High energy data, Catalogues & Data archives

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Outline

1) High energy data and FITS data files

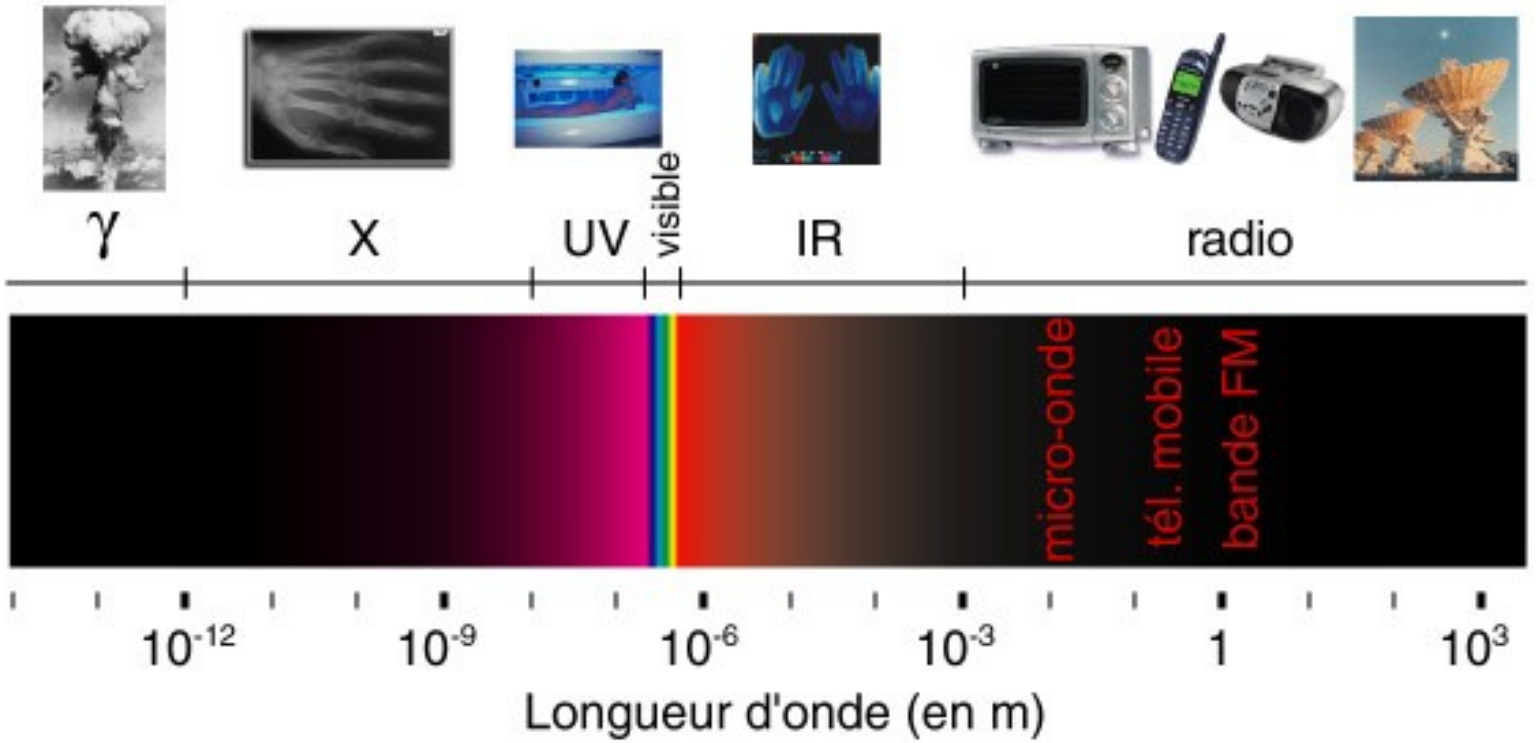
2) High energy data reduction steps, detection of point sources

3) High energy data archives/catalogues

4) Exploiting high energy archival data on line or with the software "Topcat"

High Energy data

What is high energy ?



Optical
4×10^{-19} J

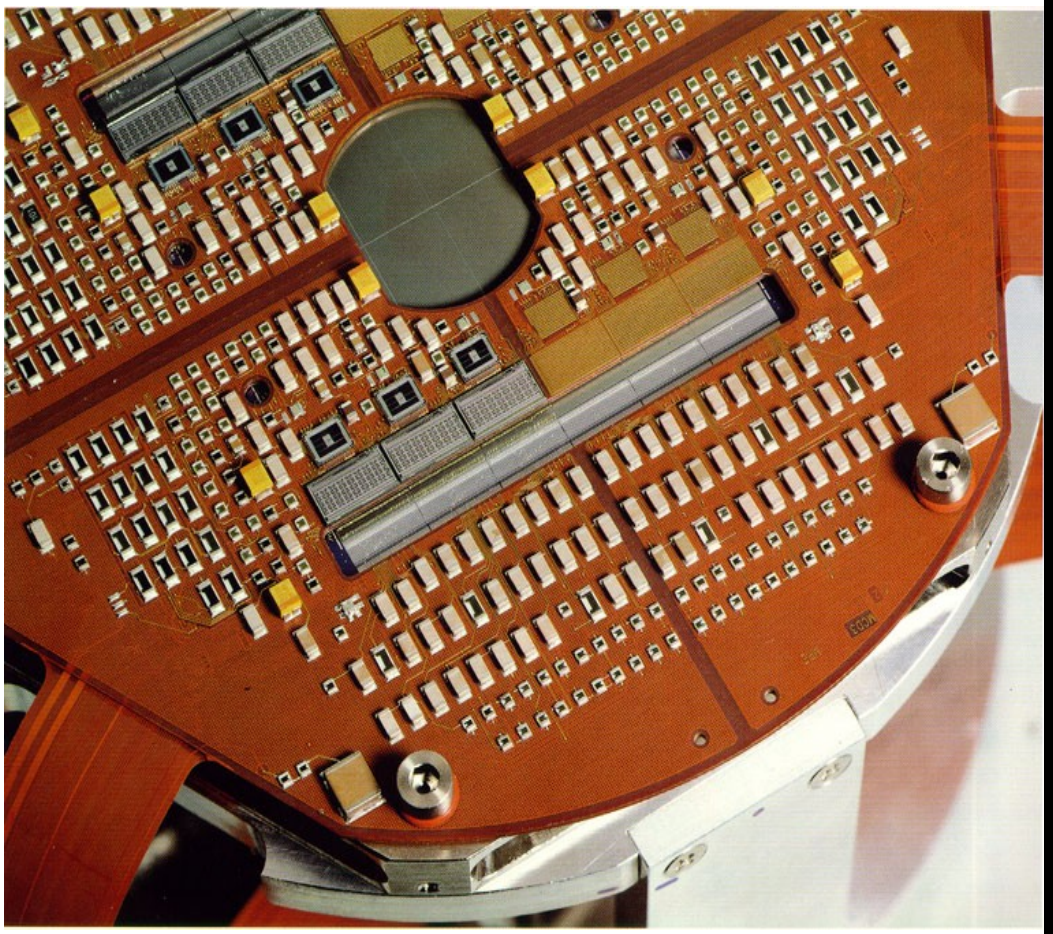
X-rays
$>2 \times 10^{-17}$ J

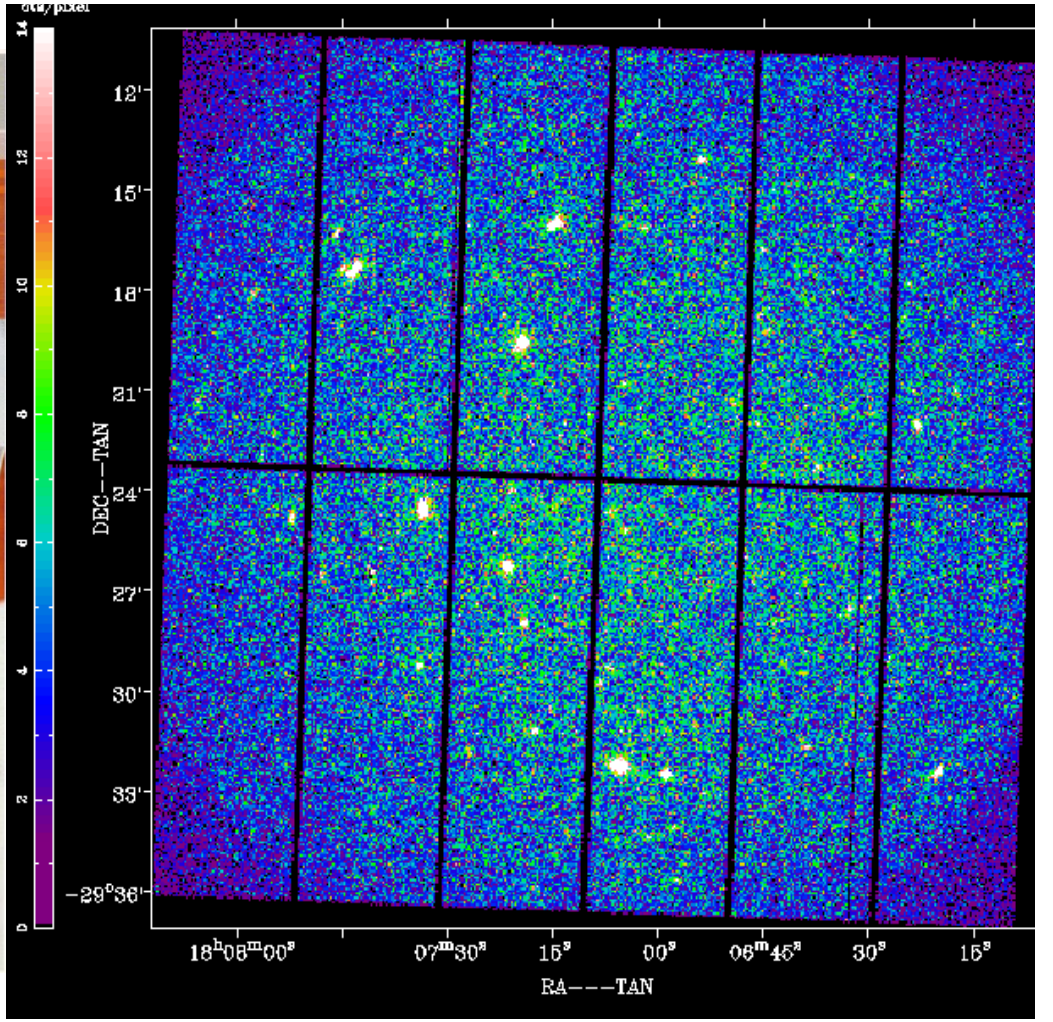
Electron volt (eV)
1.6×10^{-19} J

$c = \nu\lambda$ $\quad E = h\nu n \quad (E = hc/\lambda l)$

c = speed of light in vacuum (3.00×10^{8} m s^{-1})
ν = frequency
λ = wavelength
E = energy
h = Planck constant (6.6×10^{-34} J s)

High Energy data





Know photon: Position on CCD
Time of arrival
Energy

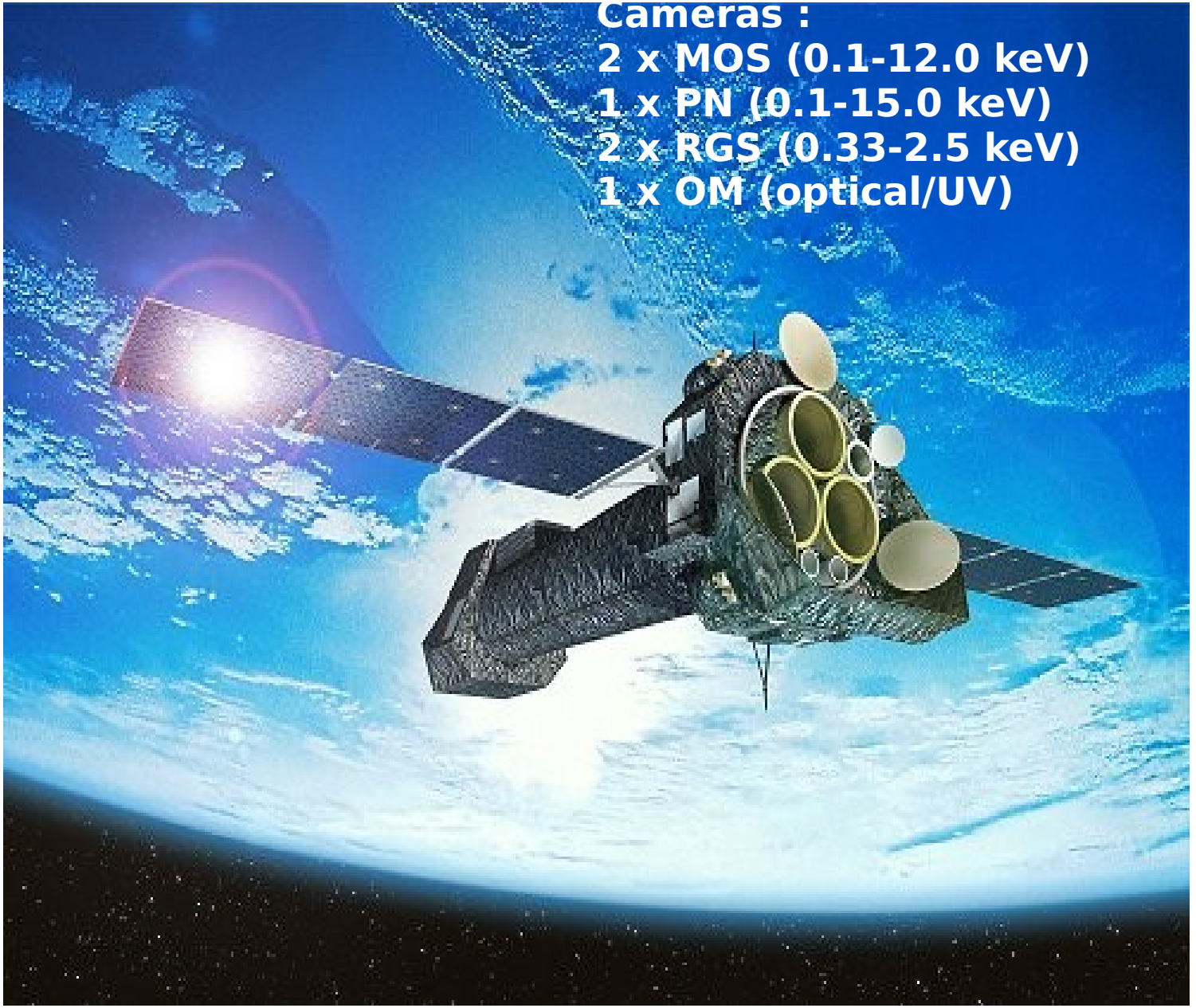
High Energy data

X-ray detectors are photon-counting => two main consequences:

- X-ray astronomy is an intrinsic Poissonian science – scientific products can have a few or even zero events in large ranges of their parameter spaces

- The event is characterised by:
  - position on the detector
  - "pulse height", which is related to the X-ray energy of the incoming photon in a complex and generally non-linear way
  - arrival time at the spacecraft
  - event "shape" (used to separate X-ray events from particles)
  - CCD number, and other secondary attributes (you don't generally have to worry about)

Example : XMM-Newton



High Energy data

From observation data file (example XMM-Newton data):

emframes on auxiliary file, event file and external GTI file (if any), to create a frame file and a CCD/node specific GTI file

badpix to add BADPIX extension to event file. If bad pix file exists, it is used instead of the CAL calls for the non-uplinked bad pixels.

emevents on event list, offset/variance & frame file, to create new event list

gtialign on external GTI file and event file

gtimerge to merge resulting aligned GTI and the CCD/node GTI.

attcalc (attitude correction) on new event list, filling the X/Y columns.

emenergy on new event list, filling the FLAG, PHA and PI columns.

The event list

File Edit Tools Help

Select / All / Invert	TIME	RAWX	RAWY	DETX	DETY	X	Y	PHA	PI	FLAG	PATTERN	PAT_ID	PAT_SEQ	CCDNR
	D	I	I	I	I	J	J	I	I	J	B	I	B	B
	s	pixel	pixel	0.05 arcsec	0.05 arcsec	0.05 arcsec	0.05 arcsec	channel	eV					
	Modify	Modify	Modify	Modify	Modify	Modify	Modify	Modify	Modify	Modify	Modify	Modify	Modify	Modify
1	2.873553184715E+08	15	142	-3418	3792	27837	28609	56	432	0	2	5121	0	1
2	2.873553185031E+08	29	81	-4648	8765	28182	33720	124	890	0	2	5121	0	1
3	2.873553185090E+08	24	140	-4170	3961	28548	28907	1077	5611	0	0	0	0	1
4	2.873553186078E+08	42	57	-5646	10759	28817	35858	767	3952	0	0	0	0	1
5	2.873553185756E+08	24	118	-4186	5785	28246	30705	364	1907	0	0	0	0	1
6	2.873553186103E+08	34	144	-5043	3611	29469	28714	1073	5652	0	0	0	0	1
7	2.873553186446E+08	54	19	-6668	13934	29270	39162	302	1533	0	0	0	0	1
8	2.873553186391E+08	13	60	-3261	10554	26504	35240	860	4300	0	0	0	0	1
9	2.873553186888E+08	9	71	-2930	9621	26341	34264	798	4009	0	0	0	0	1
10	2.873553187408E+08	45	38	-5917	12391	28800	37512	314	1632	0	0	0	0	1
11	2.873553187889E+08	32	44	-4888	11870	27877	36820	1019	5063	0	0	0	0	1
12	2.873553188425E+08	63	131	-7421	4697	31621	30198	179	988	0	0	0	0	1
13	2.873553188314E+08	64	139	-7469	3998	31791	29518	625	3433	4	0	0	0	1
14	2.873553189489E+08	56	75	-6837	9315	30242	34643	29	152	2097152	0	0	112	1
15	2.873553189541E+08	52	103	-6521	6994	30335	32303	446	4540	0	2	5121	0	1
16	2.873553191227E+08	56	88	-6821	8259	30410	33601	1648	8609	0	0	0	0	1
17	2.873553191289E+08	54	143	-6701	3725	31082	29115	679	4306	0	1	5121	0	1
18	2.873553191173E+08	22	175	-4054	1064	28939	26034	1219	6445	0	0	0	0	1
19	2.873553192505E+08	38	115	-5326	6020	29328	31135	276	1490	0	0	0	0	1
20	2.873553192389E+08	7	183	-2769	379	27793	25135	1811	9855	0	3	5121	1	1

Go to: Edit cell:

Cleaning X-ray data

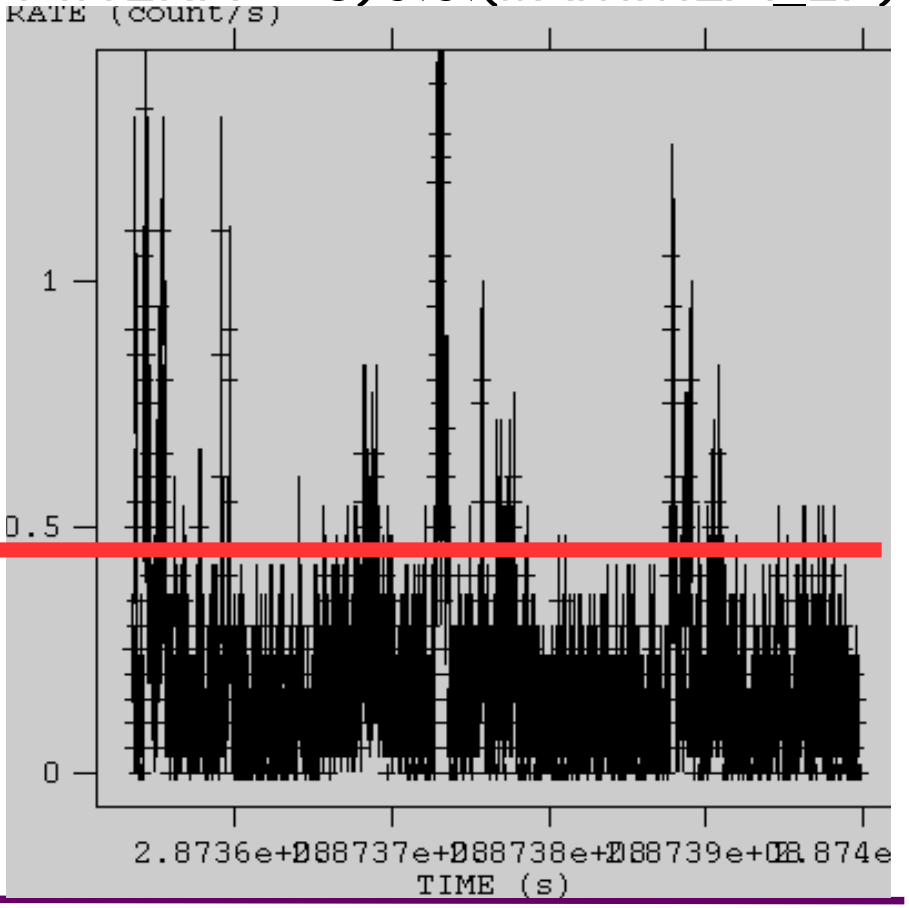
Filter for high background (soft proton flares):

Create a binned lightcurve of data above 10 keV (*evselect*)

MOS : (PI>=10000)&&(PATTERN==0)&&(#XMMEA_EM)

pn : (PI in (10000:12000))&&(PATTERN==0)&&(#XMMEA_EP)

Identify count rate above which the background is not low and stable

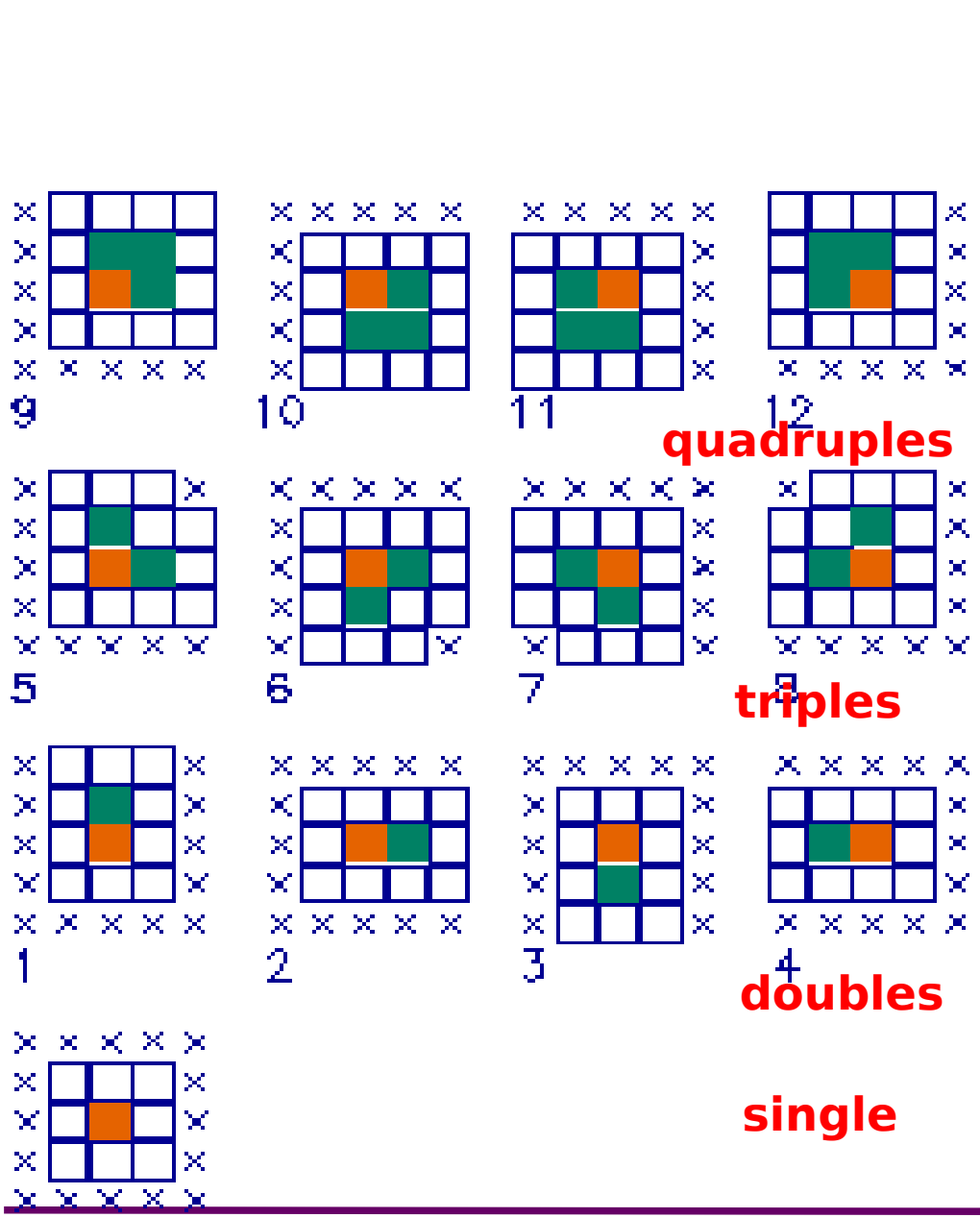


Create good time intervals (*tabgtigen*)

Filter for good time, X-ray patterns, etc (*evselect*)

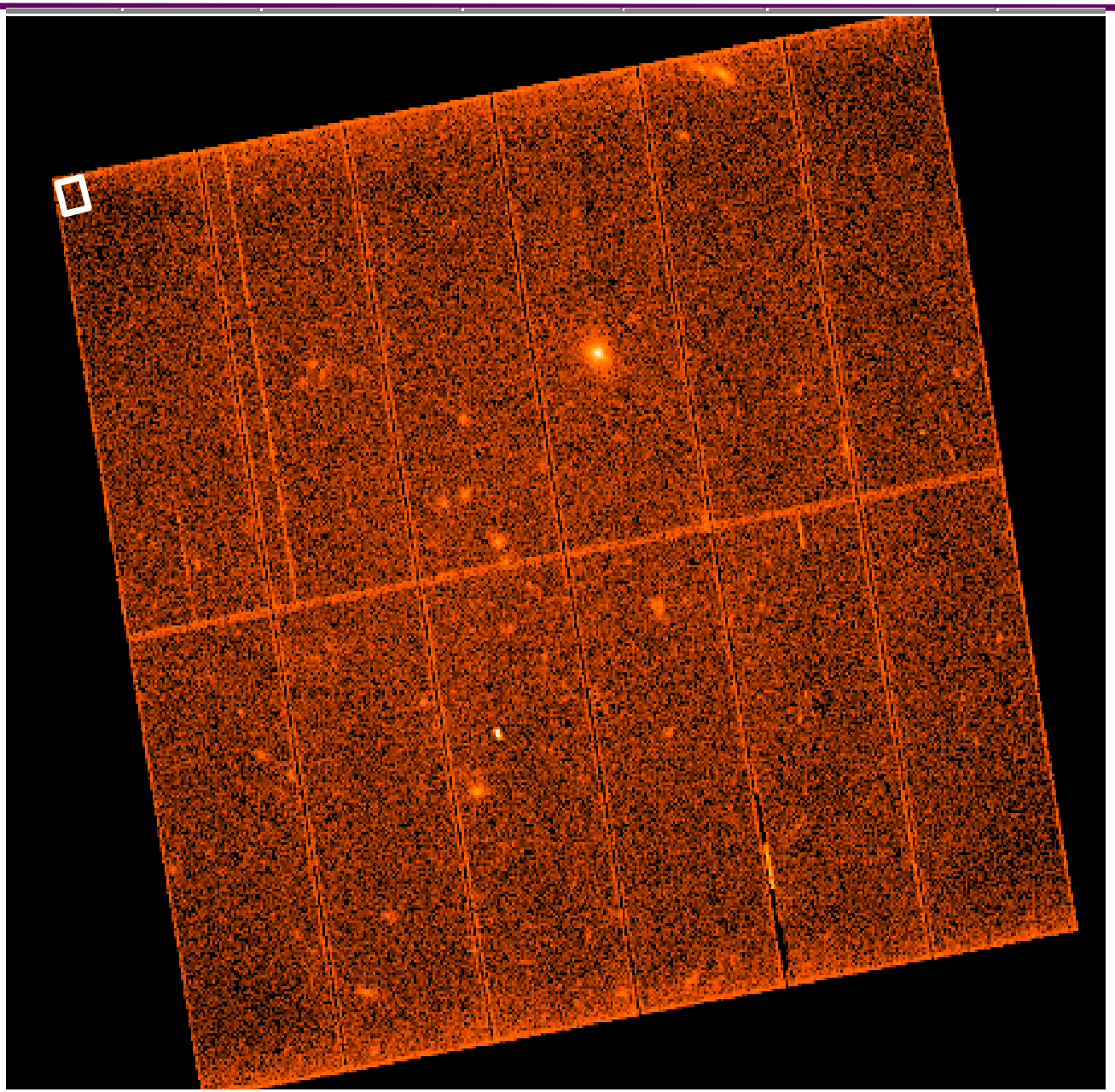
MOS : (PATTERN<=12)&&(#XMMEA_EM) &&GTI(m1.gti,TIME)&&(PI in (200:12000))

Astrophysical and non-astrophysical patterns



Non-astrophysical

X-ray source detection



X-ray source detection

edetectchain

eexpmap	creation of exposure maps	attitude file, event list, image	exposure maps
emask	creation of detection masks	exposure map	detection mask
eboxdetect (local mode)	sliding box detection	images, exposure maps, detection mask	box detect source list
esplinemap	creation of background maps	image, exposure map, detection mask, local box list	background map

eboxdetect (map mode)	box detection using background maps	images, exposure maps, detection mask, background maps	map detect source list
emldetect	maximum likelihood fitting	images, exposure maps, background maps, map detect list	final source list
esensmap	creation of sensitivity maps	exposure map, detection mask, background map	sensitivity map

Alternative : *ewavelet*, based on a Mexican hat wavelet algorithm

Catalogues

The majority of observatories today provide some form of catalogue of detections

They cover all wavelengths and contain a variety of information

Catalogues are useful for :
- Quick access to data products (fluxes, spectra, images, etc)
- Finding new objects
- Population studies
- Cross correlation for multi-wavelength studies

Existing catalogues at :http://vizier.u-strasbg.fr/viz-bin/VizieR
- 14465 catalogues

Any one catalogue is usually provided in >1 format

Catalogue formats

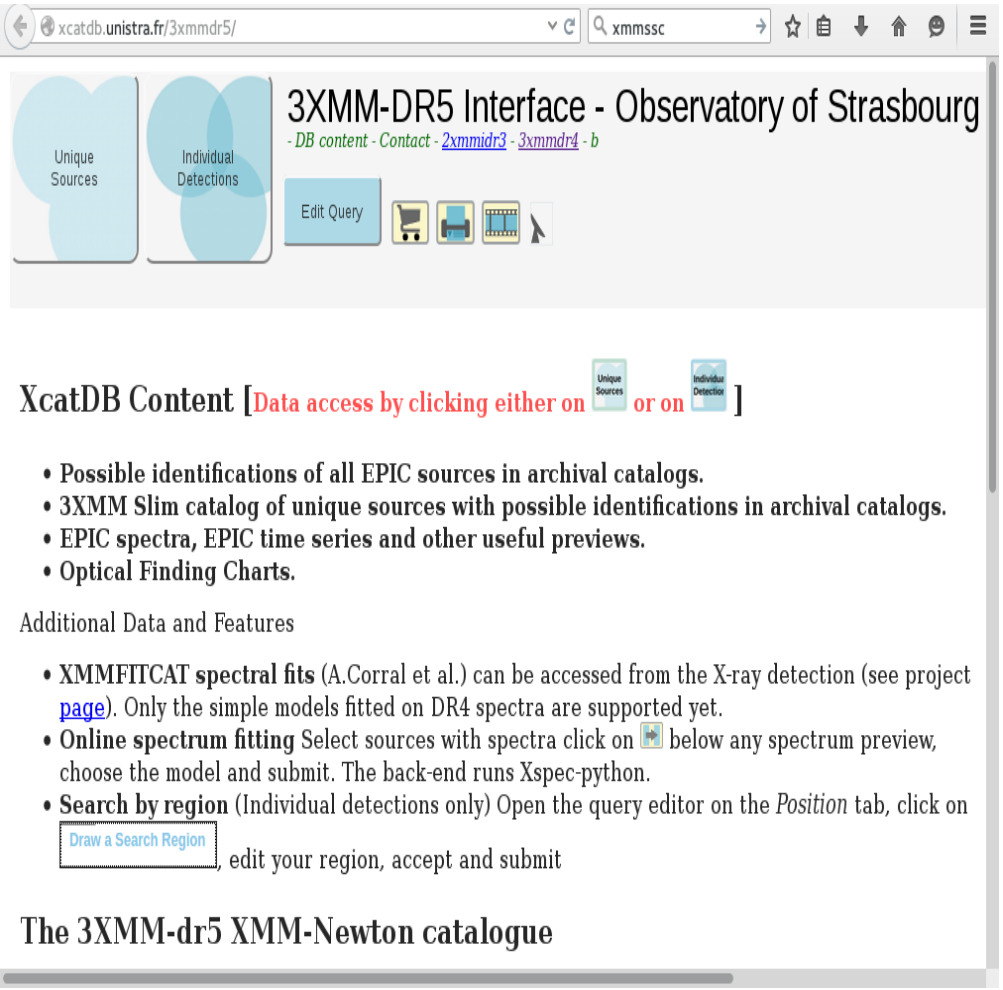
Catalogues are often provided in tabular form (fits, csv, text)

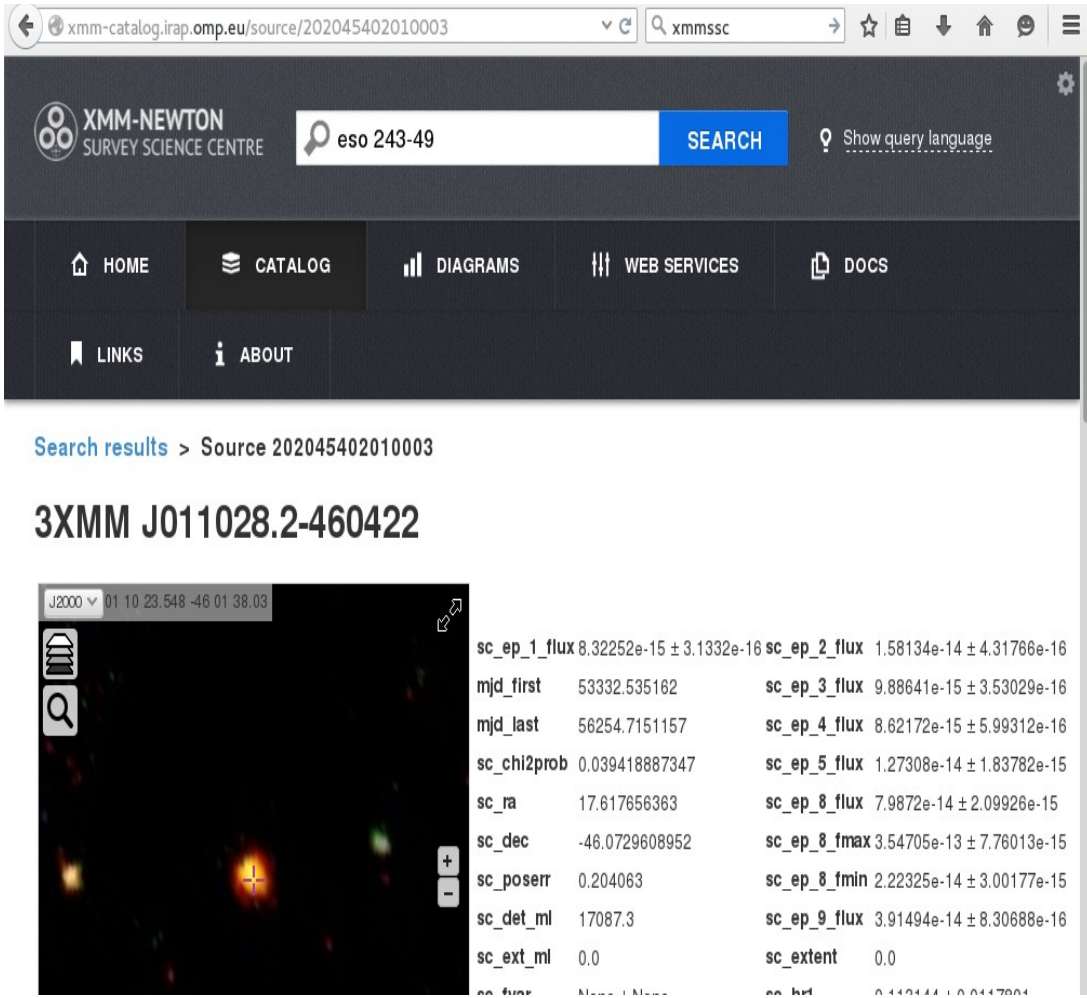
These tabular forms can be manipulated with :
- sql scripts
- ftools
- excel (or similar)
- dedicated software such as Topcat/Stilts
- scripts (python, c, idl, ...)
- many, many other things !!!

This allows you to have complete freedom to access all aspects of the catalogue

Catalogue formats, example : 3XMM

Alternatively they can be accessed via online archives, e.g. :





Inside the catalogues

In general : unique identification of each detection
position of detection
error on position
source extension
time/date of observation
measure of the quality of the detection
measure of flux/magnitude in one or several bands
error on the flux/magnitude

Can also include :
- unique source identification
- spectral/timing products
- measure of the spectra/variability
- images
- tentative source identification
- observing conditions

...and many other products !

Example the XMM-Newton catalogue : 3XMM-DR5

Released 28th April 2015

	3XMM-DR5	3XMM-DR4	Increment
Number of observations	7781	7427	354
Number of 'clean' observations (i.e., observation class < 3)	4735	4553	182
Observing interval	03-Feb-00 -- 20-Dec-13	03-Feb-00 -- 08-Dec-12	1 year
Sky coverage, taking overlaps into account (≥ 1ksec exposure)	877 sq.deg	794 sq.deg	83 sq.deg
Number of detections	565962	531261	34701
Number of 'clean' detections (i.e., summary flag < 3)	456904	432321	24673
Number of unique sources	396910	372728	24182
Number of 'cleanest' (summary flag = 0, not in high-background fields) extended detections	9082	7698	1384
Number of detections with spectra	133032	123867	9165
Number of detections with timeseries	133025	123860	9165
Number of detections where probability of timeseries being constant is $< 1 \times 10^{-5}$	4668	4612	56

Access to 3XMM-DR5

On the XMM-Newton Survey Science (SSC) webpages :

http://xmmssc.irap.omp.eu

But also at :

XSA at ESA's XMM-Newton SOC : http://xmm.esac.esa.int/xsa/

XCAT-DB at the SSC institute, Observatoire Astronomique, Strasbourg : http://xcatdb.unistra.fr/3xmmdr5

LEDAS at the SSC institute, University of Leicester :

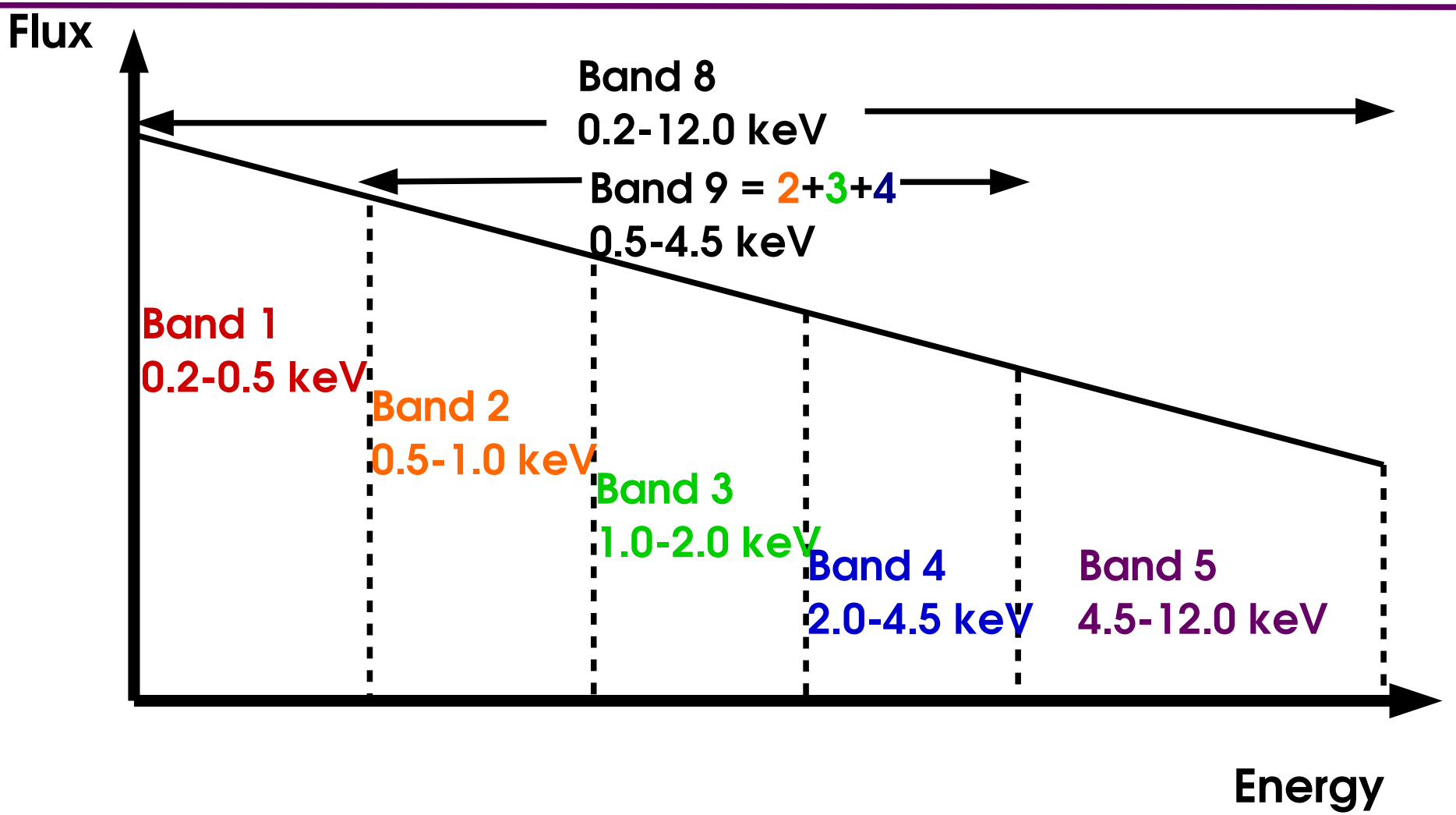
http://www.ledas.ac.uk/

Browse at HEASARC NASA GSFC :

http://heasarc.gsfc.nasa.gov/db-perl/W3Browse/w3browse.pl

The IRAP catalogue server XSA : http://xmm-catalog.irap.omp.eu/

3XMM bands and hardness ratios



$$HR_i = \frac{Band_{i+1} - Band_i}{Band_{i+1} + Band_i}$$

HR = hardness ratio

Using the online data archives

http://xmm-catalog.irap.omp.eu/

Provide a 3XMM-DR5 source name or do a cone search

e.g. 3XMM J133129.6+110755

or : cone('13 31 29.6 +11 07 55', '1deg')

or search categories of sources (CVs, ULXs, ...)

Visualise : Image (XMM and other catalogues)

Source parameters (flux in different bands, date obs., ...)

Fit spectrum

Visualise/extract lightcurve

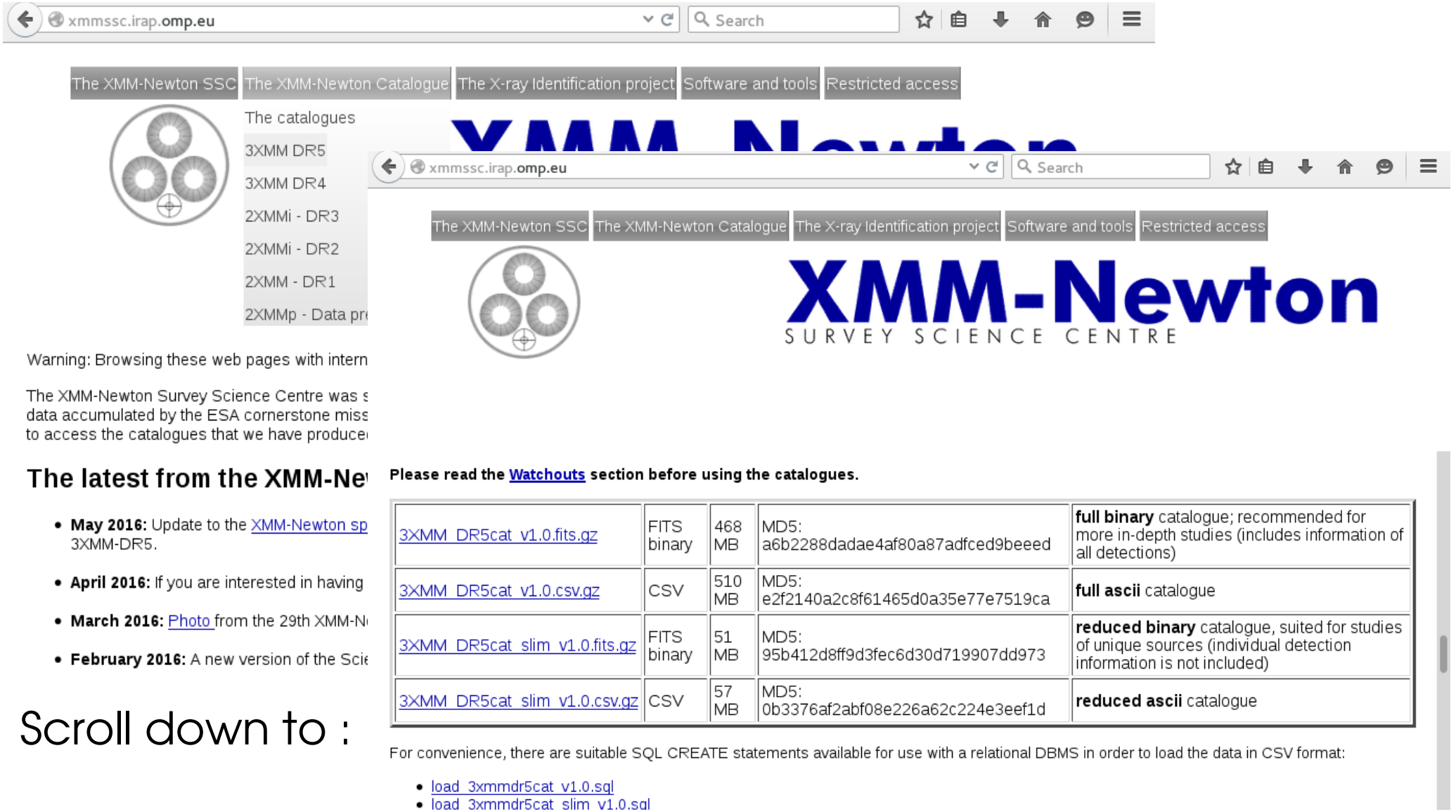
Cross correlate with other catalogues

Topcat – Tool for Operations on Catalogues And Tables

- Allows to view table and meta-data
- Perform statistics on data
- Create plots of data
- Match/concatenate tables
- Perform functions (conversions, arithmetic, format change, ...)
- Use virtual observatory data/software
- Link several virtual observatory services together

Using Topcat to manipulate the XMM catalogues

- Retreive 3XMM-DR5 at : http://xmmssc.irap.omp.eu/

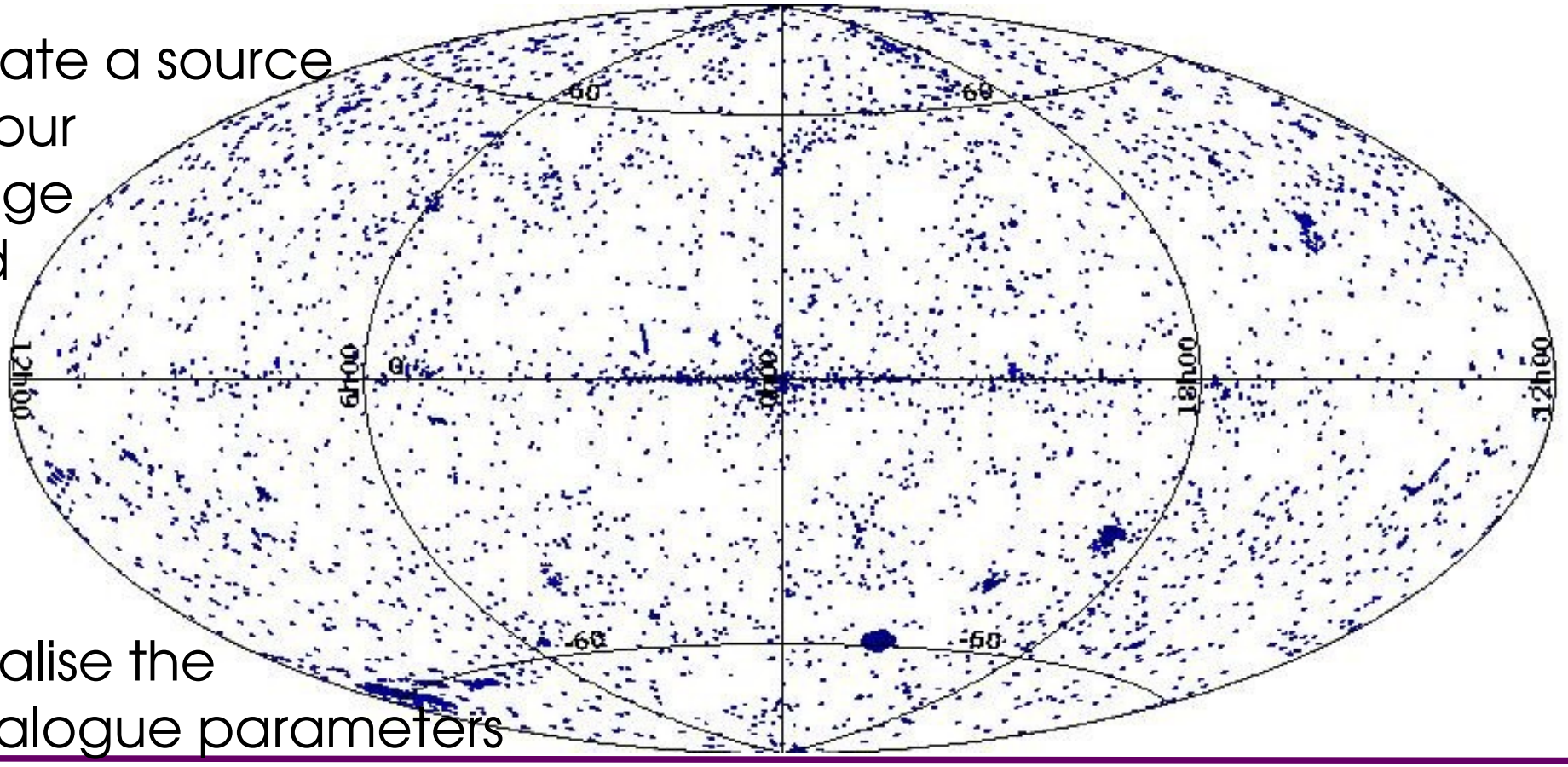


Scroll down to :

Topcat – plot the 3XMM-DR5 catalogue

How many detections in 3XMM-DR5 ?
How many unique sources in 3XMM-DR5 ?
What is the mean number of detections of a source ?
What is the maximum number of detections of a source ?
Plot the whole catalogue in a Hammer-Aitoff projection :

Locate a source in your image and

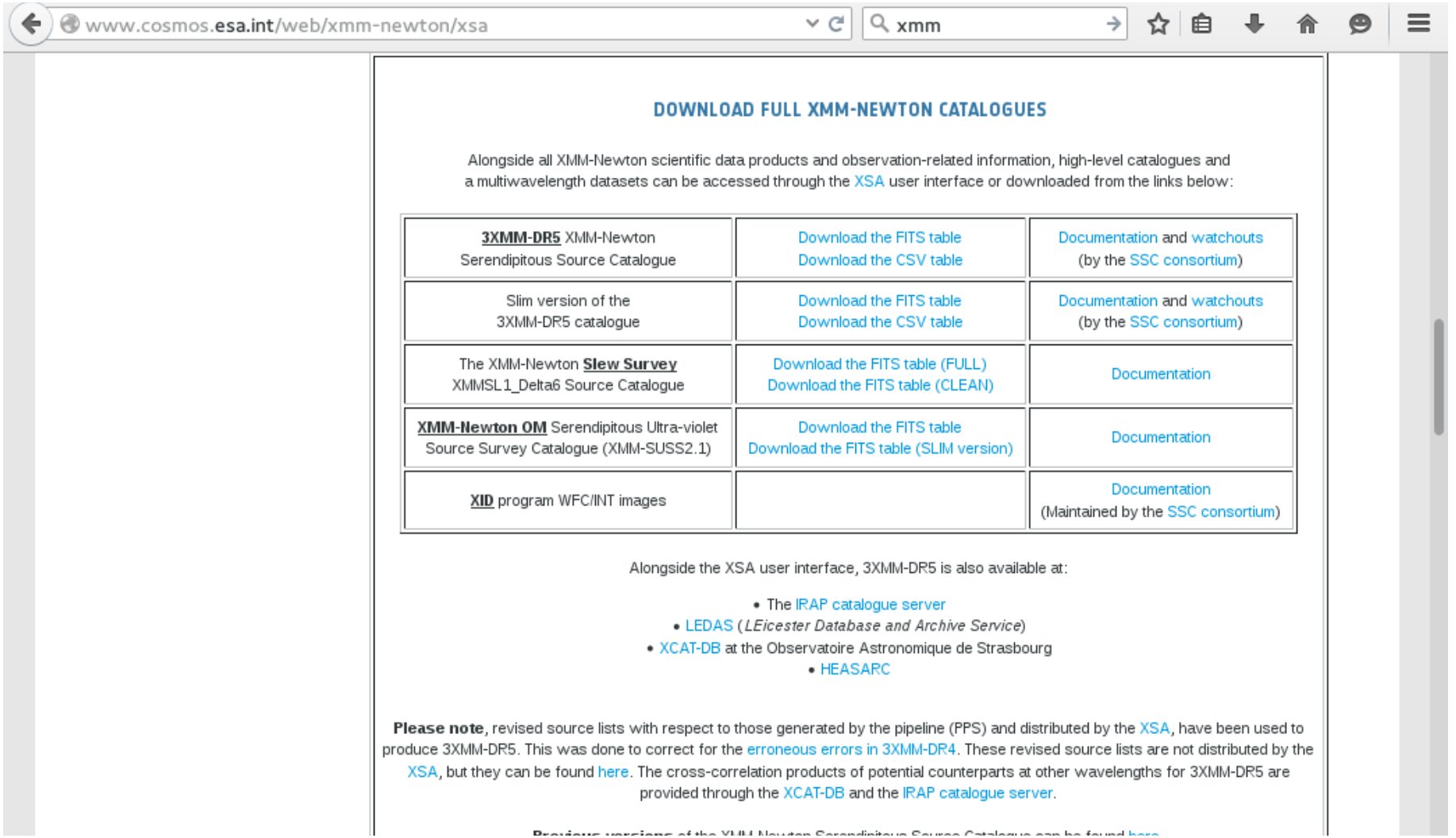


visualise the catalogue parameters

Retrieve OM catalogue : SUSS 2.1

http://www.cosmos.esa.int/web/xmm-newton/xsa

Scroll down to :



DOWNLOAD FULL XMM-NEWTON CATALOGUES

Alongside all XMM-Newton scientific data products and observation-related information, high-level catalogues and a multiwavelength datasets can be accessed through the XSA user interface or downloaded from the links below:

3XMM-DR5 XMM-Newton Serendipitous Source Catalogue	Download the FITS table Download the CSV table	Documentation and watchouts (by the SSC consortium)
Slim version of the 3XMM-DR5 catalogue	Download the FITS table Download the CSV table	Documentation and watchouts (by the SSC consortium)
The XMM-Newton **Slew Survey** XMMSL1_Delta6 Source Catalogue	Download the FITS table (FULL) Download the FITS table (CLEAN)	Documentation
XMM-Newton OM Serendipitous Ultra-violet Source Survey Catalogue (XMM-SUSS2.1)	Download the FITS table Download the FITS table (SLIM version)	Documentation
XID program WFC/INT images		Documentation (Maintained by the SSC consortium)

Alongside the XSA user interface, 3XMM-DR5 is also available at:

- The IRAP catalogue server
- LEDAS (*LEicester Database and Archive Service*)
- XCAT-DB at the Observatoire Astronomique de Strasbourg
- HEASARC

Please note, revised source lists with respect to those generated by the pipeline (PPS) and distributed by the XSA, have been used to produce 3XMM-DR5. This was done to correct for the erroneous errors in 3XMM-DR4. These revised source lists are not distributed by the XSA, but they can be found here. The cross-correlation products of potential counterparts at other wavelengths for 3XMM-DR5 are provided through the XCAT-DB and the IRAP catalogue server.

Topcat – match 3XMM-DR5 sources to SUSS 2.1 sources

How many 3XMM-DR5 and SUSS sources match to 1" ?
Plot the matching sources on the Hammer-Aitoff plot
Determine the source parameters – try to identify a source of your choice
Select all matched sources with a U magnitude brighter than 18th

Try out some of the functionality described at http://www.star.bris.ac.uk/~mbt/topcat/ under Features

Ideas

- Upper limit servers, e.g. http://www.ledas.ac.uk/flix/flix_dr5.html
-