XMM-Newton EPIC Background

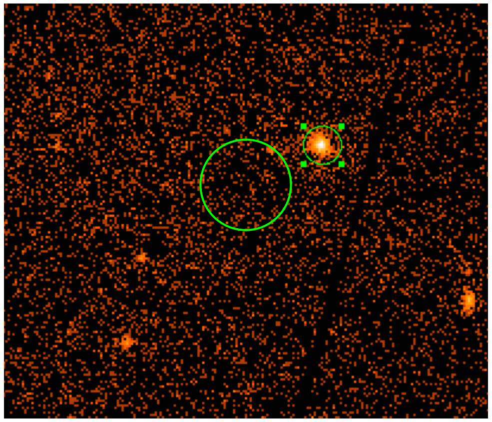
Introduction

- What is the BG?
- Why understanding the BG is important
- BG components and characteristics
- BG work at Leicester
- Useful sources of information

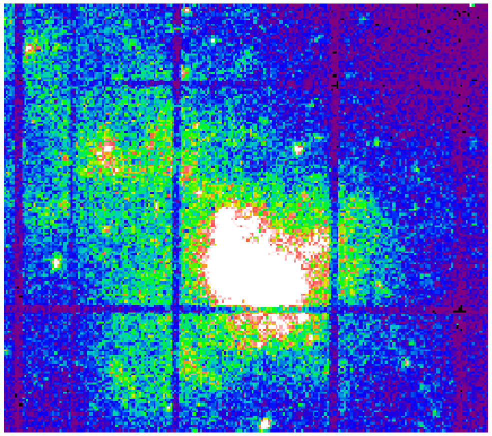
The BG problem

- Diffuse, extended source analysis – where to take the BG?

‘Normal’ BG extraction



Extended BG extraction



- Many on-axis/off-axis differences are important

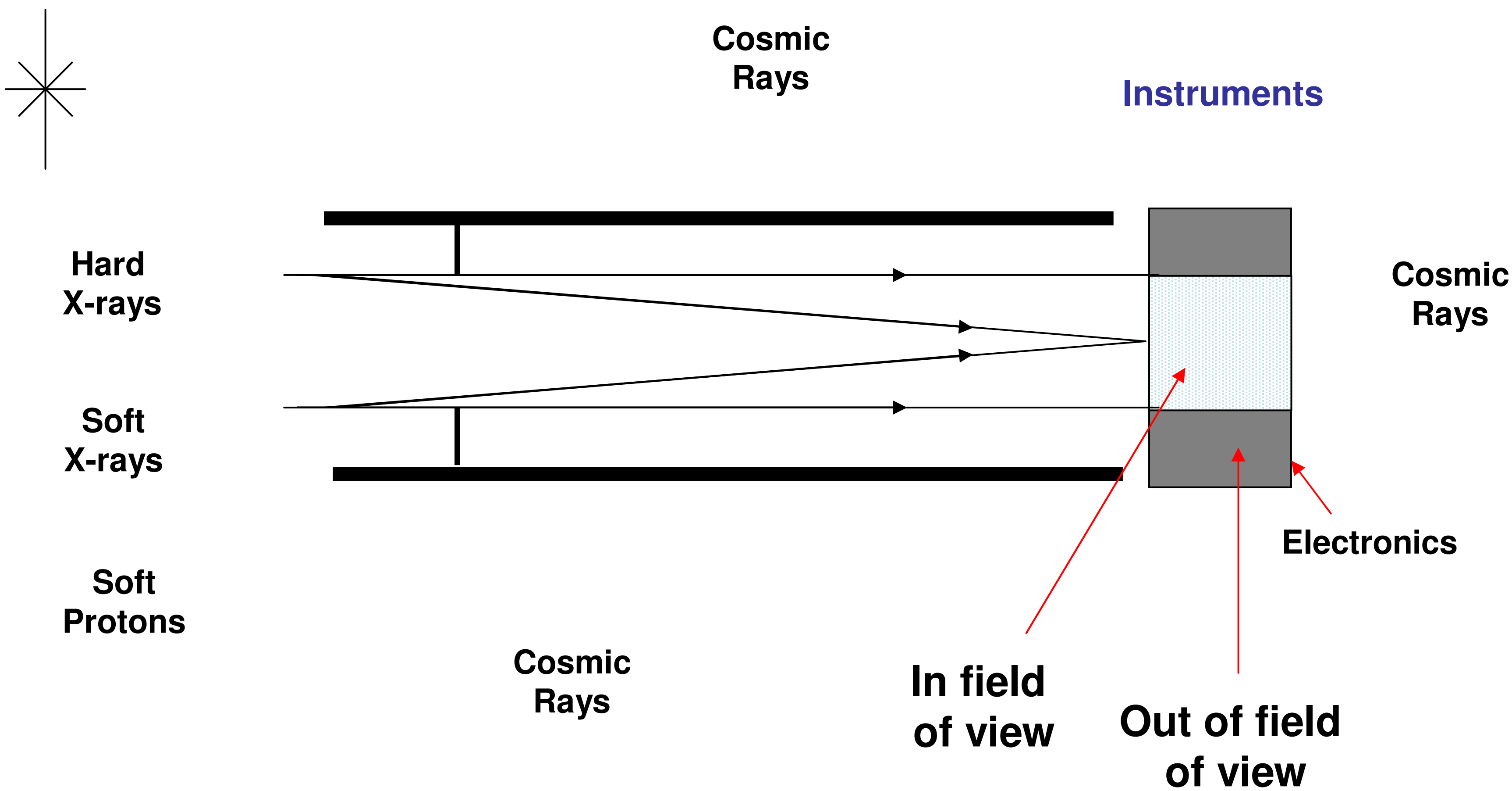
- The BGWG investigating the characteristics of the BG

The EPIC BG

- Roughly split into five major categories

	Classification	Distribution at detector	Focusing
Soft Protons	Particles	Similar to X-rays	"Focused" by mirrors
Internal BG	Particles	Not like X-rays	Not focused by mirrors
Electronic Noise	Internal	Not like X-rays	Not applicable
Hard X-rays	Photons	Genuine X-rays	Focused by mirrors
Soft X-rays	Photons	Genuine X-rays	Focused by mirrors

The telescope and BG sources



Particle component of the BG

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Soft protons

- Source: solar flares/activity
- Unpredictable
- Affect up to 40% of observation time
- Seasonal dependence: more in summer
- More far from apogee, i.e. closer to the Earth
- Vignetted – only inside the FOV
- Maybe getting worse
- Significant component remains after GTI screening

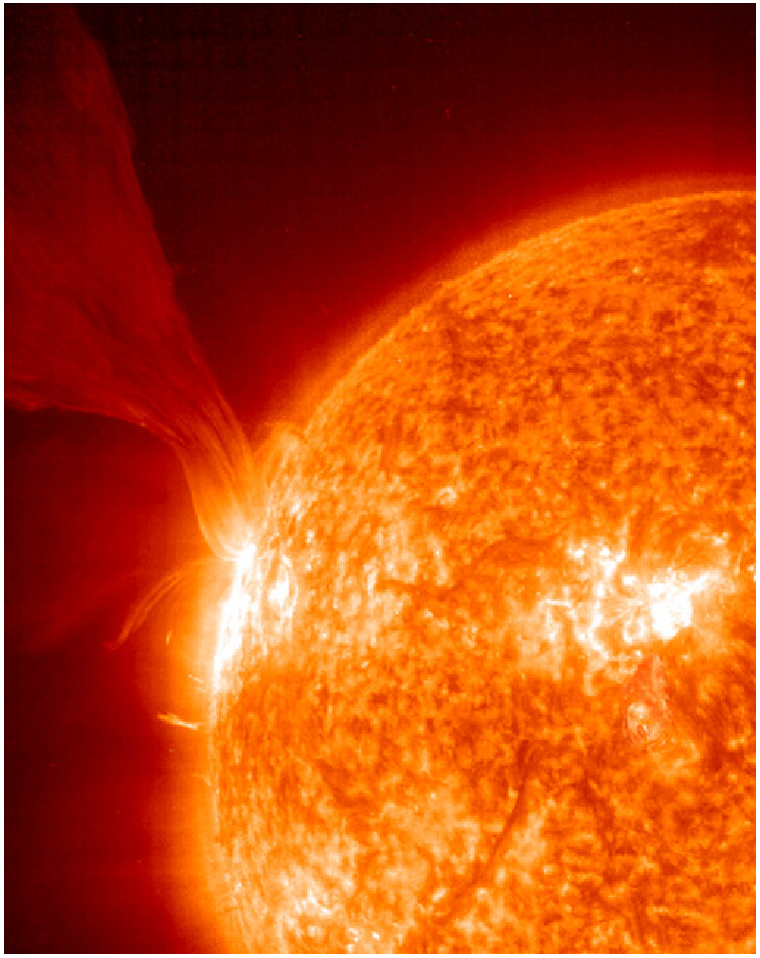
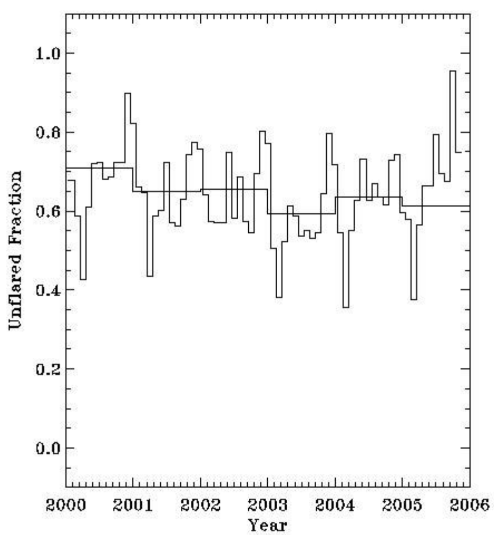
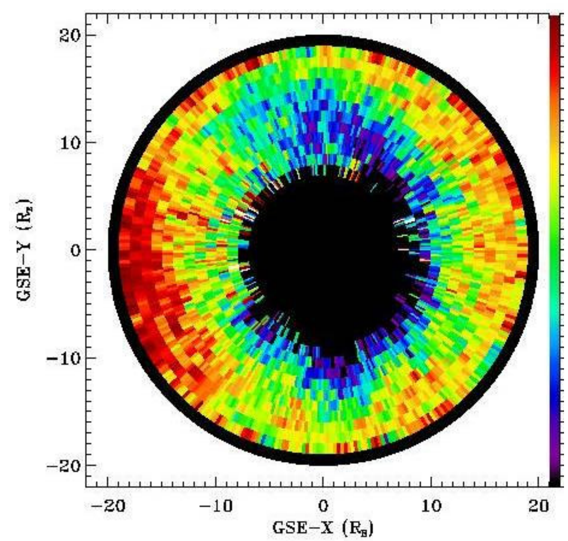


Image: SOHO (EIT), ESA/NASA

Soft protons characteristics

- Spectrally variable in intensity and shape and unpredictable
- Spectrally fitted by broken power law, with break energy at approx. 3.2 keV
- Spatial dependence:
  - – only in FOV, apart from massive flares
  - – mysterious feature seen in MOS1 CCD-2 at low-energies



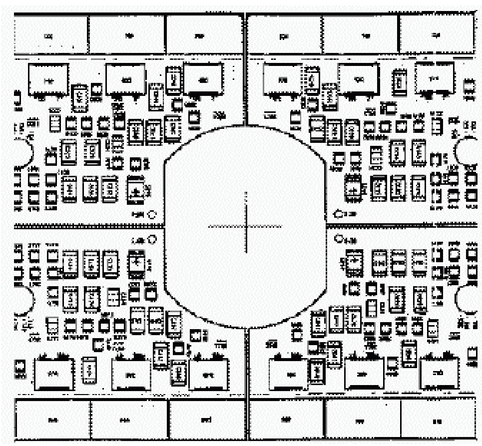


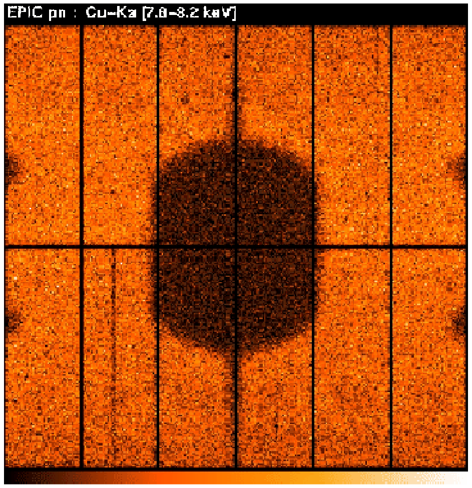
Direction of sun

Cosmic rays and XMM-Newton

- Cosmic ray induced events
  - interactions of high energy particles with the detector and housing
- causes instrumental fluorescence

- Component can vary throughout an observation by 10% or more
- Correlated with solar flares; large effect seen with intense solar flares

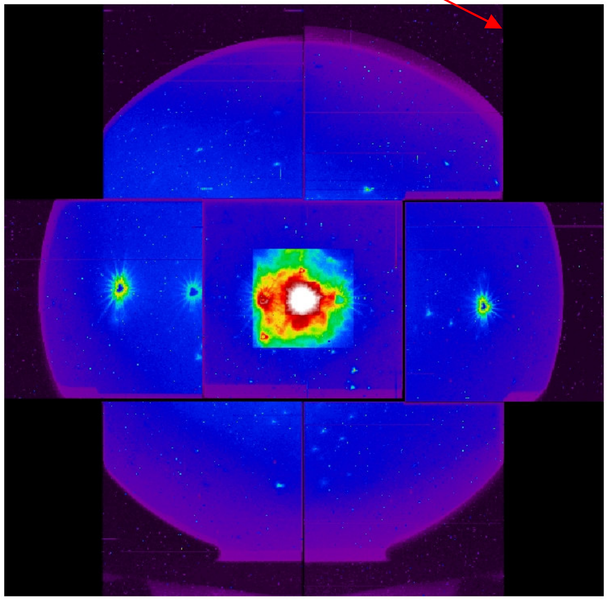




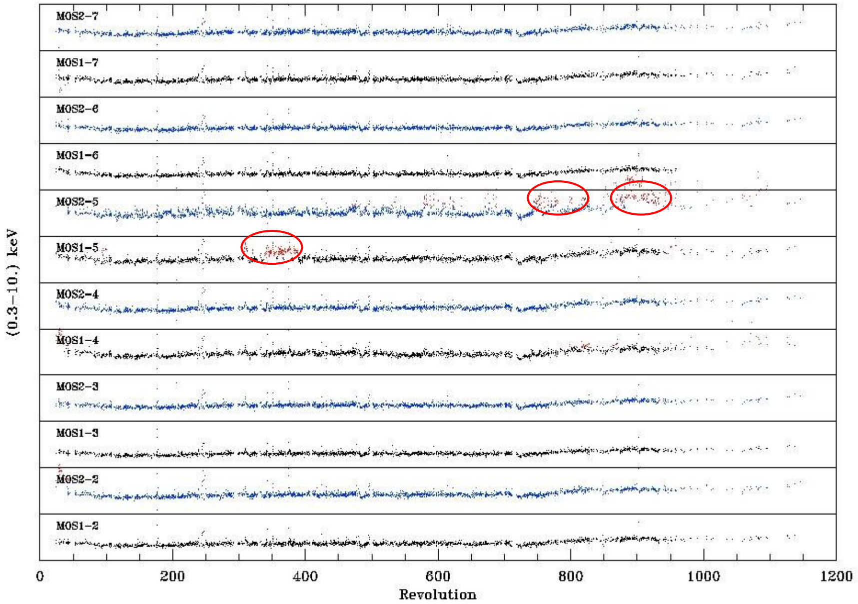
Copper hole
7.8 – 8.2 keV

Looking at the particle BG

Out of FOV



Monitoring over time

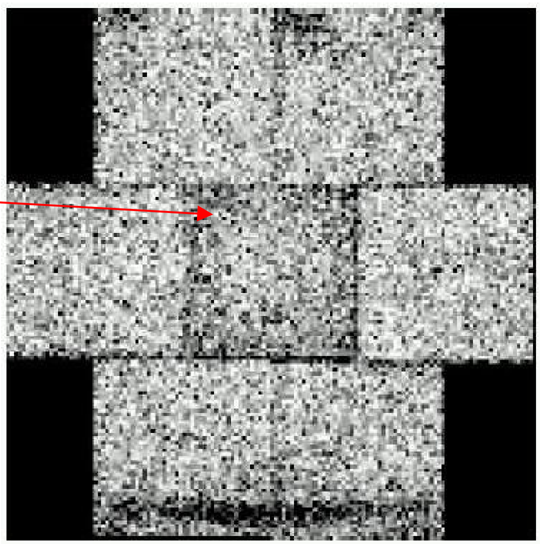


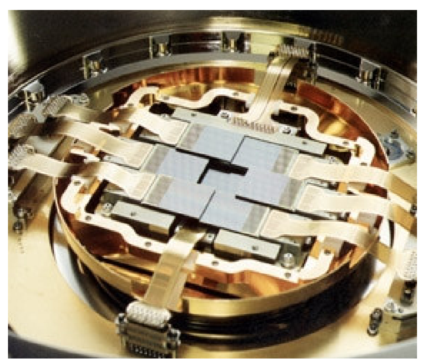
- Variations between observation
- No increase after solar flare periods

Effects of cosmic rays at the detectors

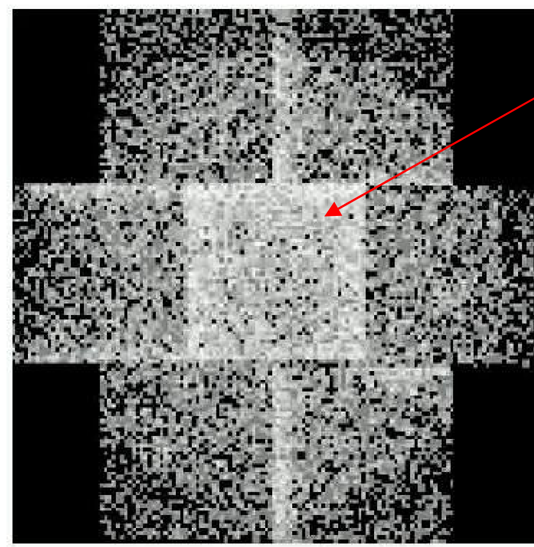
- Al shielding has a Au layer, more Au seen out-FOV
- Cr, Mn, Fe, Ni, K, Al, Au, Si contributions
- 3D structure causes shadowing and enhancements (central CCD lower)

Al-K emission





Si-K emission



Electronic component of the BG

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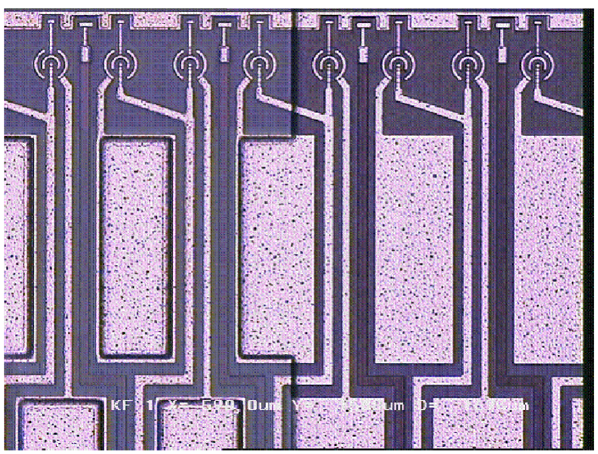
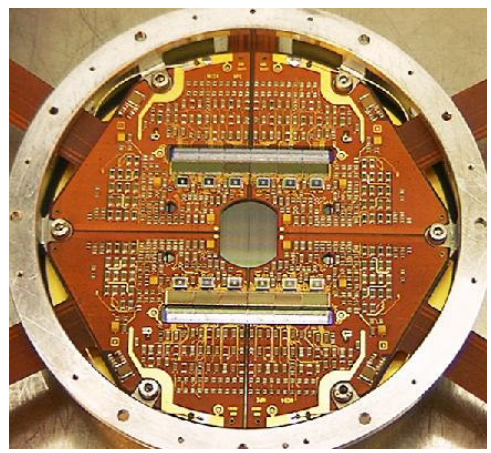
Electronics

- Detector noise below 0.3 keV
- Bright pixels and columns
- CAMEX readout noise (pn) – mode dependance
- Low-energy enhancements in the outer CCDs





Photon component of the BG

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Photon contributions to the BG

Hard X-rays:

- Unresolved AGN
- Single reflections
- Out of time events

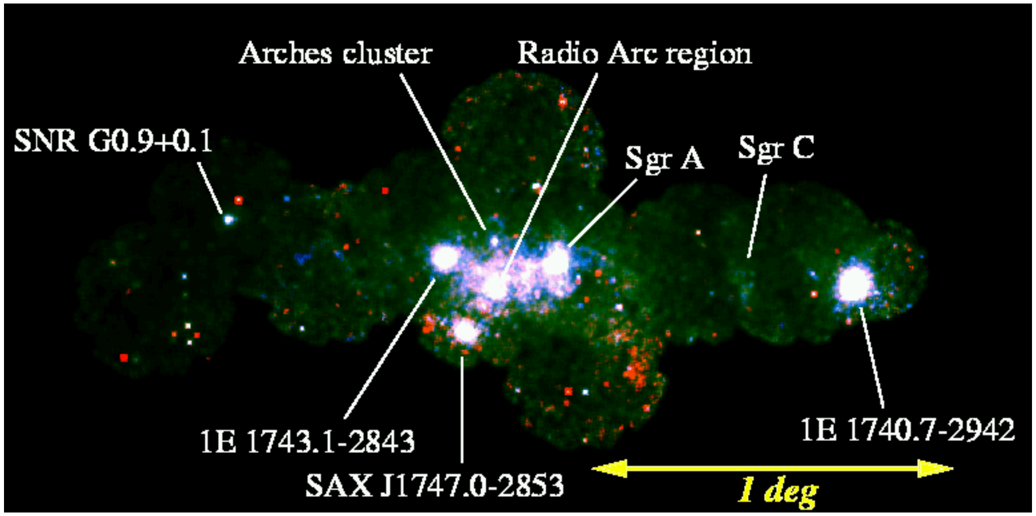


Image: EPIC MOS, University of Leicester

Soft X-rays:

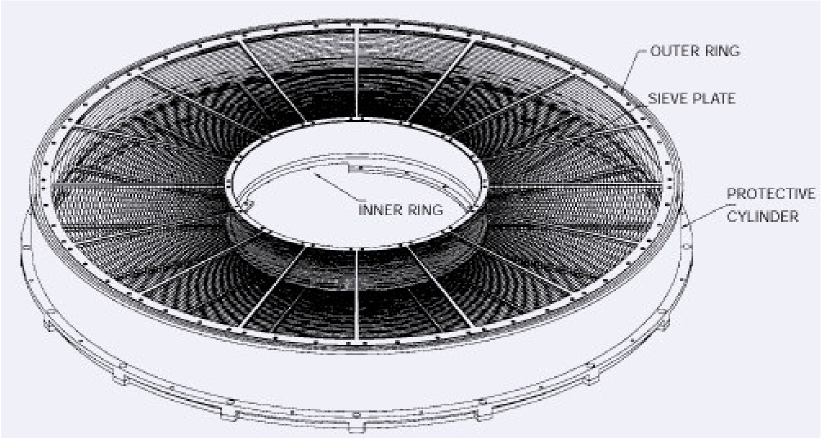
- Diffuse sources
  - Local Bubble
  - Galactic Disk
  - Galactic Halo
- Solar Wind Charge Exchange: solar wind and Earth's exosphere, or heliosphere
- Single reflections from outside the FOV
- Out of time events

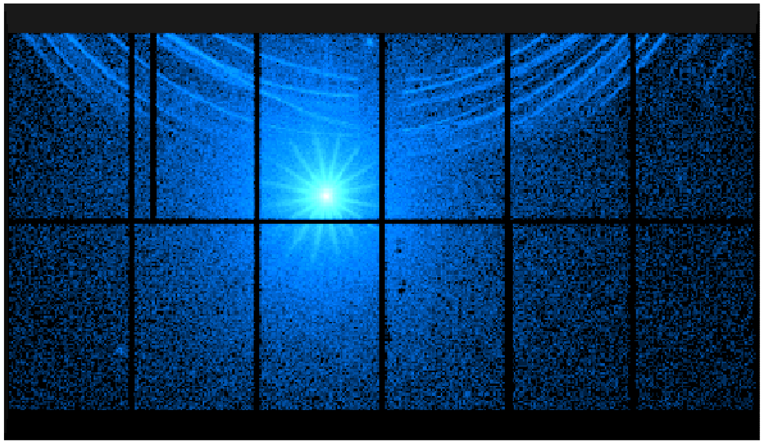
Galactic and Extra-galactic BG characteristics

- Extra-galactic component spatially uniform >0.8 keV, index = 1.4
- Galactic emission varies with pointings (RA and Dec)
- Other structures seen from actual astronomical objects
- Thermal component < 1keV for soft component, with emission lines
- Hard and soft x-rays can dominate BG (below 5keV)

Out of FOV reflections

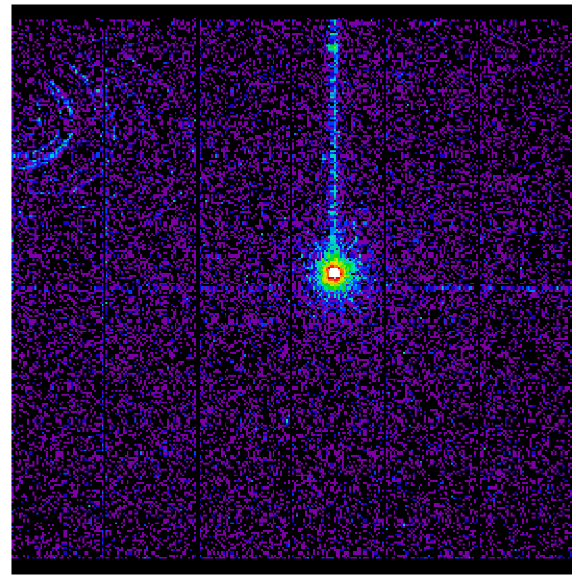
- Applies to hard and soft X-ray components
- Flux from outside FOV scattered into FOV
- Baffle used to minimise this effect

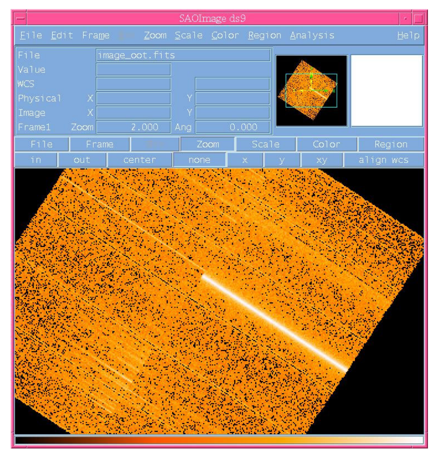




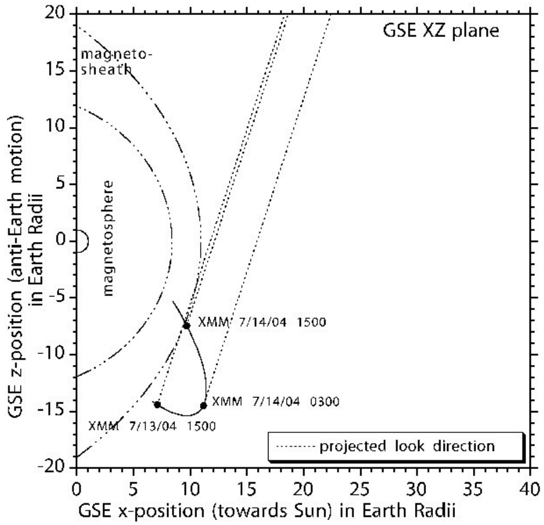
Out of time events

- Applies to hard and soft X-ray components
- Events smeared in RAWY-direction during CCD readout
- Mode dependent, as dependent on readout time:
  - full-frame mode 6.3%
  - extended full-frame mode 2.3%
  - large window mode 0.16%

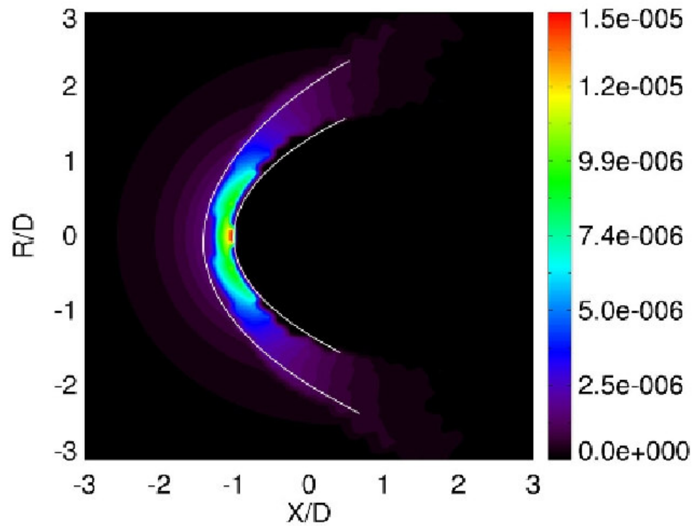


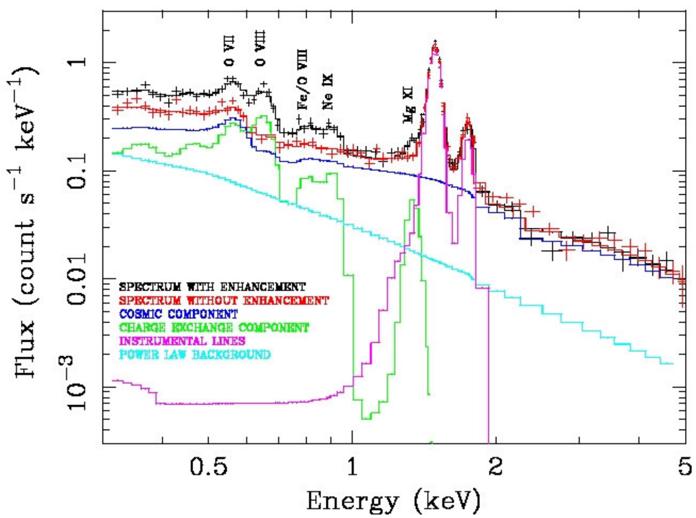


Characteristics of the SWCX



Dependent on where XMM-Newton is and where it's looking

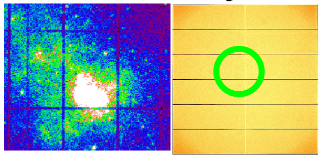




Strong Oxygen and Magnesium lines

Blank sky analysis at Leicester

- Production of files useful for extended and diffuse source analysis
- Users can select their background from these files



List of obs. with no bright sources, long exposure etc

↓

Extract 2XMM pipeline products

↓

Create event lists and exposure maps

↓

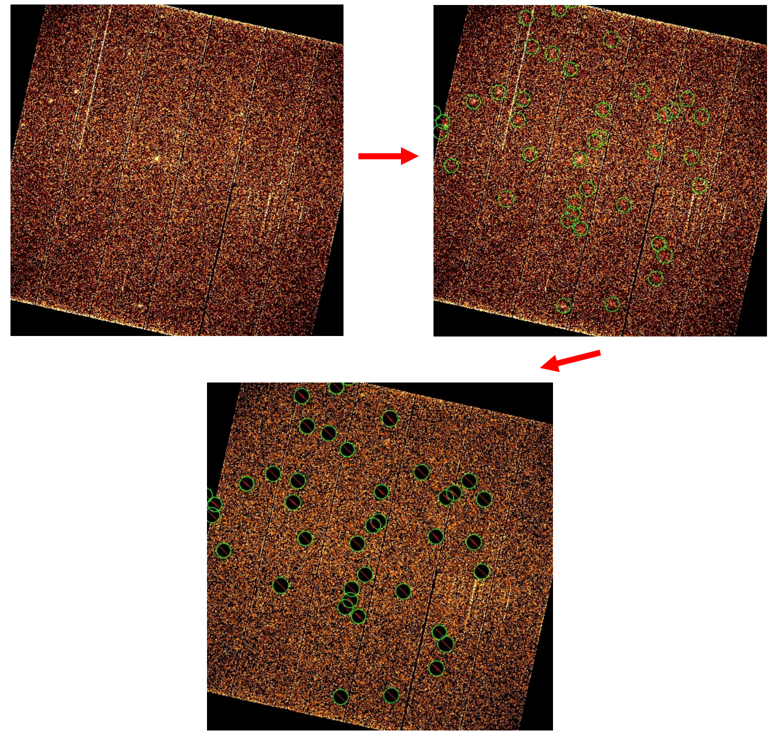
Merge event lists and exposure maps

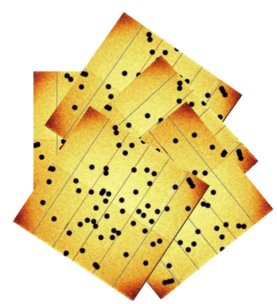
↓

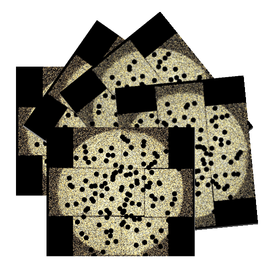
One great big event list with an accompanying exposure map for each instrument-filter-mode combination

Producing the final files

- Decide which observations to take – Lockman Hole, Marano Pointings etc.
- Remove the sources, cleaning filtering
- Fill the resultant holes of some files
- Create exposure maps
- Stacking, adjusting file attributes

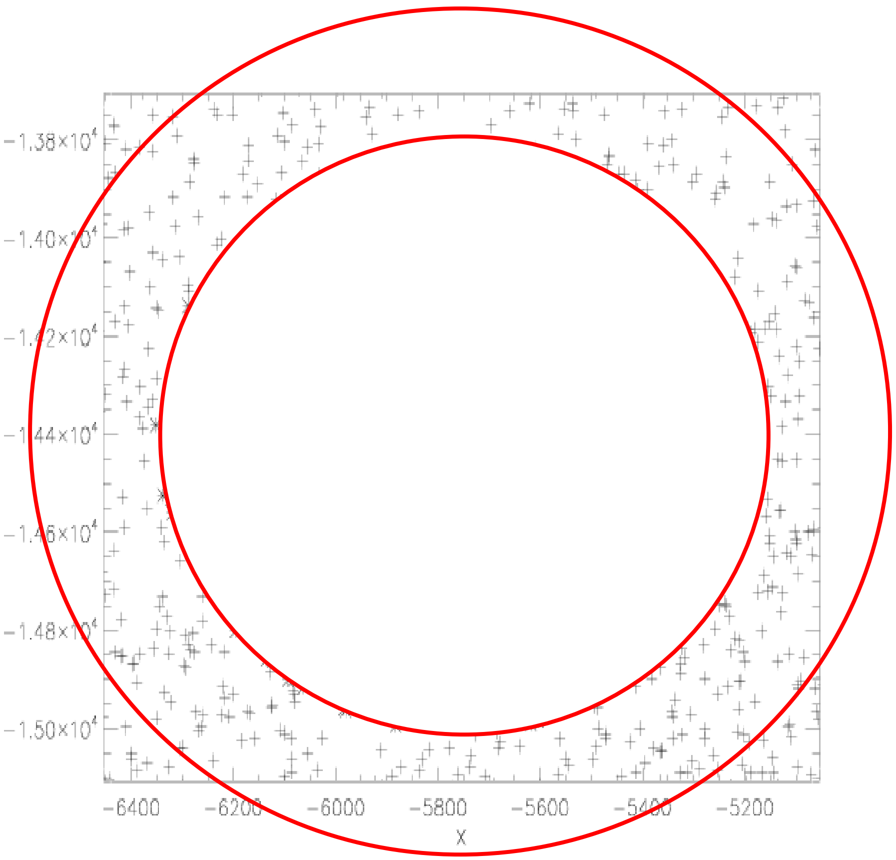


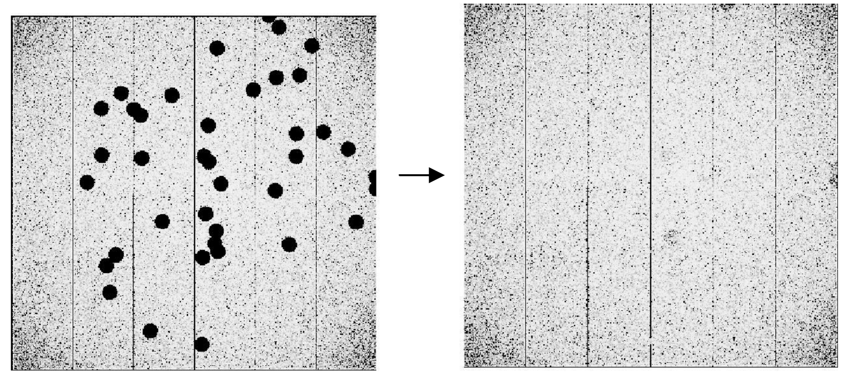


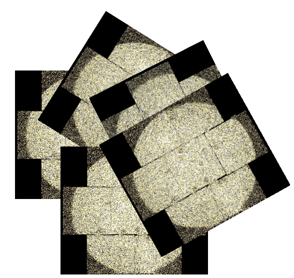


Ghosting

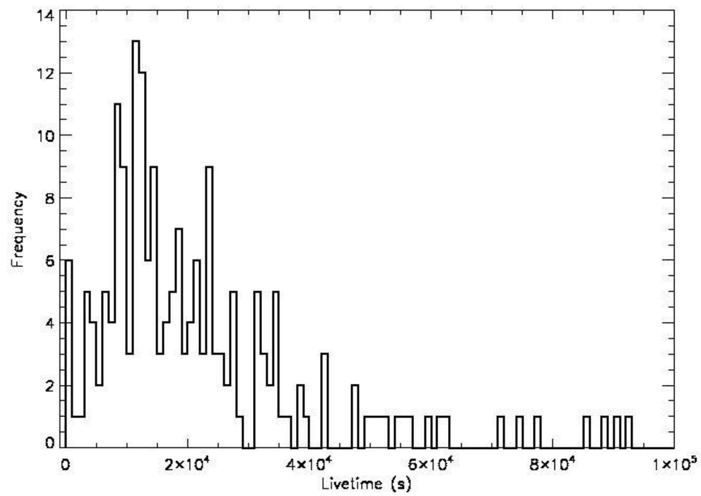
- Two types of final event file – filled and unfilled

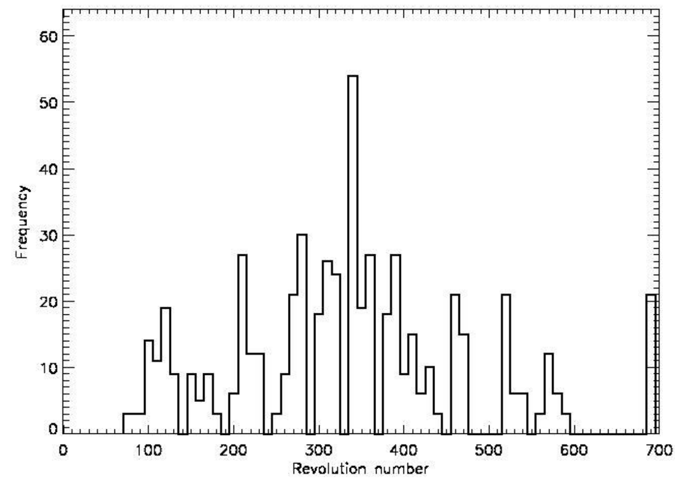


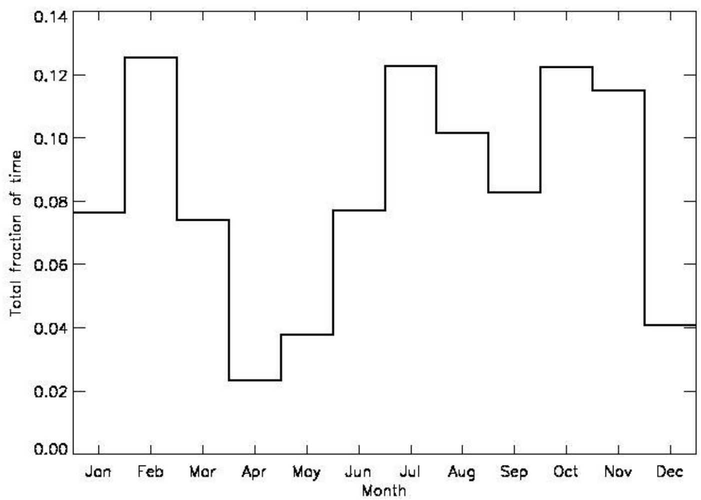


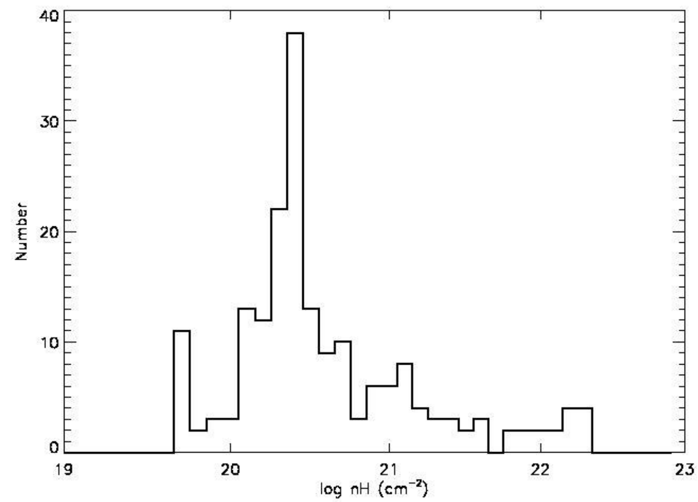


Details of the data sets



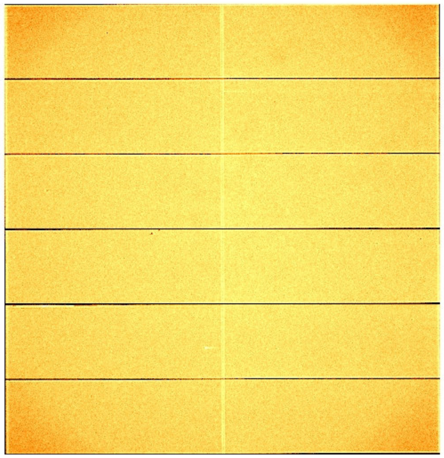


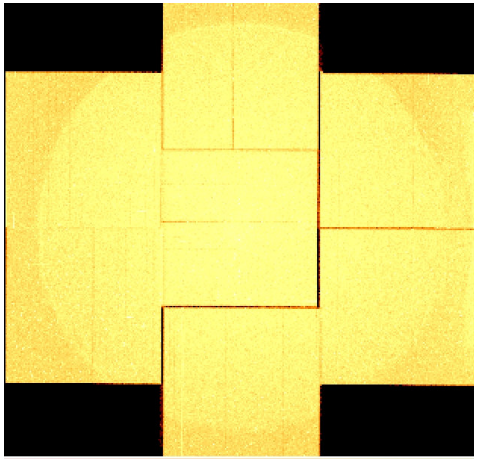




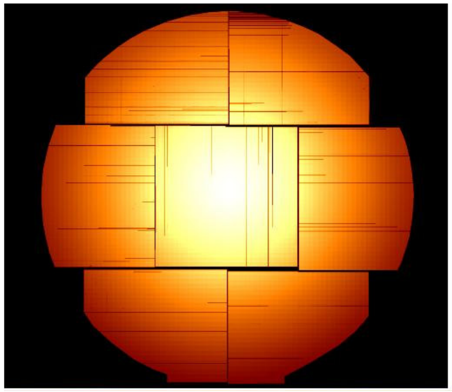
The files

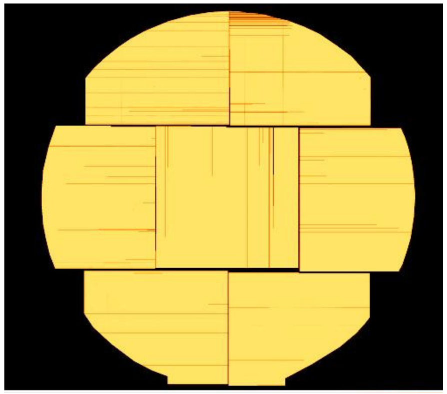
Event files examples:





Exposure map examples:

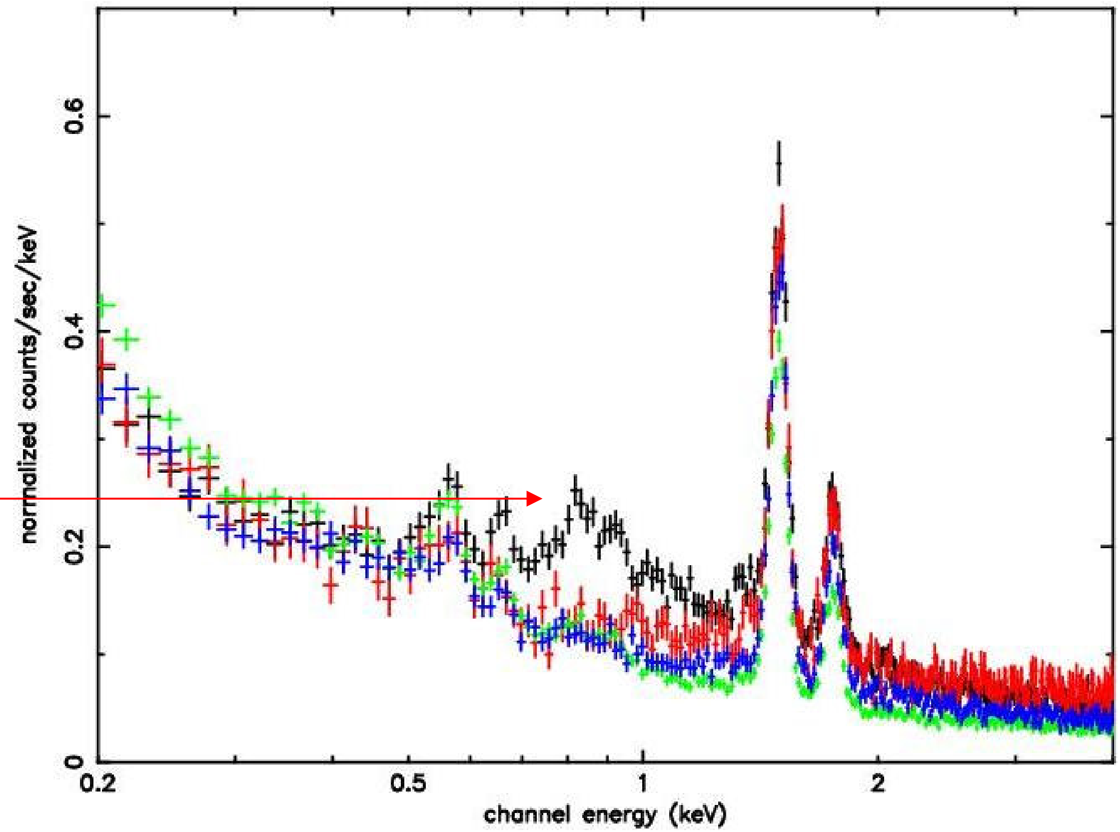




Characteristics of the final files - 1

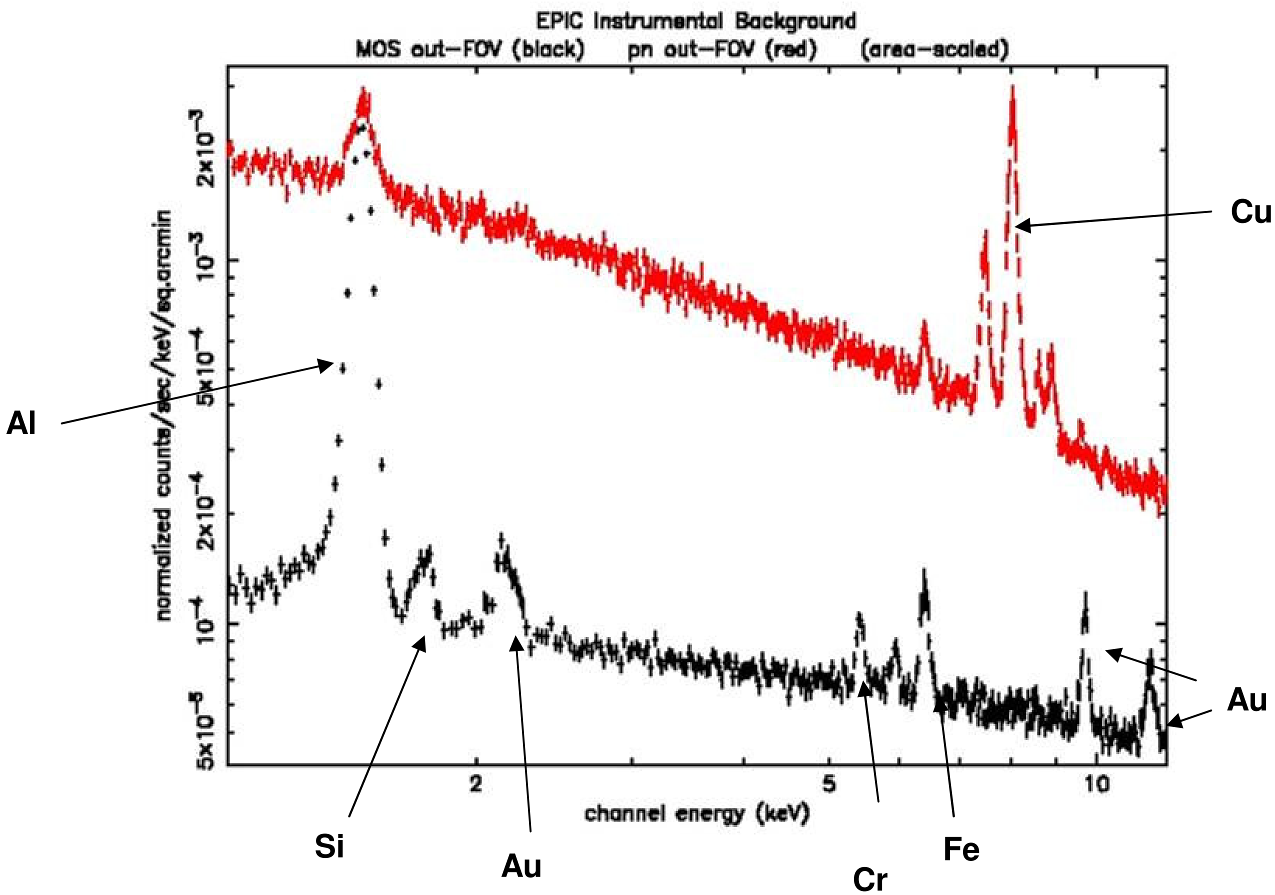
- Pointing location dependence – script available

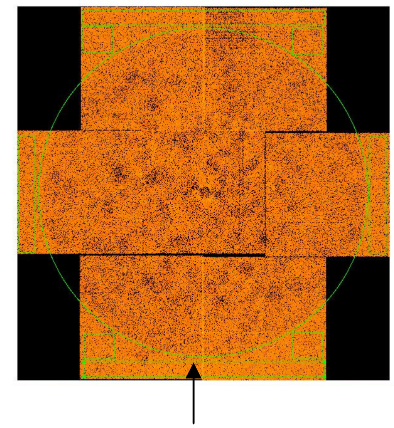
Galactic centre pointings



Characteristics of the final files - 2

- Instrumental lines

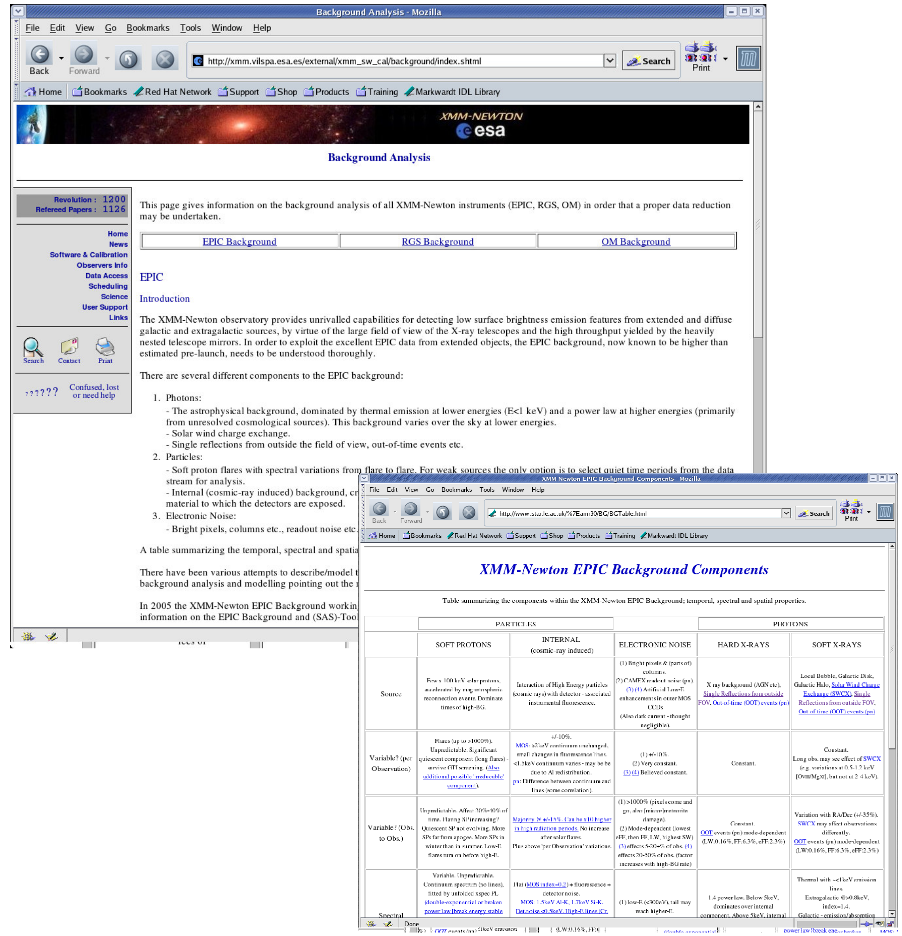




Out of FOV areas (MOS)

BGWG information

- The BGWG web pages
  - description of BG components
  - links to presentations, guidelines, papers, files and software
  - regularly updated
  - easily found through SOC site



The BGWG

- M. Ehle – ESAC, Madrid, Spain
- M. Freyberg – MPE, Garching, Germany
- M. Kirsch – ESAC, Madrid, Spain
- K. Kuntz – NASA Goddard Space Flight Centre
- A. Leccardi – Istituto di Astrofisica Spaziale e Fisica Cosmica, Italy
- S. Molendi – Istituto di Astrofisica Spaziale e Fisica Cosmica, Italy
- W. Pietsch – MPE, Garching, Germany
- A. Read – University of Leicester, U.K.
- S. Snowden - NASA Goddard Space Flight Centre

Characteristics of the filtering steps

- GTi taken for thresholds:
  - 60 counts per second (pn)
  - 2 counts per second (MOS)
- Source selection radius, 35 arcseconds (initially experimented with using a radius of 30 arcseconds)
- Discard events below 100eV, retain singles and doubles for pn, up to quadrupoles for MOS. SAS-recommended flags for EPIC.
- Bright pixel removal.
- Exposure map, 4 arcsecond binning.

Blank sky characteristics of the data sets

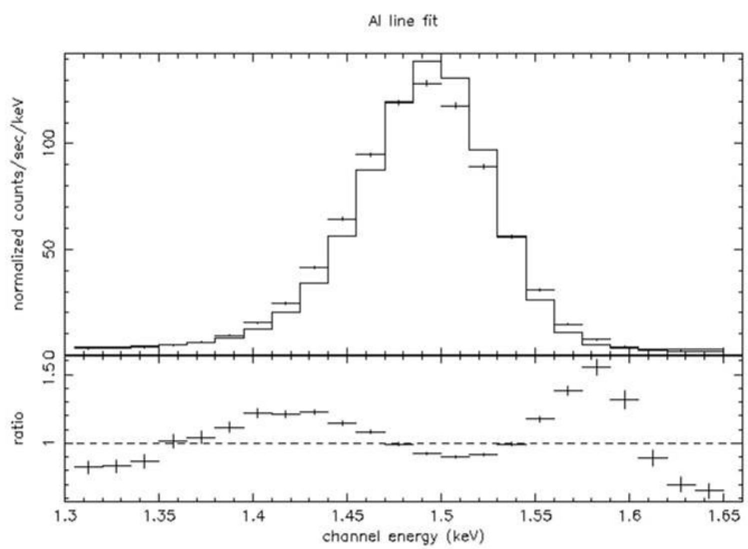
- Observations between revn. 70 and 691
- Average fraction of time removed:
  - 0.8098 (MOS1)
  - 0.8190 (MOS2)
  - 0.9577 (pn)
- Livetime after cleaning peaks around 1.8×10^4 seconds, typical of a normal observation
- Column density for obs. pointings peaks at around $2.5 \times 10^{20} \mathrm{cm}^{-2}$

Numbers of observations used

Instrument	Mode	Filter	N_{OBS}	Exp.time (s)
MOS1	FF	Thick	12	3.01e5
MOS1	FF	Medium	65	1.58e6
MOS1	FF	Thin	113	2.19e6
MOS2	FF	Thick	13	3.44e5
MOS2	FF	Medium	67	1.68e6
MOS2	FF	Thin	111	2.09e6
PN	FF	Thick	10	2.37e5
PN	FF	Medium	33	1.08e6
PN	FF	Thin	42	9.93e5
PN	FFext	Thick	3	58664
PN	FFext	Medium	30	4.62e5
PN	FFext	Thin	62	8.25e5

Al possible redistribution

- Redistribution of the tail of the Al calibration line
- Maybe explains variations in continuum below the line at 1.5 keV
- Variations result from internal cosmic ray induced events



University of Leicester

Soft Proton Flares – Kip Kuntz/Steve Snowden

- Spectro-spatial variation
  - Spectrum becomes steeper with radius
  - Little difference between chips at the same radius
    - (with the exception of the "hot" spot on MOS1-2)