EPIC Scientific Product Extraction

13th ESAC SAS Workshop

June 10 – June 14, 2013

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Camera-dependent screening criteria (I)

Experience of in-flight calibrations allowed to identify a couple of *optimal* camera-dependent screening criteria:

EPIC-MOS:

- **#XMMEA_EM: bit-wise selection expression, automatically removes "bad events" (bad rows, edge effects, spoiled frames, cosmic ray events (MIPs), diagonal events, event beyond threshold …)**

```
XMMEA_0 = '(FLAG & 0x1) != 0'  / DIAGONAL
XMMEA_1 = '(FLAG & 0x2) != 0'  / CLOSE_TO_CCD_BORDER
XMMEA_5 = '(FLAG & 0x20) != 0' / CLOSE_TO_ONBOARD_BADPIX
XMMEA_6 = '(FLAG & 0x40) != 0' / CLOSE_TO_BRIGHTPIX
XMMEA_8 = '(FLAG & 0x100) != 0' / CLOSE_TO_DEADPIX
XMMEA_9 = '(FLAG & 0x200) != 0' / CLOSE_TO_BADCOL
XMMEA_10= '(FLAG & 0x400) != 0' / CLOSE_TO_BADROW
XMMEA_11= '(FLAG & 0x800) != 0' / IN_SPOILED_FRAME
XMMEA_16= '(FLAG & 0x10000) != 0' / OUT_OF_FOV
XMMEA_17= '(FLAG & 0x20000) != 0' / IN_BAD_FRAME
XMMEA_19= '(FLAG & 0x80000) != 0' / COSMIC_RAY
XMMEA_21= '(FLAG & 0x200000) != 0' / ON_BADPIX
XMMEA_22= '(FLAG & 0x400000) != 0' / REJECTED_BY_GATTI
XMMEA_25= '(FLAG & 0x2000000) != 0' / OUT_OF_CCD_WINDOW
XMMEA_26= '(FLAG & 0x4000000) != 0' / OUTSIDE_THRESHOLDS
XMMEA_28= '(FLAG & 0x10000000) != 0' / ON_BADROW
XMMEA_29= '(FLAG & 0x20000000) != 0' / BAD_E3E4
XMMEA_30= '(FLAG & 0x40000000) != 0' / UNDERSHOOT
XMMEA_EM= '(FLAG & 0x766b0000) == 0' / Select good MOS events
```

- **PATTERN selection**
  - **IMAGING mode: PATTERN<=12**
  - **TIMING mode:**

use PATTERN<=0 and use (FLAG==0) instead of #XMMEA_EM for the source
use (PATTERN<=1 || PATTERN==3) and use (FLAG==0) instead of #XMMEA_EM for the background

Camera-dependent screening criteria (II)

EPIC-PN:

- **#XMMEA_EP: bit-wise selection expression, automatically removes "bad events" (bad rows, edge effects, spoiled frames, cosmic ray events (MIPs), diagonal events, event beyond threshold …)**

- **PATTERN selection**

  - **IMAGING mode: PATTERN<=4 and use (FLAG==0) instead of #XMMEA_EP**

  - **TIMING mode: PATTERN<=4 and use (FLAG==0) instead of #XMMEA_EP**

Note: in timing mode, for spectral extraction it is mandatory to use PATTERN<=4

Recipe to clean flaring high background (I)

XMM-Newton sometimes experiences high flaring background periods (soft protons accelerated by magnetic reconnection). They need to be removed before extracting any scientific products:

- **extract a high-energy, single event light-curve, with the expression:**

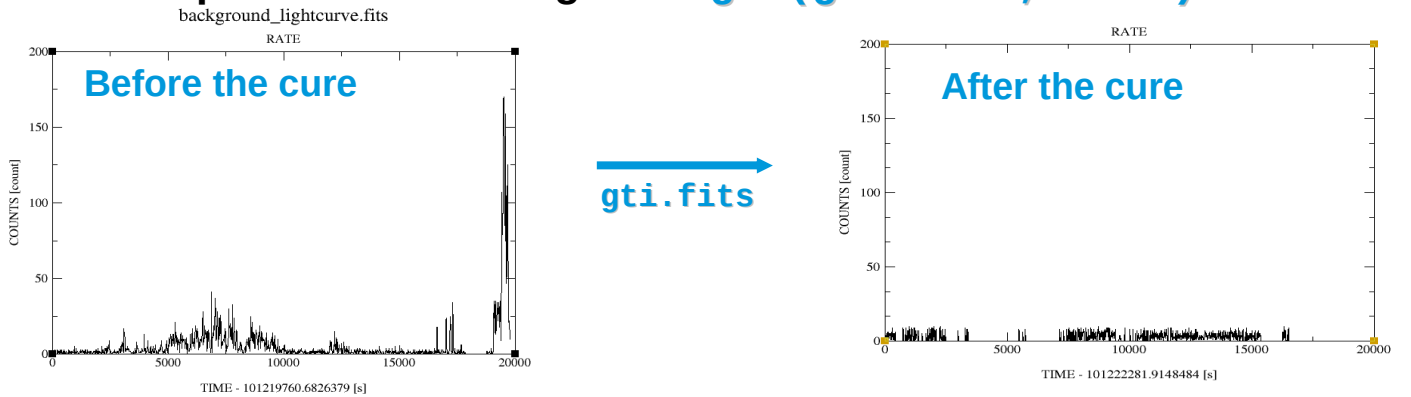
  PN:`(PI in [10000:12000])&&(PATTERN==0)&&#XMMEA_EP, timebinsize=100 (s)`

  MOS: `(PI>10000)&&(PATTERN==0)&&#XMMEA_EM, timebinsize=100 (s)`

- **create GTI, excluding all "flaring" intervals**

```
tabgtigen table=high_energy_curve.fits gtiset=gti.fits
          expression="RATE=<0.4"     for pn  - or -
          expression="RATE=<0.35"    for MOS
```

- **apply above GTI to any scientific products accumulations, adding to the selection expression the string: `".. gti(gti.fits, TIME) .."`**



Recipe to clean flaring high background (II)

Note: check lightcurves of all EPIC instruments,

GTIs needed for removal of flaring background can be quite different for different EPIC cameras in the same observation!

- **Dedicated SAS thread**

http://xmm.esac.esa.int/sas/current/documentation/threads/EPIC_filterbackground.shtml

The xmmselect window

Define selection expression here.

Currently defined selection expression can be fixed and the filtered event list used for further processing.

Circles used to define quantities to extract spectra, light curves, histograms.

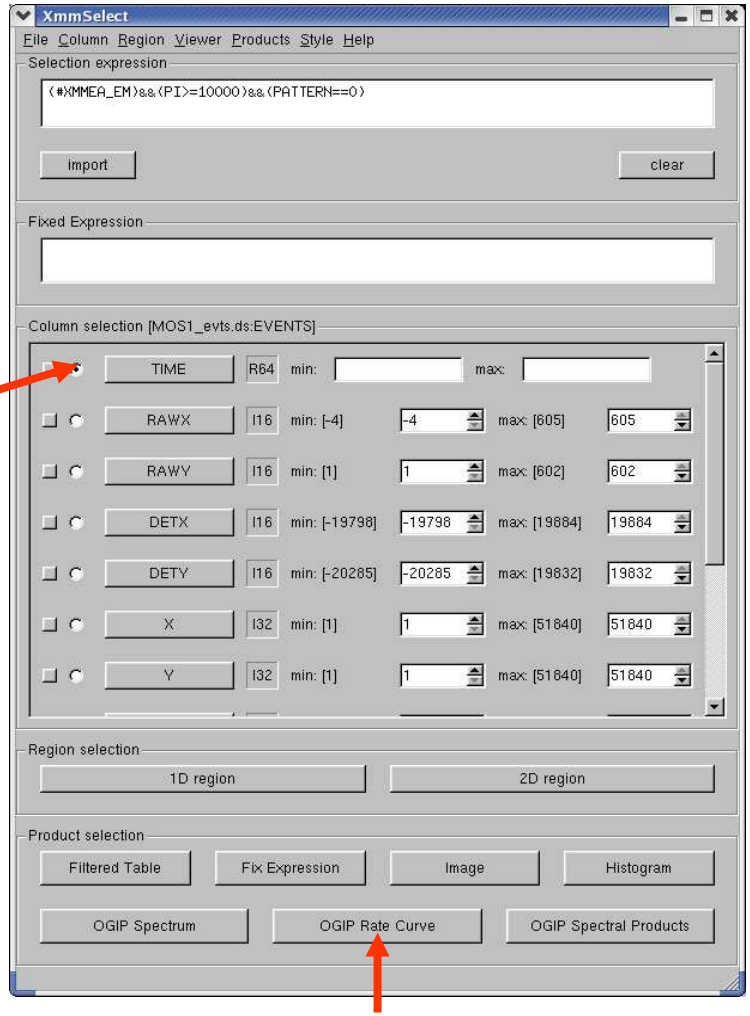
Checkboxes used to define quantities on which to extract an image.

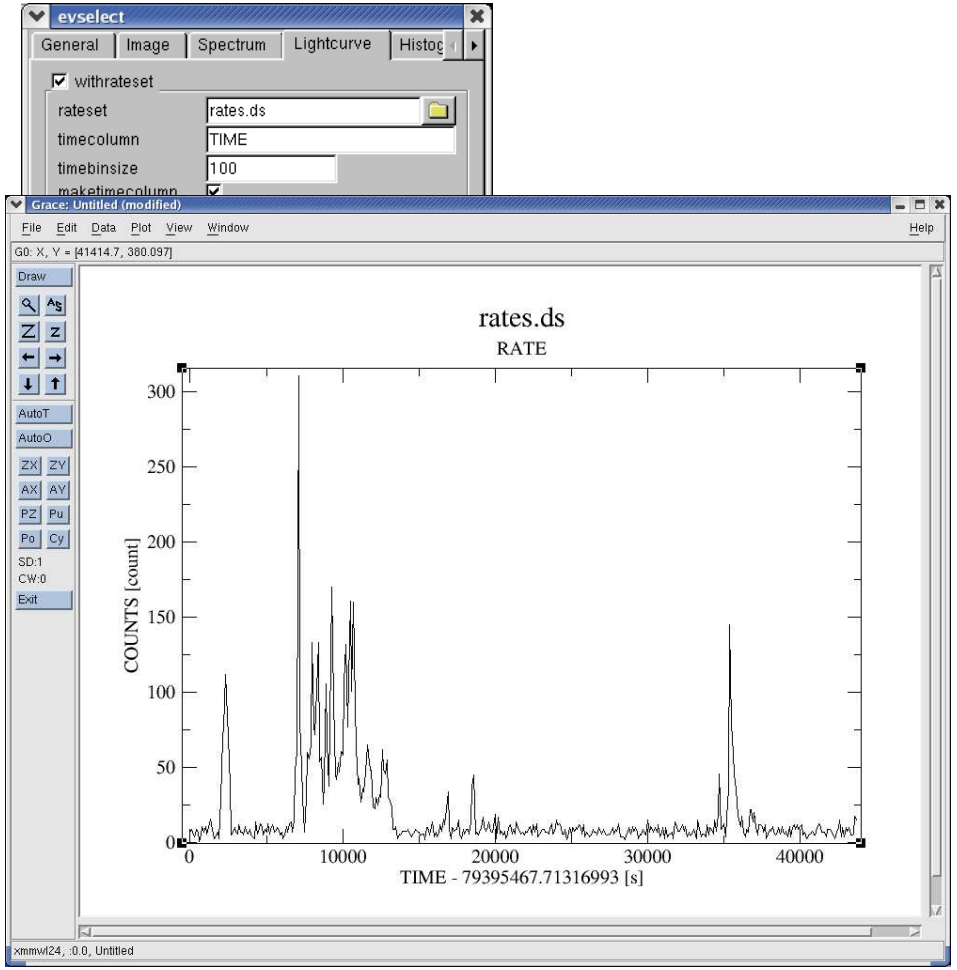
EVENTS extension columns listed. Column buttons allow to transfer ranges defined in widgets into a selection expression.

One can transfer selection regions defined in 1-D or 2-D (image) plots to selection expression widget.

Products which may be extracted: all the above plus filtered event lists.

xmmselect: creation of a rate curve

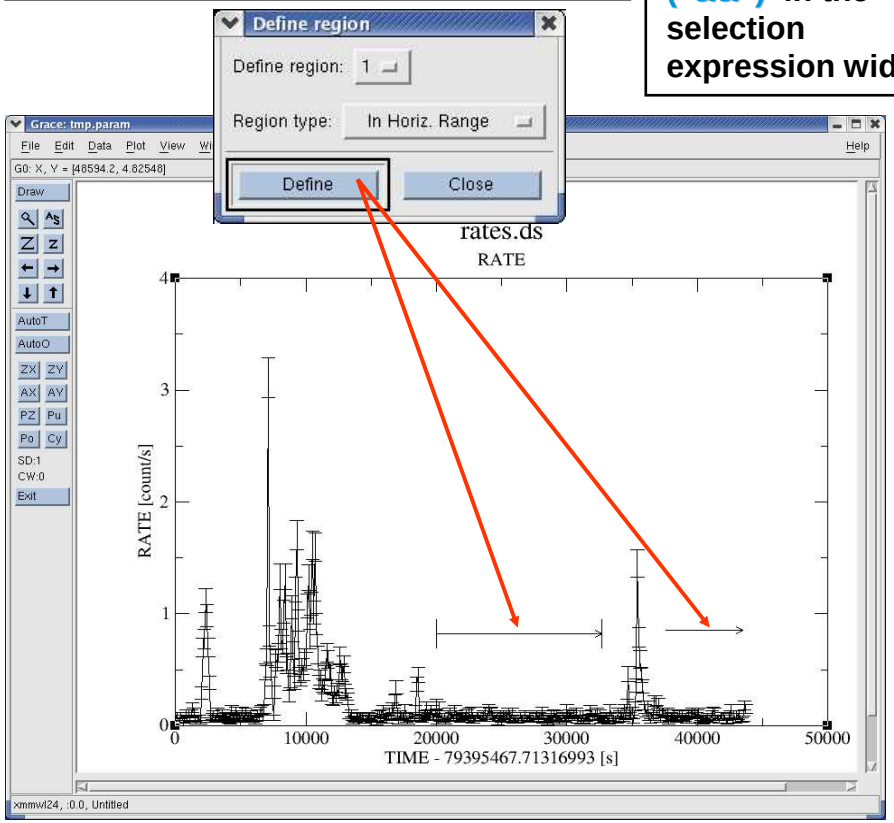


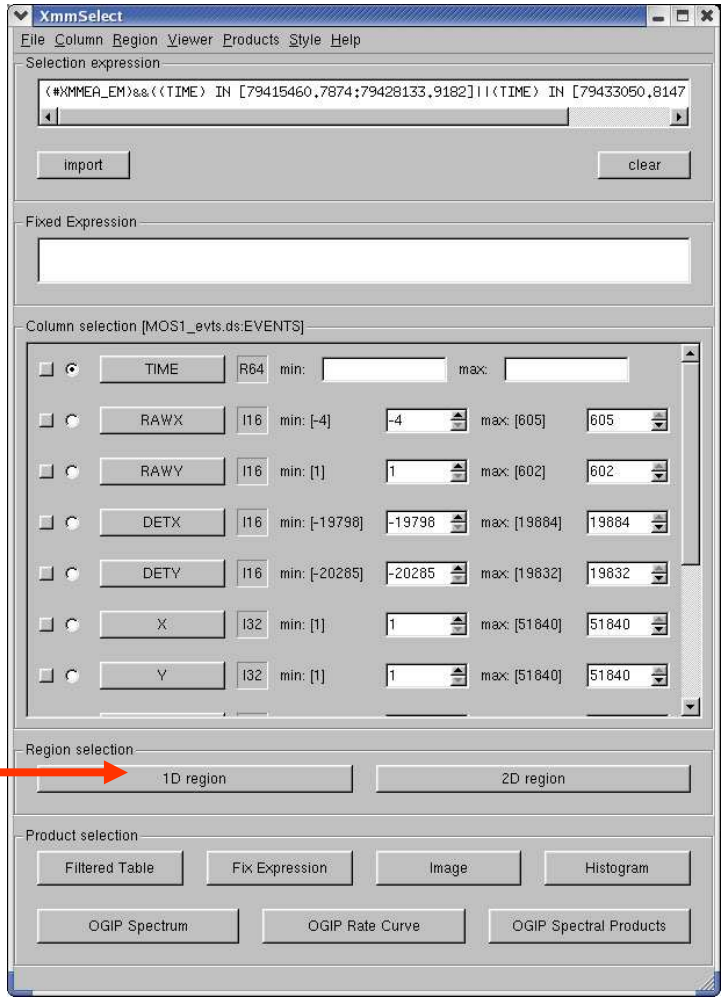


Defining interactively a 1-D (time) interval

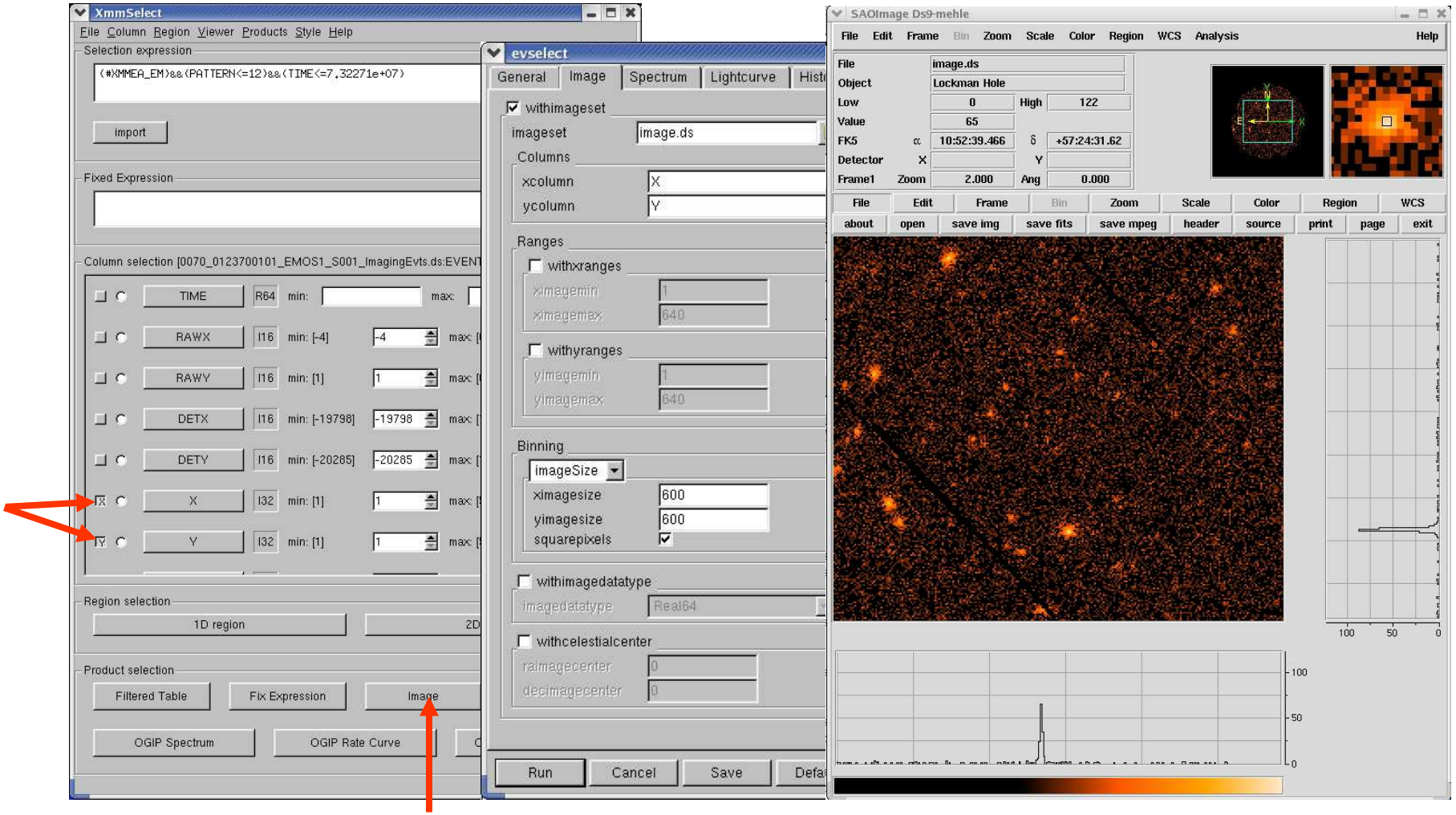
In `xmgrace` time intervals can be selected with the "Edit → Regions → Define" function.

The time filter is properly interpreted and imported ("&&") in the selection expression widget!

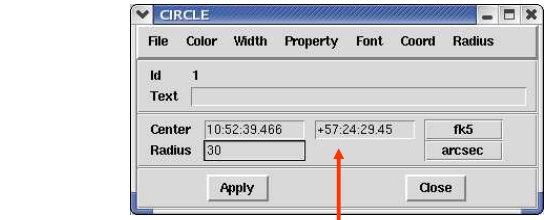


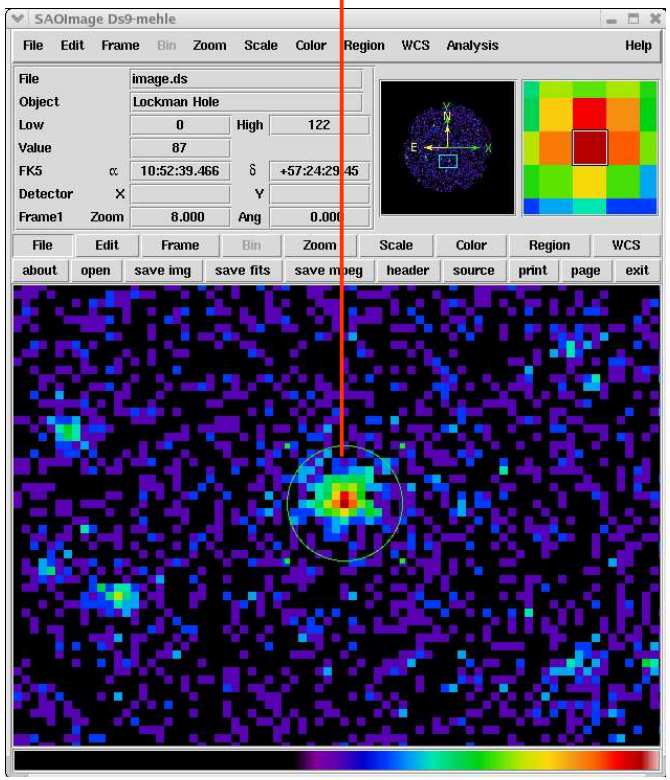


xmmselect: creation of an X-ray image



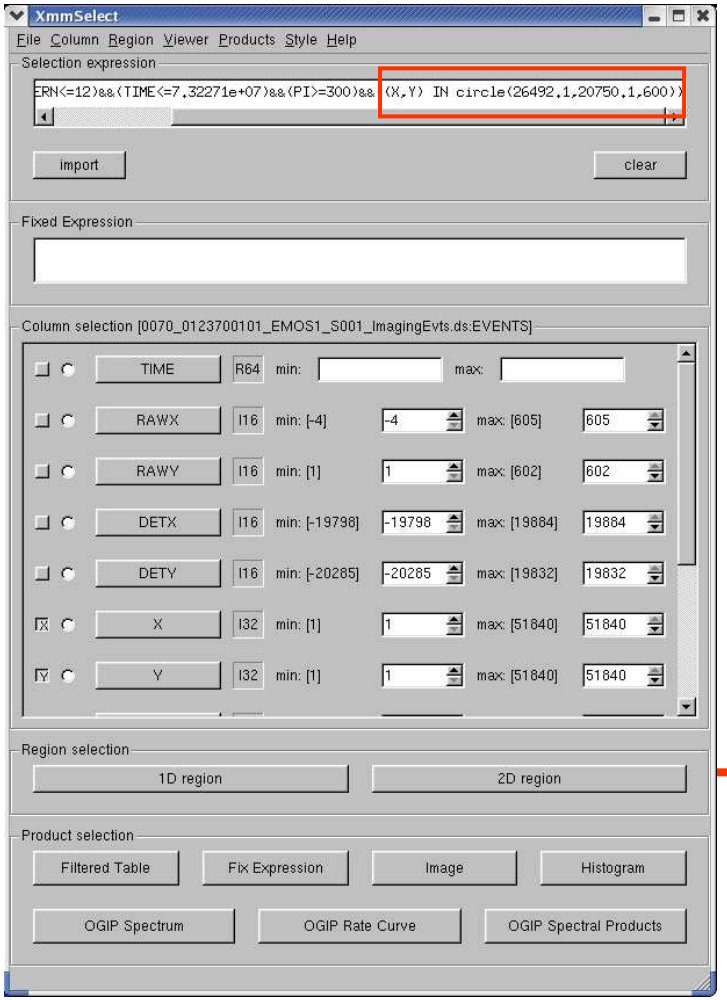
Defining interactively a 2-D spatial region



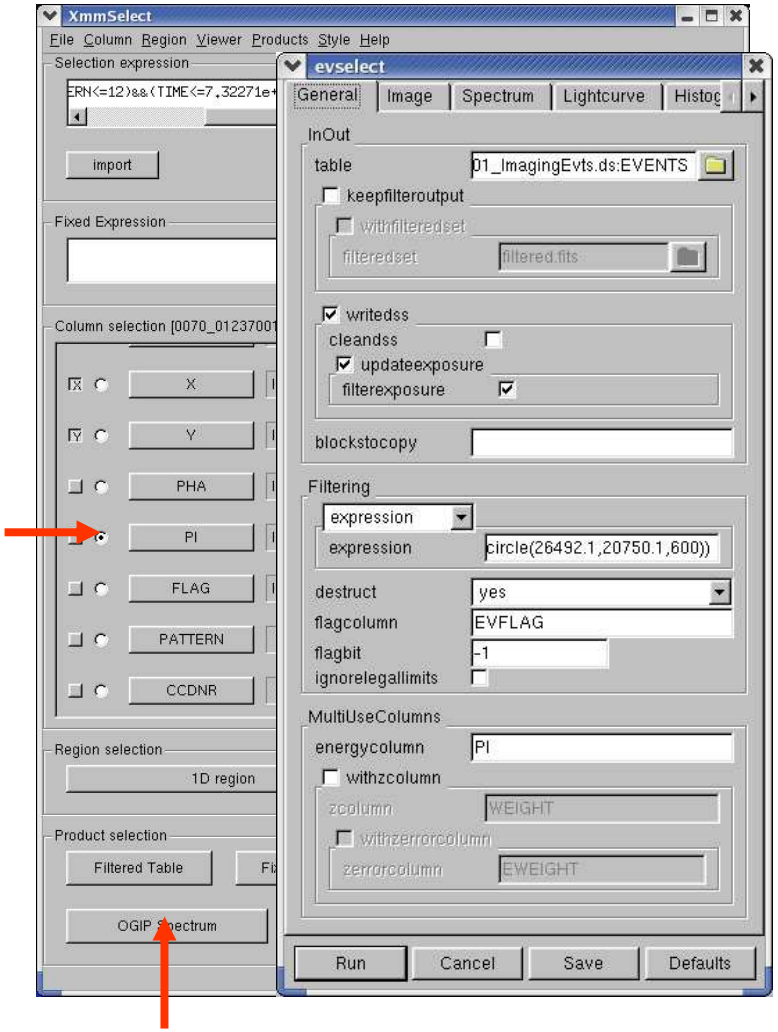


The spatial filter is properly interpreted and (“&&”) imported in the selection expression widget!

In ds9 spatial filters can be selected, defined and modified with the “Region” function

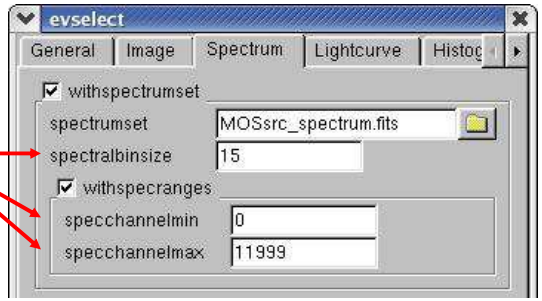


xmmselect: creation of EPIC spectra

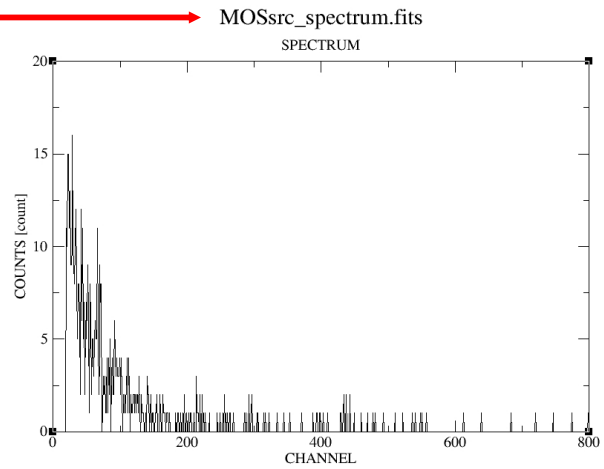


Assuming that one has cleaned the event list for high background & defined a source region (*e.g. as a circle*).

Parameters set such that MOS canned matrices can be used

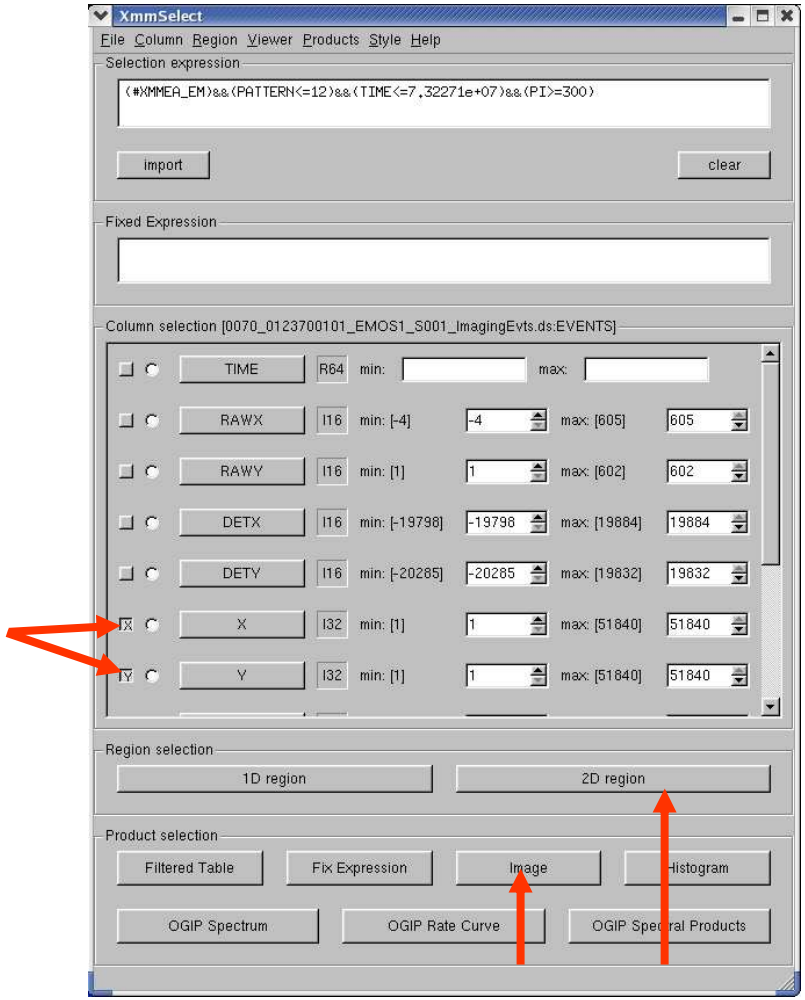


"Run": `xmgrace` window appears with the accumulated spectrum.

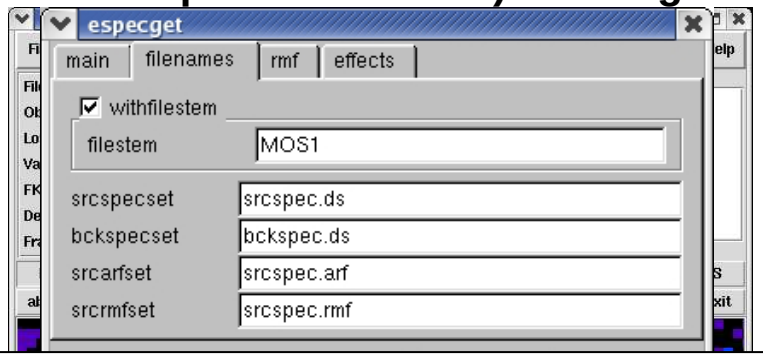


Use `specgroup` to further group the spectrum and see next presentation on *.rmf & *.arf generation

xmmselect: EPIC spectral products



Generate source & background spectra (and related response matrices) in one go:



produced files:

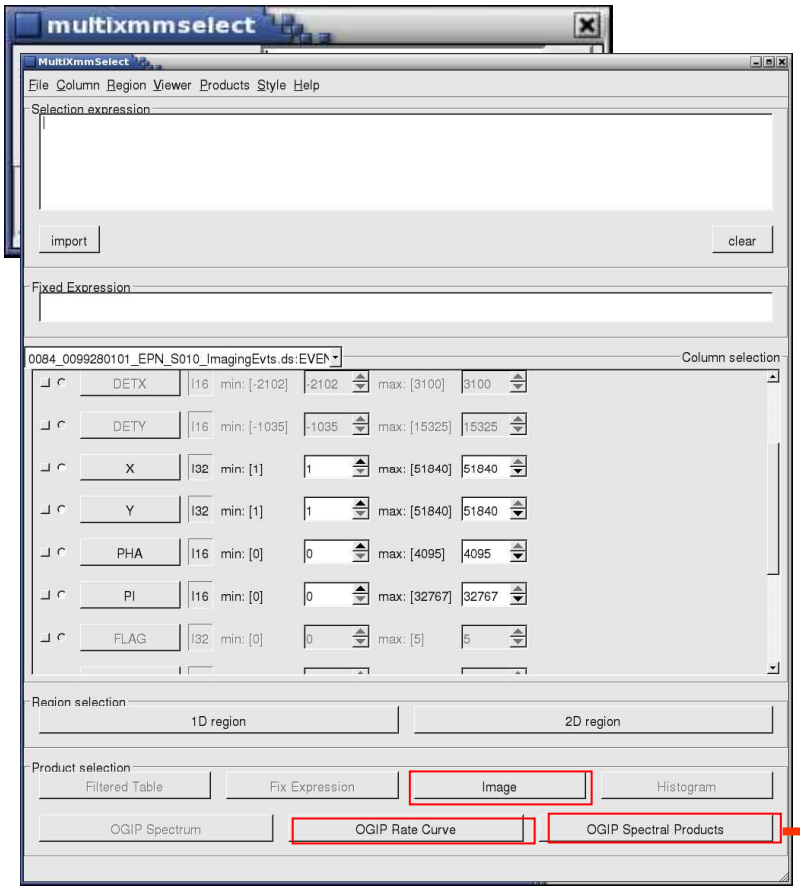
MOS1_src.ds	**source spectrum**
MOS1_bgd.ds	**background spectrum**
MOS1_src.arf	**ancillary response file (ARF) for source**
MOS1_src.rmf	**redistribution matrix file (RMF) for source**

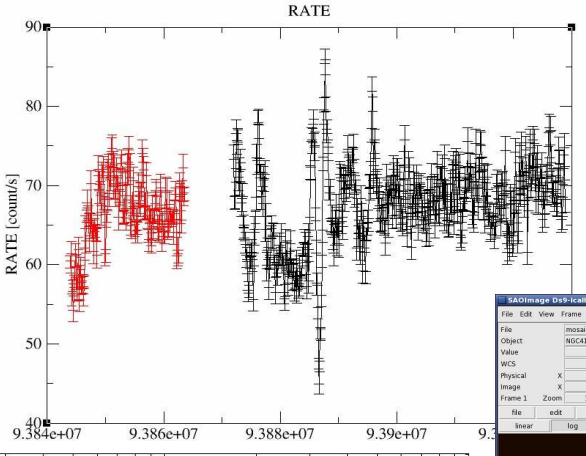
advantage: background, ARF, RMF are linked to source spectrum via header keywords

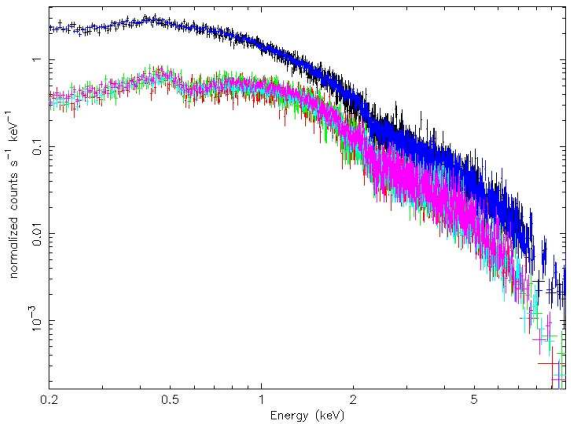
multixmmselect:
EPIC combined spectral products

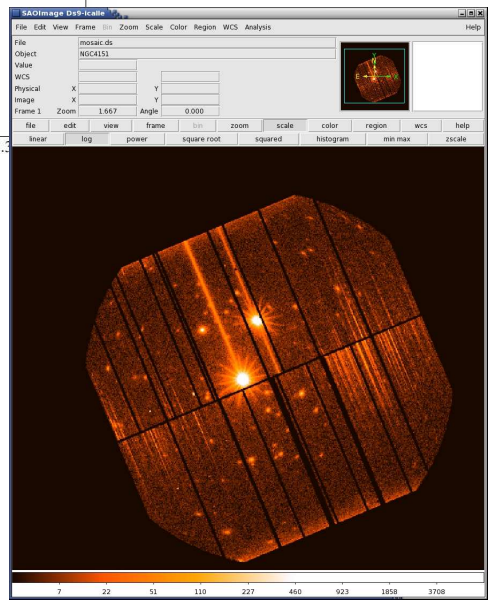
multixmmselect allows SAS users to control the generation of images, light curves and spectra of a set of EPIC event files sharing a common FOV (overlapping fields).

```
multixmmselect –d
```









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which can invoque epicspeccombine
via parameter

Background subtraction issues

1. Background regions from the same observation:

- **imaging: circular region; timing/burst: columns away from source (no RAWY selection!)**
- **MOS: same CCD (timing: evtl. outer CCDs), off-axis, away from source counts**
- **pn: ideally at same distance from CCD readout node, i.e. at same RAWY as source (evtl. on neighbouring CCD)**
- **avoid columns (RAWX) crossing source: "out of time events" ⇒ no annulus**

In this case, the background spectrum extraction follows the same procedure as source spectrum generation. Or, use `xmmselect`: Spectral Products.
Further info: see "EPIC status of calibration and data analysis".

2. Alternatively & especially for extended sources: blank fields or modelling the background (dedicated SAS-WS talk)

Further info: Background Analysis Page

http://xmm2.esac.esa.int/external/xmm_sw_cal/background/index.shtml

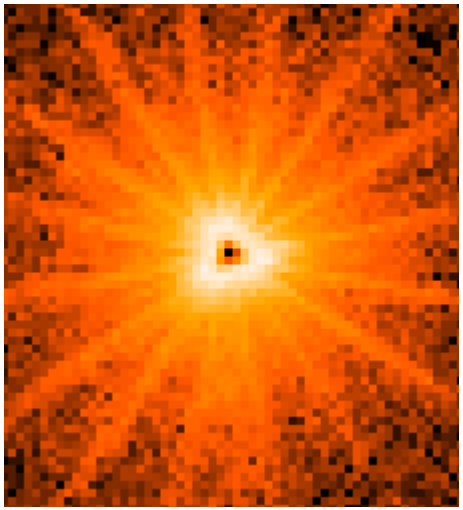
(EPIC background components; blank-sky fields, software tools, links, etc)

Pile-up, and how to deal with it

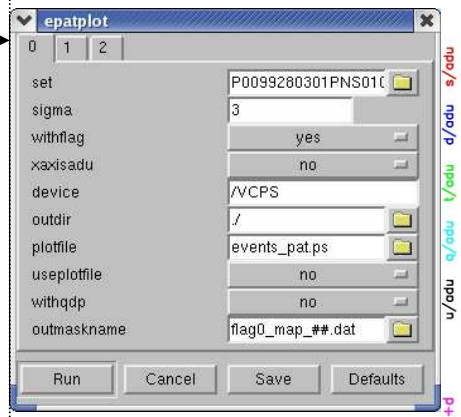
Pile-up ≡ accumulation of *n* events in the same pixel during integration time of a CCD frame.
⇒ Accumulated events interpreted one single event, whose energy $E=E_1+E_2+\ldots+E_n$.
⇒ Pile-up produces both **flux loss** *and* **spectral distortion**.

Pile-up may be a problem for *e.g.* Full Frame exposures, if count rate > 0.7 s^{-1} (MOS) / 6 s^{-1} (pn)

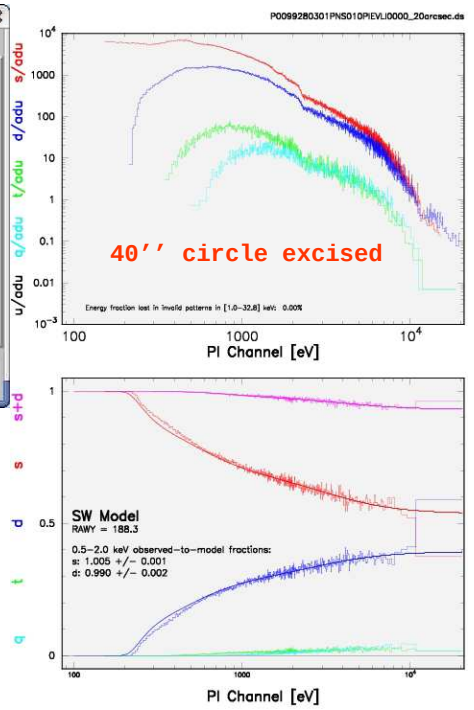
How to recognise it?



“Holes” in the PSF core



PATTERN distribution with energy (data versus model)



How to cure it?

Excising the PSF core

Using single events only

Simulating events

NEW SAS v13

xmm-newton
European Space Agency

Pile-up correction method in SAS

The new pile-up correction method is available in SAS v13. The method is implemented in the SAS task `rmfgen`

- run `epchain` or `epproc` with options:

```
epchain keepintermediate=all

epproc pileuptempfile=yes
```

→ This will produce an intermediate event file

events04.dat

- run `rmfgen`:

```
rmfgen specturmset=spectrum.ds rmfset=myresp.rmf \
   correctforpileup=yes raweventfile=events04.dat
```

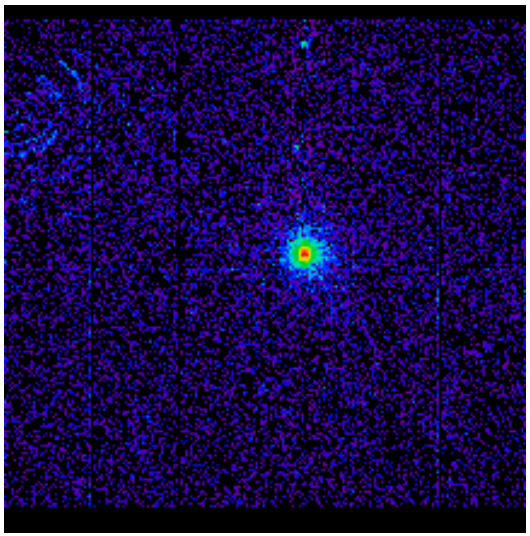
Recommendation: run both methods, excise core and pile-up correction, and see if they agree. If they do, use the pile-up correction method, which will give you better statistics.

Pile-up Thread http://xmm.esac.esa.int/sas/current/documentation/threads/epatplot.shtml

Out-of-time events, and how to deal with them

Out-of-time (OoT) events: photons not only registered during actual integration interval but also during readout of CCD.
OoT events broaden spectral features (wrong CTI correction) and create in images a strip of wrongly reconstructed event positions in RAWY.
Fraction of Oot events scales with mode-dependent ratio of integration and readout time: highest for pn full frame (6.3%) and extended full frame (2.3%) mode (see UHB for further details).

How to recognise it?



image_clean.fits

How to cure it?

Run pipeline task twice:
first creating OoT event list and then the 'normal' calibrated event list:
- OoT event list produced by calling epevents with non-default parameter setting withoutoftime=yes
- new RAWY values simulated by randomly shifting pattern along RAWY axis and performing gain and CTI correction afterwards.

Correcting spectra:
(mostly not needed; in any case only if OoT events overlap with source)
evselect **to create spectra from 'normal' and OoT event list;**
ftools **to copy OoT counts into 'normal' spectrum,**
to scale down and subtract them (see SAS Guide for details).

Out of Time Events Thread
http://xmm.esac.esa.int/sas/current/documentation/threads/EPIC_OoT.shtml

Is my spectrum good enough?

There are four main sources of information to answer this question:

1. **CCF release notes: report expected accuracy associated with each individual CCF component.**

   http://xmm2.esac.esa.int/external/xmm_sw_cal/calib/rel_notes/index.shtml

2. **EPIC status of calibration and data analysis (XMM-SOC-CAL-TN-0018, via Calibration Portal page): status/quality of calibration implemented in SAS release; outlook on future improvements.**

   http://xmm2.esac.esa.int/docs/documents/CAL-TN-0018.pdf

3. **Status of cross-calibration (XMM-SOC-CAL-TN-0052): comparing XMM-Newton instruments' calibration (with public SAS & CCFs) amongst each other & with other missions.**

   http://xmm2.esac.esa.int/docs/documents/CAL-TN-0052.ps.gz

4. **SAS validation reports: compare expected calibration accuracies on a pre-defined set of XMM-Newton observations. An update of the report is issued for every (major) SAS release.**

   http://xmm.esac.esa.int/external/xmm_data_analysis/sas_validation/index.shtml

xmmextractor

Is a metatask for general processing of all the XMM-Newton data corresponding to one observation, for all instruments (since SASv12 includes OM) and given sky coordinates.

Analysis thread available:

http://xmm.esac.esa.int/sas/current/documentation/threads/xmmextractor.shtml

Task documentation:

http://xmm.esac.esa.int/sas/current/doc/xmmextractor/index.html

- **Create your own pipeline products starting at the ODF level with a single tool, and interactively extract point source-specific products: spectra plus responses, light curves, images etc.**

Keep in mind that at this stage xmmextractor is an experimental task

xmmextractor: how to run it

- **Before runinng xmmextractor, another SAS task needs to be run: odfParamCreator**

  This task, creates an XML file with all the observation information needed to by xmmextractor

- **The procedure to run xmmextractor is thus as follows:**

  download the odf

  set SAS_ODF variable pointing to the odf directory

  run `odfParamCreator`

  ```
  odfParamCreator outputFileName=MyFile.xml
  ```

  run `xmmextractor`

  ```
  xmmextractor paramfile=MyFile.xml outputfile=xmmextractor_date.xml
  ```

xmmextrator: MyFile.xml

MyFile.xml

The file can be edited by hand with a text editor

In the next SAS version, an interface to this file will be provided

```
-<BODY>
 -<CONFIG SASVersion="xmmsas_20110223_1801">
  -<OBSERVATION>
    <PARAM id="analysisoption" default="0:all"/>
    <PARAM id="epicsrc" default="no"/>
    <PARAM id="ra" default="-999"/>
    <PARAM id="dec" default="-999"/>
    <PARAM id="sourcename" default="V723_Cas"/>
    <PARAM id="obsid" default="0652070101"/>
    <PARAM id="EPN" default="yes"/>
    <PARAM id="EMOS1" default="yes"/>
    <PARAM id="EMOS2" default="yes"/>
    <PARAM id="RGS1" default="yes"/>
    <PARAM id="RGS2" default="yes"/>
    <PARAM id="OM" default="yes"/>
    <PARAM id="OM_sourcematch" default="0.000277777"/>
  </OBSERVATION>
  -<INSTRUMENT value="EMOS1">
   -<EXPOSURE mode="PrimePartialW2" expid="S001" duration="50140" process="yes">
    -<PRODUCT value="EventList" process="yes">
     -<TASK purpose="EMOS1_processing" name="emproc">
        <PARAM id="withinstexpids" default="yes"/>
        <PARAM id="instexpids" default="M1S001"/>
      </TASK>
     </PRODUCT>
```

0:all (default)
1:events
2:gti
3:edetectchain
4:epic_spectra
5:epic_lightcurve
6:rgs_lightcurve