Analysis of EPIC data of Extended Sources

13th XMM-Newton SAS Workshop

June 10 – June 14, 2013

Ignacio de la Calle

XMM-Newton Science Operations Centre

Status

- **Analysis of extended sources is *complex*, *challenging* and *time-consuming***
  - ***The analysis of extended sources is reduced to the knowledge of the background***

- **There are some "official" SAS recipes**

- **Since 2005: XMM-Newton EPIC Background working group (BGWG) *"A steering and supervising committee to provide the user with clear information on the EPIC Background and (SAS)-Tools to treat the EPIC Background correctly for various TBD scenarios"***

  http://xmm2.esac.esa.int/external/xmm_sw_cal/background/ (also info on RGS/OM)

  - **Table summarizing temporal, spectral & spatial properties of EPIC background components**
  - **Progress & Meetings of the XMM-Newton EPIC Background working group**

  - **Products:**
    - **XMM-Newton Blank Sky background files & related software**
    - **Filter Wheel Closed data**
    - **XMM-Newton Extended Source Analysis Software package (ESAS)**
    - **Links to related papers**

(new threads just available)

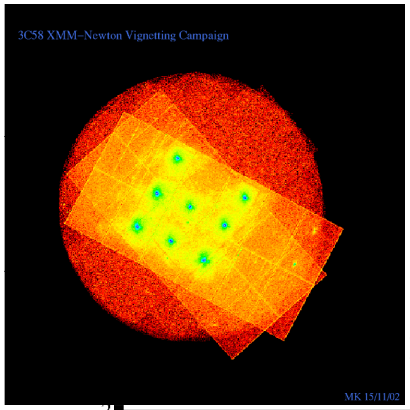
Status

BKG components & their temporal, spectral, spatial properties are summarized at

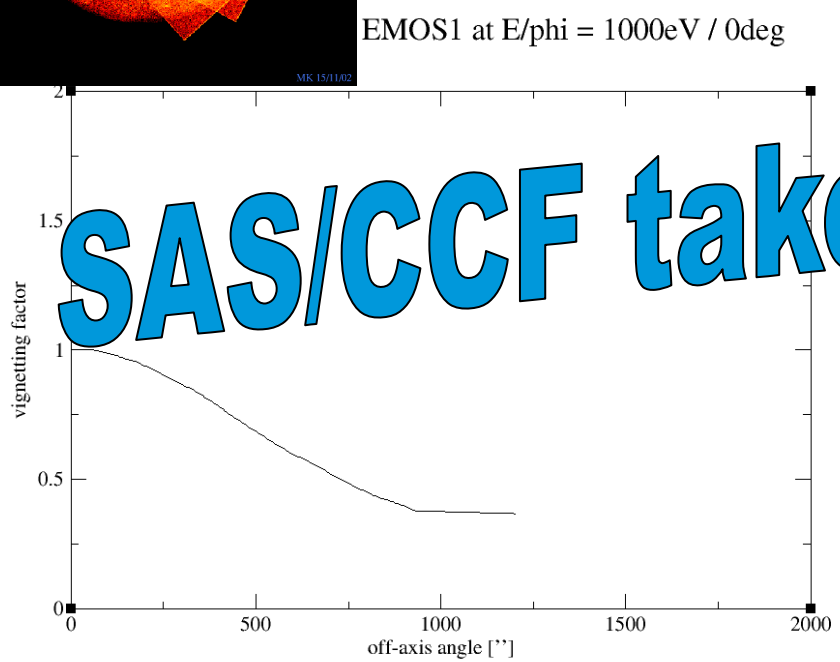
http://www.star.le.ac.uk/~amr30/BG/BGTable.html

- **Particles**:
  - High energy penetrating (CR) hitting directly the CCD or indirectly by fluorescence when hitting satellite components
  - Soft protons flares
- **Electronic Noise**:
  - Bright pixels or columns, readout noise, etc ….
- **Photons**:
  - Cosmic X-ray background
  - Solar wind charge exchange
  - Reflections from out of FoV sources, OoT events etc….

Why is it so difficult ?

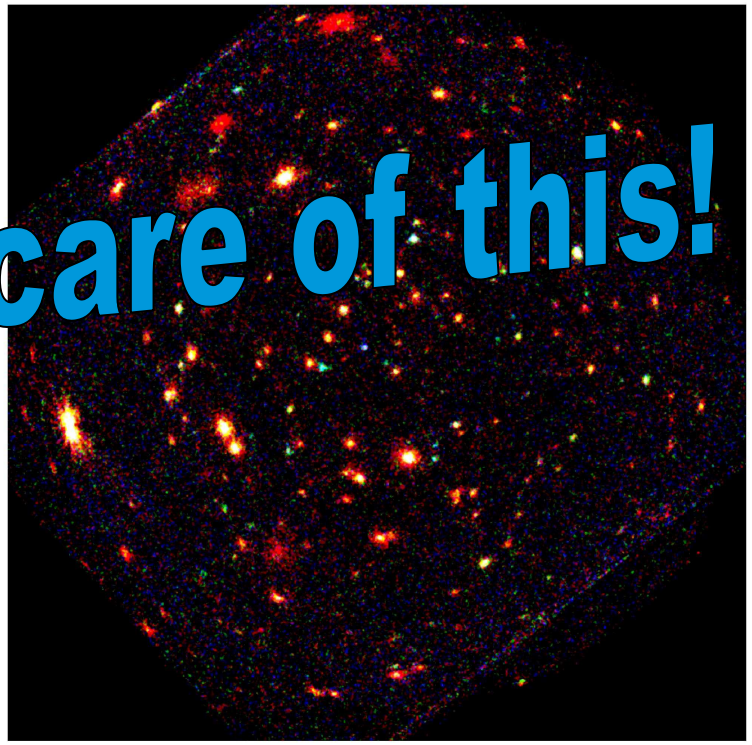


I. Vignetting



II. Point Spread Function

XMM-NEWTON SCIENCE RESULTS

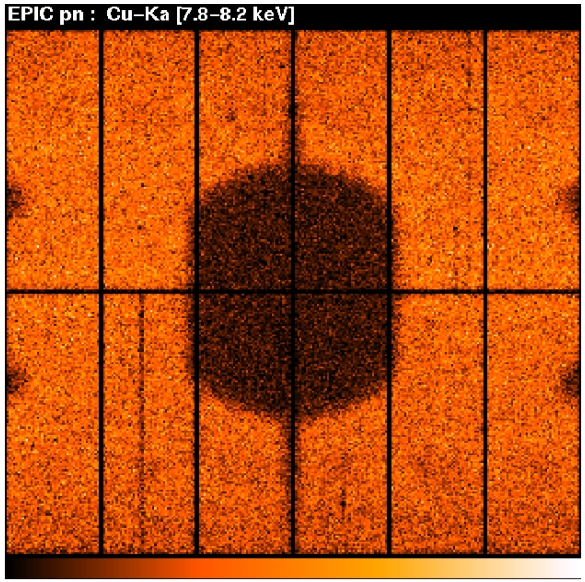


6 December 2000 Fig. 8

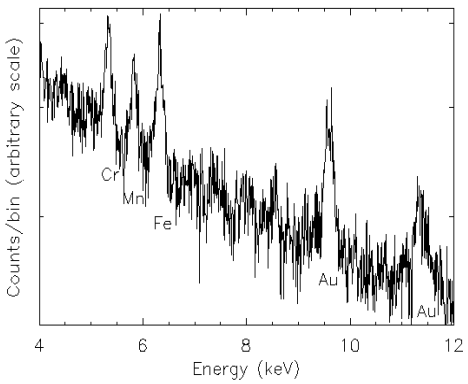
SAS/CCF takes care of this!

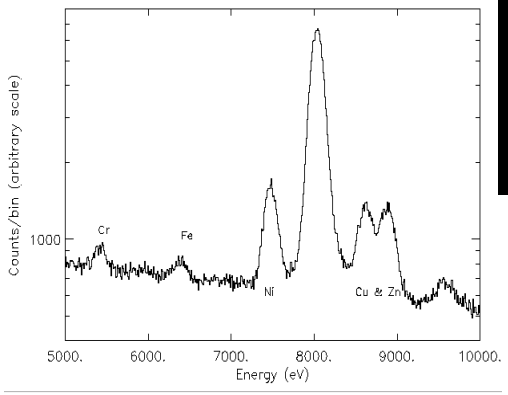
xmm-newton
European Space Agency

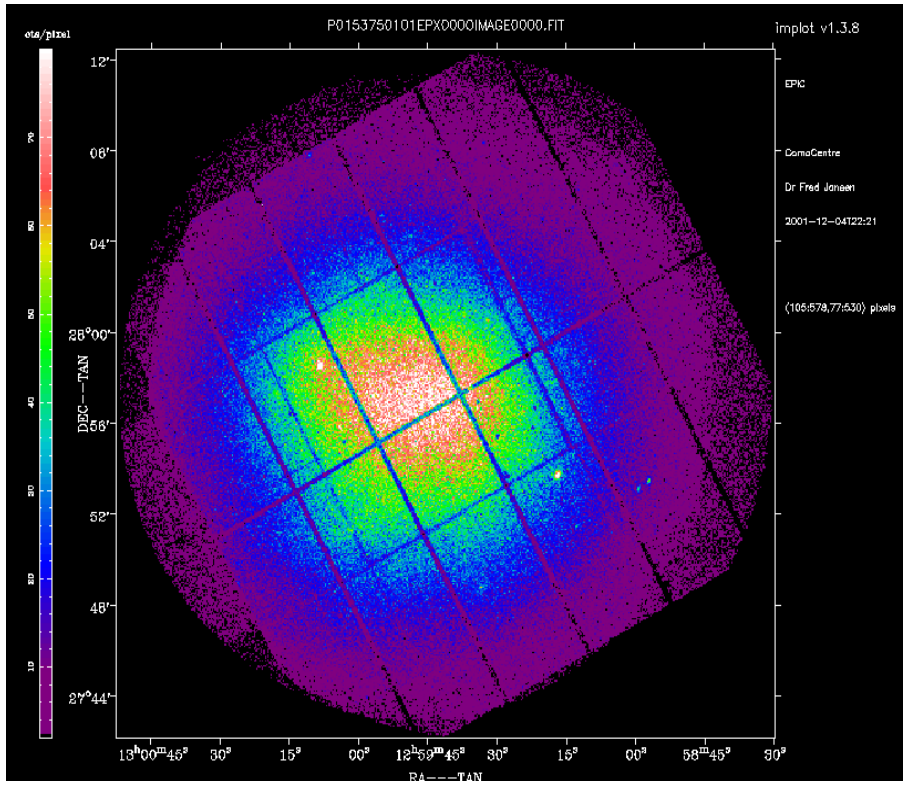
Why is it so difficult (still) ?



III. Spatial background variability





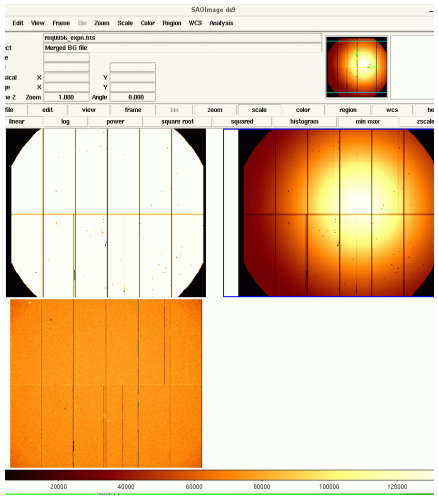


IV. Lack of background in FOV

The EPIC Background Analysis Web Page: Products of the EPIC BGWG

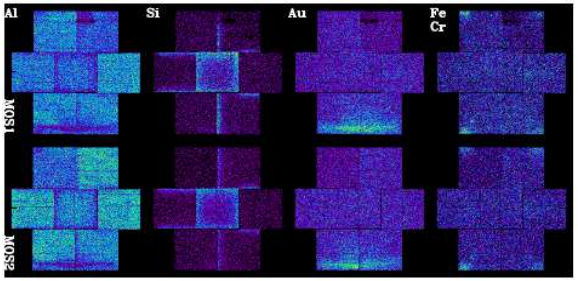
- **I. Blank Sky Background Event Files**

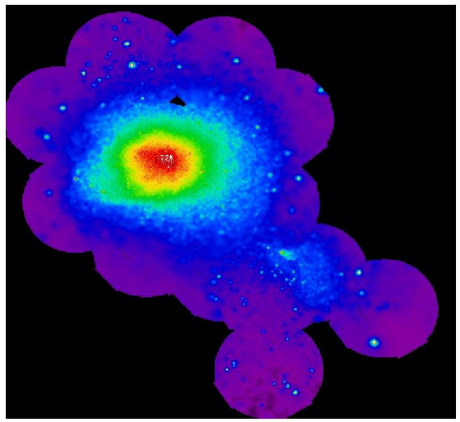
  Developed and maintain at LUX by the EPIC Blank Sky team based on the work of J. Carter and A. Read (A&A 464, p1155, 2007)



- **II. Filter Wheel Close Data (FWC)**

  Repository of FWC Data





- **III. XMM-Newton Extended Source Analysis Software (XMM-ESAS)**

  Developed by S.Sembay at the NASA/GSFC XMM-Newton Guest Observer Facility (GOF) in cooperation with the XMM-Newton SOC and the Background Working Group.

Which background to use? – 1. Blank Sky Fields

- Often no statistically useful background region in the observation field-of-view
  ⇒ use "blank sky fields" to generate background spectra

- Need to extract BKG far from target source. Source may be so extended that no local background is visible in FoV.

  - Off-axis BKG can be highly inappropriate in analysing (nominally on-axis located) targets:

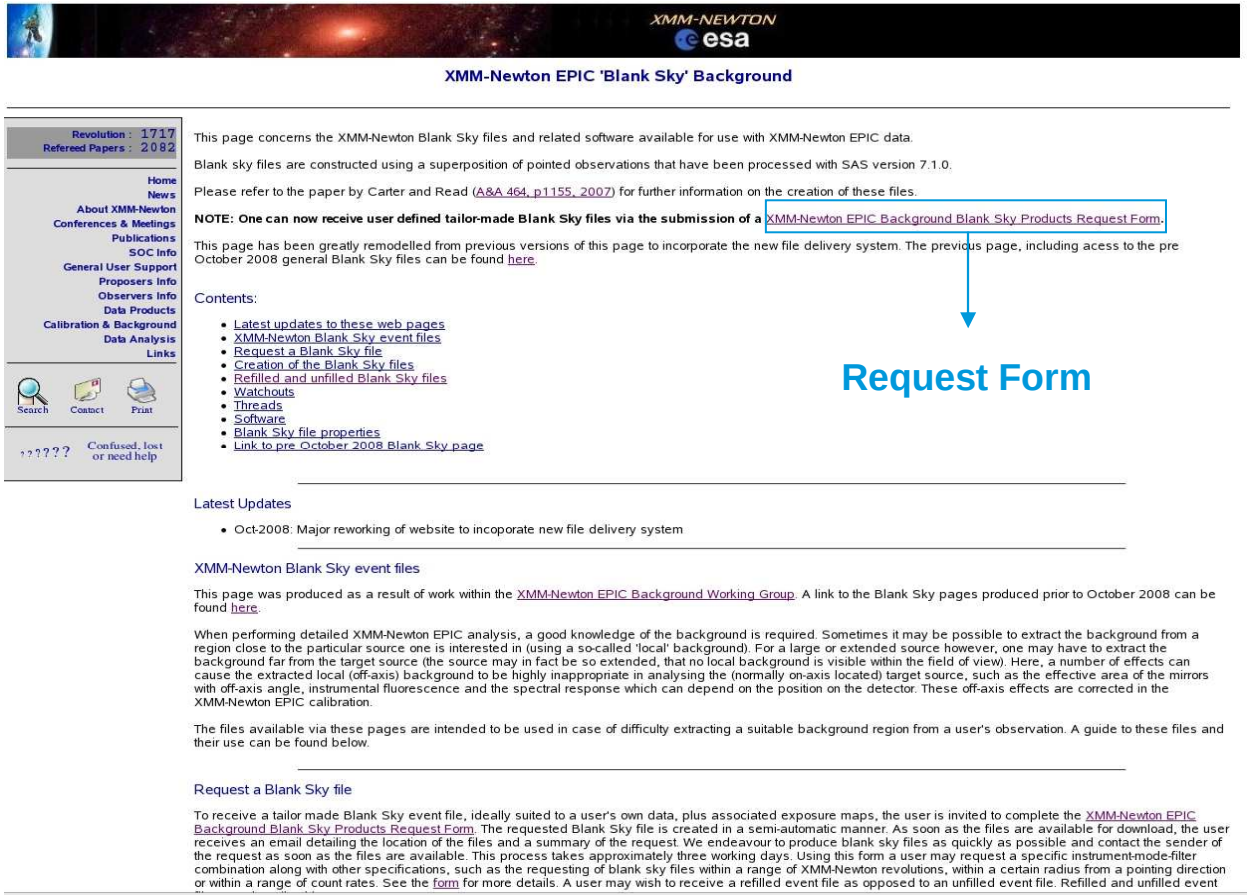
    - effective area of mirrors changes with off-axis angle
    - instrumental fluorescence
    - spectral response depends on detector position

- Recommended option **(files produced for by Read & Carter, Uni. Leicester): Paper by Carter & Read; A&A, 1155, 2007**

Which background to use? – 1. Blank Sky Fields

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

How to access Blank Sky Files



XMM-NEWTON esa

XMM-Newton EPIC 'Blank Sky' Background

Revolution : 1717
Refereed Papers : 2082

Home
News
About XMM-Newton
Conferences & Meetings
Publications
SOC Info
General User Support
Proposers Info
Observers Info
Data Products
Calibration & Background
Data Analysis
Links

Search Contact Print

?????? Confused, lost or need help

This page concerns the XMM-Newton Blank Sky files and related software available for use with XMM-Newton EPIC data.

Blank sky files are constructed using a superposition of pointed observations that have been processed with SAS version 7.1.0.

Please refer to the paper by Carter and Read (A&A 464, p1155, 2007) for further information on the creation of these files.

NOTE: One can now receive user defined tailor-made Blank Sky files via the submission of a XMM-Newton EPIC Background Blank Sky Products Request Form.

This page has been greatly remodelled from previous versions of this page to incorporate the new file delivery system. The previous page, including acess to the pre October 2008 general Blank Sky files can be found here.

Contents:

- Latest updates to these web pages
- XMM-Newton Blank Sky event files
- Request a Blank Sky file
- Creation of the Blank Sky files
- Refilled and unfilled Blank Sky files
- Watchouts
- Threads
- Software
- Blank Sky file properties
- Link to pre October 2008 Blank Sky page

Request Form

Latest Updates

- Oct-2008: Major reworking of website to incoporate new file delivery system

XMM-Newton Blank Sky event files

This page was produced as a result of work within the XMM-Newton EPIC Background Working Group. A link to the Blank Sky pages produced prior to October 2008 can be found here.

When performing detailed XMM-Newton EPIC analysis, a good knowledge of the background is required. Sometimes it may be possible to extract the background from a region close to the particular source one is interested in (using a so-called 'local' background). For a large or extended source however, one may have to extract the background far from the target source (the source may in fact be so extended, that no local background is visible within the field of view). Here, a number of effects can cause the extracted local (off-axis) background to be highly inappropriate in analysing the (normally on-axis located) target source, such as the effective area of the mirrors with off-axis angle, instrumental fluorescence and the spectral response which can depend on the position on the detector. These off-axis effects are corrected in the XMM-Newton EPIC calibration.

The files available via these pages are intended to be used in case of difficulty extracting a suitable background region from a user's observation. A guide to these files and their use can be found below.

Request a Blank Sky file

To receive a tailor made Blank Sky event file, ideally suited to a user's own data, plus associated exposure maps, the user is invited to complete the XMM-Newton EPIC Background Blank Sky Products Request Form. The requested Blank Sky file is created in a semi-automatic manner. As soon as the files are available for download, the user receives an email detailing the location of the files and a summary of the request. We endeavour to produce blank sky files as quickly as possible and contact the sender of the request as soon as the files are available. This process takes approximately three working days. Using this form a user may request a specific instrument-mode-filter combination along with other specifications, such as the requesting of blank sky files within a range of XMM-Newton revolutions, within a certain radius from a pointing direction or within a range of count rates. See the form for more details. A user may wish to receive a refilled event file as opposed to an unfilled event file. Refilled and unfilled event

Which background to use? – 1. Blank Sky Fields

Users can now receive user defined tailor-made Blank Sky files via the submission of a Web form

http://www.star.le.ac.uk/~jac48/BG/UserRequest/blankskyform.html

REQUIRED

1. User information:

Name
Institute
Email

2. Select instrument specifications:

Instrument MOS1 Filter Thin Mode Full-Frame Filled status Unfilled

OPTIONAL

1. Select by various criteria:

Time, e.g. 1.0e8 to 2.5e8 (s)	Low:	High:
OR		
Date, e.g. 2001-10-23 to 2002-04-05	Low:	High:
OR		
Revolution, e.g. 0301 to 0852	Low:	High:
Exposure, e.g. 20.4 to 57.3 (ks)	Low:	High:
Galactic column nH, e.g. 1.0e19 to 2.0e21 (cm-2)	Low:	High:
Count rate, e.g. 1.0 to 4.2 (cts s-1)	Low:	High:

2. Select by coordinates:

Right Ascension, e.g. 74.523 Declination, e.g. -45.012
OR
Galactic longitude, e.g. 114.025 Galactic latitude, e.g. -52.6
Radius (degrees)

3. Select by number of events:

Max. number of events, e.g. 5e6

Submit Query Reset

For more information contact:epic-bg@star.le.ac.uk

Request Form

Users can as of Oct 2008 make requests for different instruments, filters and modes:

- Time based requests
  Time, Date, Revolution, Exposure
- Sky region requests
  Coordinates, N_H
- Other
  Count Rate, Max. Number of Events per file

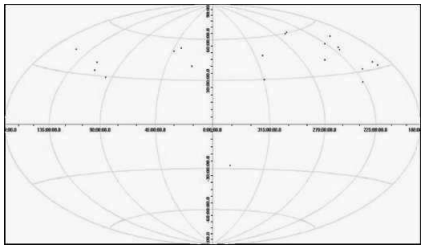
Which background to use? – 1. Blank Sky Fields

XMM-Newton EPIC Background Blank Sky Products Delivery

Request id:
0045

Delivered files:

1. Blank sky event file 1: blanksky_events.fits
2. Blank sky exposure file, non-vignetted 1: blanksky_expn.fits
3. Blank sky exposure file, vignetted 1: blanksky_expv.fits



Request sent:
Mon, 16 Jan 2009

Request summary:

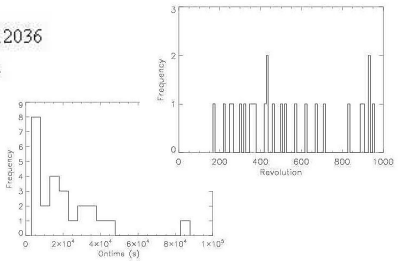
Instrument:	MOS1
Filter:	Medium
Mode:	Full-Frame
Type:	Ghosted

Advanced selection:

Revolution:	No selection
Date:	No selection
Time (s):	No selection
Exposure (ks):	No selection
Galactic column (cm-2):	3.0e20 to 4.0e20
Count rate:	No selection

Positional selection:

Equatorial coordinates selected:	193.274, -9.2036
Galactic coordinates selected:	No selection
Radius selected (degrees):	100



Number of events:
Maximum number of events: 1.0e6

Diagnostic files:

1. Revolution histogram 1: revnhist.jpg
2. Ontime histogram (post flare cleaning) 1: ontimehist.jpg
3. Component map (galactic coordinates) 1: map_selection.jpg

Comment: Files were created for the selection requested. Details of the selection procedure:

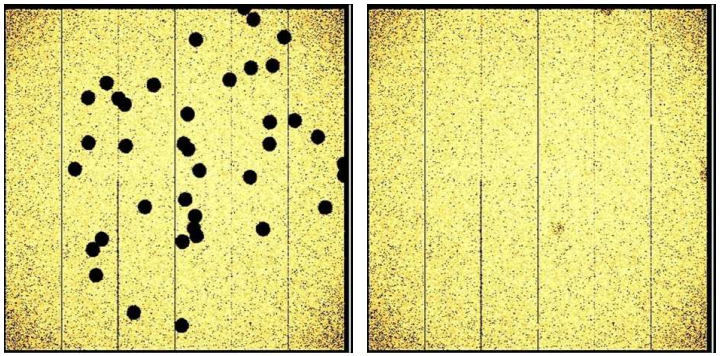
1. The instrument, filter, mode and filled status selection was completed successfully, events were found
2. The selection by coordinates was completed successfully, events were found
3. The selection by galactic column density was completed successfully, events were found
4. The selection by maximum number of events was completed successfully, events were found

Request from the EPIC Blank Sky team:
We politely request that should the files here contribute to work that leads to publication, that the reference to the Blank Sky work (Carter and Read (A&A 464, p1155, 2007)) be cited.

User Request

The user is sent an url with a summary of *Products Delivery* from where the corresponding files can be downloaded.

Each Blank Sky file is constructed from several different event files



Which background to use? – 1. Blank Sky Fields

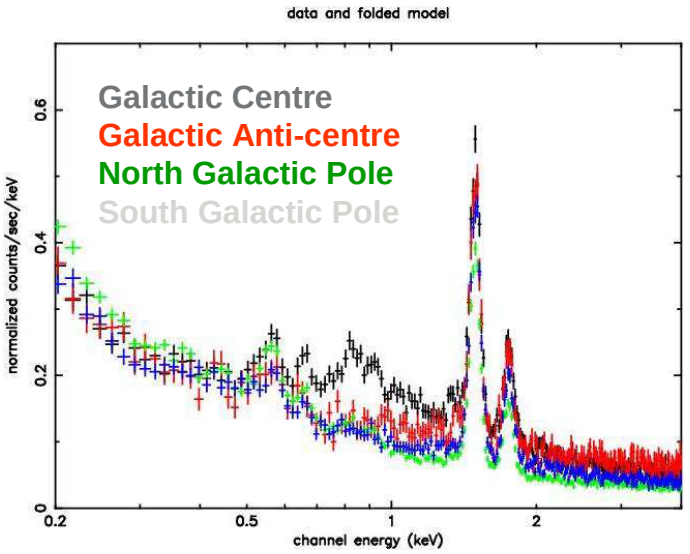
Software available related to background files (shell scripts calling SAS/FTOOLS):

- Skycast: to cast an EPIC background dataset onto the sky, at the position given by an input template event dataset (e.g. the event file you are interested in producing a background for); *attcalc SAS task*
- BGrebinimage2SKY: to re-bin and re-project exposure maps onto the sky to the spatial scale and sky position of a user-input image.
- Ghostholes_ind: to fill in regions that are extracted from each individual image.

Caveats: Variations in spectra…

1. … with count rate &
2. … over the sky:

   Note: higher count rate of galactic center due to higher levels of soft X-ray emission



Which background to use? – 2. XMM-ESAS

- Alternative approach ⇒ use "model" to generate background spectra
- Recommended option: **(tool produced for BGWG by Snowden & Kuntz, US GOF):**

  XMM-ESAS: Extended Source Analysis Software package

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

  - Allows to model quiescent particle background for MOS & PN
  - Produces background spectra for user-defined regions & background images
  - Output files are FITS standard
  - Package consists of PERL scripts (calling SAS tasks) & stand-alone Fortran 77 programs

- Documentation:

  - XMM-ESAS is based on software used for background modeling described in Snowden, Collier & Kuntz (2004, ApJ, 610, 1182) and updated & applied to catalog of cluster observations in Snowden et al. (2008, A&A, 615).

  - Cookbook: incl. example data & recipe of spectral & image data processing

    http://xmm.esac.esa.int/sas/current/howtousesas.shtml

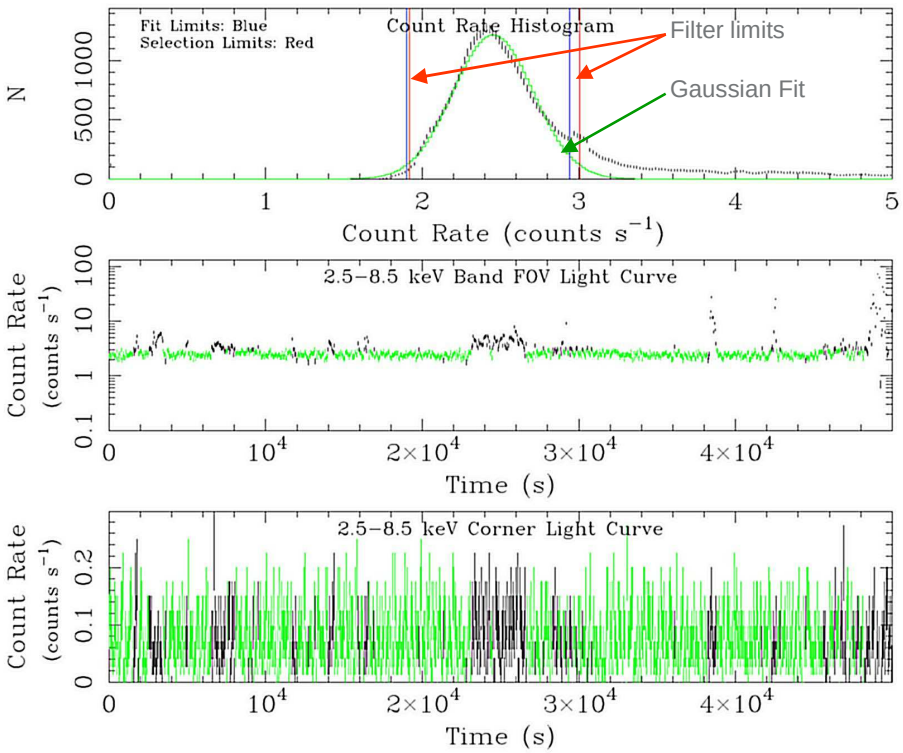
  - Threads: recipe of spectral & image data processing

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

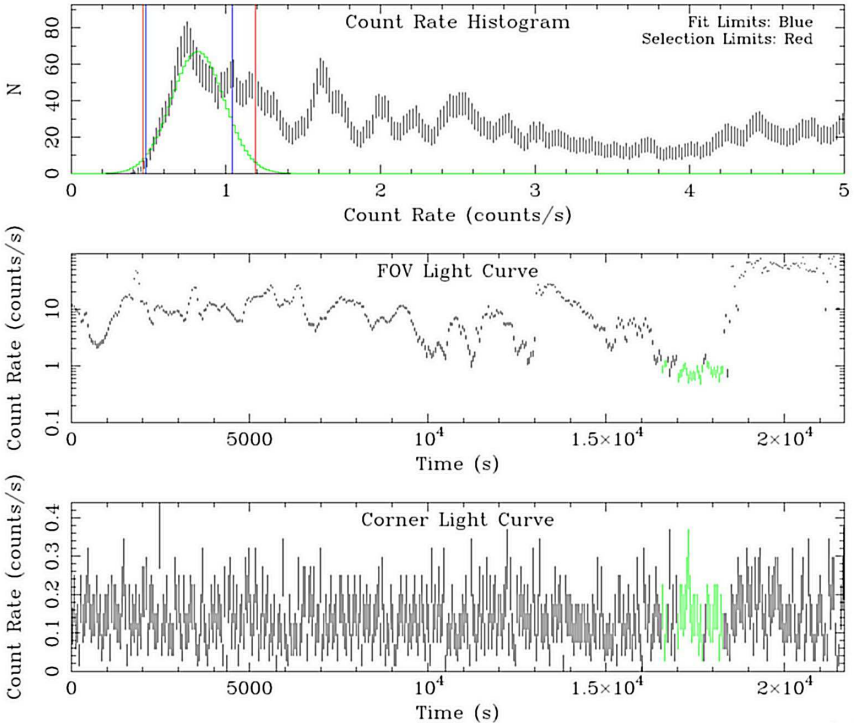
Background flare removal: the ESAS way

Instead of GTIs from count-rate limits > 10 keV…

XMM-ESAS: filtering in user def. band & based on count rate histogram: SAS task espfilt (MOS & pn)



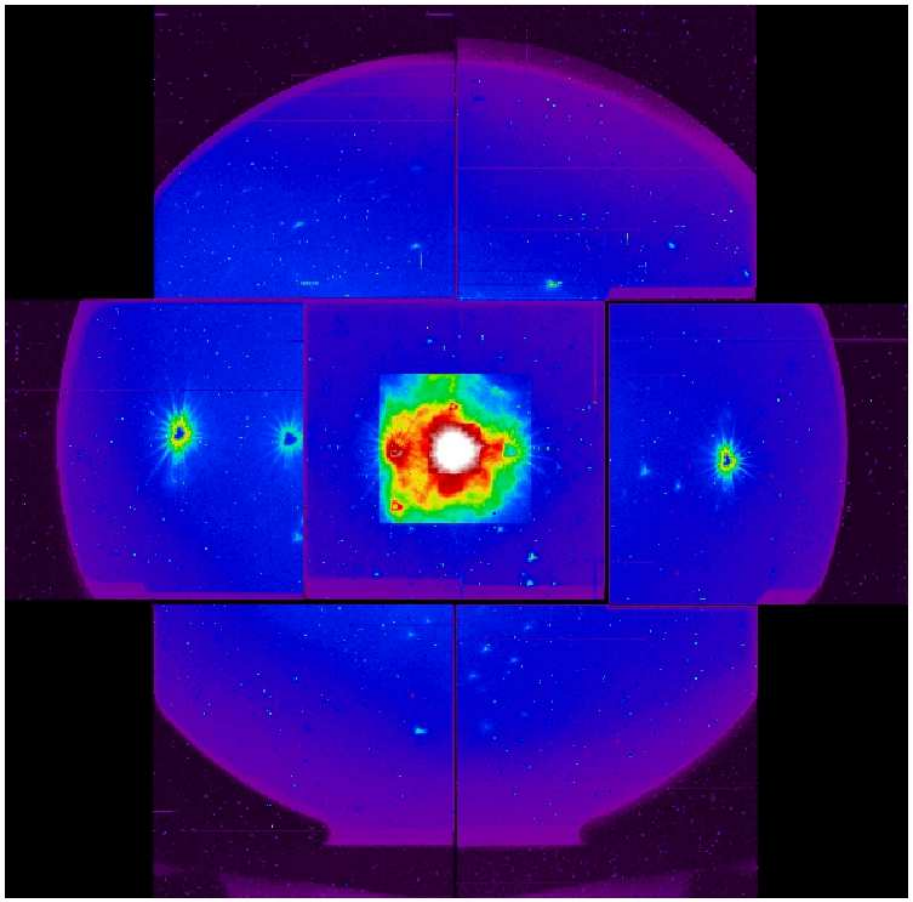
High count rate excursions due to soft protons rather than higher-energy particles (which would produce increase in corner data)



Strong soft proton flaring ⇒data not useful for study of diffuse emission; 2 ks left are likely to be still contaminated

Which background to use? – 2. XMM-ESAS

- Method: MOS **corner pixels are a measure of the particle background**



- Use as many known parameters as possible rather than relying on local bkg determinations and blank-sky background data sets

- E.g., use FWC data, RASS, soft proton distribution, archived observation data sets

Which background to use? – 2. XMM-ESAS

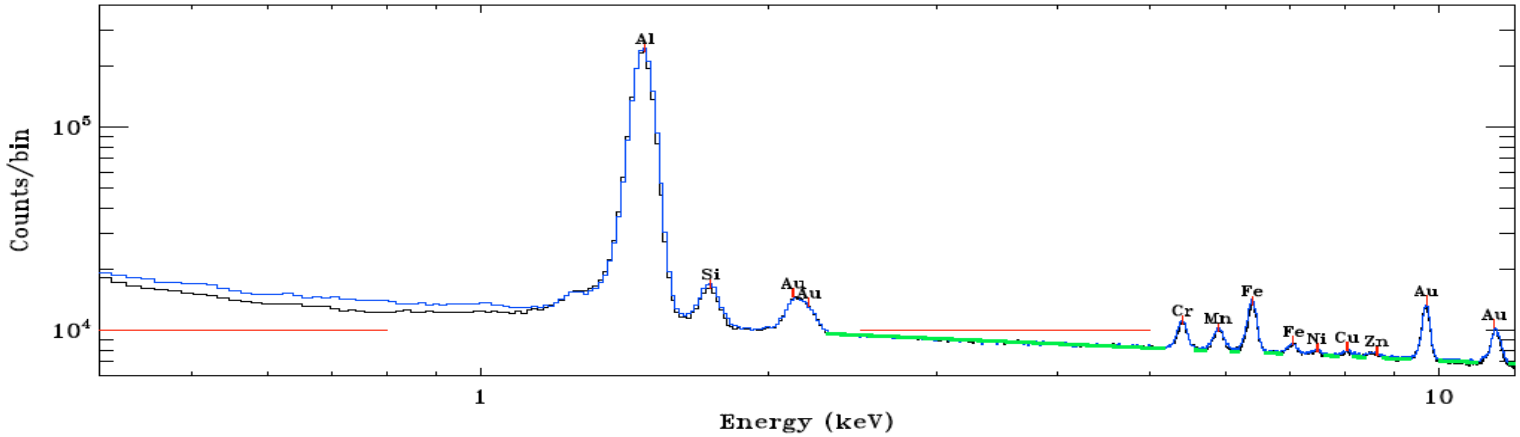
- Model the Quiescent Particle Background (QPB)

  (after removal of flaring background)

- **<u>Determine the corner spectral parameters</u>: high-energy power law slope [2.4-12.0 keV] and hardness ratio [(2.5-5.0)/(0.4-0.8)] from the observation data set**

Which background to use? – 2. XMM-ESAS

- Quiescent Particle Background (QPB)



Mean QPB spectrum derived from unexposed corner pixel data from all public screened data (~76 Msec for each camera). MOS1 black, MOS2 blue.

Red lines: two regions used to measure hardness ratio (HR)
Green line: fitted power law above 2.4 keV

HR & slope used for parameterization of QPB; Prominent background lines are labeled.

Both continuum and line contributions are both position and temporally varying

Which background to use? – 2. XMM-ESAS

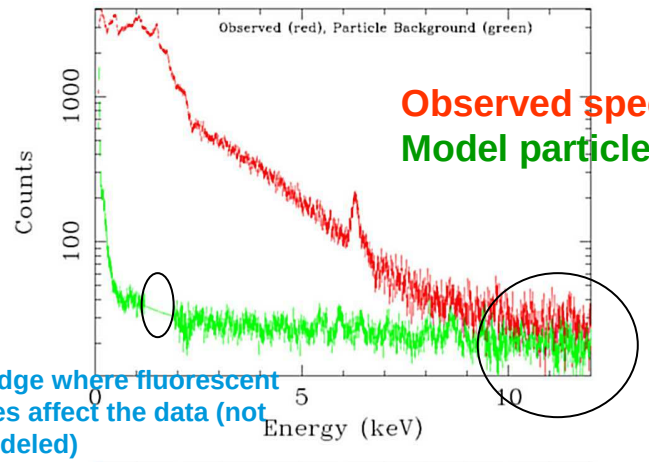
- Model the Quiescent Particle Background (QPB)
  (after removal of flaring background)

- **Determine the corner spectral parameters: high-energy power law slope [2.4-12.0 keV] and hardness ratio [(2.5-5.0)/(0.4-0.8)] from the observation data set**

- **Search an archived-observation data base for observations with similar parameters**
- **Augment the observation data set corner spectra with data from the archived-observation data base**
- **Scale the Filter Wheel Closed (FWC) spectra (treat each CCD separately) for the region of interest by the ratio of the augmented observation corner spectra to the FWC corner spectra**
- **Combine augmented & corrected corner-region spectra from different CCDs, correctly weighted, to form single bkg spectrum for object region**

XMM-ESAS: Spectral analysis

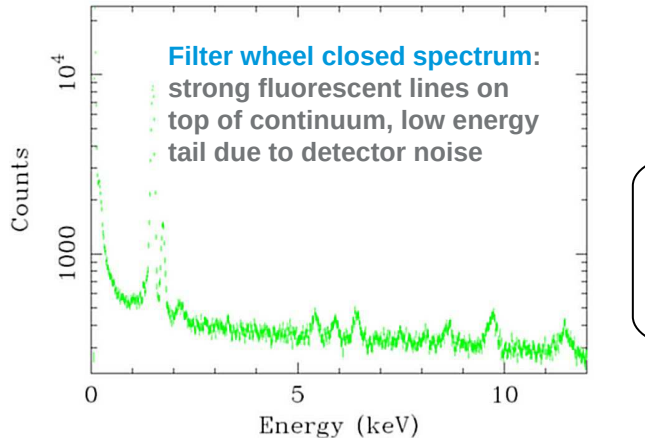
- Some results from XMM-ESAS (Abell 1795):



Observed spectrum
Model particle bkg.

Discrepancy due to residual soft proton contamination

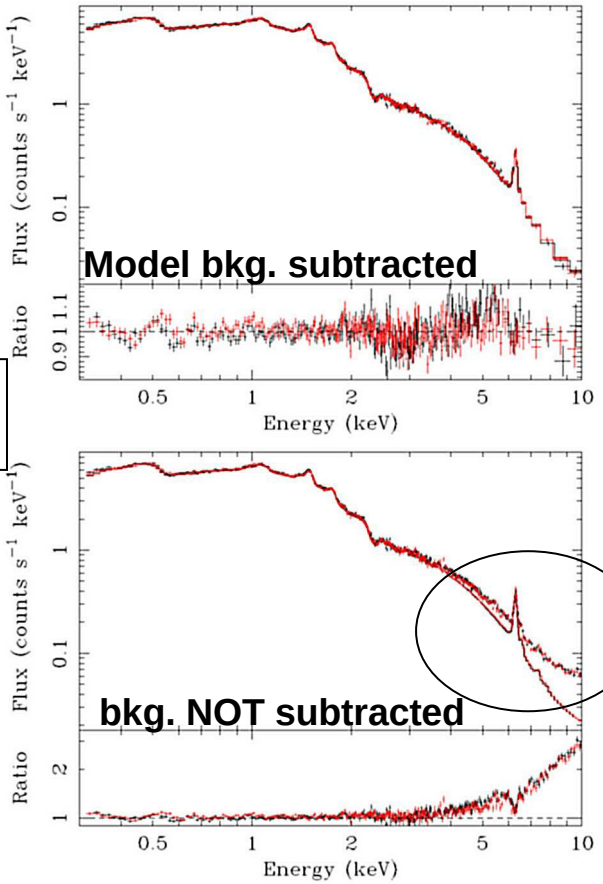
Bridge where fluorescent lines affect the data (not modeled)



Filter wheel closed spectrum: strong fluorescent lines on top of continuum, low energy tail due to detector noise

Fitted MOS1 & MOS2 spectra

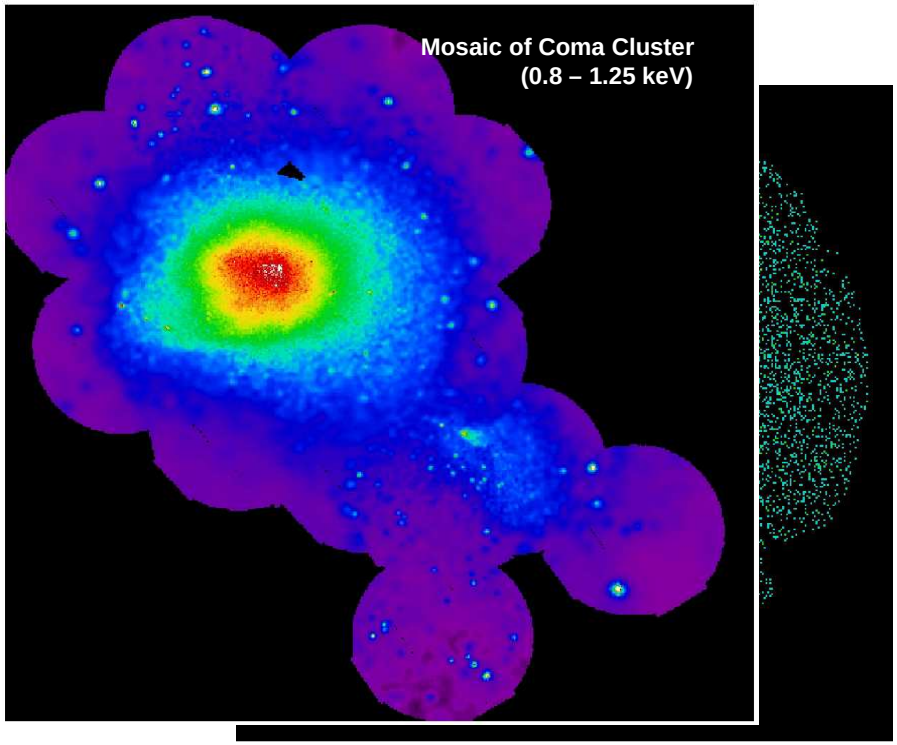
Details of the rather complex fit model are given in the ESAS Cookbook …



XMM-ESAS: Image generation

SAS task *asmooth* is one option …

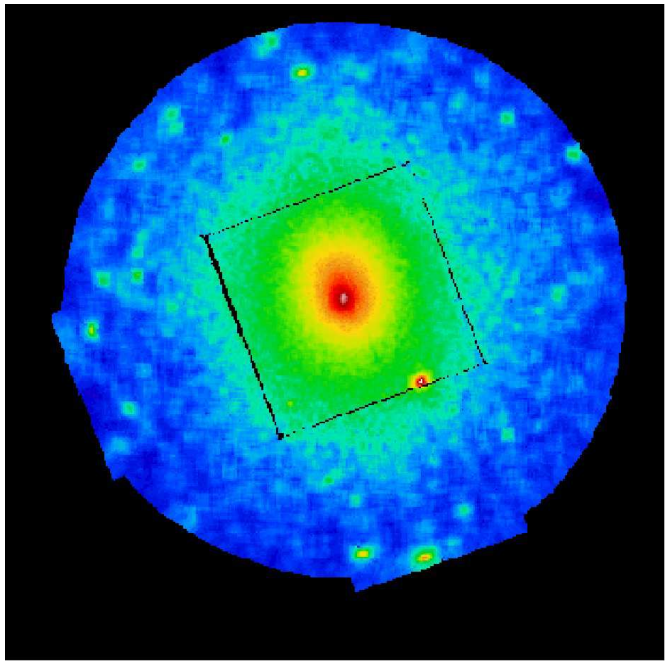
XMM-ESAS: adaptive smoothing of background subtracted & exposure corrected images & merging of EPIC data & mosaicing of multiple pointings (see ESAS Thread)



observed counts

&

Abell 1795 (0.35-1.25 keV)



bkg-subtracted & exp. corrected, smoothed image

Addition: Filter wheel closed data

- Filter Wheel Closed (FWC) data
  - From calibration obs. with filter wheel in closed position
  - Released in September 2006:
    stacked collections of FWC data available for MOS and pn

- What for?
  - Closed position ⇒ blocking X-rays & soft protons from outside
  - Cosmic rays, however, still penetrate to the detectors

    ⇒ allows clean measure of (internal) bkg components:
    - high energy particles producing charge directly in CCDs
    - particle induced X-rays (continuum and fluorescent lines), generated inside the camera
    - electronic readout noise (at lowest energies)

- BGWG provides them for MOS (fullframe) & PN (all modes), see,
  http://xmm2.esac.esa.int/external/xmm_sw_cal/background/filter_closed/

- These components are distributed non-homogeneously and are time dependant !

Filter Wheel Closed Data: MOS

- MOS FWC Data:
  http://xmm2.esac.esa.int/external/xmm_sw_cal/background/filter_closed/mos/index.shtml

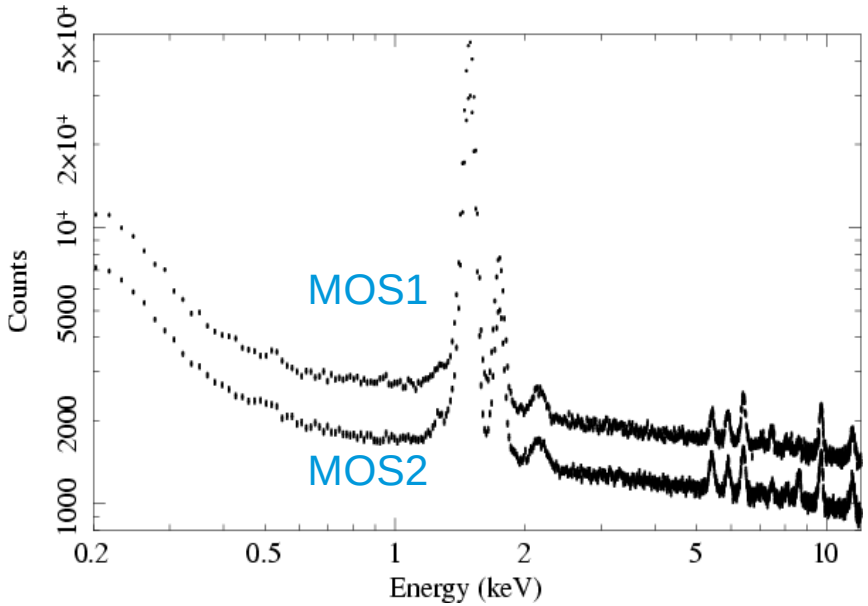
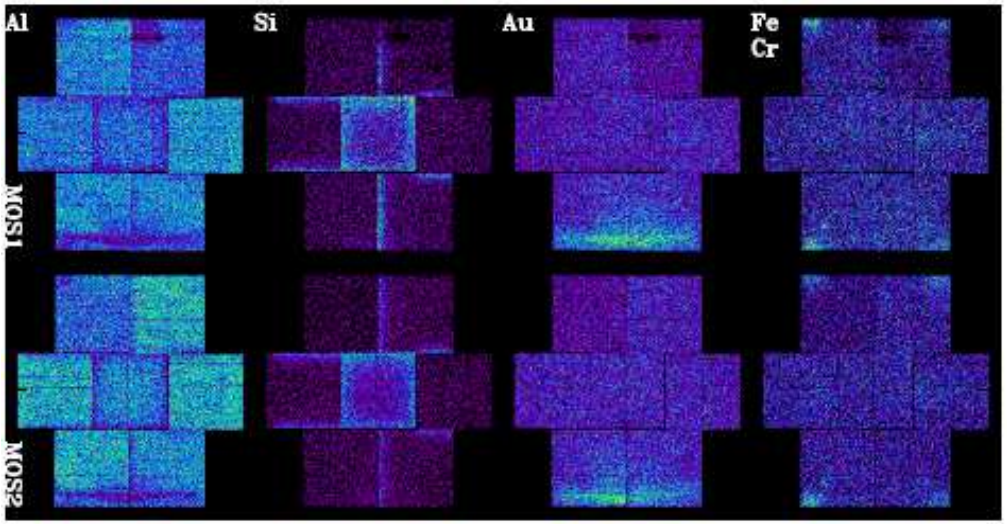


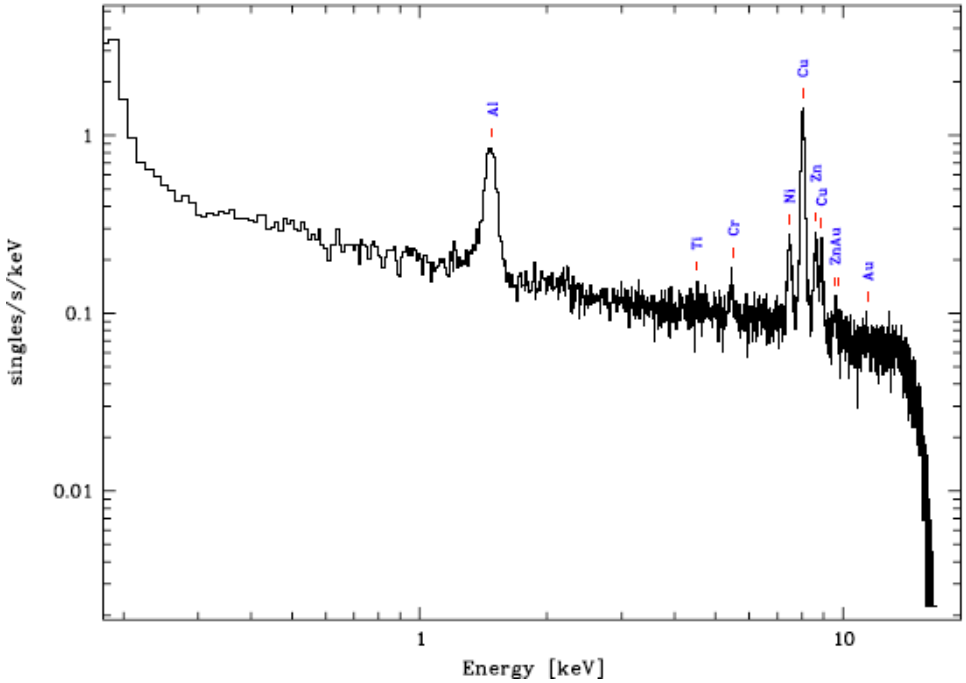
Fig. from Snowden et al. 2008, A&A 478, 615

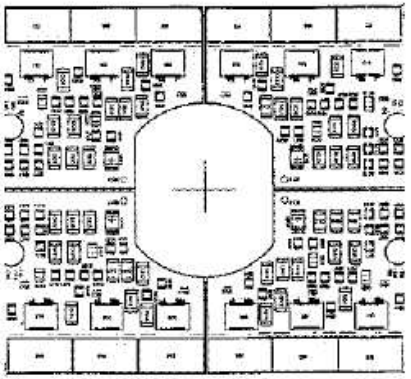
Very strong Al & Si fluorescent instrumental lines (~1.49 keV and ~1.75 keV) on top of QPB continuum. Other fluorescent lines at higher energies; strong low-energy tail due to detector noise

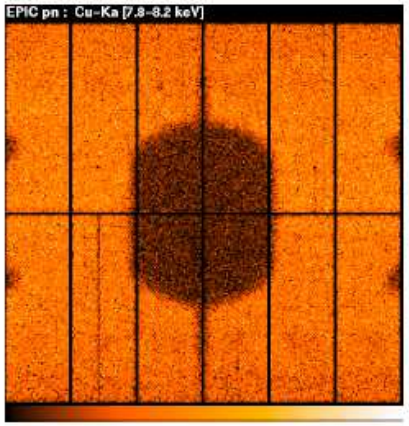


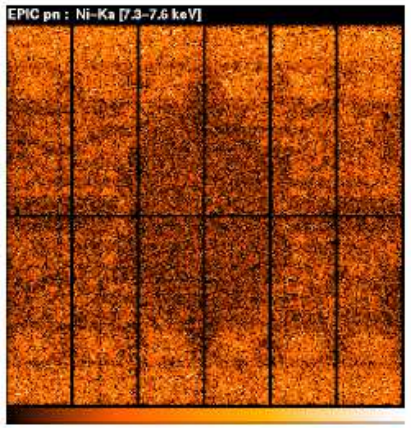
Filter Wheel Closed Data: PN

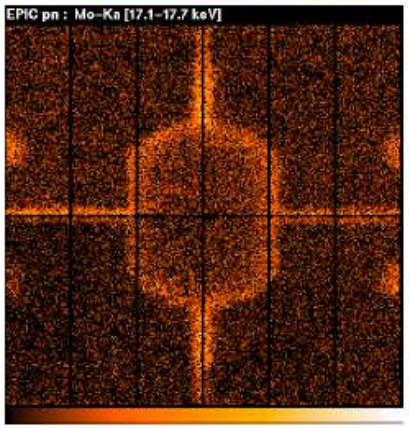
- PN FWC data:
  http://xmm2.esac.esa.int/external/xmm_sw_cal/background/filter_closed/pn/index.shtml







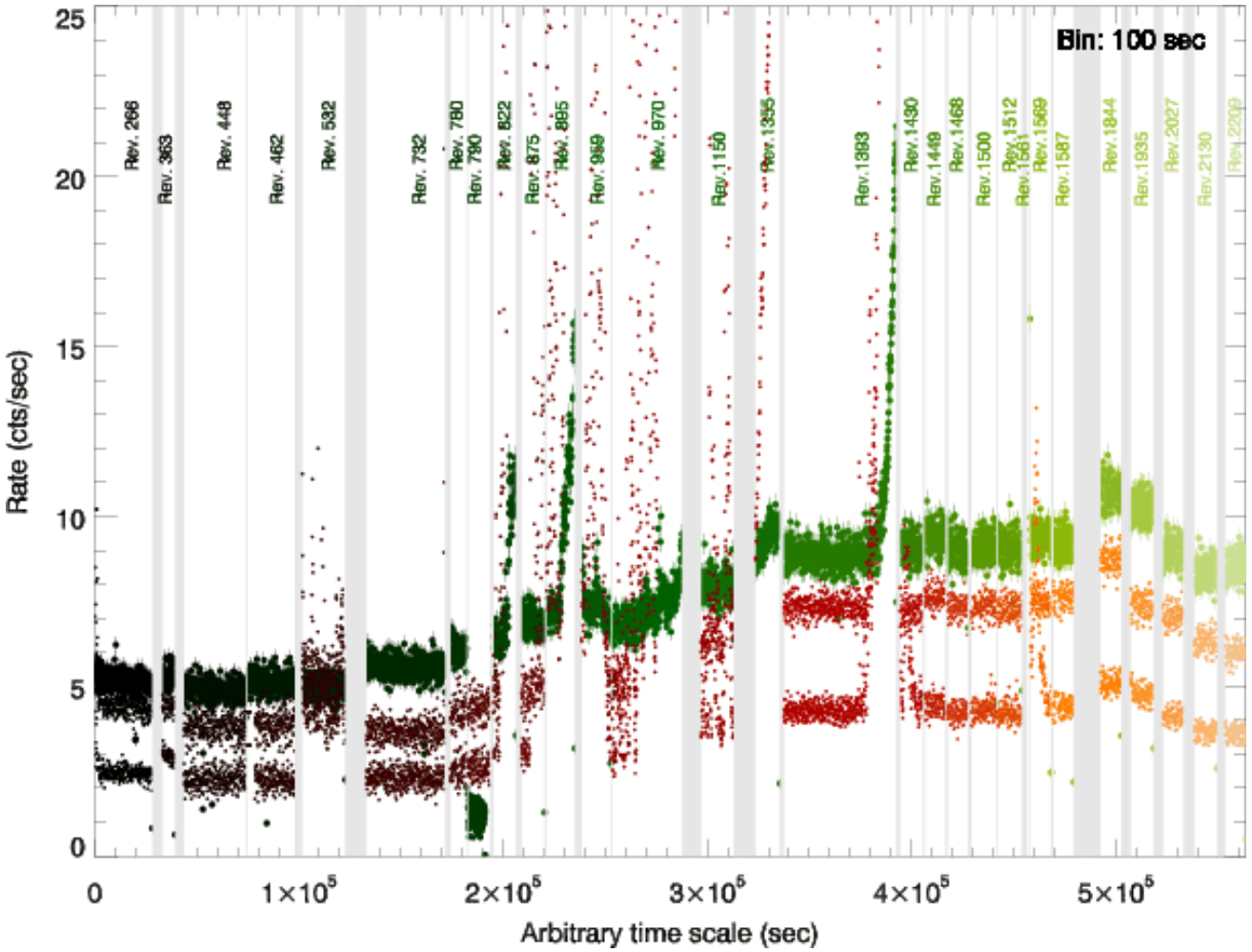




⇒ It is highly recommended not to combine event files from different readout modes!

Filter Wheel Closed Data: Time Evolution

- Time Evolution (example, pn Full Frame mode)



Useful References

XMM-Newton BKG pages:

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

XMM-Newton BKG components & their temporal, spectral, spatial properties:

http://www.star.le.ac.uk/~amr30/BG/BGTable.html

Blank Sky Fields:

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

ESAS Package:

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

Filter Wheel Close Data:

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