Calibration files in XMM-Newton - the CCF concept and more

Carlos Gabriel, Richard Saxton & the
SAS & PPS Maintenance and Development Team

Where's Wally? ... and When?

The XMM-Newton CCF and `cifbuild`

- The calibration of XMM-Newton instruments is partially independent from the development of its data analysis software, SAS

- XMM-Newton calibration data is contained in Current Calibration File (CCF)
  - CCF = the collection of **all** the XMM-Newton calibration files ever made public
  - Note: the calibration files are **updated continuously** → **NO CCF version number but individual calibration files versions**

- Calibration Index File (CIF) necessary for data analysis, pointing to the relevant files, according to:
  - observation date
  - analysis date

- cifbuild operates on the calibration directory $SAS_CCFPATH
  - setenv SAS_CCFPATH <ccf_dir>

- Command: cifbuild
  - **It produces a FITS file ccf.cif in the working directory, using :**
    - **$SAS_ODF for observation Date and**
    - **'now' for analysis date, unless explicitly specified**

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File Edit Tools

	TELESCOP	SCOPE	TYPEID	ISSUE	VALDATE
	4A	6A	32A	I	19A yyyy:dd:mmZhh:mm:ss
40	XMM	EPN	LINCOORD	9	1998-01-01T00:00:00
41	XMM	EPN	MODEPARAM	3	1999-01-01T00:00:00
42	XMM	EPN	PATTERNLIB	1	1998-01-01T00:00:00
43	XMM	EPN	QUANTUMEF	8	2000-01-01T00:00:00
44	XMM	EPN	REDIST	5	1998-01-01T00:00:00
45	XMM	EPN	TIMECORR	4	1998-01-01T00:00:00
46	XMM	OM	ASTROMET	8	1998-01-01T00:00:00
47	XMM	OM	BADPIX	2	1998-01-01T00:00:00
48	XMM	OM	COLORTRANS	5	1998-01-01T00:00:00
49	XMM	OM	DARKFRAME	3	1998-01-01T00:00:00
50	XMM	OM	DIFFUSEGALA	1	1998-01-01T00:00:00
51	XMM	OM	HKPARMINT	3	1999-01-01T00:00:00
52	XMM	OM	LARGESCALESENS	2	1998-01-01T00:00:00
53	XMM	OM	LINCOORD	1	1998-01-01T00:00:00
54	XMM	OM	PHOTTONAT	3	1998-01-01T00:00:00
55	XMM	OM	PIXTOPIXSENS	3	1998-01-01T00:00:00
56	XMM	OM	PSF1DRB	4	1998-01-01T00:00:00
57	XMM	OM	QUICKMAG	2	1998-01-01T00:00:00
58	XMM	OM	ZODIACAL	1	1998-01-01T00:00:00
59	XMM	RGS1	ADUCONV	5	2000-02-06T16:49:60
60	XMM	RGS1	BACKGROUND	1	1998-01-01T00:00:00
61	XMM	RGS1	BADPIX	5	2000-02-06T16:49:60
62	XMM	RGS1	CALSOURCEDATA	1	1998-01-01T00:00:00
63	XMM	RGS1	CLOCKPATTERNS	1	1998-01-01T00:00:00
64	XMM	RGS1	CROSSPSF	2	2000-01-01T00:00:00
65	XMM	RGS1	CTI	2	2000-02-06T16:49:60
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67	XMM	RGS1	HKPARMINT	6	1999-01-01T00:00:00
68	XMM	RGS1	LINCOORD	7	1998-01-01T00:00:00
69	XMM	RGS1	LINESPREADFUNC	3	1999-01-01T00:00:00

CIF is a FITS file

- **The CIF file is in FITS format (you may use any FITS tool to view or work on it, e.g. fv).**

- **Once the Calibration Index file has been produced:**

setenv SAS_CCF ccf.cif

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cifbuild uses single CCF keywords:

- VALDATE as start of calibration validity period
- EVALDATE as end of validity period
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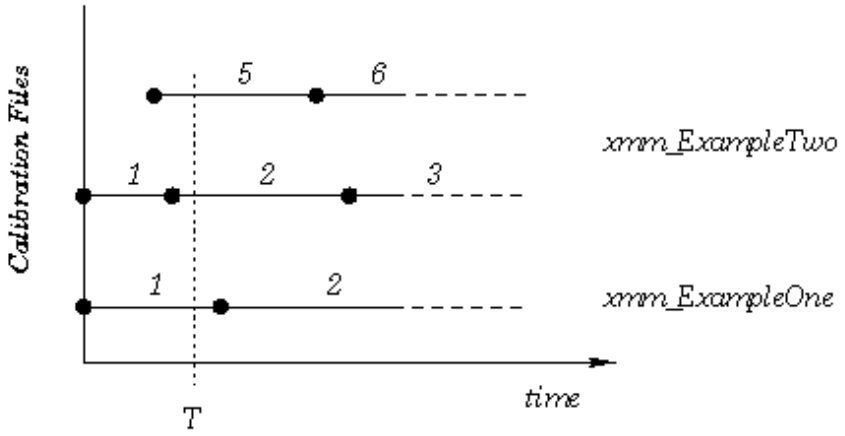

Figure 2: Current calibration file with two files: update. At the time T the current calibration file consists of *xmm_ExampleOne_0001.ccf* and *xmm_ExampleTwo_0005.ccf*

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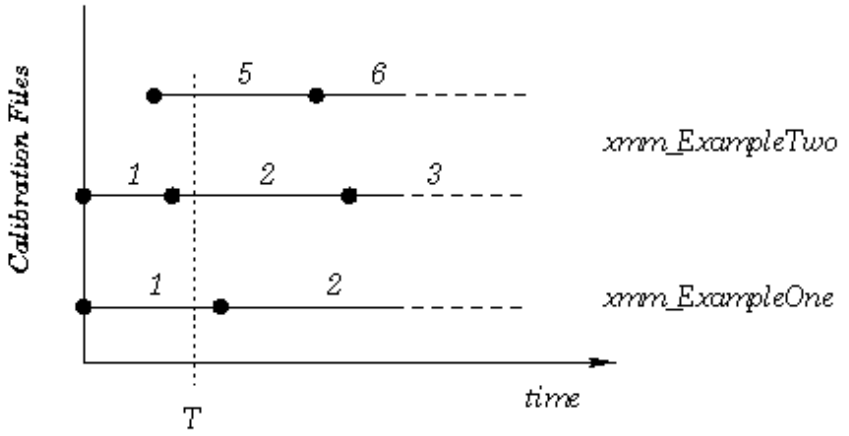

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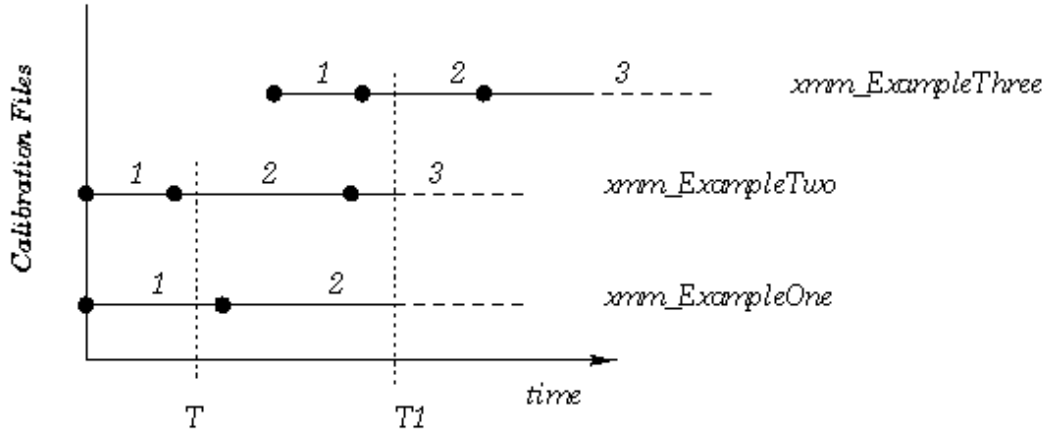

Figure 3: Current calibration file with three files. At the time $T1$ the current calibration file consists of *xmm_ExampleOne_0002.ccf* and *xmm_ExampleTwo_0009.ccf* and *xmm_ExampleThree_0002.ccf*

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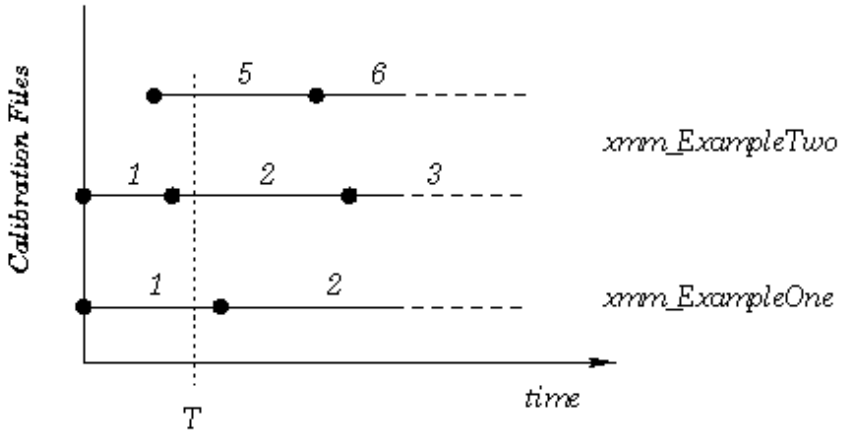

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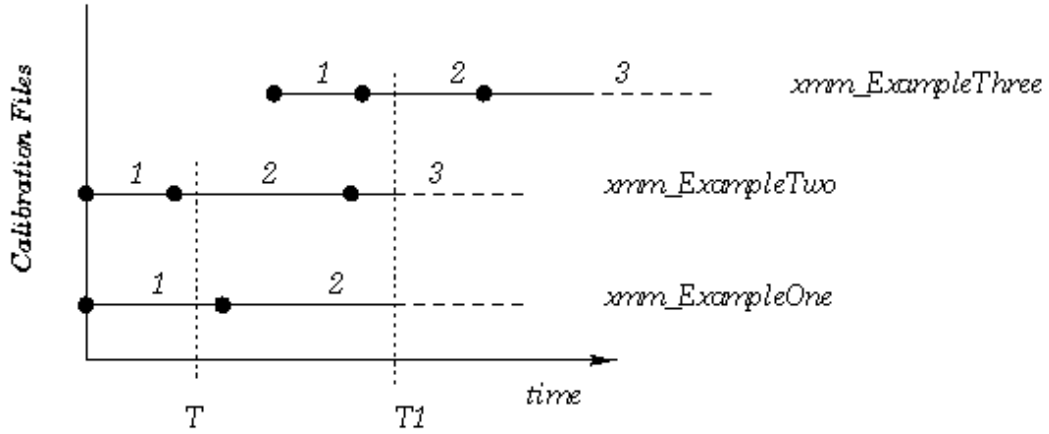
Rule: out of all the CCF calibration files take the highest issue with VALDATE lower AND EVALDATE higher than observation date AND DATE lower than analysis date.



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The *cif* on-line

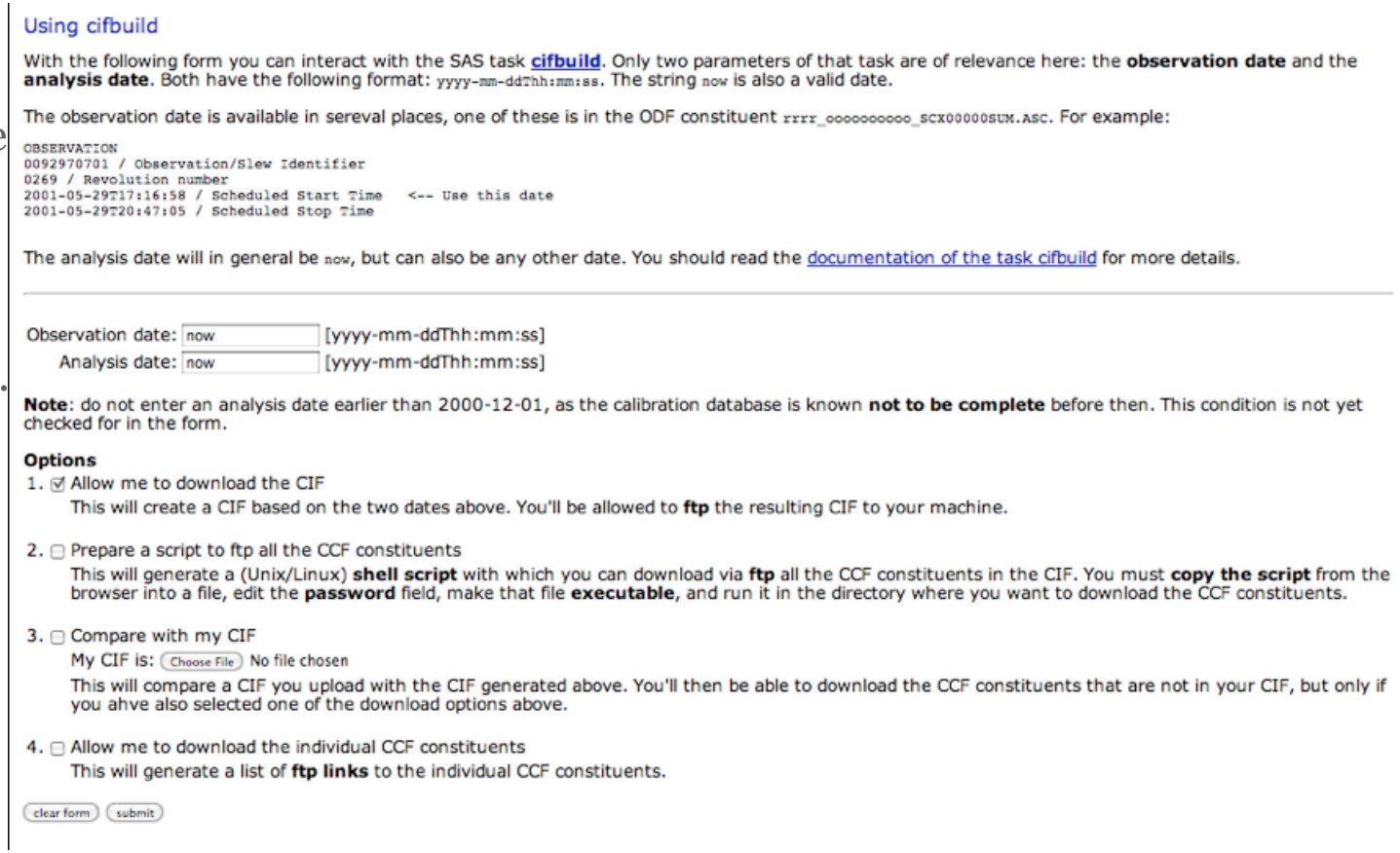
- On the XMM-Newton calibration web pages [https://www.cosmos.esa.int/web/xmm-newton/cifbuild]:

✓ updated cif can be generated on-line and compared to the provided one

✓ required (missing) CCF constituents can also be downloaded

✓ Local CCF library can be mirrored from XMM web site.

- Via the **rsync** or **mirror** commands (see doc web pages)



Using cifbuild

With the following form you can interact with the SAS task **cifbuild**. Only two parameters of that task are of relevance here: the **observation date** and the **analysis date**. Both have the following format: `yyyy-mm-ddThh:mm:ss`. The string `now` is also a valid date.

The observation date is available in sereval places, one of these is in the ODF constituent `rrrr_oooooooooo_SCX00000SUM.ASC`. For example:

```
OBSERVATION
0092970701 / Observation/Slew Identifier
0269 / Revolution number
2001-05-29T17:16:58 / Scheduled Start Time   <-- Use this date
2001-05-29T20:47:05 / Scheduled Stop Time
```

The analysis date will in general be `now`, but can also be any other date. You should read the documentation of the task cifbuild for more details.

Observation date: now [yyyy-mm-ddThh:mm:ss]
Analysis date: now [yyyy-mm-ddThh:mm:ss]

Note: do not enter an analysis date earlier than 2000-12-01, as the calibration database is known **not to be complete** before then. This condition is not yet checked for in the form.

Options

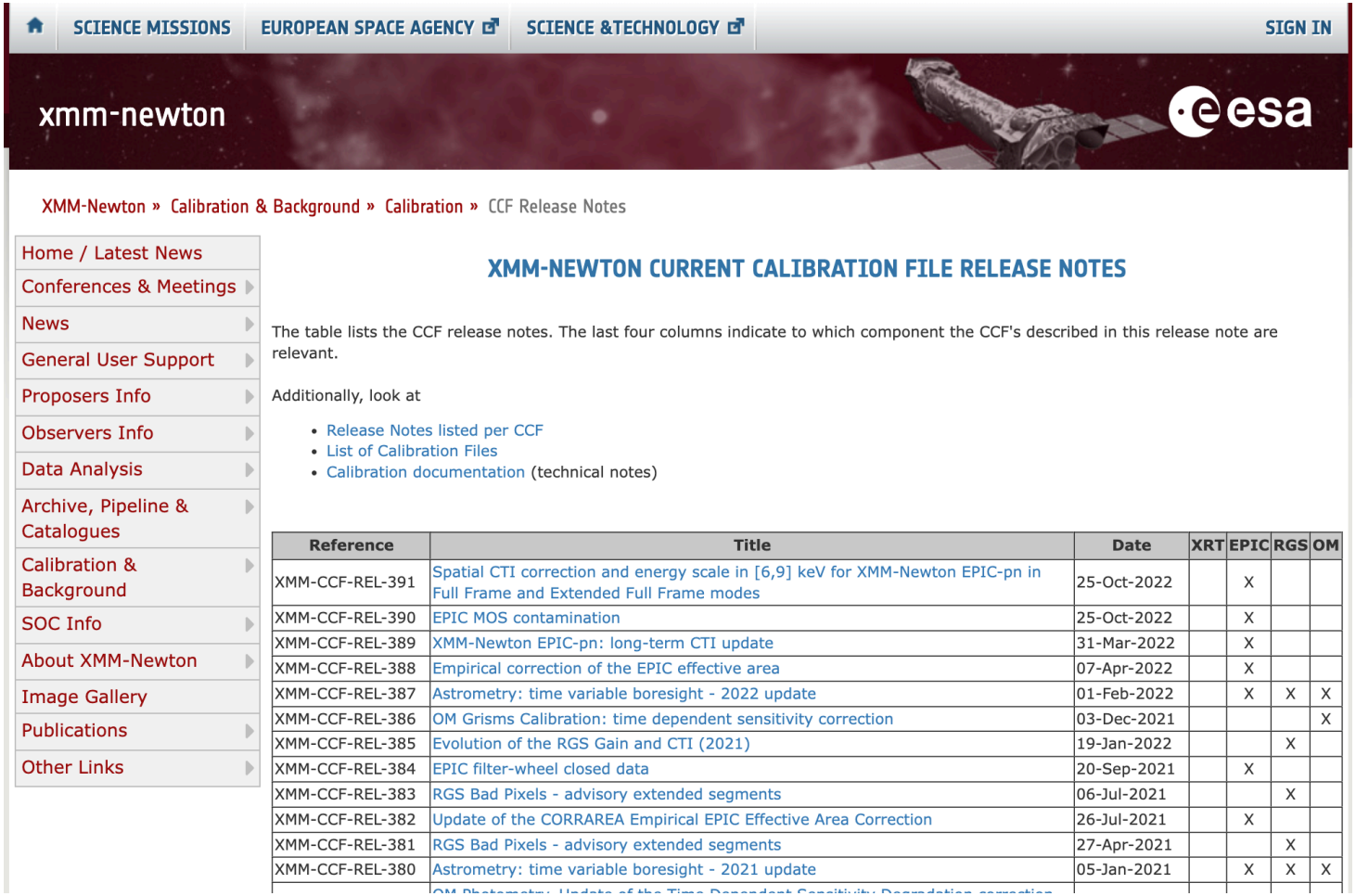
1. ☑ Allow me to download the CIF
   This will create a CIF based on the two dates above. You'll be allowed to **ftp** the resulting CIF to your machine.
2. ☐ Prepare a script to ftp all the CCF constituents
   This will generate a (Unix/Linux) **shell script** with which you can download via **ftp** all the CCF constituents in the CIF. You must **copy the script** from the browser into a file, edit the **password** field, make that file **executable**, and run it in the directory where you want to download the CCF constituents.
3. ☐ Compare with my CIF
   My CIF is: Choose File No file chosen
   This will compare a CIF you upload with the CIF generated above. You'll then be able to download the CCF constituents that are not in your CIF, but only if you ahve also selected one of the download options above.
4. ☐ Allow me to download the individual CCF constituents
   This will generate a list of **ftp links** to the individual CCF constituents.

clear form submit

The *CCF* release notes

- CCF release note shall be consulted, at least periodically.
  - ✓ Subscribing to the CCF mailing list is also useful, to get the RNs and CCFs only when there is something new:

https://www.cosmos.esa.int/web/xmm-newton/ccf-release-notes



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xmm-newton

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- Archive, Pipeline & Catalogues
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XMM-NEWTON CURRENT CALIBRATION FILE RELEASE NOTES

The table lists the CCF release notes. The last four columns indicate to which component the CCF's described in this release note are relevant.

Additionally, look at

- Release Notes listed per CCF
- List of Calibration Files
- Calibration documentation (technical notes)

Reference	Title	Date	XRT	EPIC	RGS	OM
XMM-CCF-REL-391	Spatial CTI correction and energy scale in [6,9] keV for XMM-Newton EPIC-pn in Full Frame and Extended Full Frame modes	25-Oct-2022		X		
XMM-CCF-REL-390	EPIC MOS contamination	25-Oct-2022		X		
XMM-CCF-REL-389	XMM-Newton EPIC-pn: long-term CTI update	31-Mar-2022		X		
XMM-CCF-REL-388	Empirical correction of the EPIC effective area	07-Apr-2022		X		
XMM-CCF-REL-387	Astrometry: time variable boresight - 2022 update	01-Feb-2022		X	X	X
XMM-CCF-REL-386	OM Grisms Calibration: time dependent sensitivity correction	03-Dec-2021				X
XMM-CCF-REL-385	Evolution of the RGS Gain and CTI (2021)	19-Jan-2022			X	
XMM-CCF-REL-384	EPIC filter-wheel closed data	20-Sep-2021		X		
XMM-CCF-REL-383	RGS Bad Pixels - advisory extended segments	06-Jul-2021			X	
XMM-CCF-REL-382	Update of the CORRAREA Empirical EPIC Effective Area Correction	26-Jul-2021		X		
XMM-CCF-REL-381	RGS Bad Pixels - advisory extended segments	27-Apr-2021			X	
XMM-CCF-REL-380	Astrometry: time variable boresight - 2021 update	05-Jan-2021		X	X	X

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- **All** the calibration files are **kept** in the **CCF repository** only to be able to **reproduce** calibration conditions met in the past (SAS can reduce data as it would have been done with the calibration knowledge of years ago).
- Many CCF files have been superseded by more accurate calibration and will never be used by a normal observer (ie. using the default “analysisdate=now”).
- We have produced a reduced repository for all those observers, who do not want to mirror the entire repository but only the **relevant part** for an up-to-date data reduction.
- All the calibration files which would never be used when “analysisdate=now” are NOT present in this repository.
- The full repository has as of today a volume of ~ 4.3 GB (~ 1550 files), while the reduced repository is about ~ 1.18 GB (~ 515 files)

All the important bits for you together

- CCF Library: All CCF ever made public
  - ftp: see page https://www.cosmos.esa.int/web/xmm-newton/current-calibration-files
  - rsync: rsync -v -a --delete --delete-after --force --include='*.CCF' --exclude='*/' sasdev-xmm.esac.esa.int::XMM_CCF <dir>/

- Reduced CCF Library:
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  - rsync: rsync -v -a --delete --delete-after --force --include='*.CCF' --exclude='*/' sasdev-xmm.esac.esa.int::XMM_VALID_CCF <dir>/

- CCF on the net:
  - https://www.cosmos.esa.int/web/xmm-newton/cifbuild

- CCF Release Notes: justifying calibration files releases
  - https://www.cosmos.esa.int/web/xmm-newton/ccf-release-notes

`calview`: plotting CCF data and more

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XMM-Newton Calibration DB: Calibration Access Layer CAL
(calibration algorithms & access functions) + CCF

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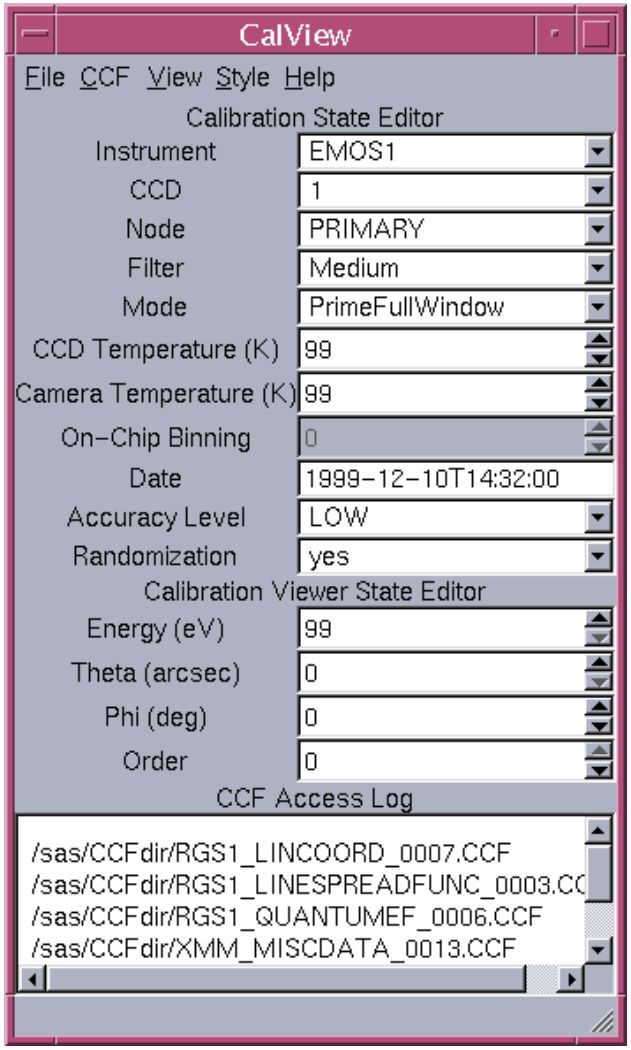

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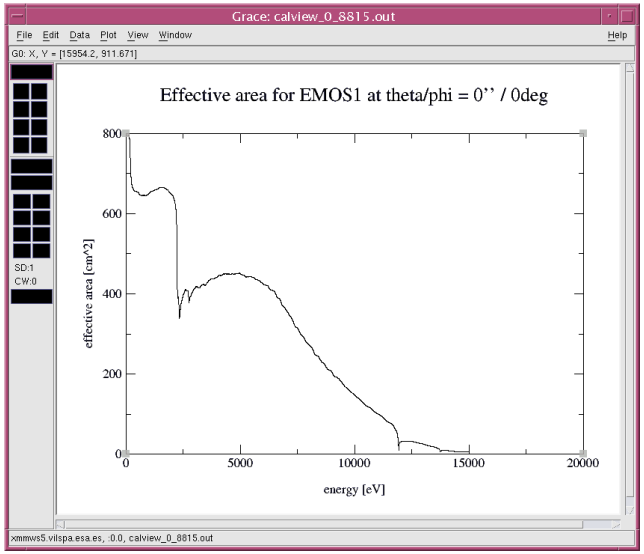

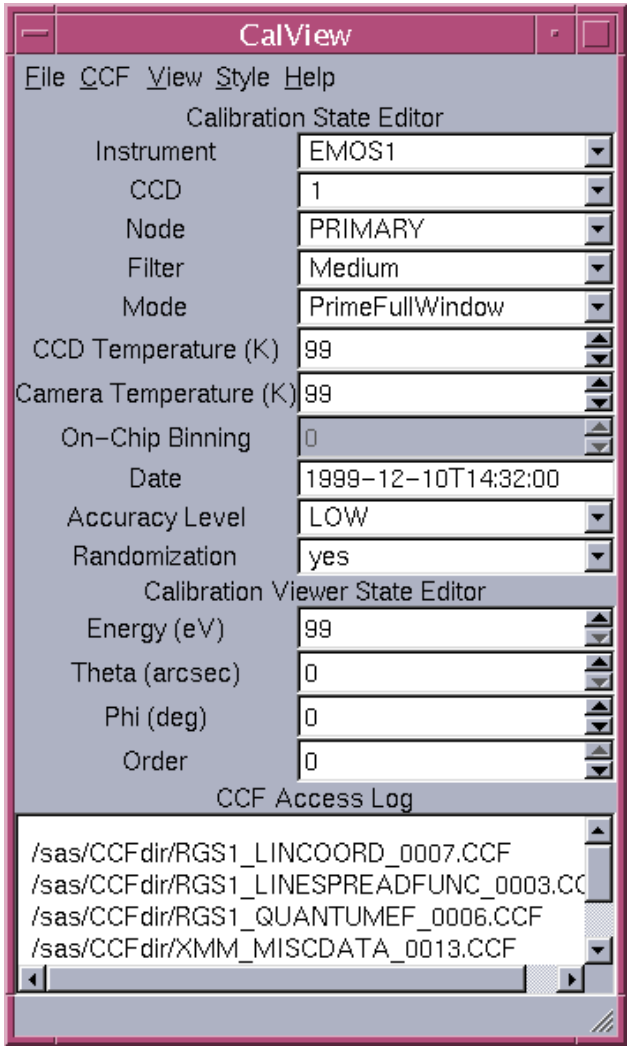

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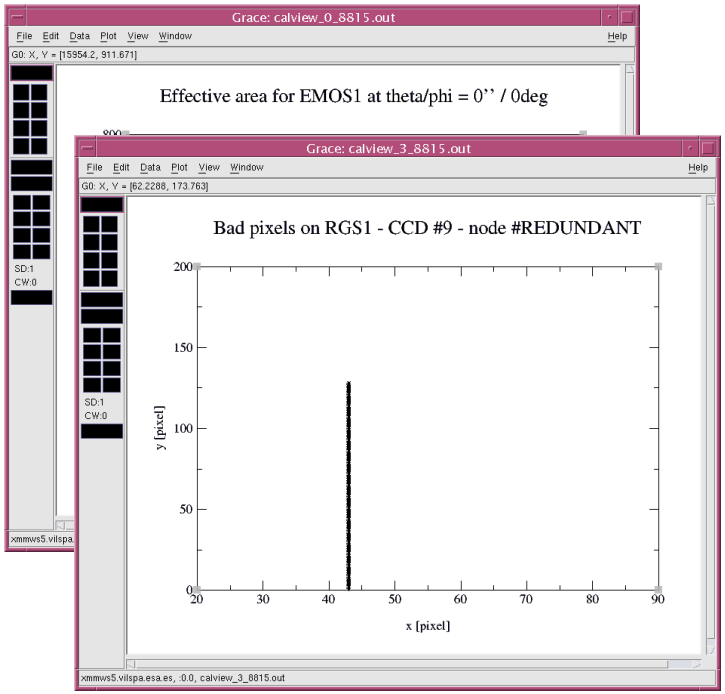

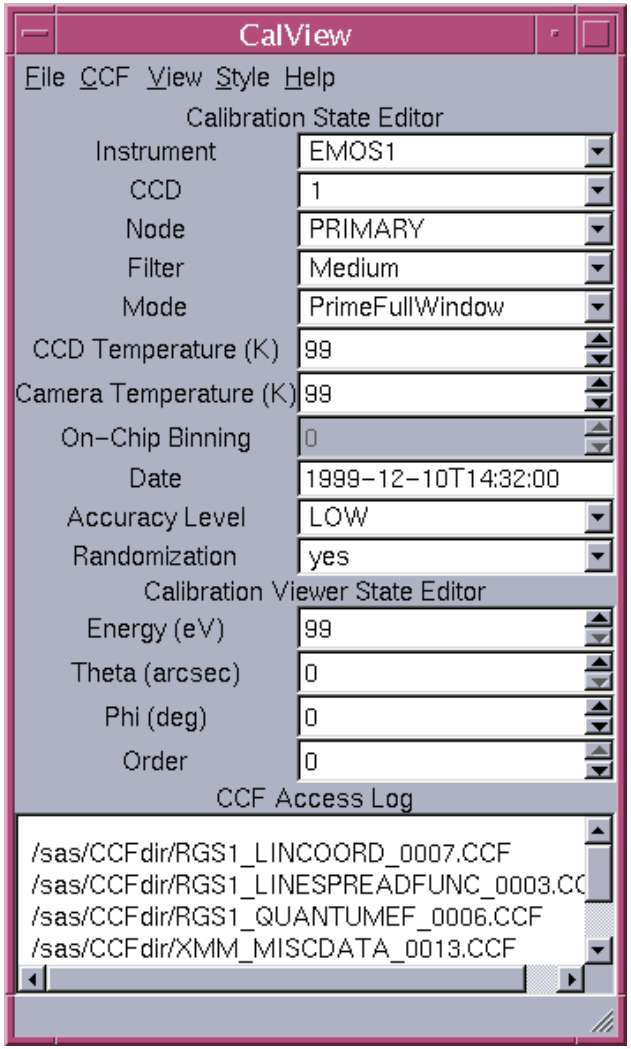

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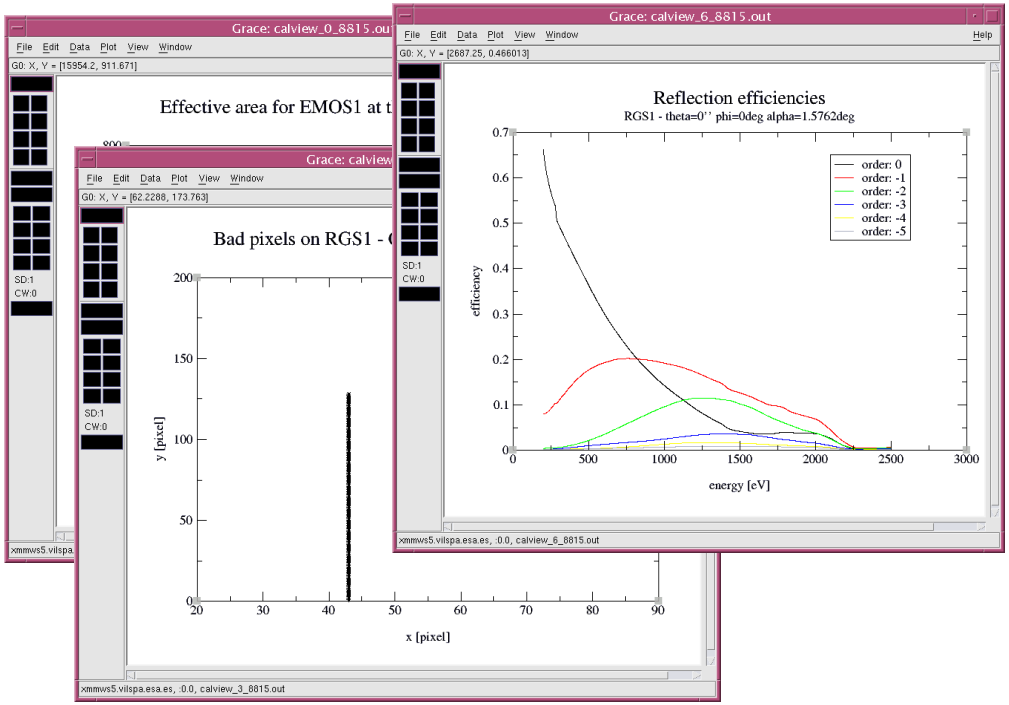

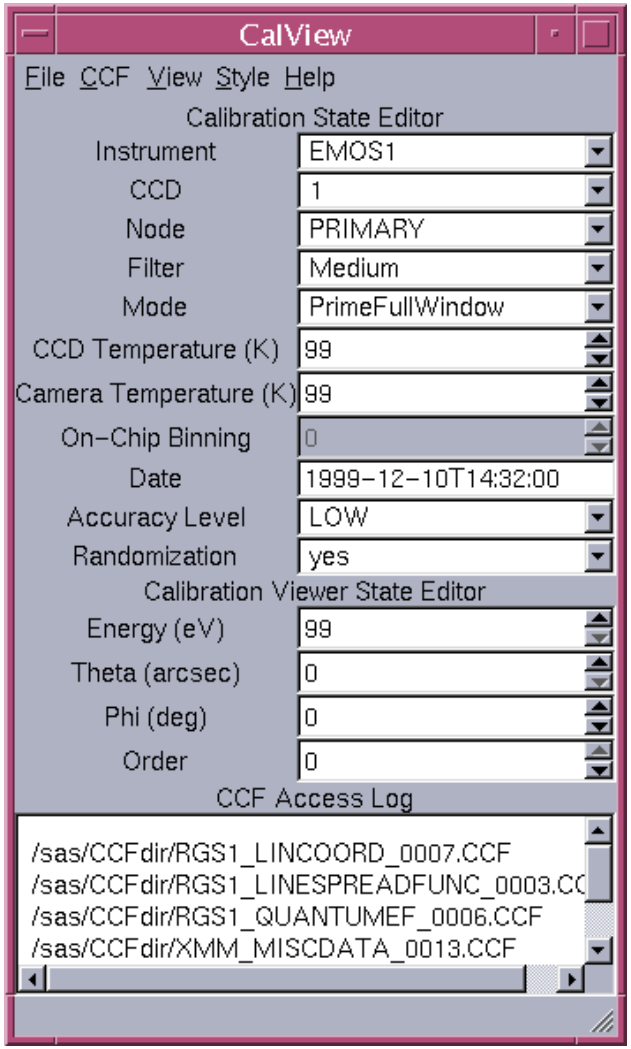

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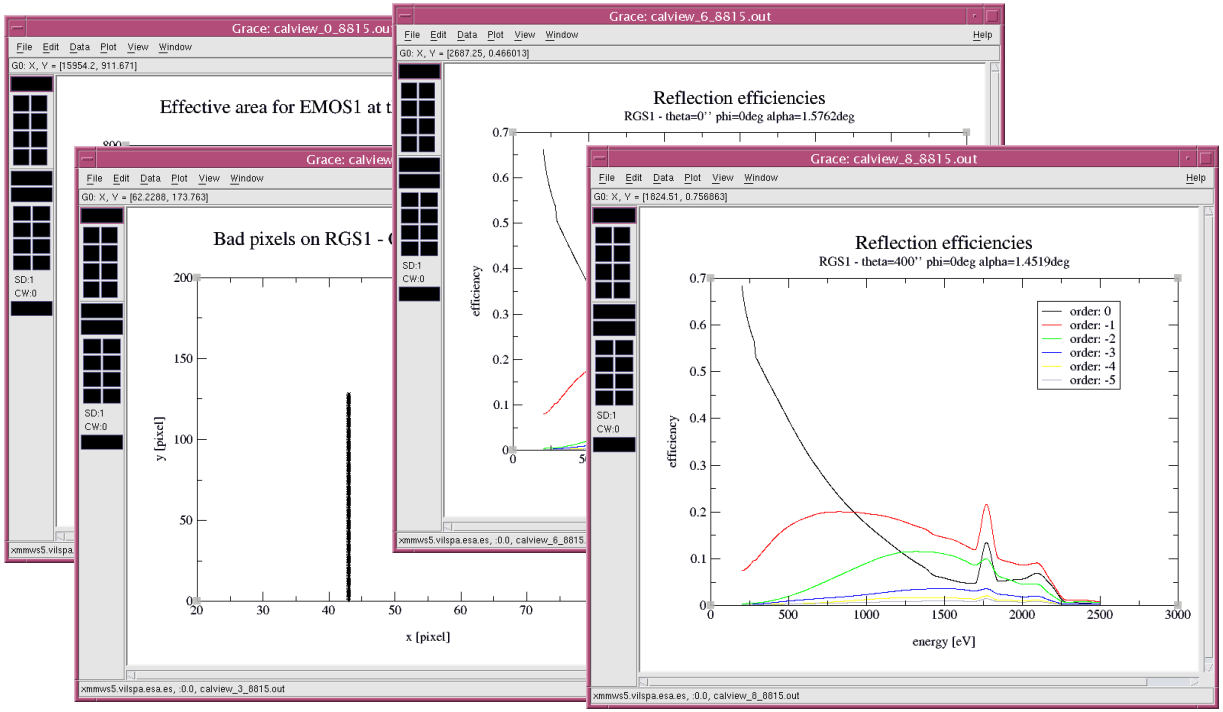

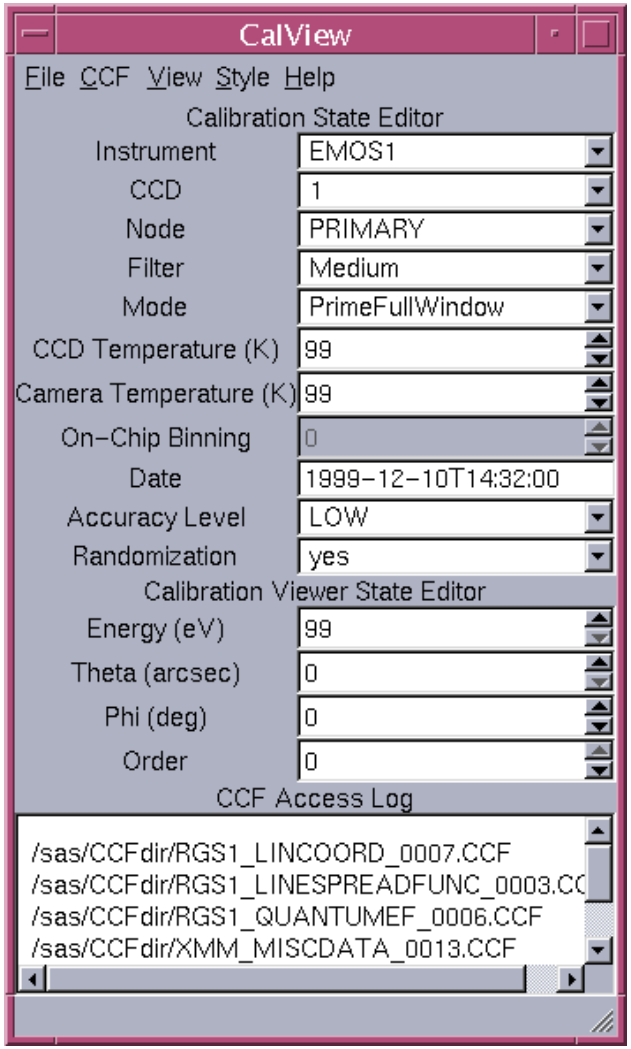

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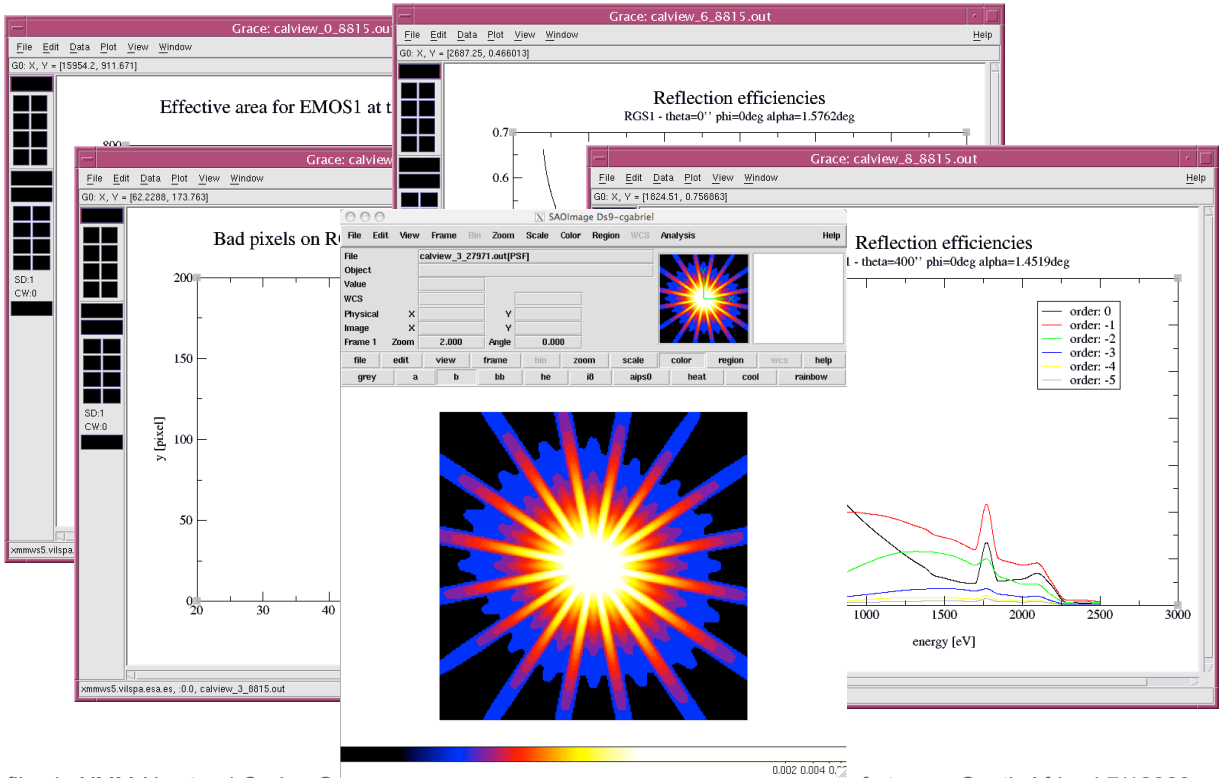

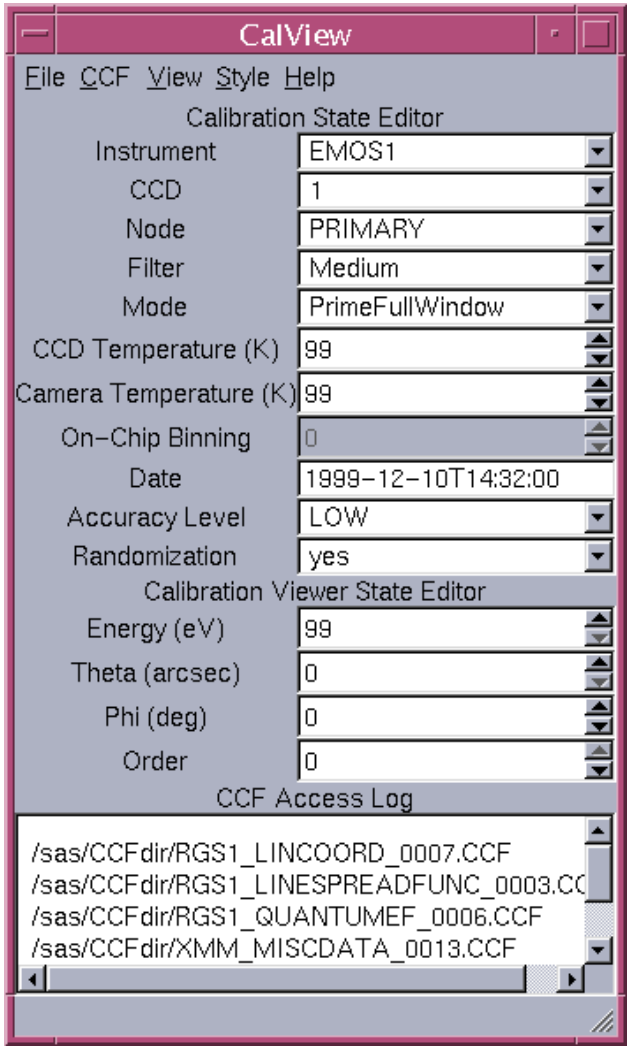

There are more calibration files

ESAS - a package for extended sources

- standalone package written at GSFC, “sasified” partly from 2012 on
- modules in FORTRAN 77 converted into FORTRAN 90 with C++ wrappers…
- but calibration files still standalone: **esas-caldb**

- SAS 21 - to be released soon will contain **esas** calibration files as part of the CCF

- If you plan to use it you need to download esas-caldb from
  https://heasarc.gsfc.nasa.gov/docs/xmm/xmmhp_xmmesas.html

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Version 5.9: April 15, 2014

COOKBOOK FOR ANALYSIS PROCEDURES FOR *XMM-NEWTON*
EPIC OBSERVATIONS OF EXTENDED OBJECTS AND THE
DIFFUSE BACKGROUND

Updated for SAS Version 13.5

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ABSTRACT

The following manual/cookbook is for the use of the *XMM-Newton* Extended Source Analysis Software (XMM-ESAS) package for the analysis of imaging mode EPIC MOS and pn observations. XMM-ESAS, which was a stand-alone package of FORTRAN 77 routines and perl scripts in the initial public release, became an integral part of SAS with the release of MOS tasks with SAS V9.0. With the release of SAS V11.0, analysis of pn data was also supported completing the basic set of tools. With the release of SAS V13.0 all FORTRAN 77 routines were converted to FORTRAN 90/95. The next major upgrade will be to have most CalDB files included directly in the CCF system.

Background analysis

BACKGROUND ANALYSIS

This page gives information on the background analysis of all XMM-Newton instruments (EPIC, RGS, OM) in order that a proper data reduction may be undertaken.

EPIC Background	RGS Background	OM Background	XMM-Newton Background

EPIC

INTRODUCTION

The XMM-Newton observatory provides unrivalled capabilities for detecting low surface brightness emission features from extended and diffuse galactic and extragalactic sources, by virtue of the large field of view of the X-ray telescopes and the high throughput yielded by the heavily nested telescope mirrors. In order to exploit the excellent EPIC data from extended objects, the EPIC background, now known to be higher than estimated pre-launch, needs to be understood thoroughly.

There are several different components to the EPIC background:

1. Photons:
   - The astrophysical background, dominated by thermal emission at lower energies (E<1 keV) and a power law at higher energies (primarily from unresolved cosmological sources). This background varies over the sky at lower energies.
   - Solar wind charge exchange.
   - Single reflections from outside the field of view, out-of-time events etc.
2. Particles:
   - Soft proton flares with spectral variations from flare to flare. For weak sources the only option is to select quiet time periods from the data stream for analysis.
   - Internal (cosmic-ray induced) background, created directly by particles penetrating the CCDs and indirectly by the fluorescence of satellite material to which the detectors are exposed.
3. Electronic Noise:

https://www.cosmos.esa.int/web/xmm-newton/background

Redistribution matrix and effective area

SAS provides

rmfgen *- Calculates the redistribution matrix (RMF)*

e.g. **rmfgen spectrumset=spectrum.ds rmfset=myspec.rmf**

arfgen *– Calculates the instrument effective area (ARF)*

e.g. **arfgen spectrumset=spectrum.ds arfset=myspec.arf**

Standard matrices ("canned" in XMM jargon)

The SAS provides a set of standard RMFs to allow calibration developments to proceed independently of SAS releases.

These are available from:

https://www.cosmos.esa.int/web/xmm-newton/epic-response-files

EPIC-MOS - RMFs

Standard Matrices:

m1_e1_im_pall_c.rmf - Mos-1, epoch 1, imaging mode, event patterns 0-12, centre-patch

m2_e6_im_p0_w.rmf - Mos-2, epoch 6, imaging mode, event patterns 0, wings of patch

m1_e11_tu_p0_o.rmf - Mos-1, epoch 11, timing mode event pattern 0, off the patch

Time-dependent matrices, currently 14 epochs (last one 2011-present)

EPIC-MOS - RMFs

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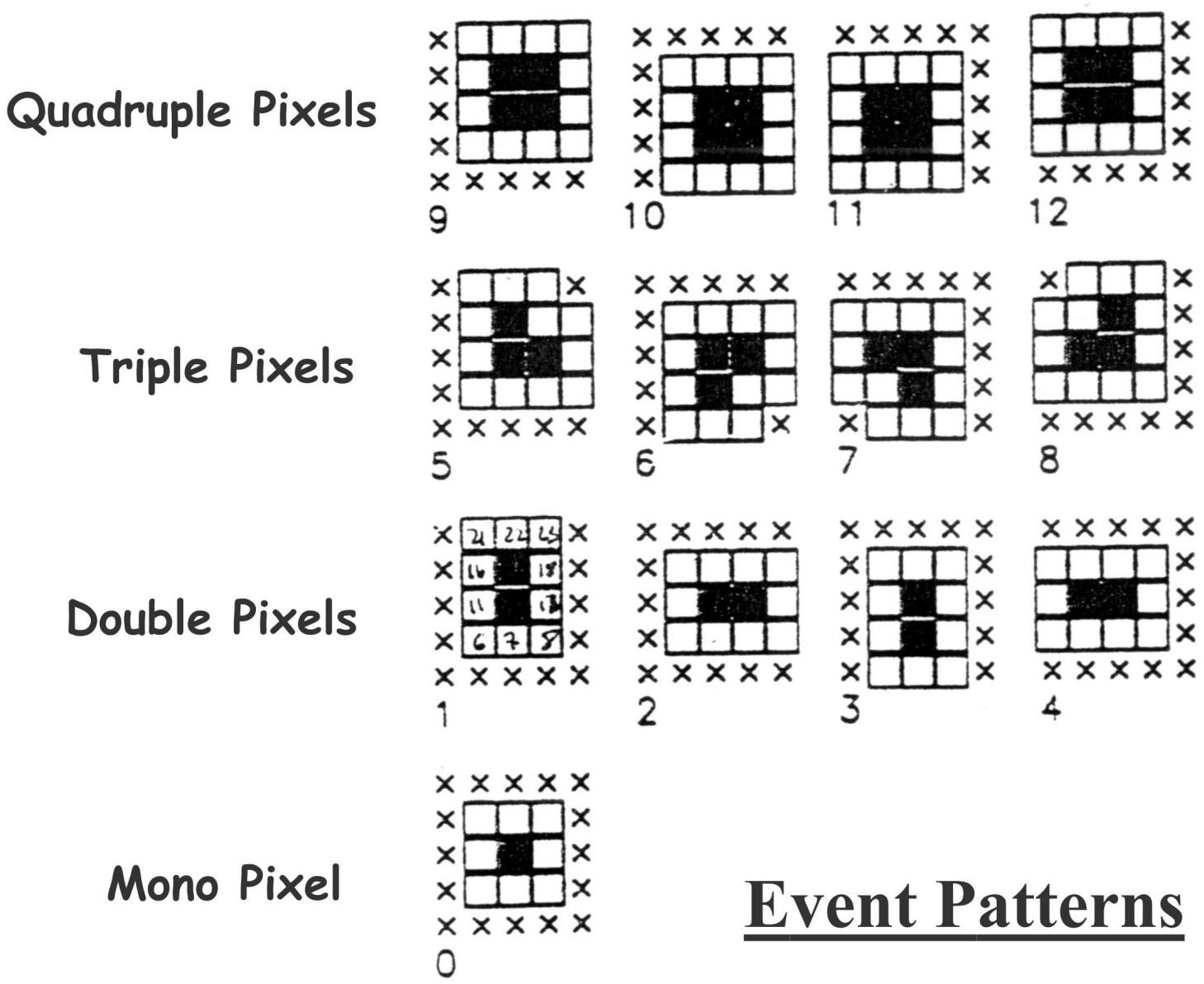
Time-dependent matrices, currently 14 epochs (last one 2011-present)

Do NOT use them for analysis - only for proposal preparation

Event patterns

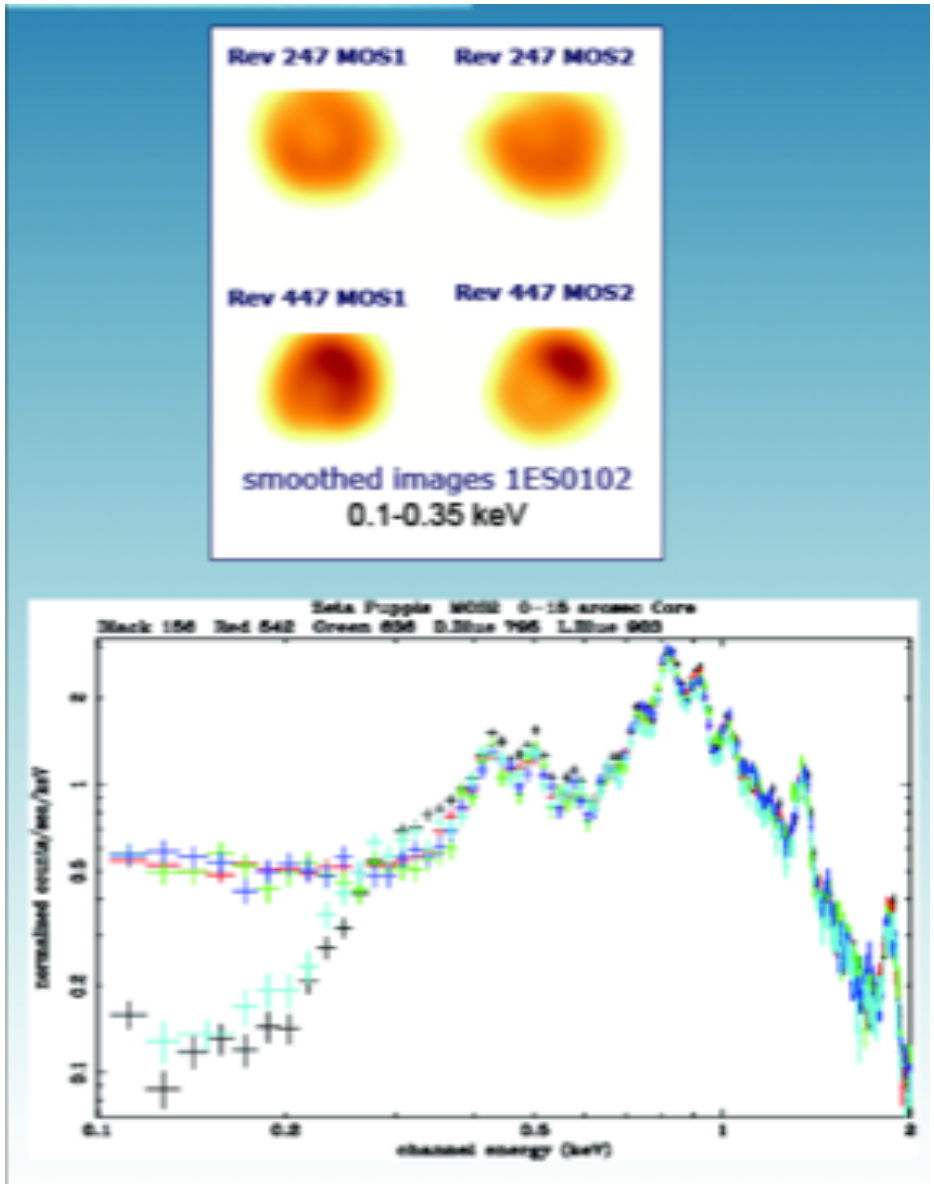


The MOS patch

- A small patch (width 30”) has been discovered on each of the MOS cameras where the spectral response is degraded.

- The calibration is divided into ‘centre’, ‘wings’ and ‘off’ patch regions, each of which have their own response function.

- The patch coincides with the instrument boresight and is believed to be due to the accumulated X-ray dose.



EPIC-PN: RMFs

Standard Matrices:

<camera>_<epoch>_<mode><adu>_<pattern><rows>_<version>.rmf

Where: e1: 2000-02-01 - 2007-01-01
e2: 2007-01-01 - 2014-01-01
e3: 2014-01-01 - present

epn_e1_ff20_sY9.rmf - e1 - Full frame mode, pattern 0 only, on-axis

epn_e1_ff20_sY0.rmf - e1 - Full frame, pattern 0 only, at edge of field

epn_e2_ff20_dY5.rmf - e2 - Full frame, patterns 1-4, centre of CCD

epn_e2_ff20_sdY9.rmf - e2 - Full frame, patterns 0-4, on-axis

epn_e3_ef20_sY9.rmf - e3 - Extended full frame, pattern 0, on-axis

epn_e3_sw20_sY9.rmf - e3 - Small window mode, pattern 0, on-axis

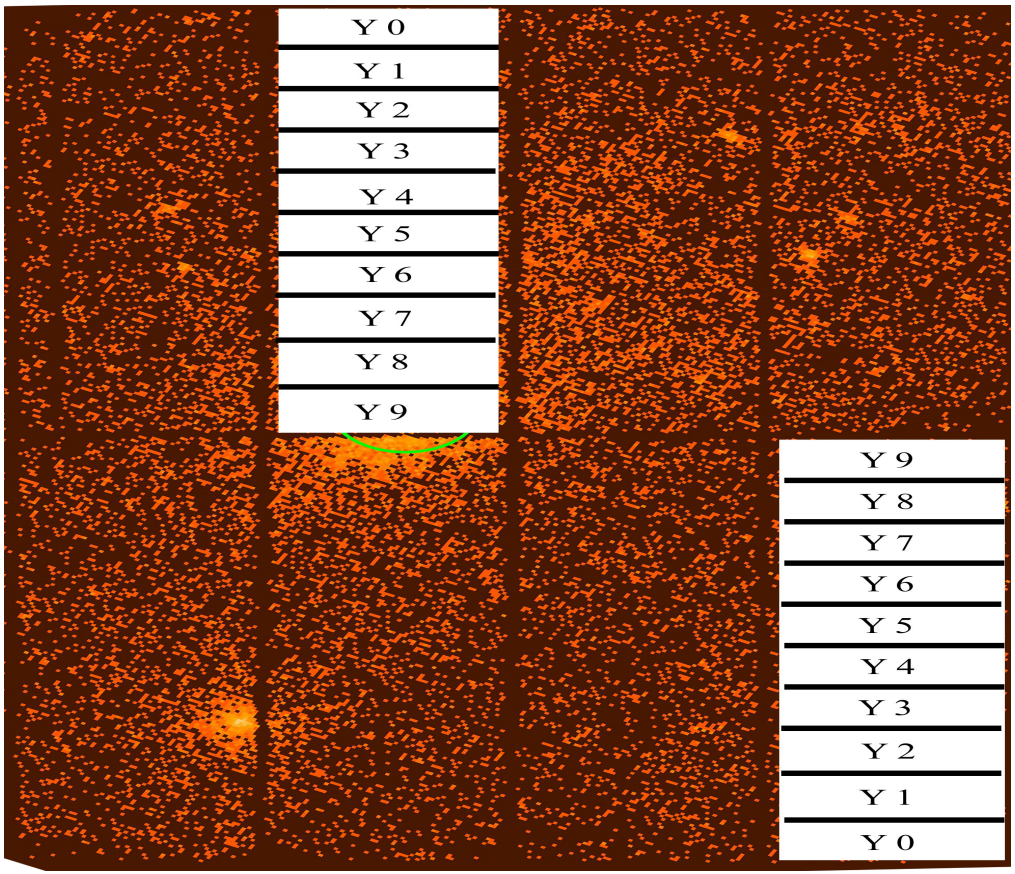
epn_e1_lw20_sY9.rmf - e1 - Large window mode, pattern 0, on-axis

epn_e2_ti20_sY9.rmf - e2 - Timing mode, pattern 0, on-axis

epn_e3_bu20_sY9.rmf - e3 - Burst mode, pattern 0, on-axis etc.

EPIC-PN: RMFs II

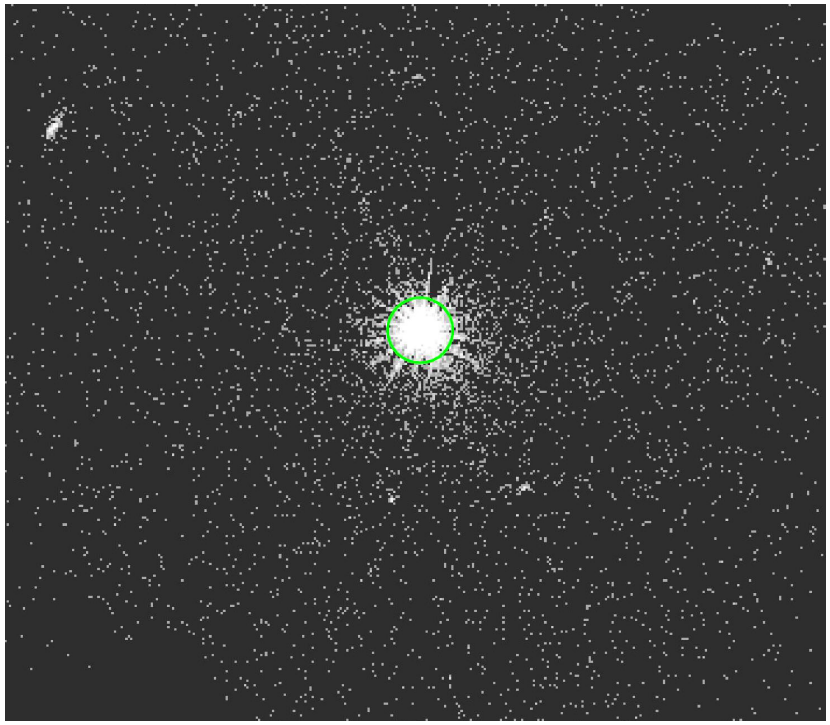
Function of epoch, observing mode, patterns, position

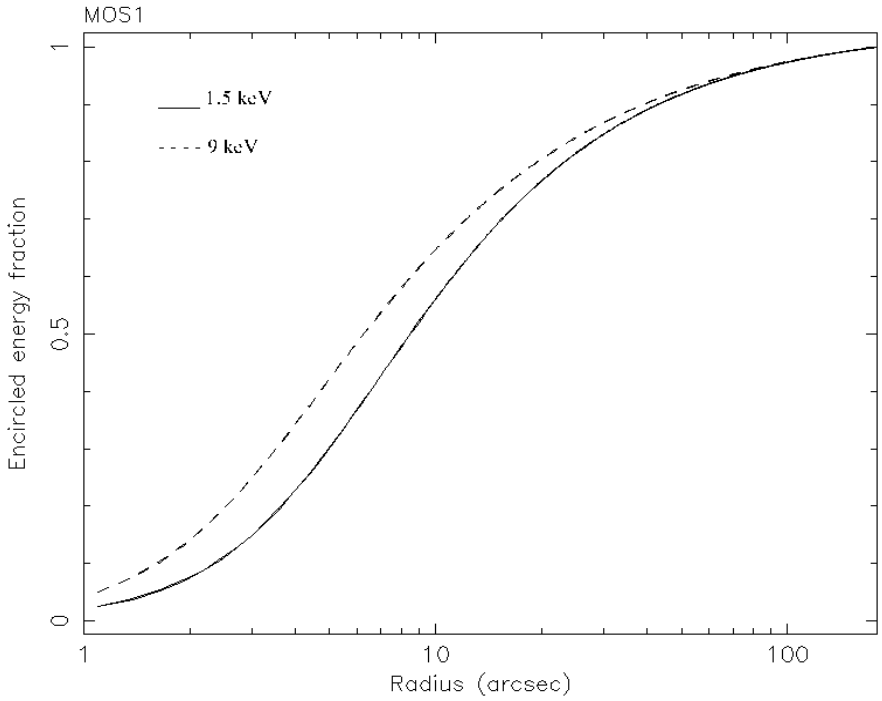


arfgen: effective area contributions

- Telescope effective area
- Vignetting
- Filter transmission
- Detector quantum efficiency
- Encircled energy correction
- Flux loss due to CCD gap, bad pixels and offset columns

Encircled energy correction

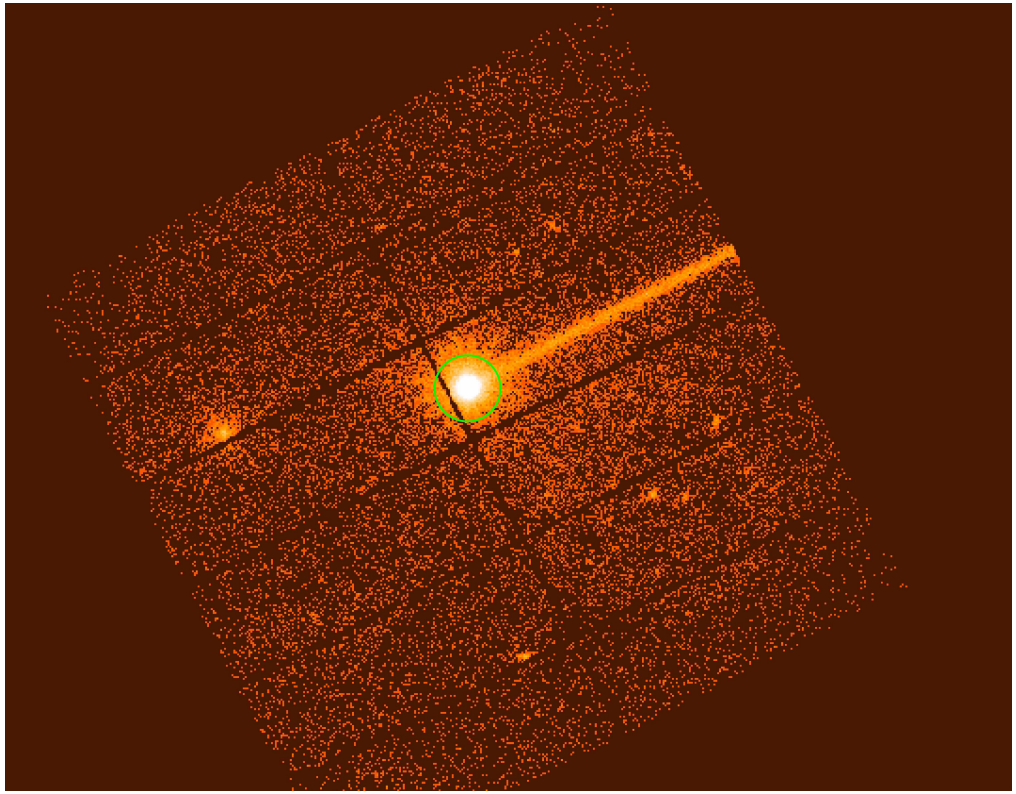




arfgen corrects for flux scattered out of the source extraction region.

This is weakly dependent on energy and off-axis angle.

CCD gaps and Bad Pixels



arfgen corrects for the effective area lost due to chip gaps, bad pixels and offset columns.

Bad pixel and offset column information is stored in the event file header

Options: *withbadpixcorr*=yes (default) *badpixlocation*=myevents.fit

Point source: *arfgen* commands

Point source:

```
> arfgen spectrumset=spectrum.ds arfset=myspec.arf
        badpixlocation=myevents.FIT detmaptype=psf
```

Using a canned matrix:

```
> arfgen spectrumset=spectrum.ds arfset=myspec.arf
    badpixlocation=myevents.FIT detmaptype=psf withrmfset=yes
    rmfset=epn_ff20_sdY9.rmf
```

Extended source: *arfgen* commands

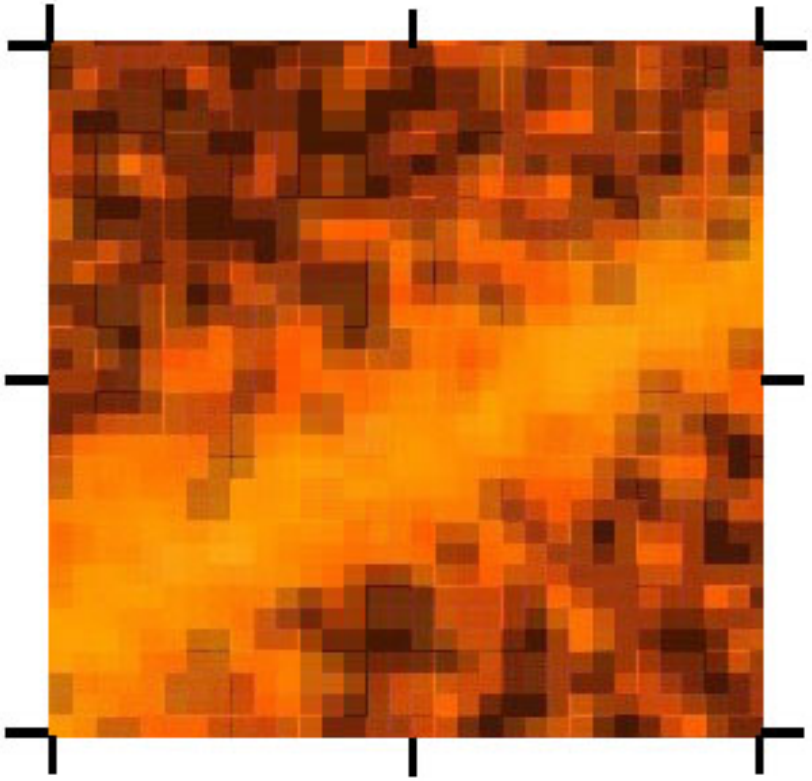
Extended source:

```
> arfgen spectrumset=spectrum.ds arfset=myspec.arf
  extendedsource=yes badpixlocation=myevents.FIT detmaptype=flat
```

Using a detector map:

```
> arfgen spectrumset=spectrum.ds arfset=myspec.arf  extendedsource=yes
  badpixlocation=myevents.FIT  detmaptype=dataset datamaparray=coarseimage.ds
```

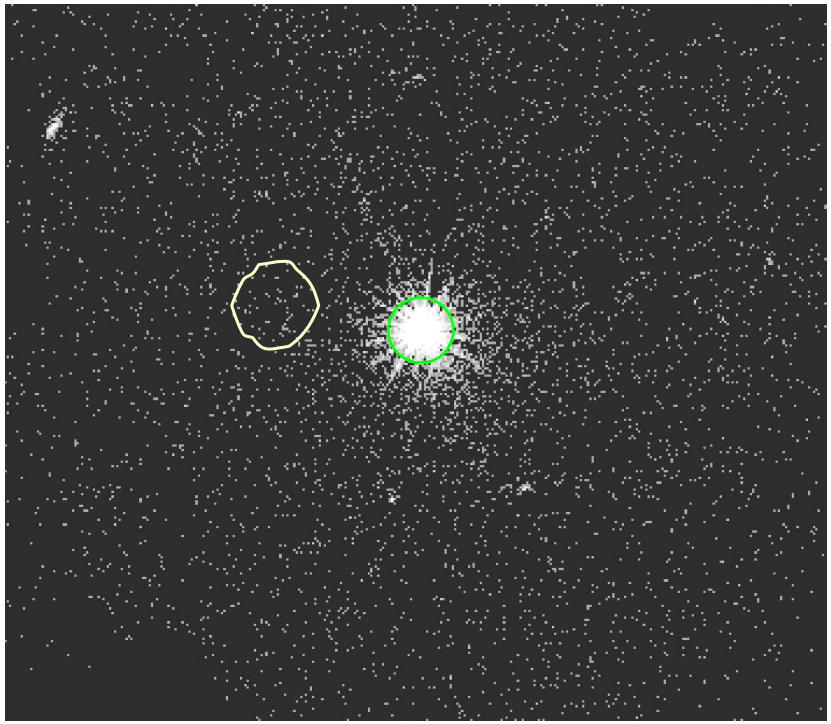
Extended source: detector map



- Create a coarsely binned image in detector coordinates.
- Run ***arfgen*** in extendedsource mode and flux-weight the ARF

```
arfgen spectrumset=spec.ds arfset=myspec.arf extendedsource=yes
    detmaptype=dataset detmaparray=coarseimage.ds
```

Influence of other sources



arfgen spectrumset=cluster.ds

detmaptype=dataset datamaparray=coarseimage.ds

crossregionarf=yes crossreg_spectrumset=pointsource.ds

To calculate the contribution of flux from one region onto another region use the CROSSARF technique. The detector map must cover both regions and have at least 300 pixels within each area.

Making life easy

Single task ***especget*** available:

- ✓ Takes source and background region
- ✓ Calculates centroid and optimum extraction radius
- ✓ Produces source and background spectra
- ✓ Generates appropriate ARF
- ✓ Optionally generates RMF
- ✓ Prepares files for spectral fitting

Use directly from ***xmmselect,*** *"*OGIP spectral products*"*