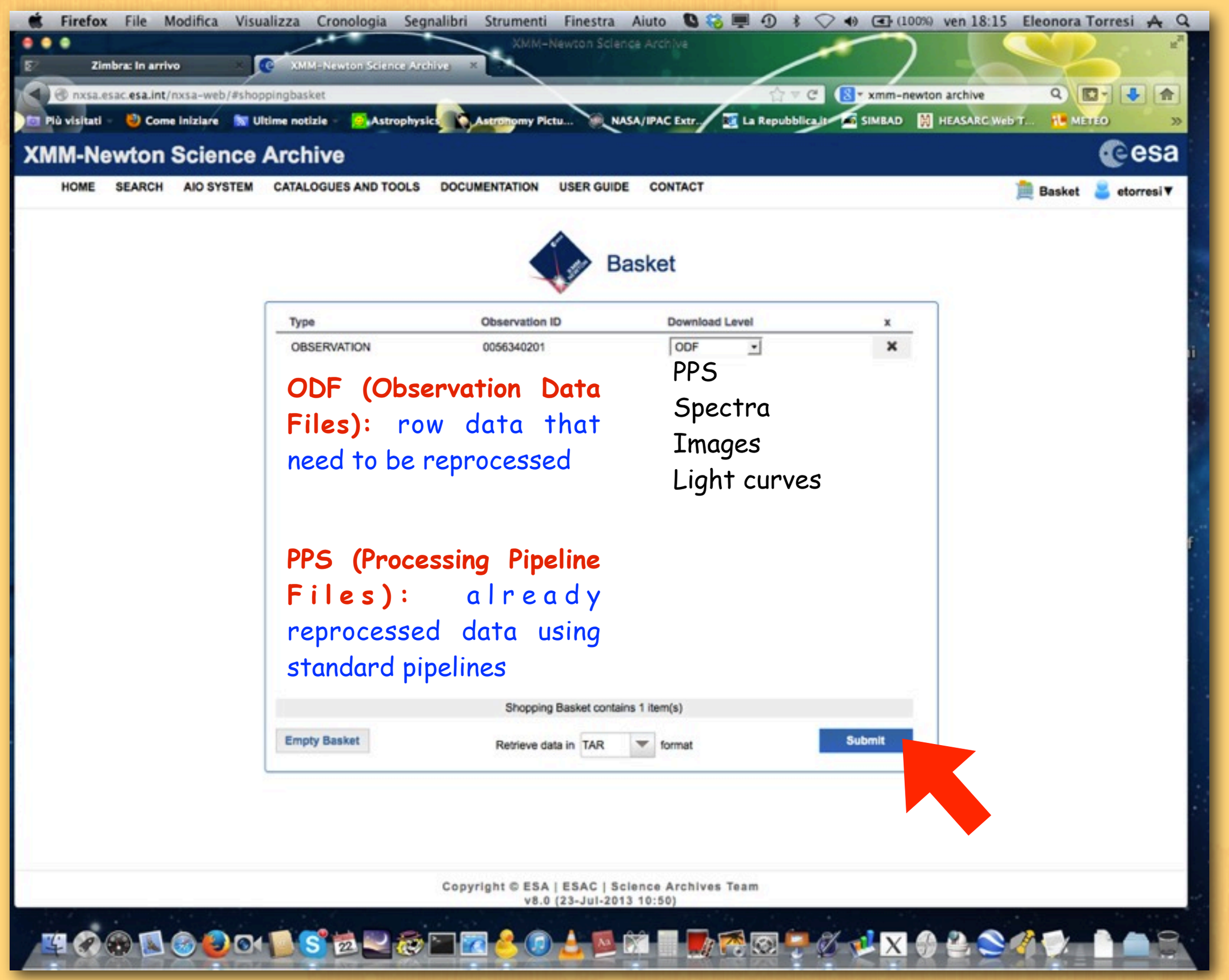
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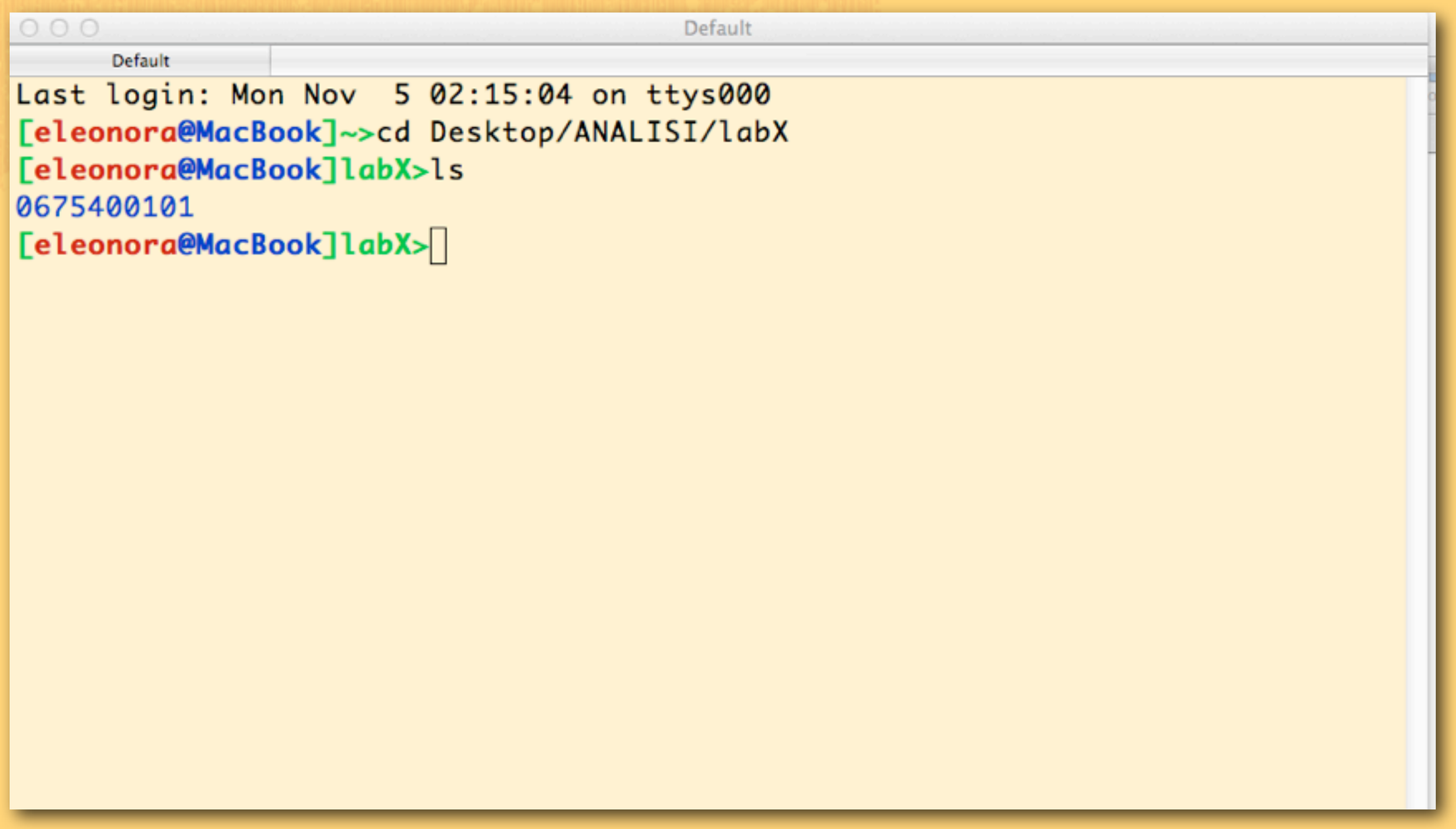
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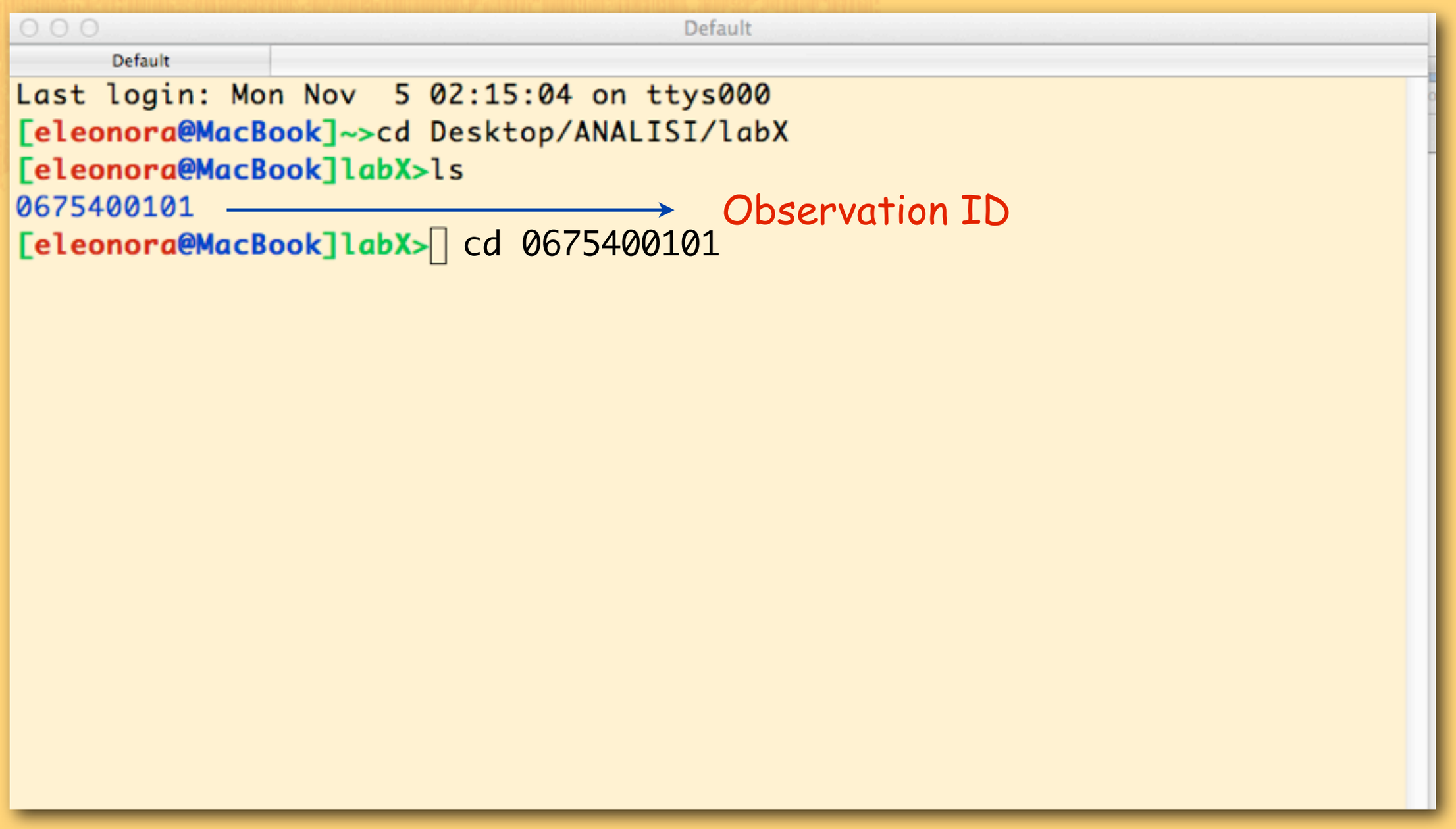
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Revolution number

FITS files

ObsID

Instrument (pn, MOS1, MOS2)

Content

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

FITS files

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

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 nomefile.fits
```

FITS files

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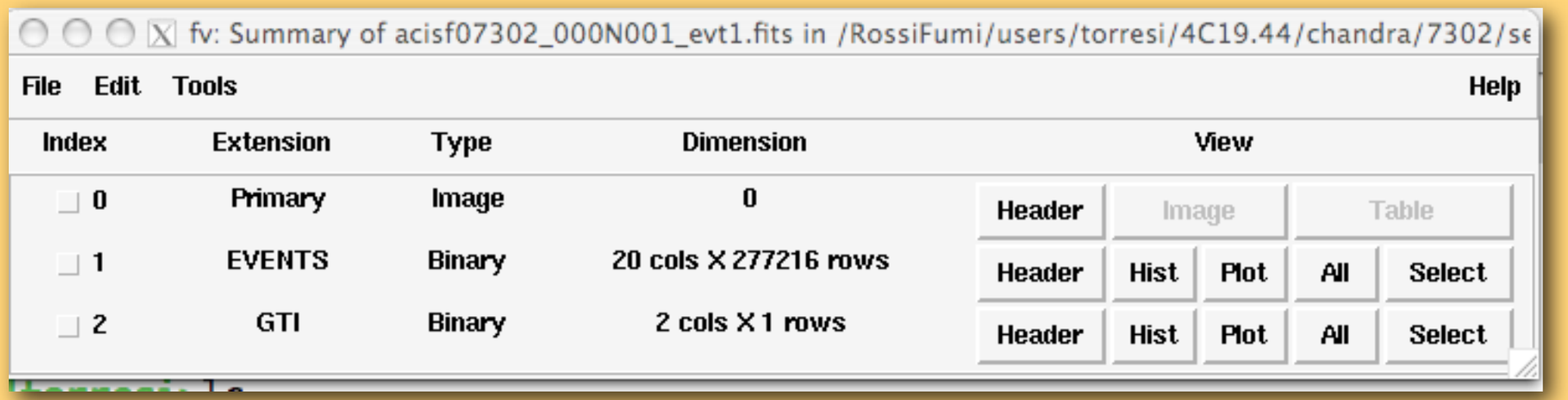
You can visualize it by using the FTOOL command fv:

> fv nomefile.fits



FITS files

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

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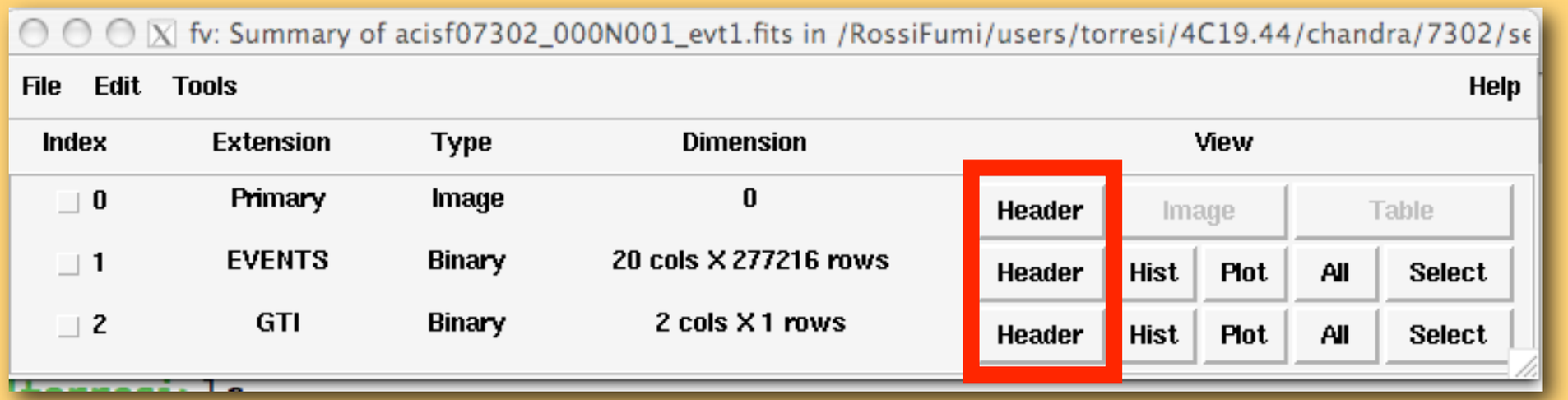

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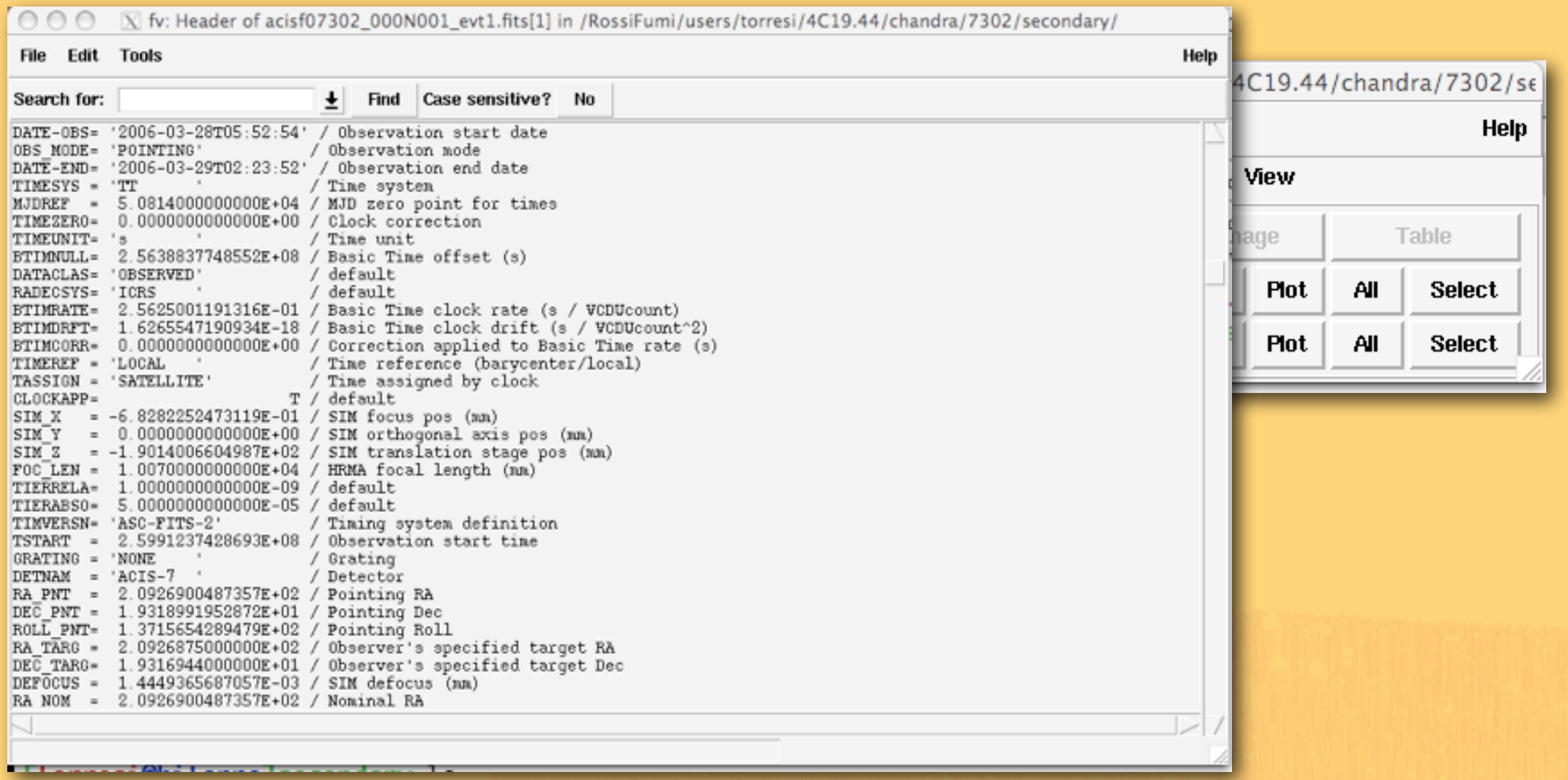

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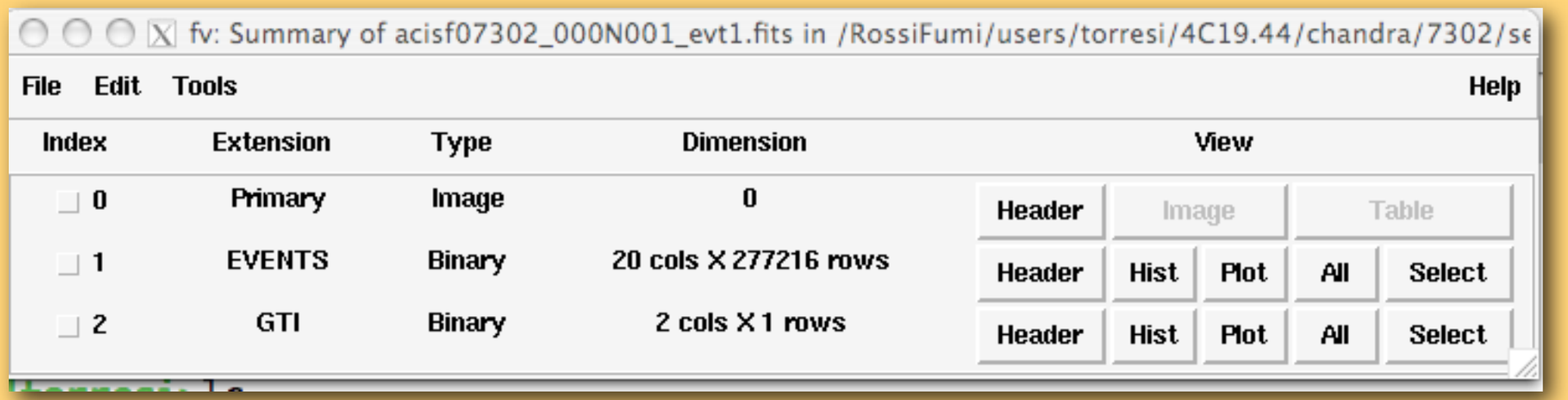

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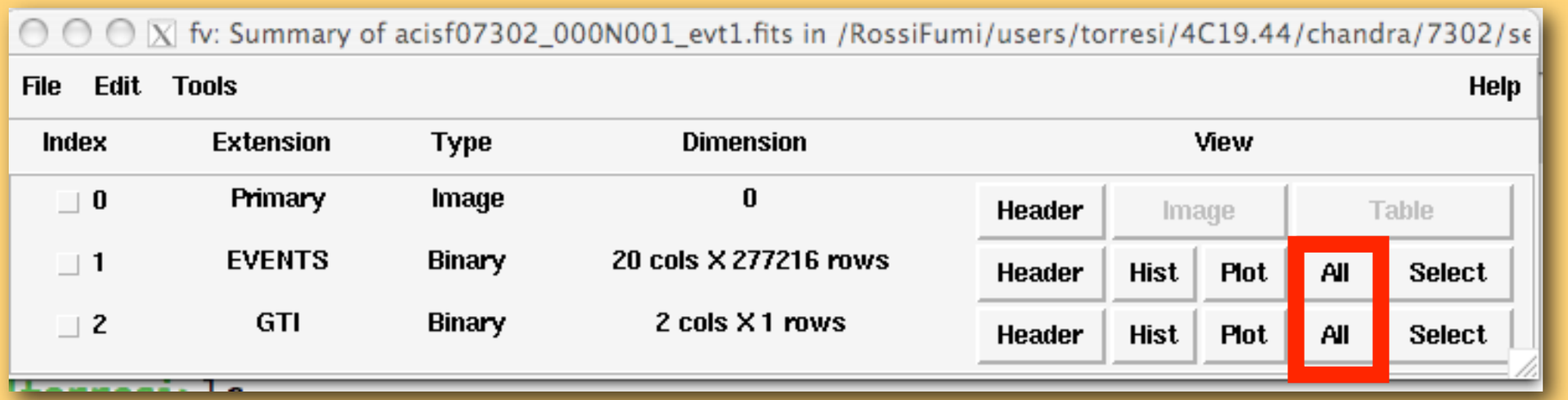

FITS files

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You can visualize it by using the FTOOL command fv:

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

File Edit Tools

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

andra/7302/se

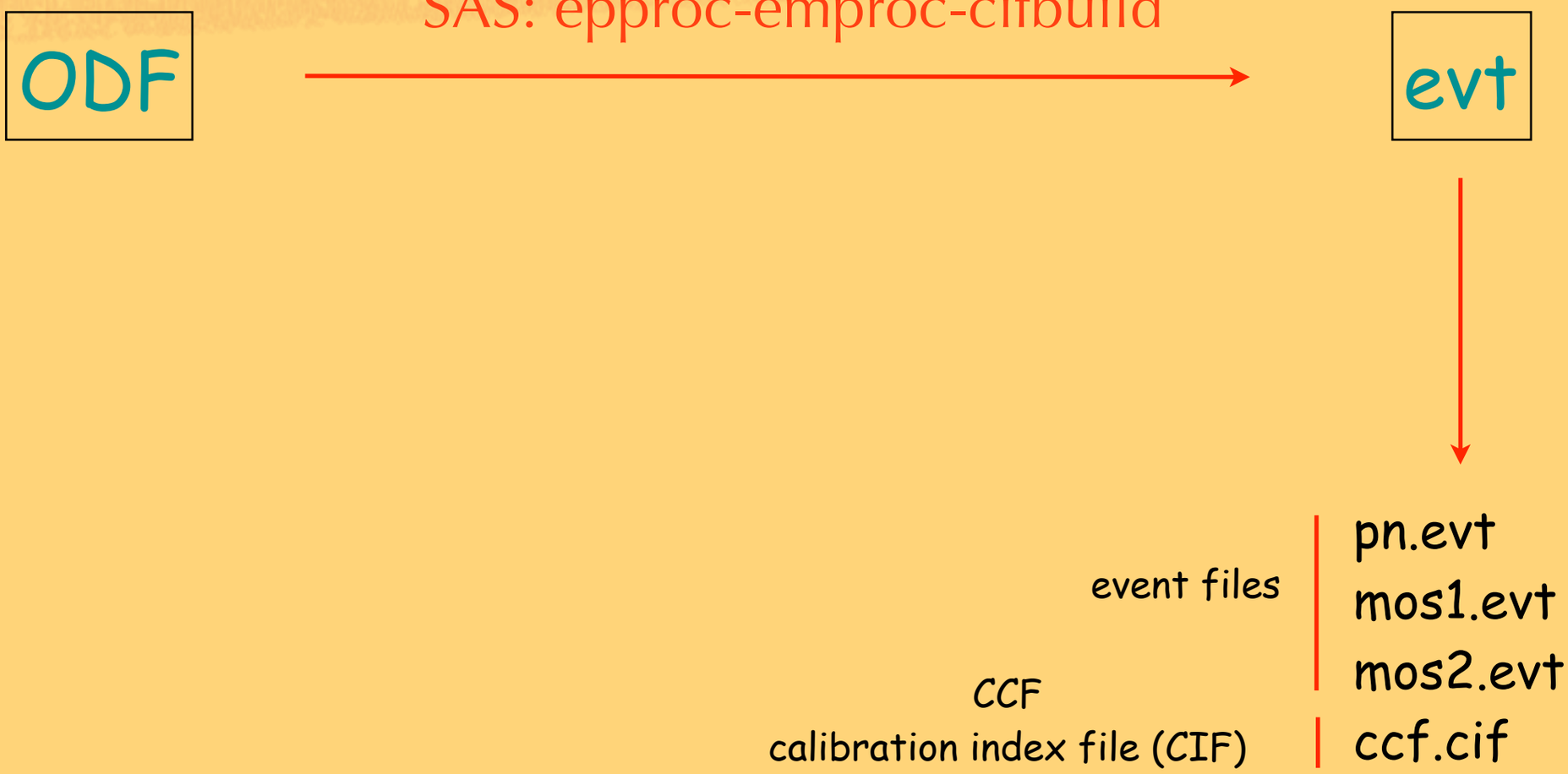
Help

Table

Select

Select

Creation of event files



> pn, MOS1 and MOS2 data reduction

After reprocessing the row data you are ready to start the reduction

> pn, MOS1 and MOS2 data reduction

After reprocessing the row data you are ready to start the reduction

1. Extract of a high energy light curve (>10 keV) to identify interval of flaring particle background

EPIC background

EPIC background

Cosmic X-ray background

Instrumental background

detector noise component
(important below 300 eV)

second component due to the interaction of particles with the detectors and the structures surrounding them
(important at high energies, e.g. above a few keV)

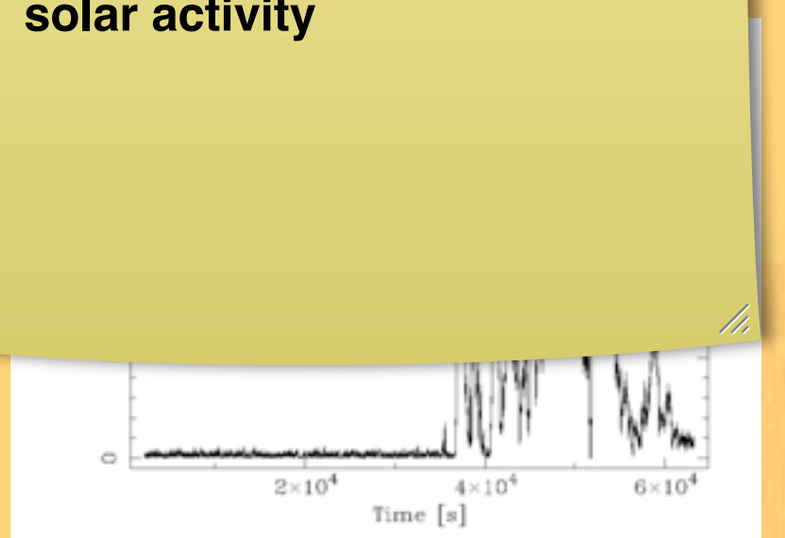
For more information refer to the XMM-Newton User's Handbook

EPIC particle induced background

External 'flaring' component

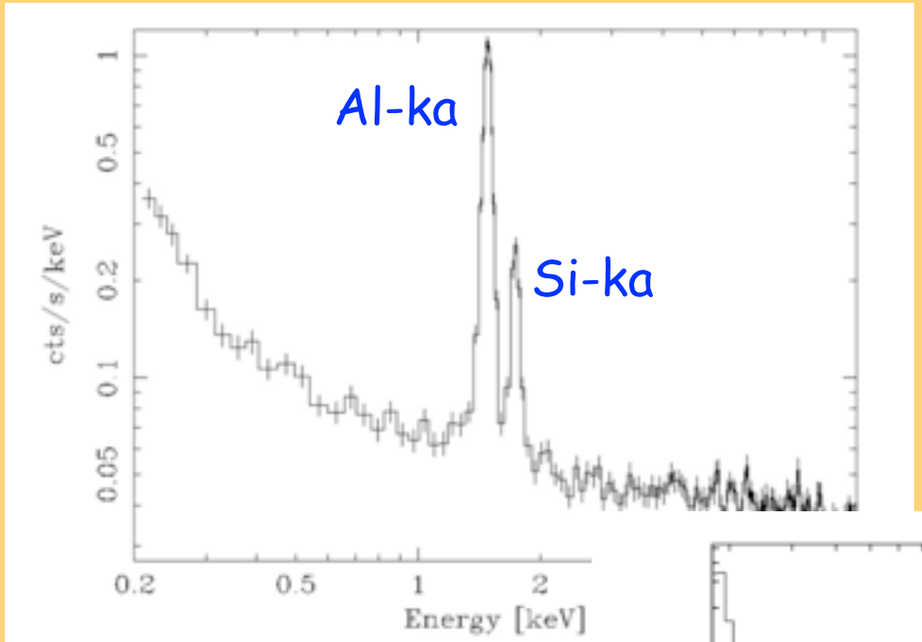
strong and rapid

The current understanding is that soft protons are most likely organised in **clouds populating the Earth's magneto-sphere.** The number of such clouds encountered by XMM-Newton in its orbit depends upon many factors, such as the **altitude of the satellite**, its **position with respect to the magneto-sphere,** and the **amount of solar activity**



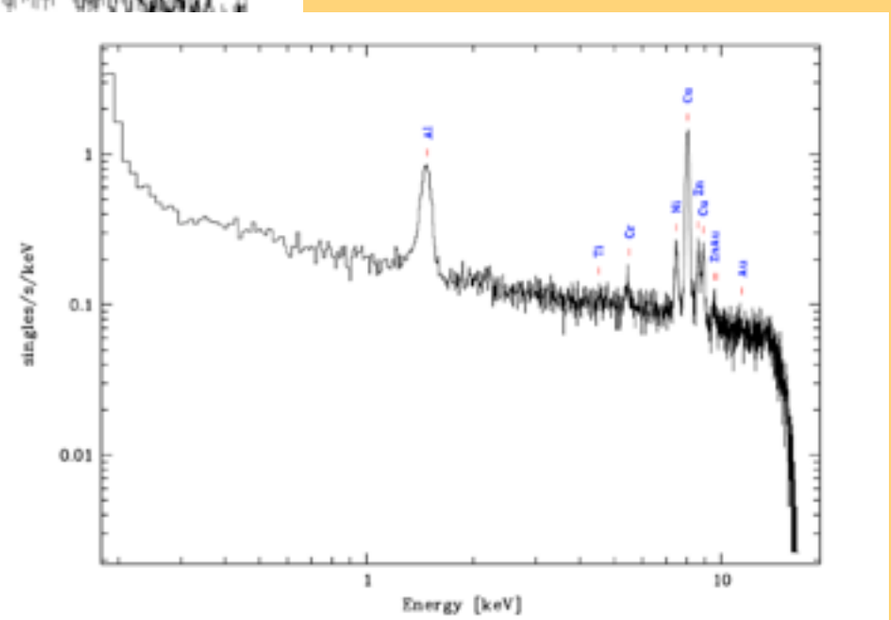
Internal 'quiescent' component

high energy particles interacting with the structure surrounding the detectors and the detectors themselves



MOS1

pn



> pn, MOS1 and MOS2 data reduction

After reprocessing the row data you are ready to start the reduction

1. Extract of a high energy light curve to identify interval of flaring particle background

```
evselect table=pn.evt energycolumn=PI expression='#XMMEA_EP && (PI>10000) && (PATTERN==0)' withrateset=yes rateset="lcurve_sup10.lc" timebinsize=100 maketimecolumn=yes makeratecolumn=yes
```

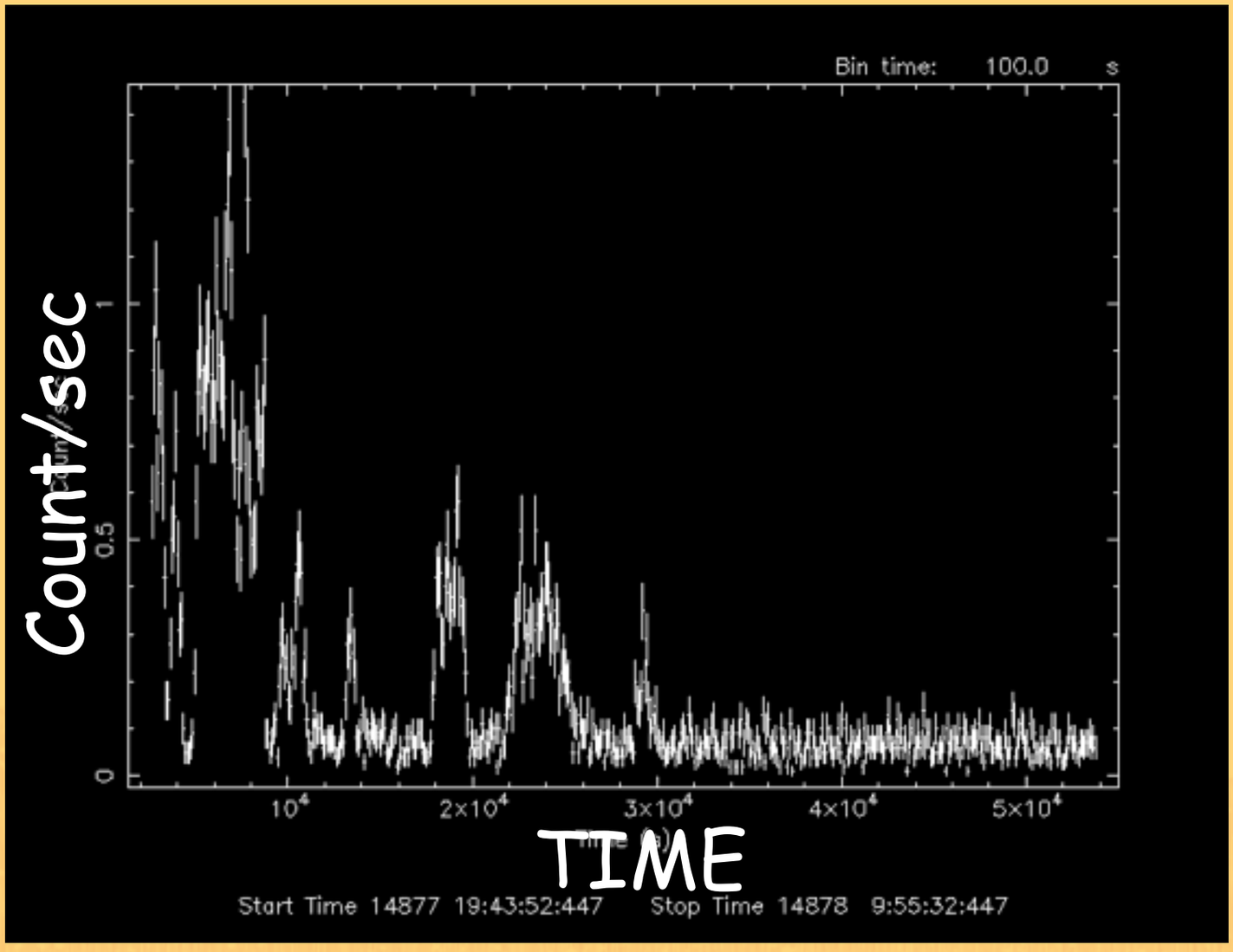
> pn, MOS1 and MOS2 data reduction

After reprocessing the row data you are ready to start the reduction

1. Check for the presence of soft proton flares above 10 keV

```
evselect table=pn.evt energycolumn=PI expression='#XMMEA_EP && (PI>10000)
&&    (PATTERN==0)'    withrateset=yes    rateset="lcurve_sup10.lc"
timebinsize=100 maketimecolumn=yes makeratecolumn=yes
```

Light curve above 10 keV



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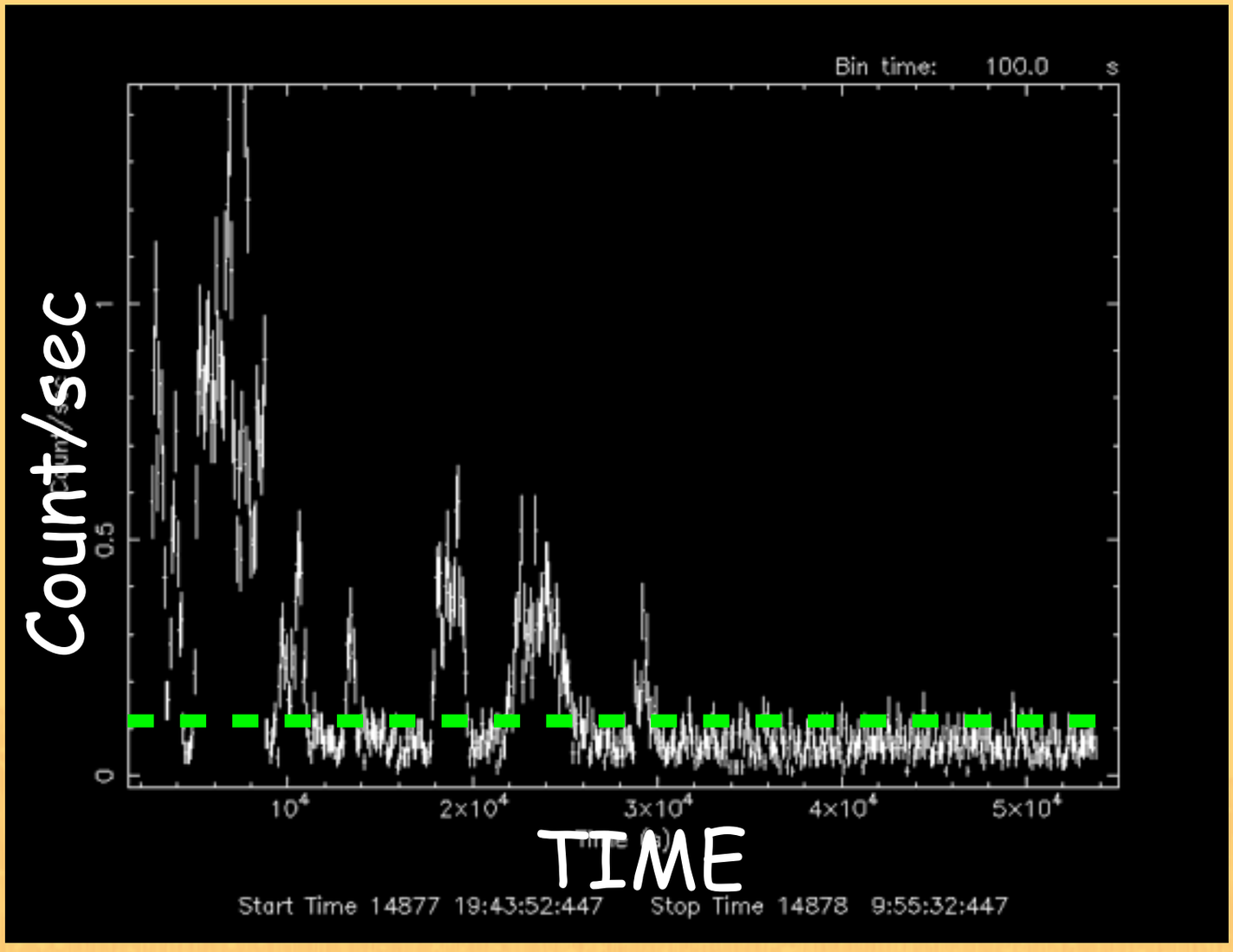
&&    (PATTERN==0)'    withrateset=yes    rateset="lcurve_sup10.lc"
timebinsize=100 maketimecolumn=yes makeratecolumn=yes
```

Light curve above 10 keV

pn < 0.4 cts/s
MOS < 0.35 cts/s



> pn, MOS1 and MOS2 data reduction

2. Selection of Good Time Intervals (GTI)

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```
tabgtigen table=lcurve_sup10.lc gtiset=good_bkg.gti expression='RATE<'
```

> pn, MOS1 and MOS2 data reduction

2. Selection of Good Time Intervals (GTI)

```
tabgtigen table=lcurve_sup10.lc gtiset=good_bkg.gti expression='RATE<'
```

3. Generation of the cleaned event file

```
evselect table=pn.evt expression='#XMMEA_EP (EM) && (PI > 150) &&
(GTI(good_bkg.gti,TIME))' withfilteredset=yes keepfilteroutput=yes
filteredset=pn_new.evt(mos1_new.evt)updateexposure=yes cleandss=yes
writedss=yes
```

> pn, MOS1 and MOS2 data reduction

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```

pn_new.evt
mos1_new.evt
mos2_new.evt

> pn, MOS1 and MOS2 data reduction

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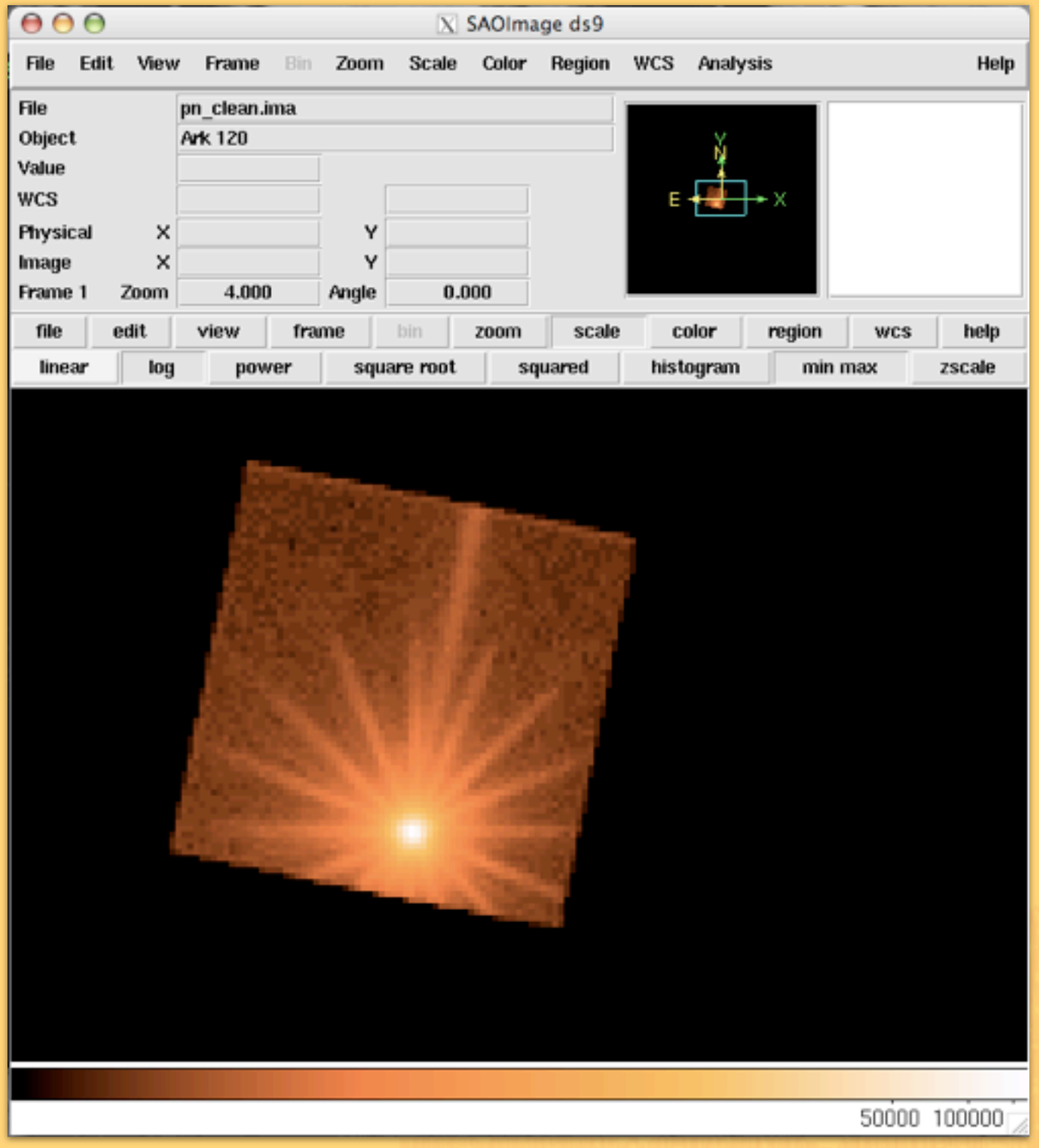
writedss=yes
```

pn_new.evt
mos1_new.evt
mos2_new.evt

You start here!

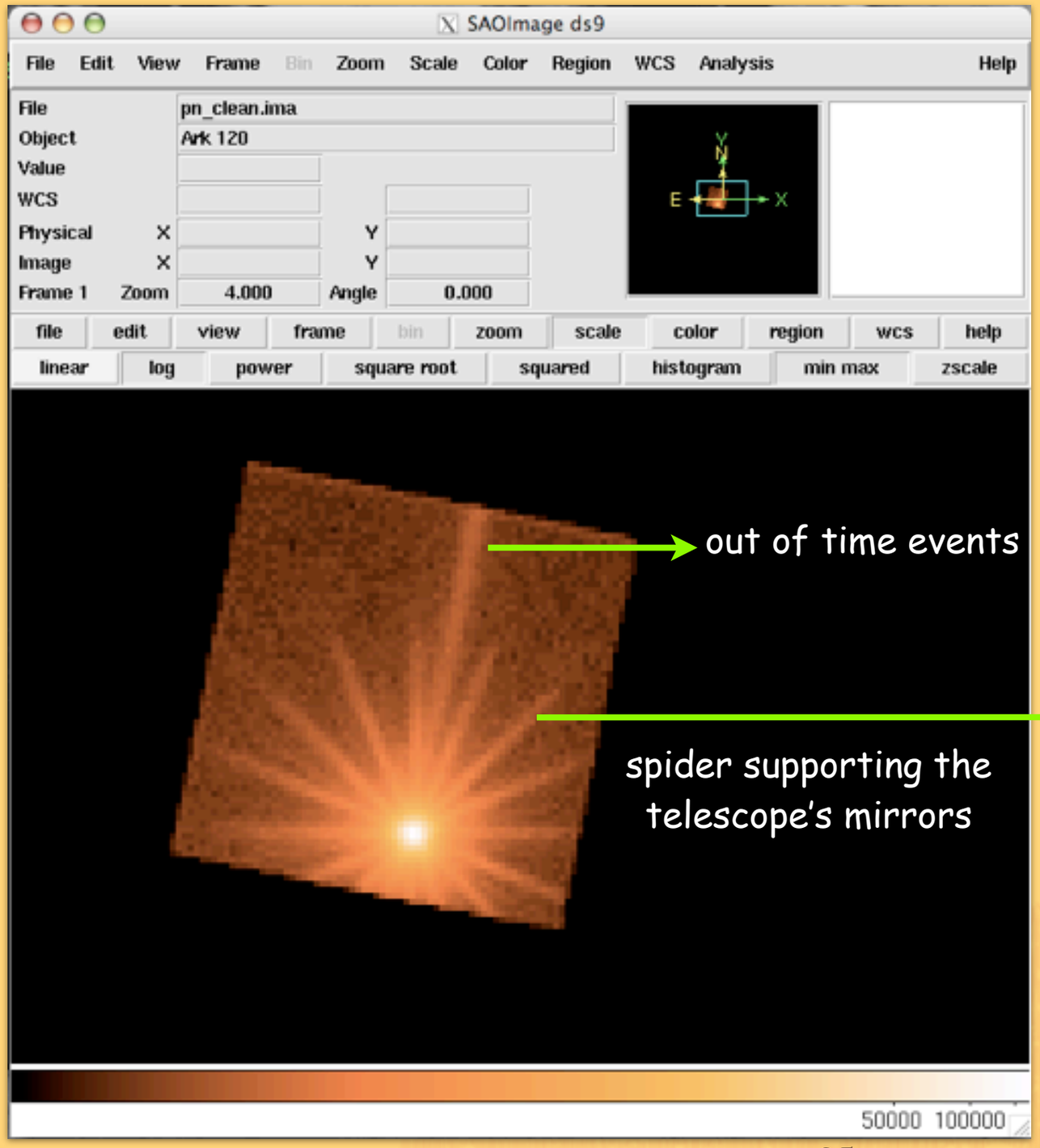
4. Source and background regions selection

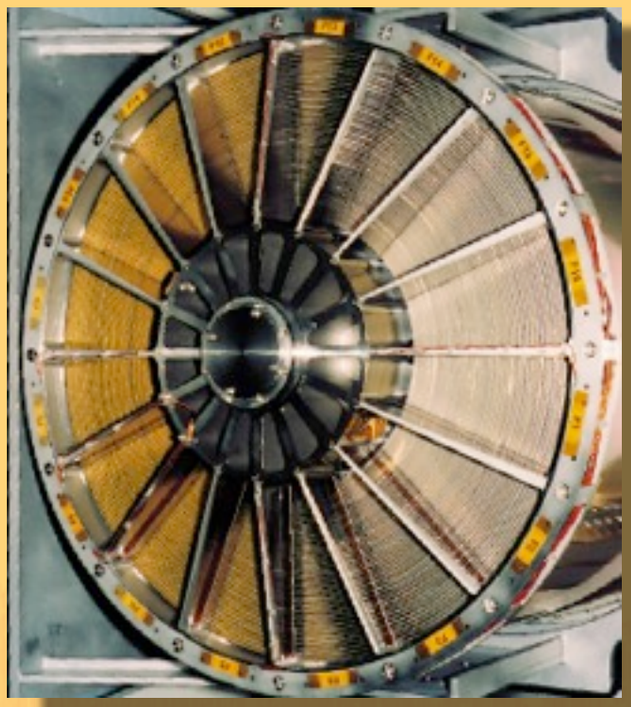
open event list file with ds9 `> ds9 pn_new.evt`



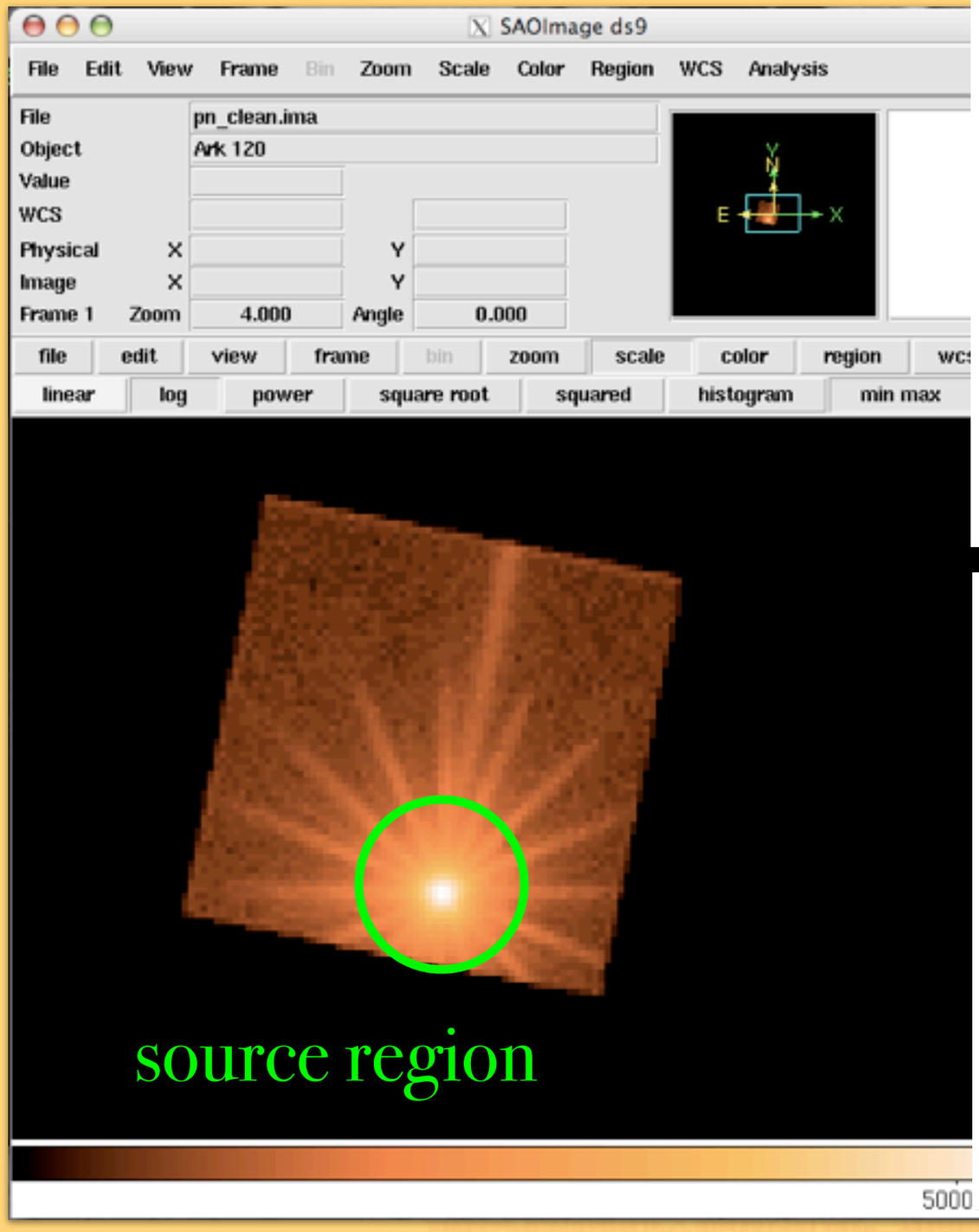
4. Source and background regions selection

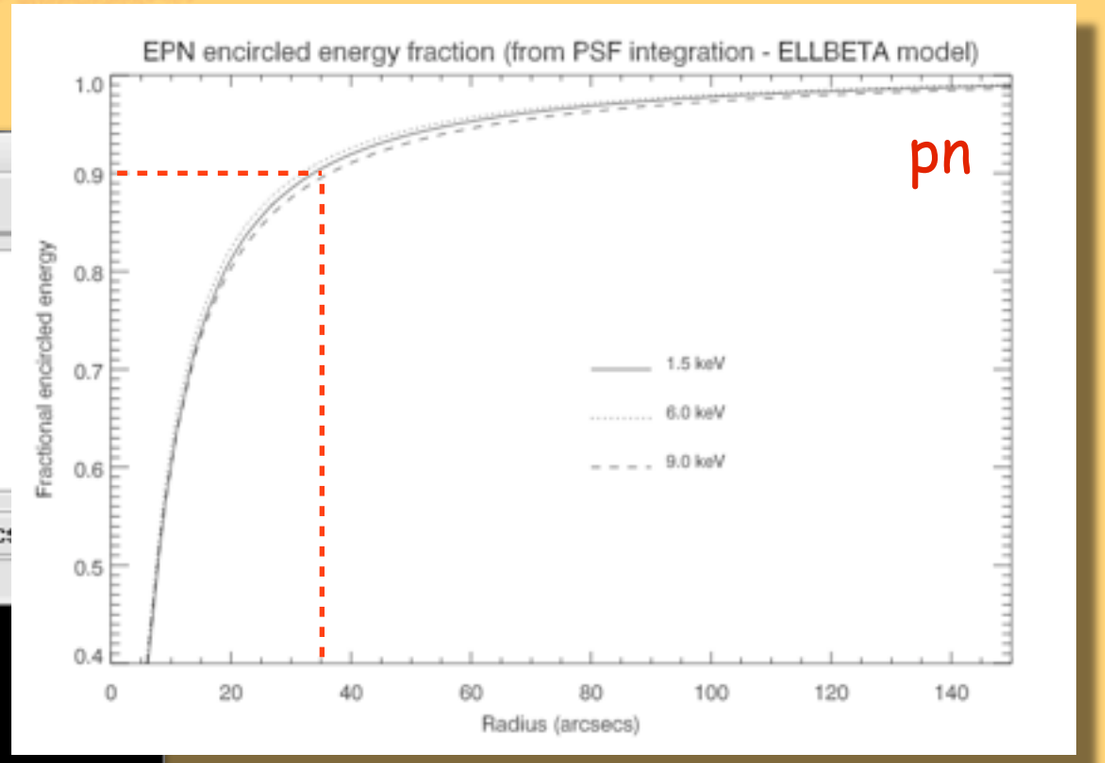
open event list file with ds9 > ds9 pn_new.evt

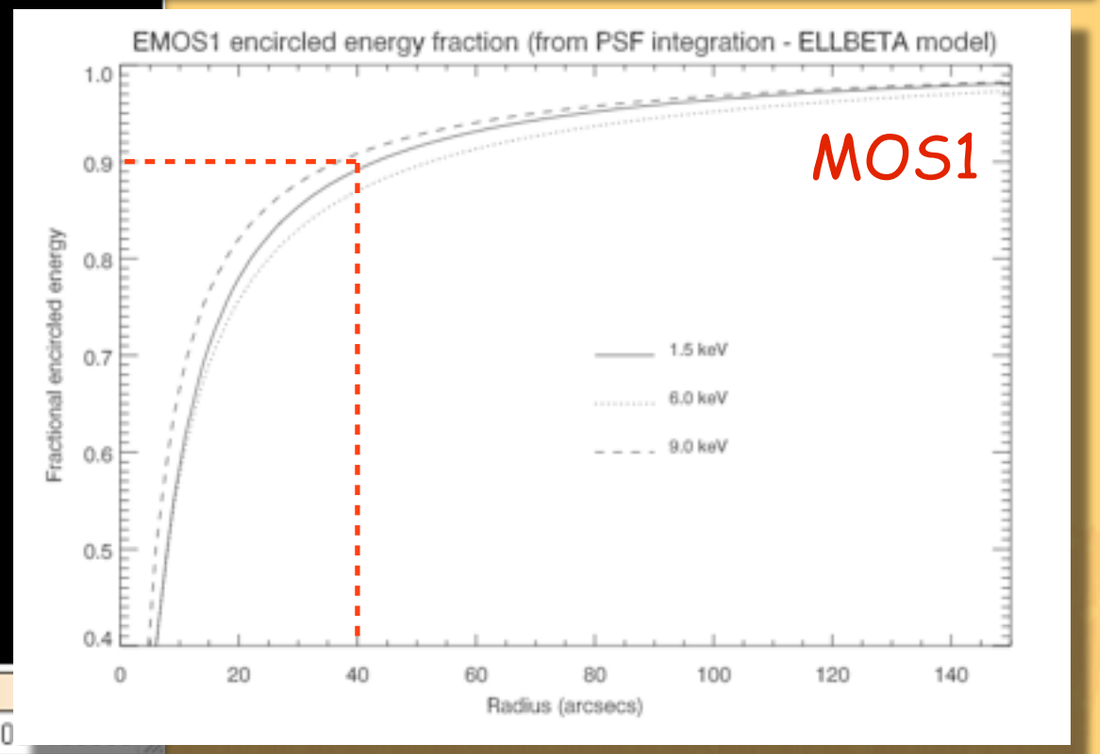




4. Source and background regions selection

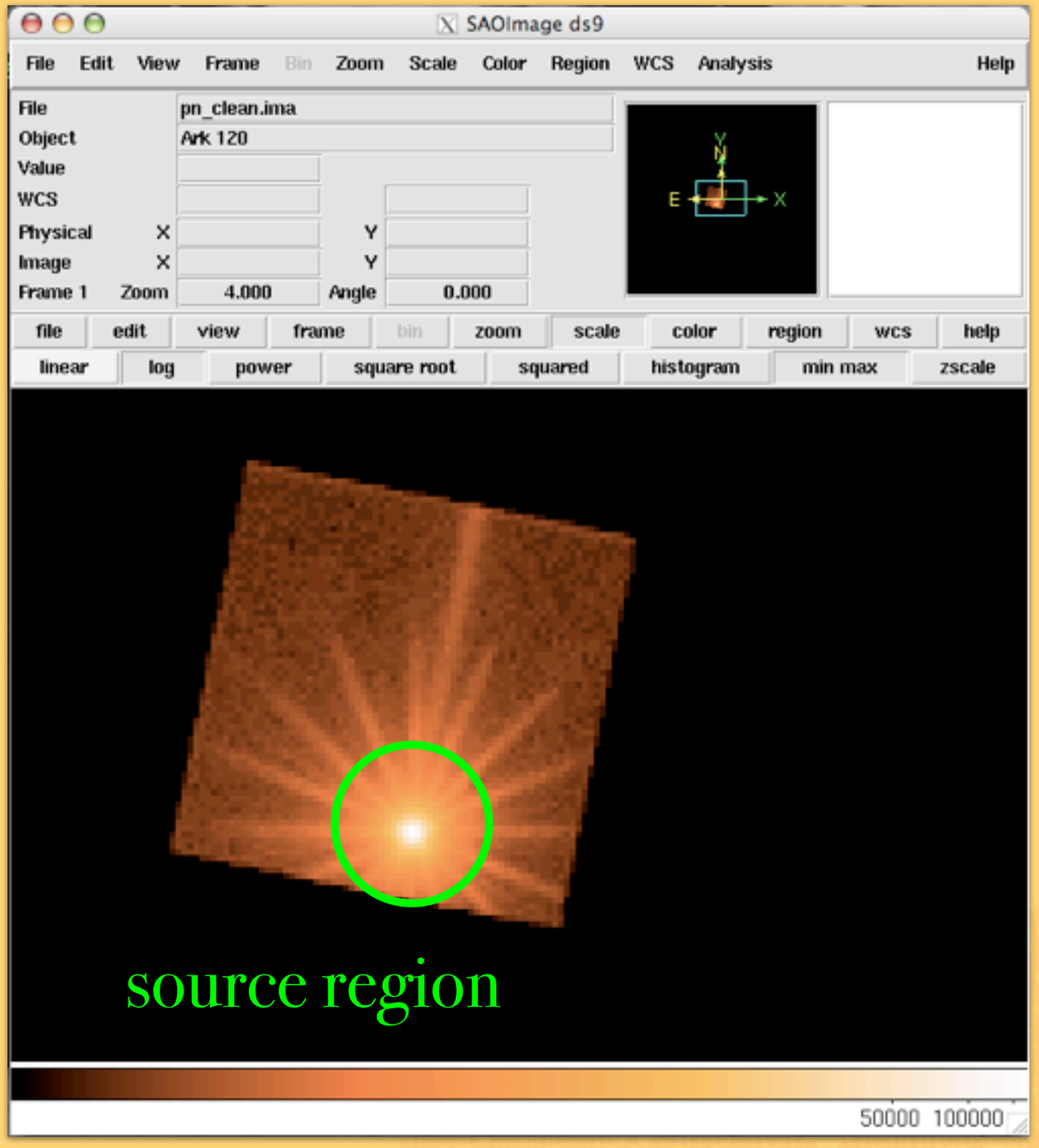






4. Source and background regions selection

open event list file with ds9



Region ->

save region ->

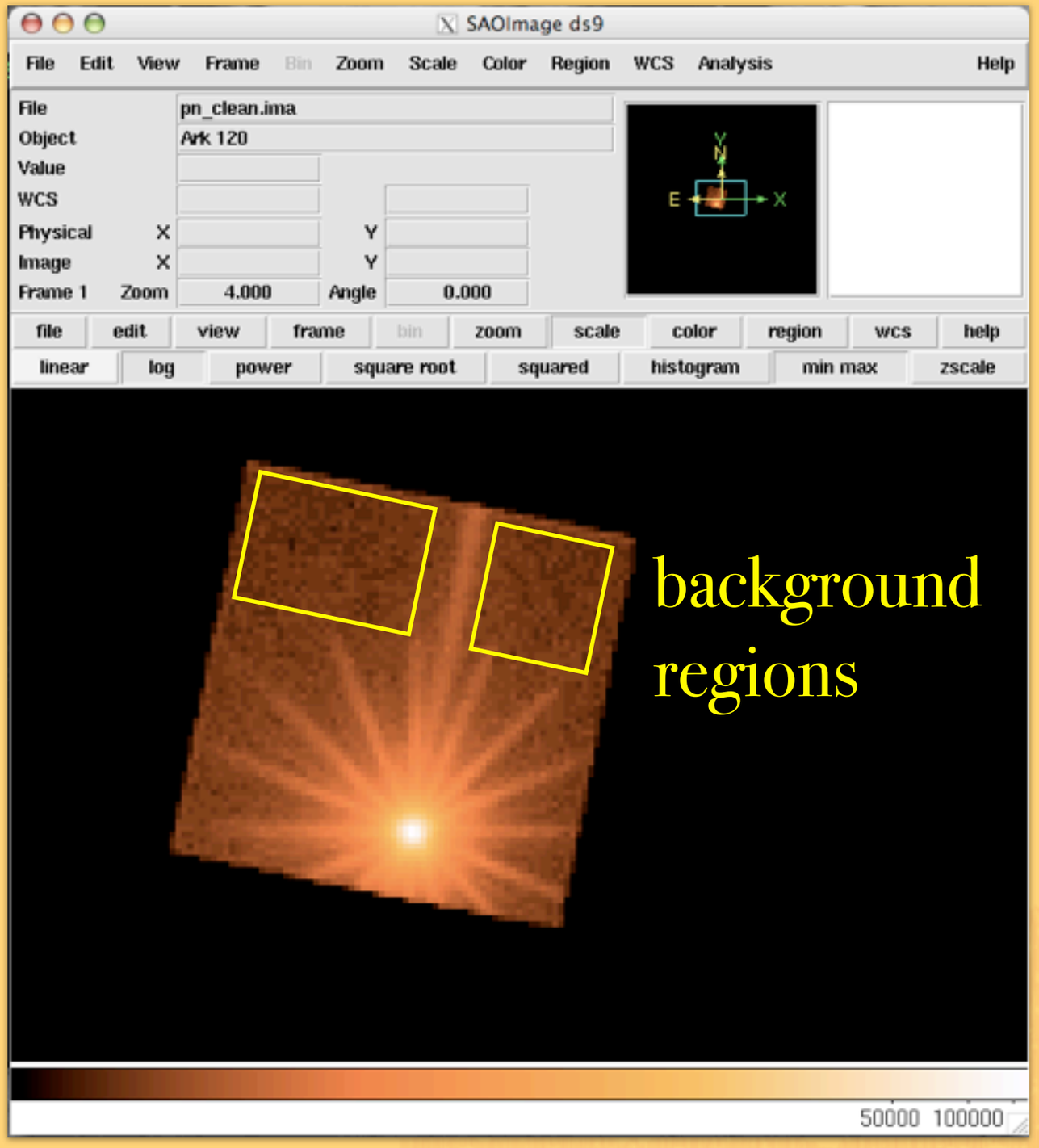
file format 'ds9' ->

coordinates 'physical' ->

source.reg

4. Source and background regions selection

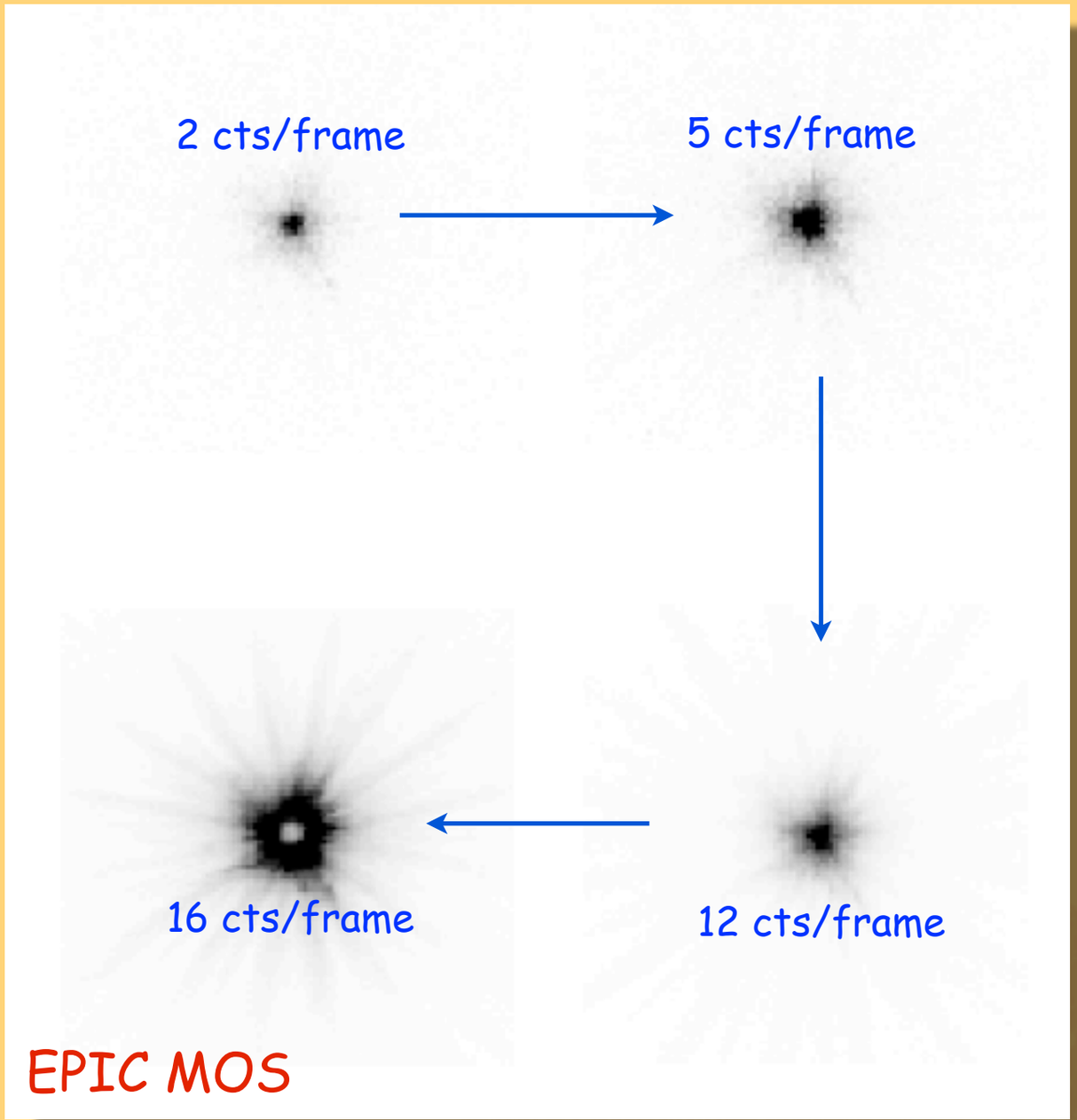
open event list file with ds9



Region ->
save region ->
file format 'ds9' ->
coordinates 'physical' ->
back.reg

5. Check for the presence of photon pile-up

Arrival of more than one X-ray photon in one camera pixel or in an adjacent pixel before it is read out



Can affect the PSF (in its core many photons arrive at almost the same time) and the EPIC spectral response (artificial "hard" X-ray photons are created where there have been two or more soft photons)

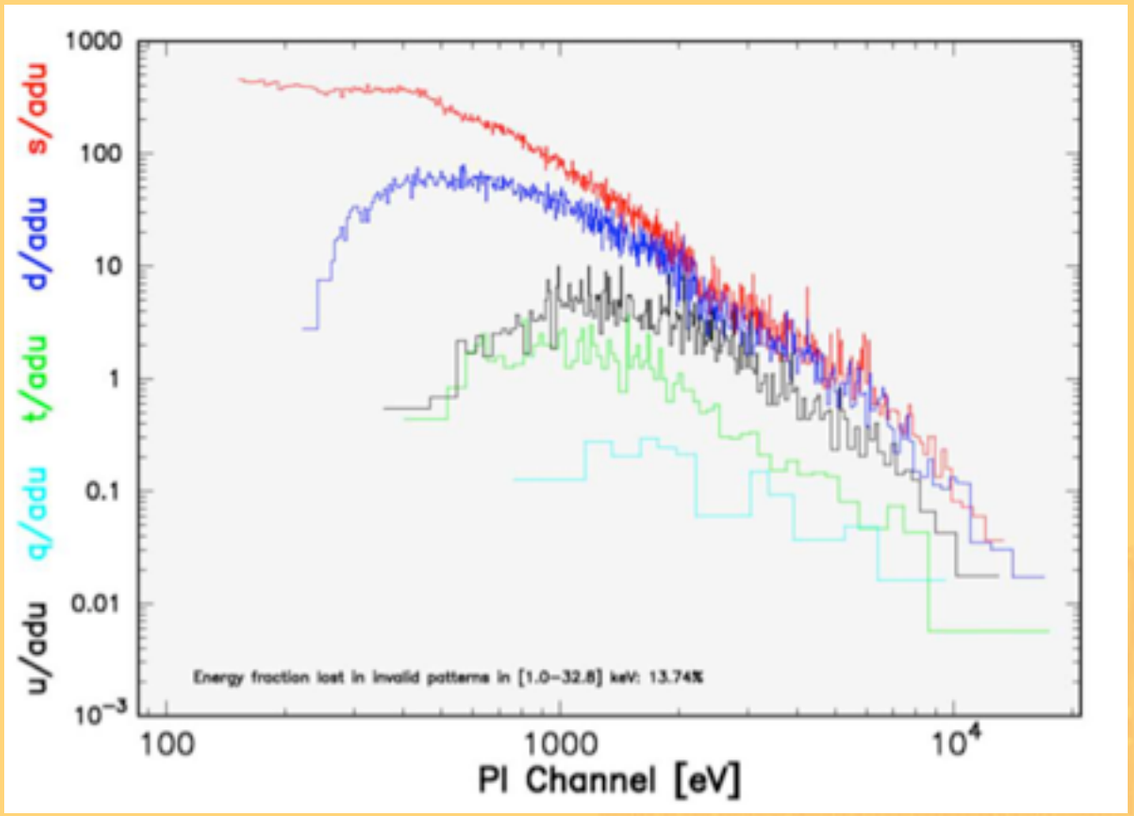
5. Check for the presence of photon pile-up (the epatplot task)

```
evselect table=pn_new.evt withfilteredset=yes
filteredset=pnf.evt keepfilteroutput=yes expression="((X,Y)
IN circle (source region))"

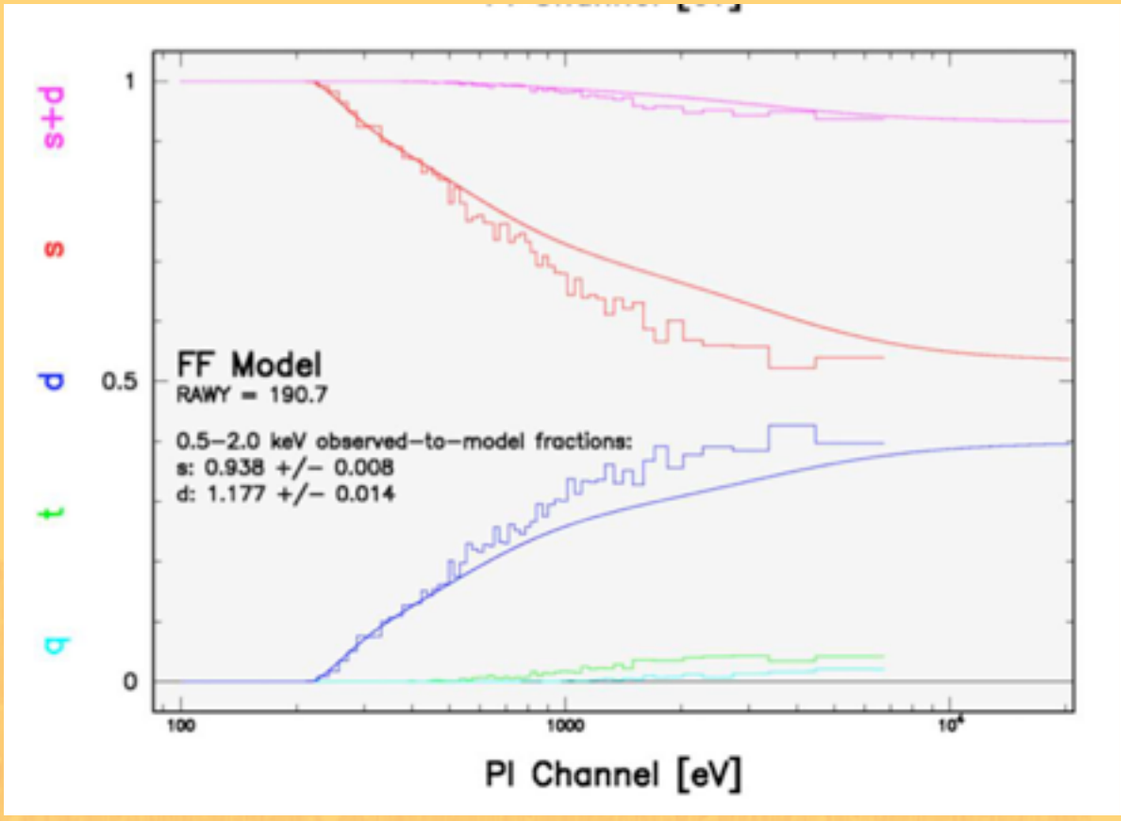
epatplot set=pnf.evt device="/CPS" plotfile="pnf_pat.ps"

gv pnf_pat.ps
```

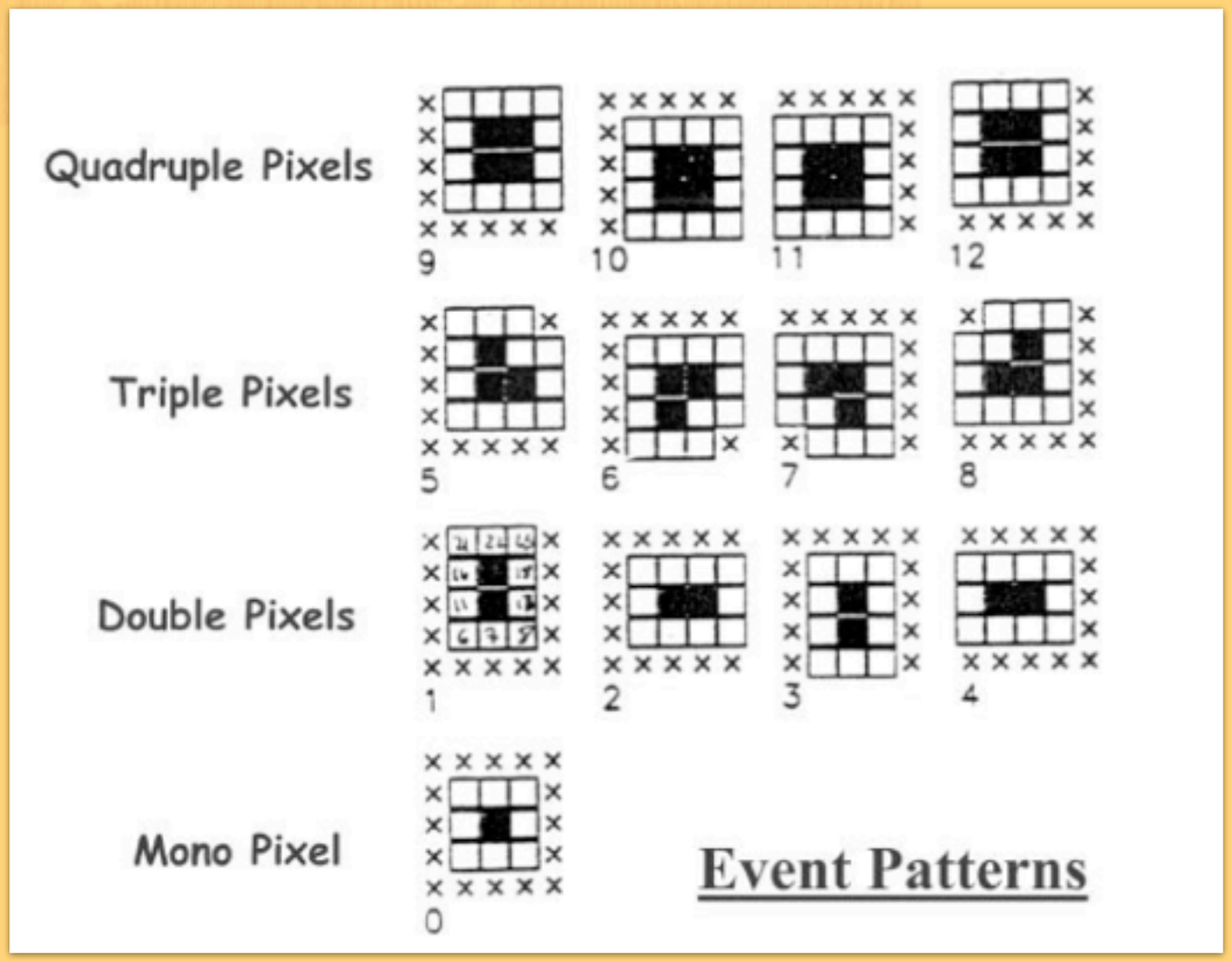
spectral distributions as function of PI channels for single- double- triple- and quadruple- events



fraction of the four valid event types



Single- double- triple- quadruple- events are the four types of valid events which can be created by an X-ray photon



Double events can be produced only if the enrgy of both events is above the event threshold. Triple (quadruples) events start at 3 (4) times the event threshold.

6. Spectrum extraction (source)

pn:

```
evselect table=pn_new.evt withspectrumset=yes
spectrumset=source_spectrum.fits energycolumn=PI
spectralbinsize=5 withspecranges=yes specchannelmin=0
specchannelmax=20479 expression='(FLAG==0) && (PATTERN<=4) &&
((X,Y) IN circle (27874.528,26645.58,699.99999))'
```

mos:

```
evselect table=mos1_new.evt withspectrumset=yes
spectrumset=source_spectrum.fits energycolumn=PI
spectralbinsize=15 withspecranges=yes specchannelmin=0
specchannelmax=11999 expression='(FLAG==0) && (PATTERN<=12) &&
((X,Y) IN circle (28090.5,24221.5,775.48791))'
```

PATTERN==0 (single events); PATTERN==[1-4] (double events); PATTERN==[5-12] (triple and quadruple events)

> pn, MOS1 and MOS2 data reduction

7. Spectrum extraction (background)

pn:

```
evselect   table=pn_new.evt   withspectrumset=yes
spectrumset=back_spectrum.fits   energycolumn=PI
spectralbinsize=5   withspecra
specchannelmax=20479 expression=
((X,Y) IN circle (27874.528,2664
```

FLAG > encoding of various event conditions, e.g. near hot pixels or outside the field of view.
Setting FLAG==0 is the most conservative screeing criteria and should be applied when serious spectral analysis is done

mos:

```
evselect   table=mos1_new.                                  es
spectrumset=back_spectrum.fits en                           15
withspecranges=yes   specchanne                             99
expression='(FLAG==0)  &&  (PATTE                           le
(28090.5,24221.5,775.48791))'
```

If you have more than o

```
evselect   table=pn_new.                                    t=yes
spectrumset=back_spectrum.fits                              nsize=5
withspecranges=yes   specchan                               =20479
expression='(FLAG==0) && (PATTERN<=4) && (((X,Y) IN circle( )) || ((X,Y)
IN circle( )))'
```

8. Calculate the area of source and background regions used to make the spectral files

```
backscale spectrumset=source_spectrum.fits badpixlocation=pn_new.evt

backscale spectrumset=back_spectrum.fits badpixlocation=pn_new.evt
```

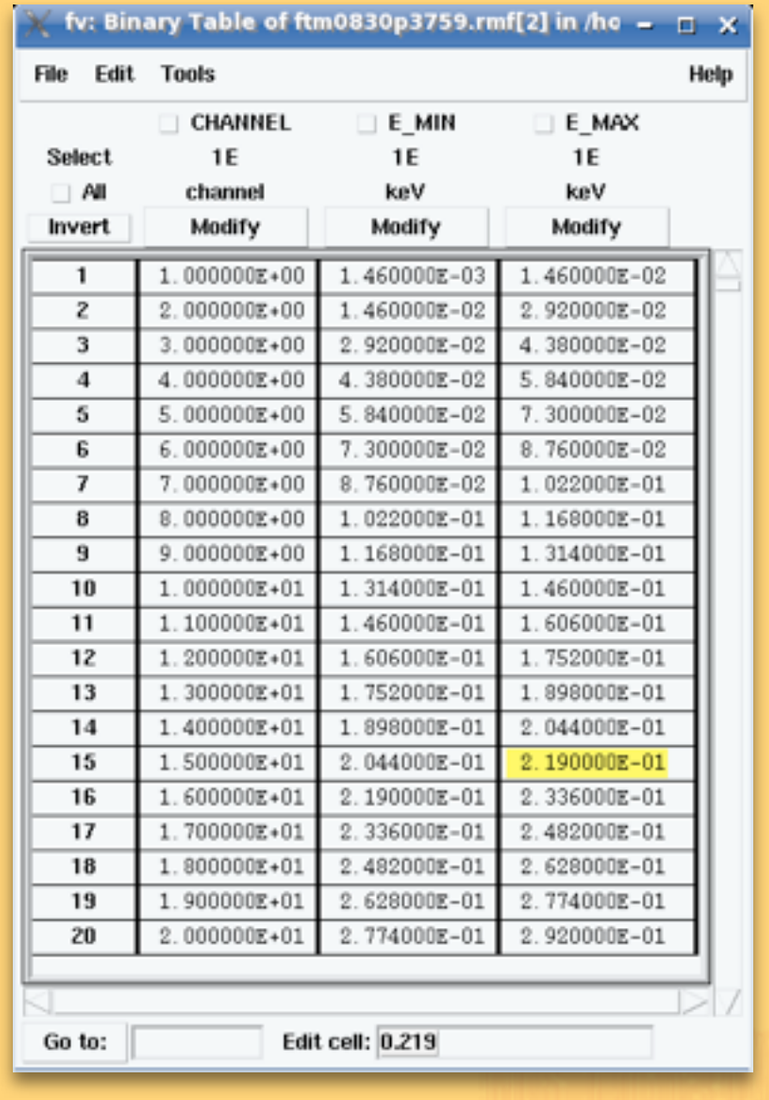
The backscale task takes into account any bad pixels o chip gaps and writes the result into the BACKSCAL keyword of the spectrum table

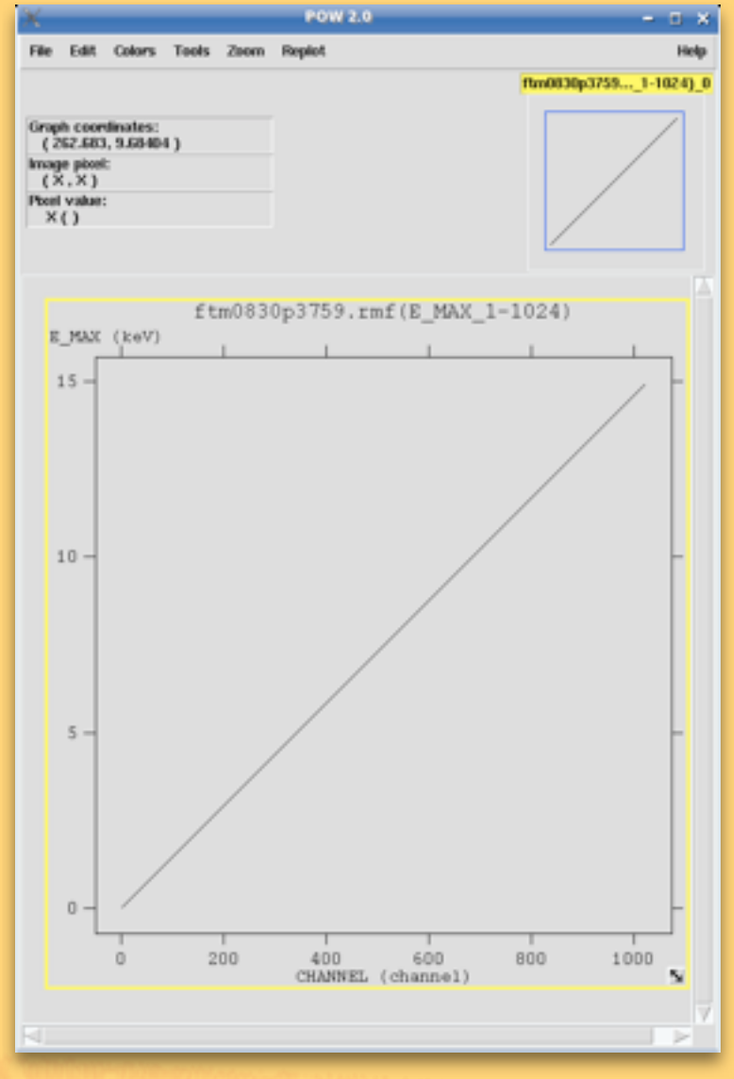
> pn, MOS1 and MOS2 data reduction

9. Creation of the Response Matrix Function (RMF)

9. Creation of the Redistribution Matrix File (RMF)

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



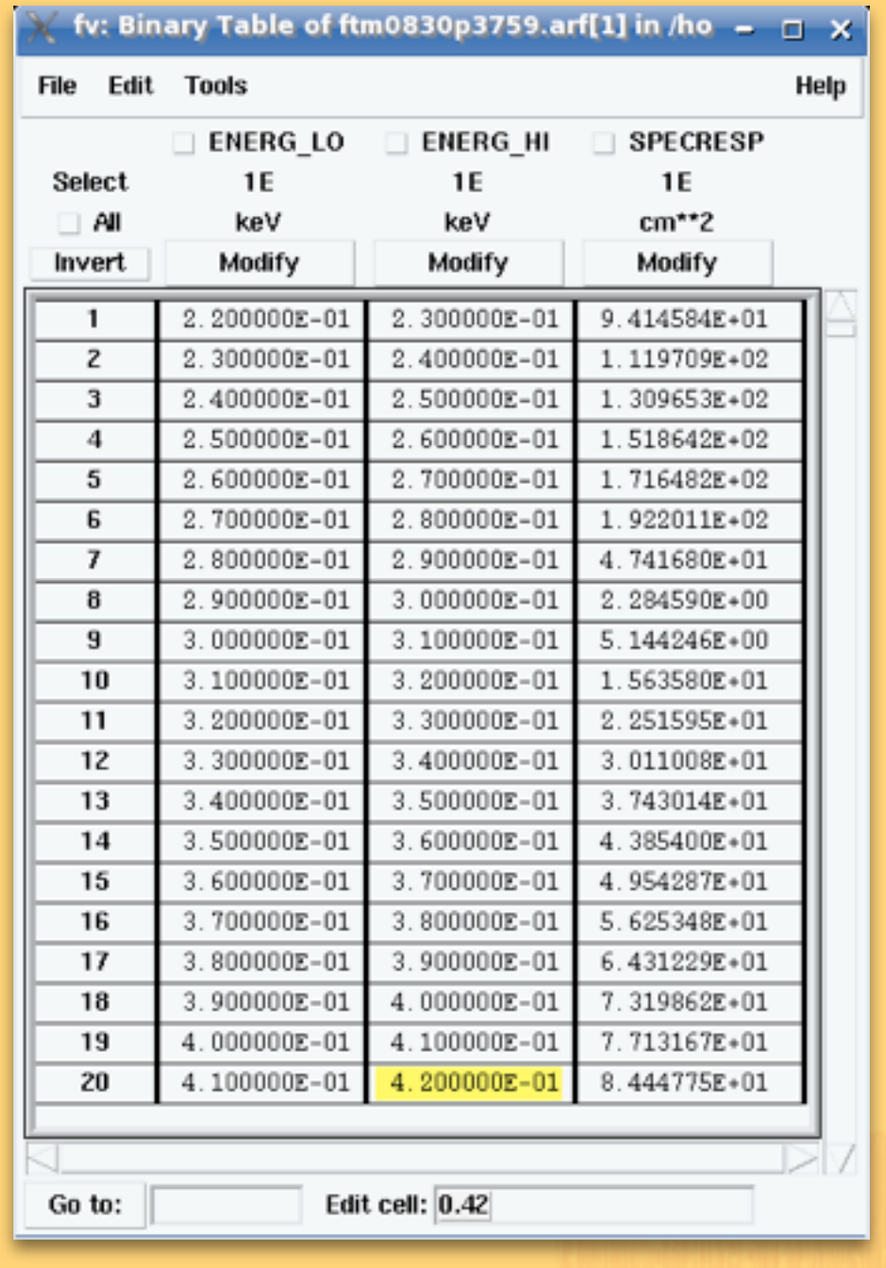


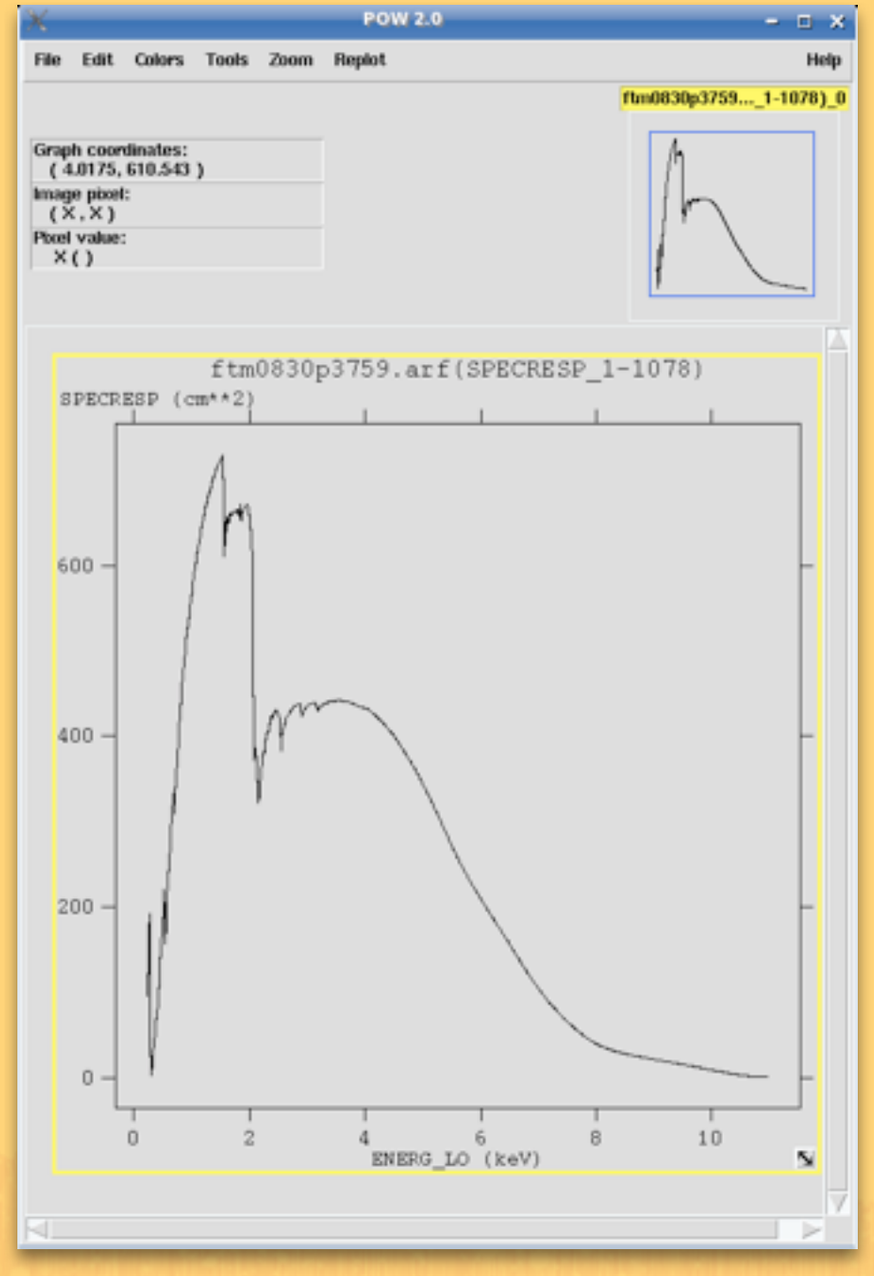

```
rmfgen spectrumset=source_spectrum.fits rmfset=pn.rmf
```

> pn, MOS1 and MOS2 data reduction

9. Creation of the Auxiliary Response File (ARF)

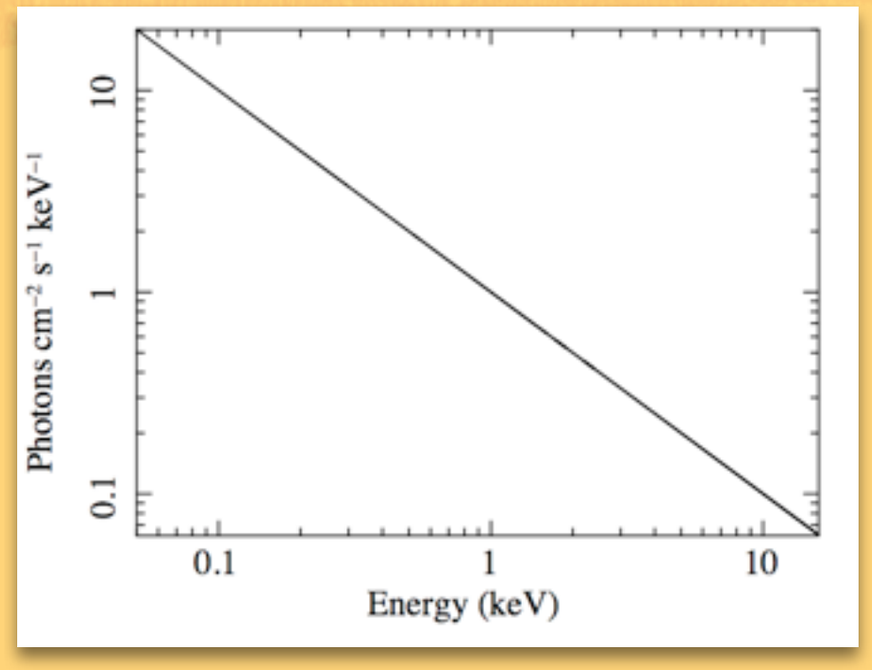
The Auxiliary Response File (ARF) includes information on the effective area, filter transmission and any additional energy-dependent efficiencies, i.e. the efficiency of the instrument in revealing photons.

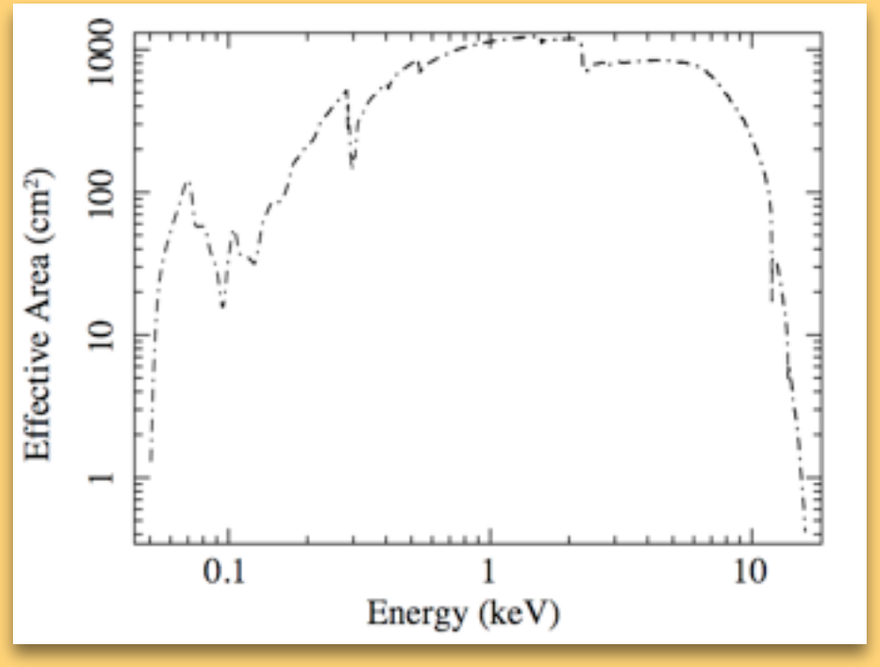




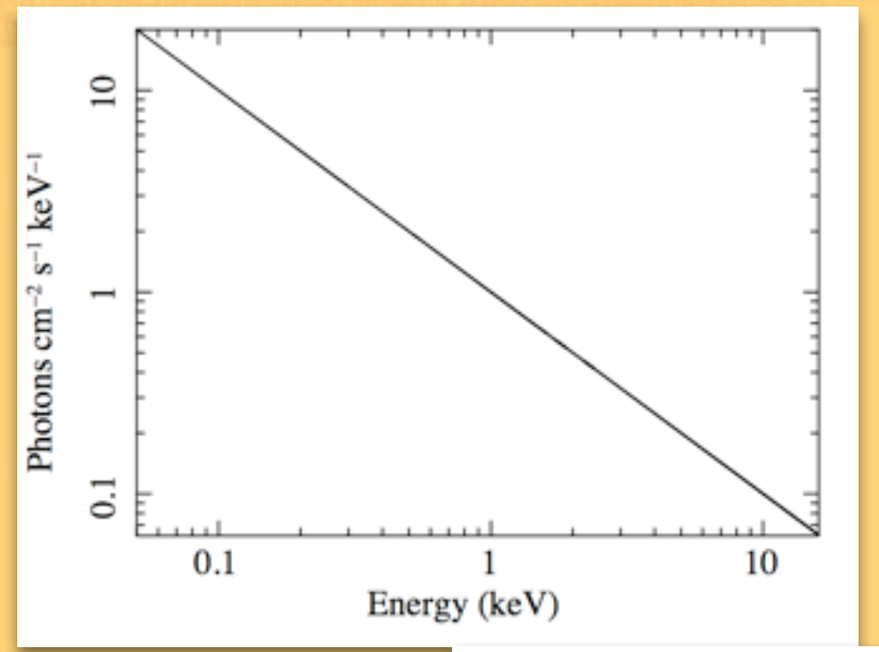

```
arfgen spectrumset=source_spectrum.fits arfset=pn.arf withrmfset=yes
rmfset=pn.rmf badpixlocation=pn_new.evt detmaptype=psf
```

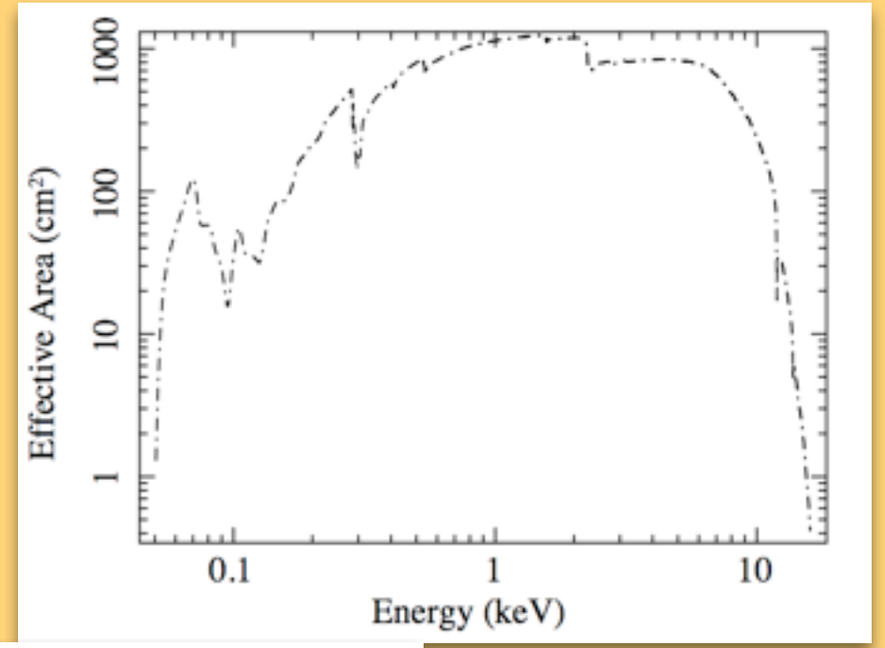
The combination of RMF and ARF produces the input spectrum weighted by telescope area and detector efficiencies versus energy.



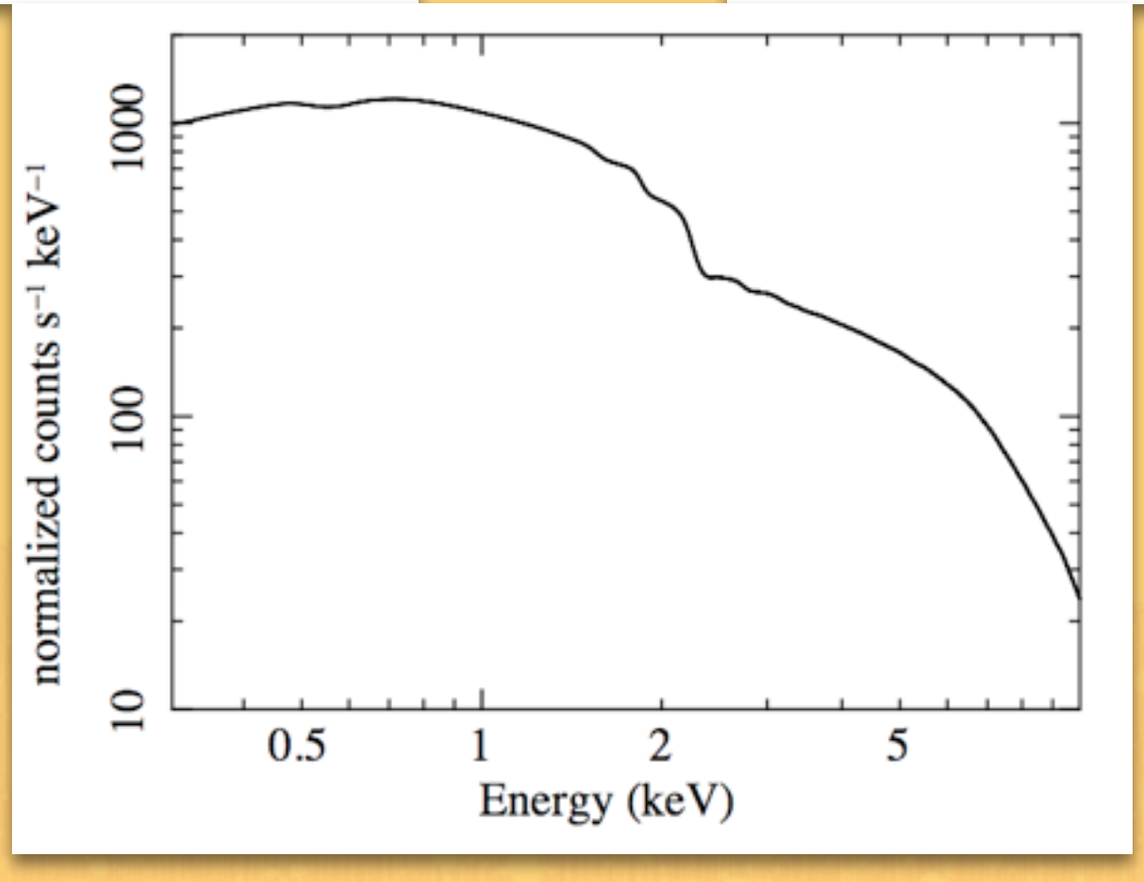


The combination of RMF and ARF produces the input spectrum weighted by telescope area and detector efficiencies versus energy.





=



10. Grouping of the spectra

In order to apply the chi2 statistics (Gaussian distribution) you need to have at least 25 counts in each bin of your spectrum. Otherwise Cash statistics (Poisson distribution) is preferred (see also Statistics Tutorial).

```
grppha source_spectrum.fits pn_25.grp comm= "chkey RESPFILE
pn.rmf & chkey ANCRFILE pn.arf & chkey BACKFILE
back_spectrum.fits & group min 25 & exit"
```

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```
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```