Status of the EPIC/MOS Calibration

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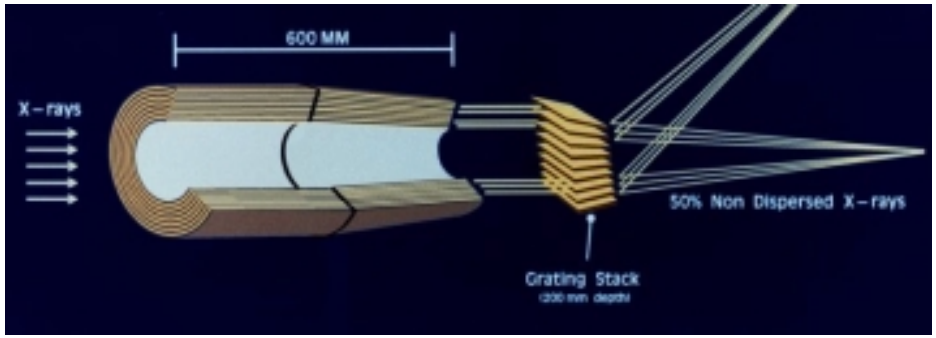
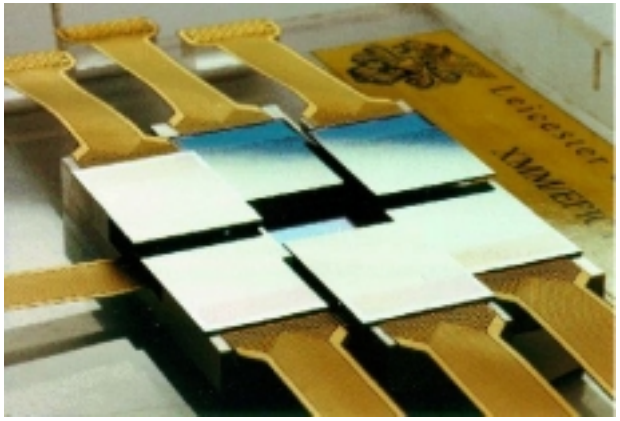
EPIC + SSC + ESA team

Hardware and calibration items





Telescope

- On axis effective area
- PSF
- Vignetting

Grating Stack

- Transmission
- Azimuthal modulation

MOS Cameras

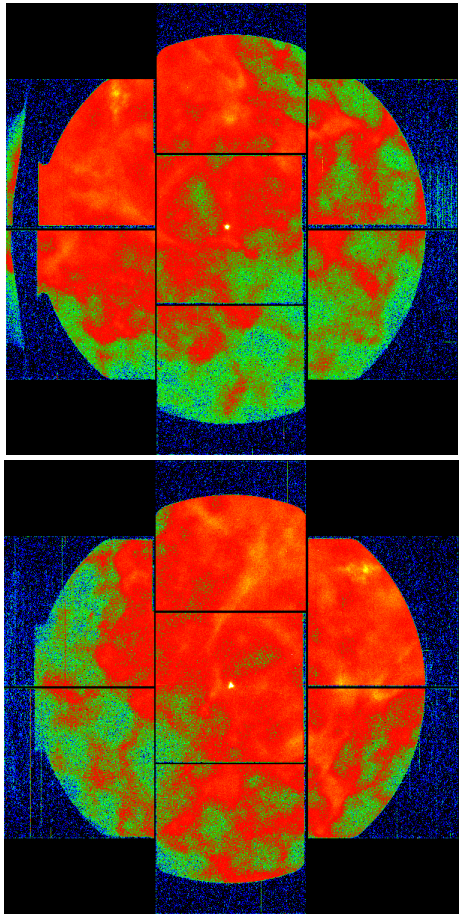
Filters : 2 thin, 1 medium, 1 thick

- Transmission
- Homogeneity

CCDs : 7 with 600×600 pixels of size 1.1 arcsec^2

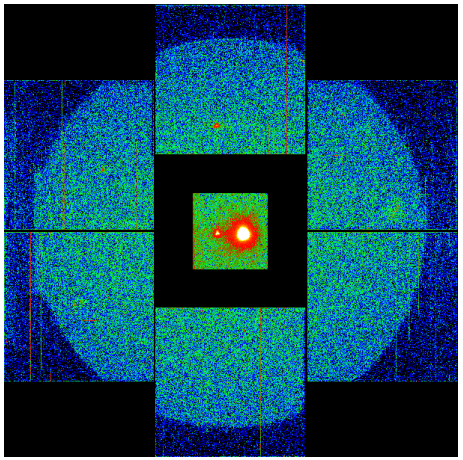
- Quantum efficiency
- Charge transfer inefficiency
- Redistribution matrix
- Energy scale
- Pile-up
- Background
- Metrology
- Homogeneity
- Timing

Basic EPIC/MOS modes



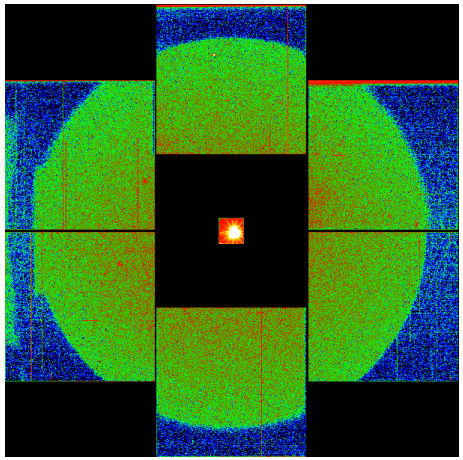
Full Frame

Frame time : 2.6 s



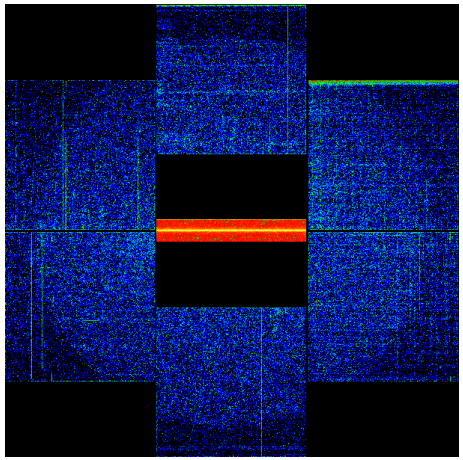
Large Window

Frame time (sync)
0.9 s central CCD
2.7 s outer CCDs



Small Window

Frame time (sync)
0.3 s central CCD
2.7 s outer CCDs



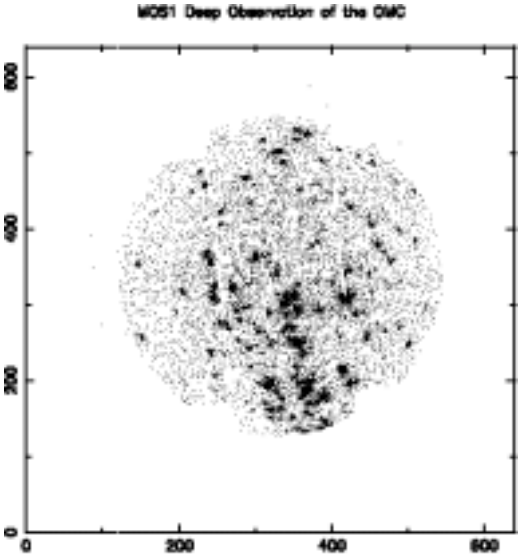
Timing

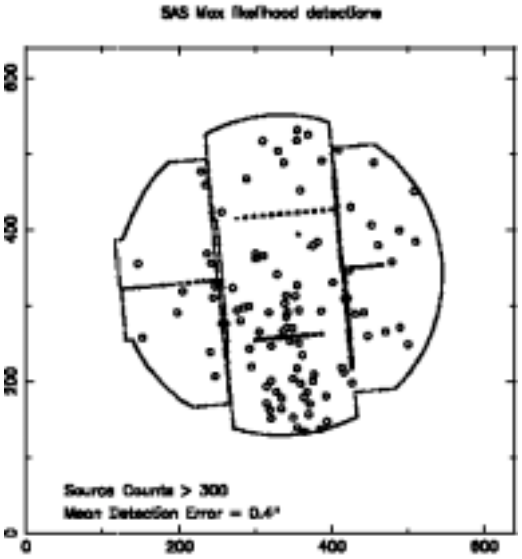
Time resolution :
1.8 ms central CCD

Frame time
2.6 s outer CCDs

Main input for calibration values

	Item	Ground	Flight	Workshop	
Telescope	Effective area	X			P
	PSF		X	P	
	Vignetting		X		
Gratings	Transmission	X			P
	Azimuthal modulation	X			
Filters	Transmission	X			P
	Homogeneity	X			
CCDs	Quantum efficiency	X	X		P
	Charge Transf. Ineffic.		X	P	
	Redistribution matrix	X	X	P	P
	Homogeneity	X			
	Background		X	P	
	Metrology, astrometry		X	P	
	Timing		X		





Metrology

(Mike Denby *et al.*)

- Done with Lockman Hole, NGC 2516, and Orion Molecular Cloud fields
- Compare X-ray source positions derived with SAS source detection chain with positions from USNO catalogue
- Remove gross offsets of central chip and then optimise outer CCDs displacement

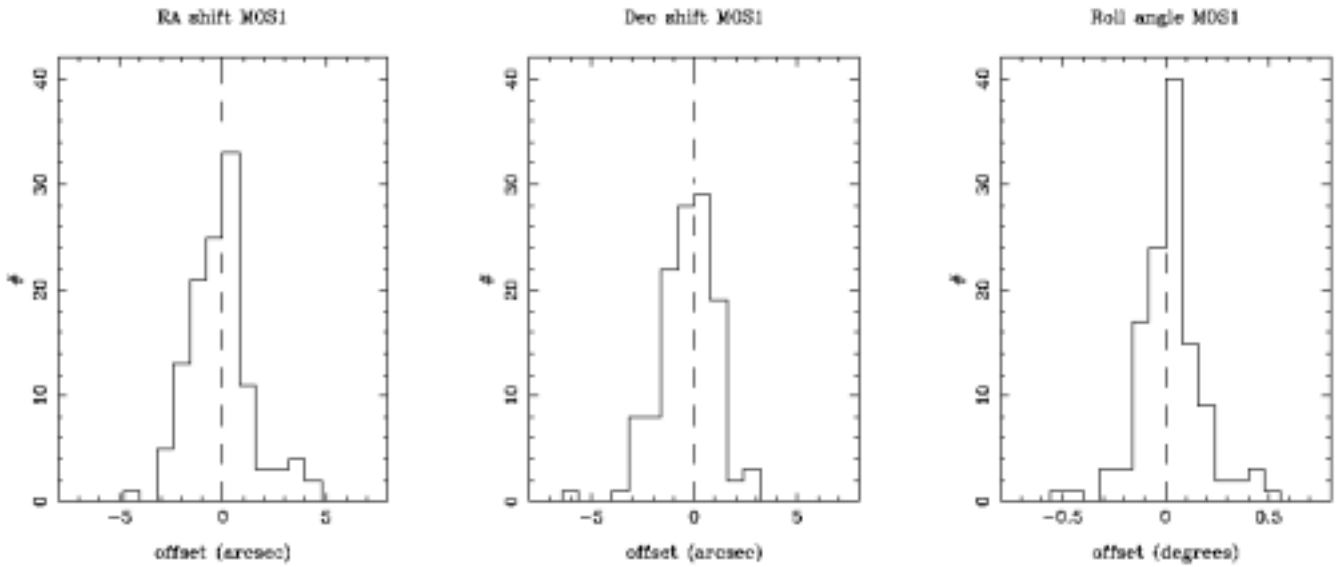
- Accuracy achieved (MOS1 and MOS2)

RMS error of 0.5 arcsec

Implemented in latest CCF file

Absolute Astrometry

(J. Tedds & M. Watson, SSC, poster WB1-7)



- Systematic correlation of source positions with USNO catalogue, based on the *eposcorr* SAS task, and a sample of about 150 source lists per camera

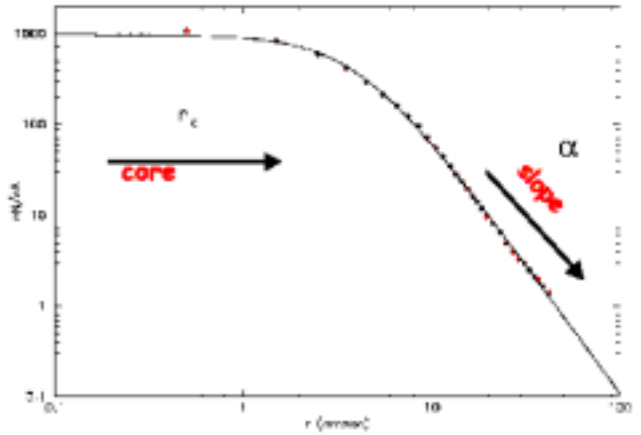
- Frequency distributions FWHM are : 4” in RA, Dec,
  0.3° in roll angle

Point Spread Function

(S. Ghizzardi & S. Molendi, poster WA2-4)

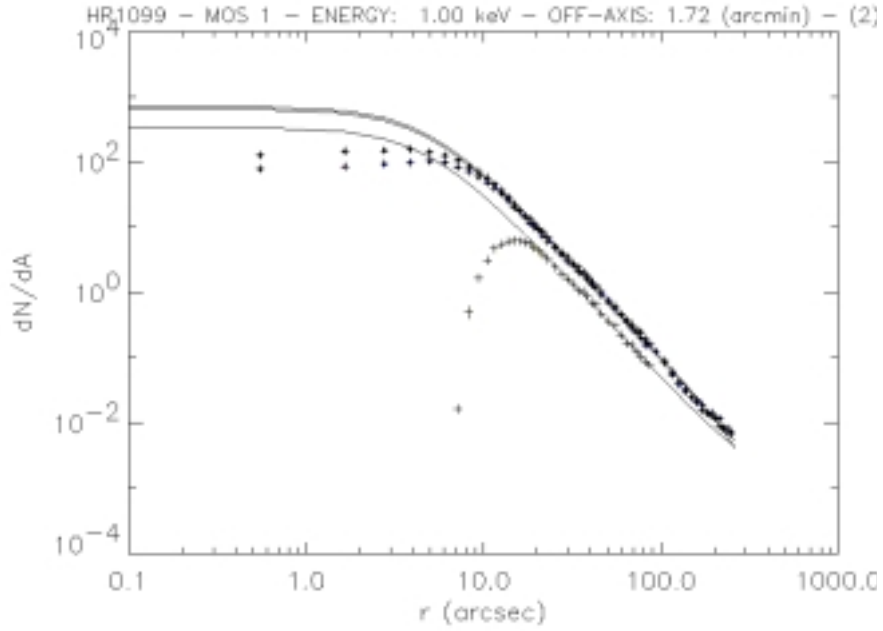
Have searched for an analytical representation of the PSF in azimuthal symmetry, with a large data set, up to 12 arcmin off-axis

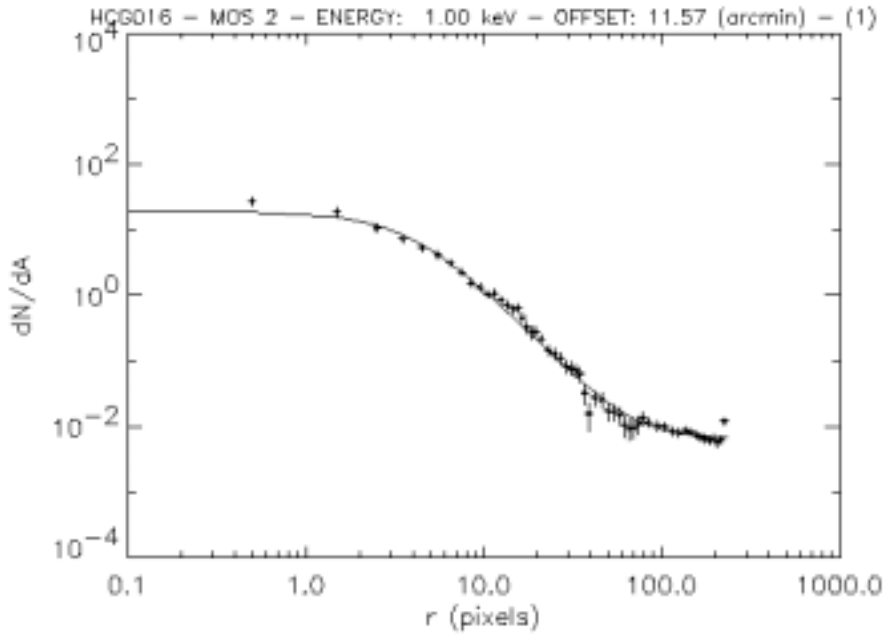
King model found adequate for radial profile, with parameters : Rc and α



$$King = \frac{A}{\left[1+\left(\frac{r}{r_c}\right)^2\right]^{\alpha}}$$

PSF - Examples of fits





Fit takes into account a background component and rejects piled-up regions

PSF - Results

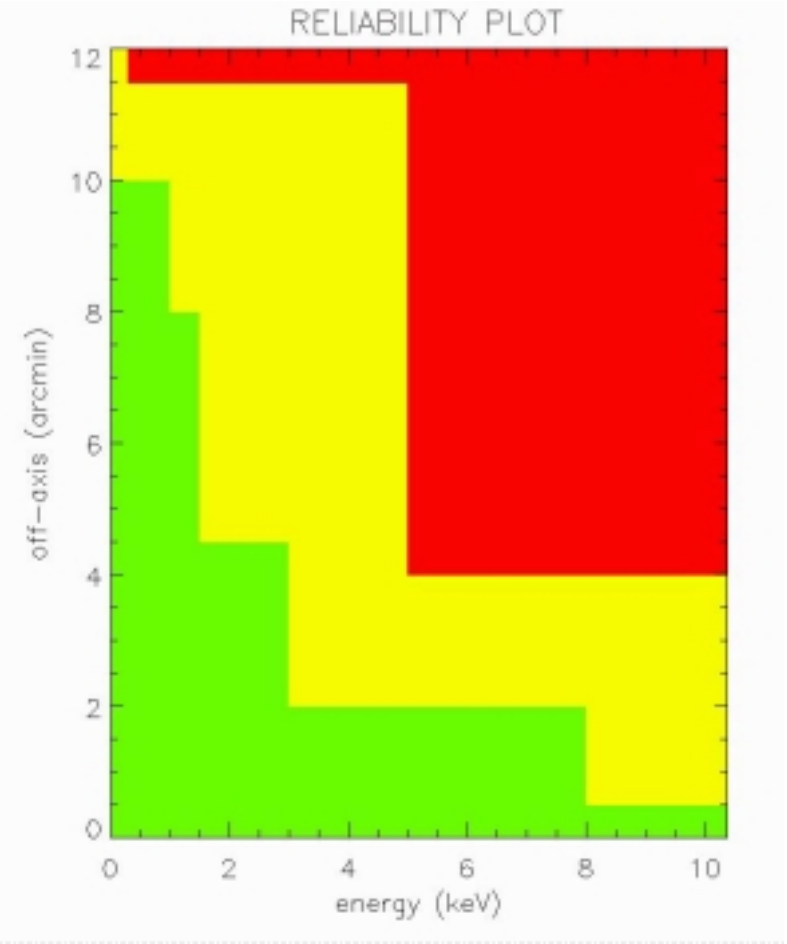
Core radius and slope are linear in energy and off-axis angle :

$$Rc(E, \theta) = a + b.E + c.\theta + d.E.\theta$$
$$\alpha(E, \theta) = x + y.E + z.\theta + w.E.\theta$$

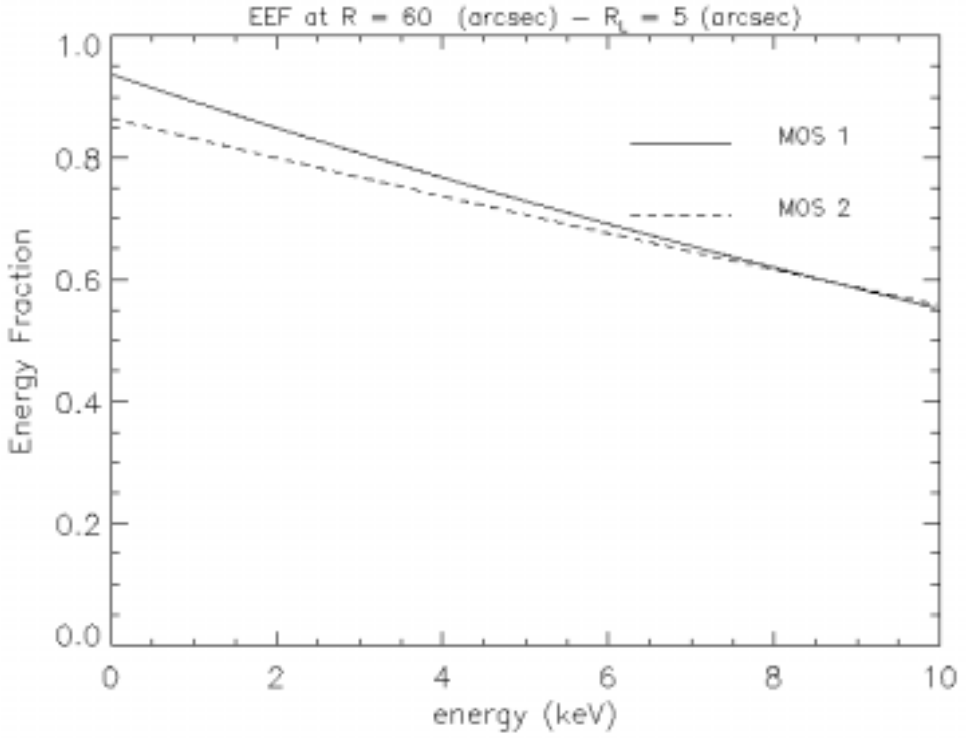
Table 1: r_c and α best fit according to eqns. (7) an

	MOS 1		
r_c	$a = 5.074 \pm 0.001$	$b = -0.236 \pm 0.001$	$c = 0.002 \pm 0.001$
α	$x = 1.472 \pm 0.003$	$y = -0.010 \pm 0.001$	$z = -0.001 \pm 0.002$
	MOS 2		
r_c	$a = 4.759 \pm 0.018$	$b = -0.203 \pm 0.010$	$c = 0.014 \pm 0.017$
α	$x = 1.411 \pm 0.001$	$y = -0.005 \pm 0.001$	$z = -0.001 \pm 0.002$

Validity range of model identified :



PSF - Results relative to piled-up sources

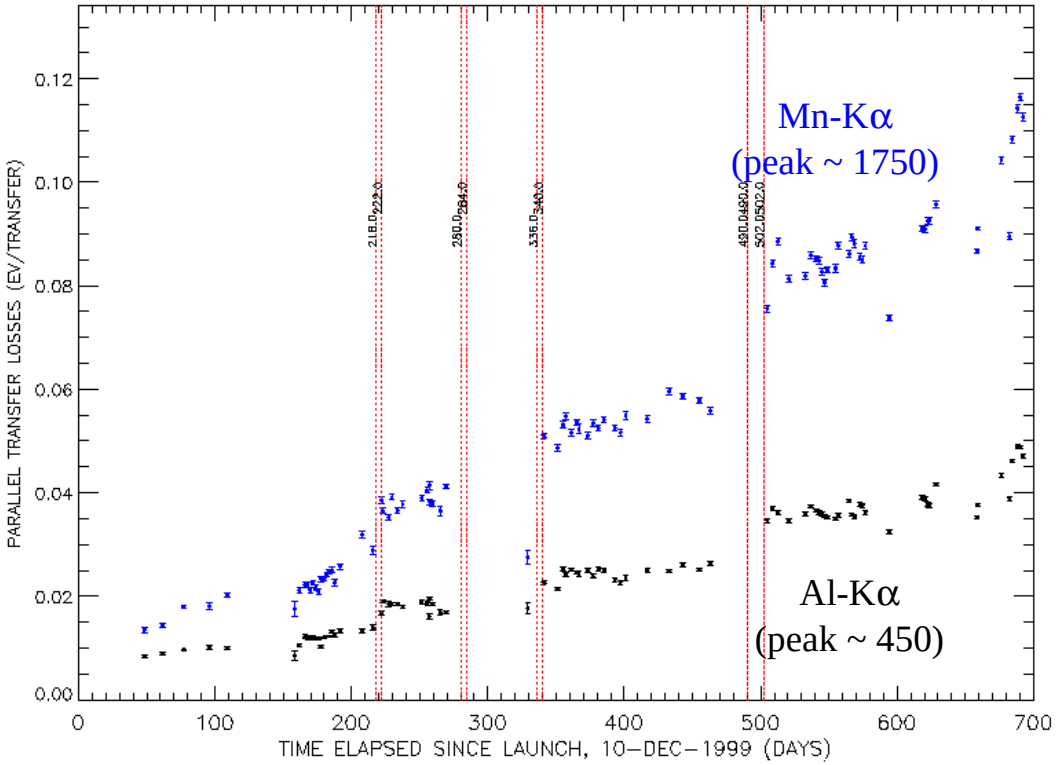


Slight difference in encircled energy between MOS1 and MOS2 (e.g. here, $\Delta\gamma \sim 0.03$ for power laws and cut at 5 arcsec)

Charge Transfer Inefficiency

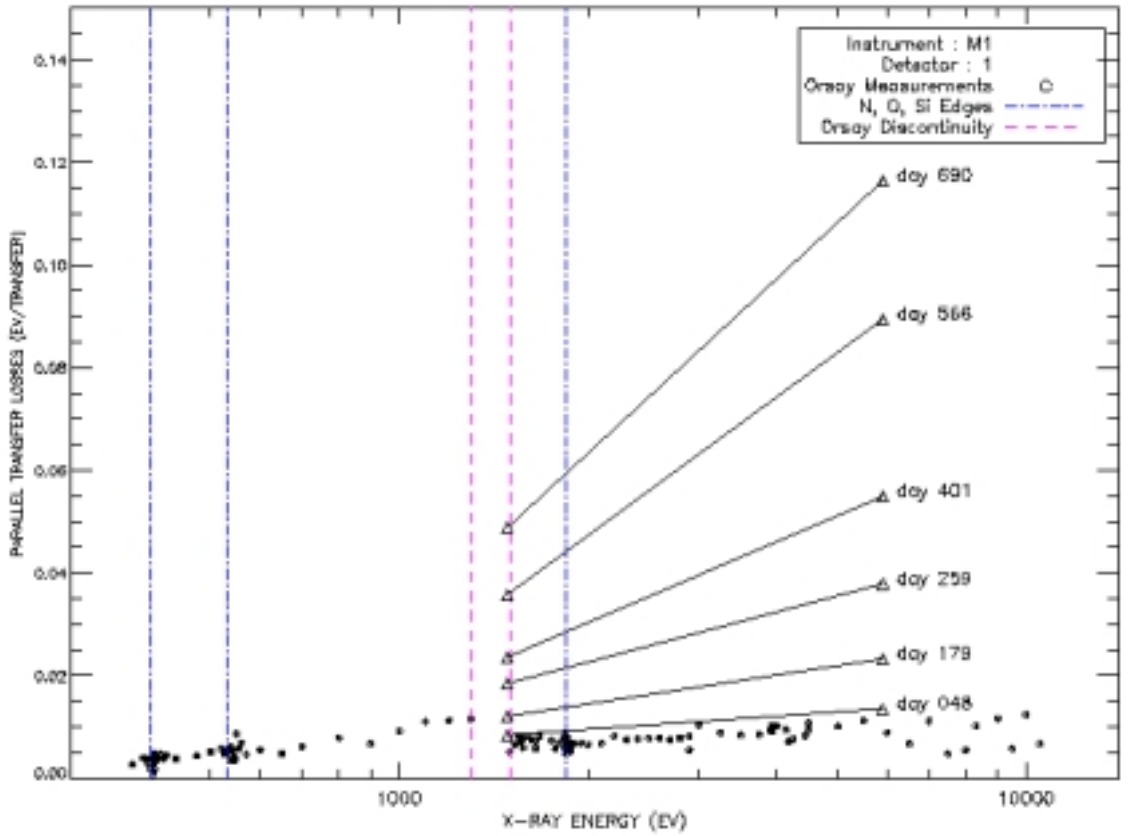
(P. Bennie *et al.*, poster WA2-18)

- CTI results in an apparent shift of lines and broadening
- CTI has been very regularly monitored via the Al-Kα and Mn-Kα (1.5, 5.9 keV) lines from the onboard calibration source



Linear increase with additional steps related to large solar flares

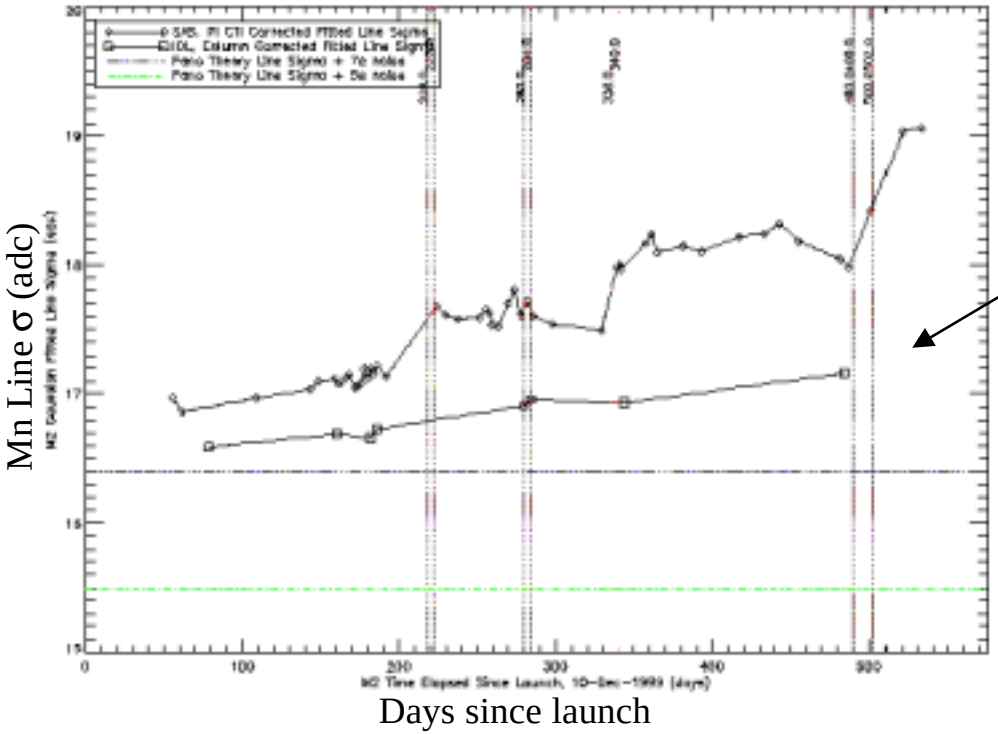
CTI time and energy dependence



Note : not well reproduced by SAS v5.2, which underestimates the CTI (25 eV shift at Mn). New version in test for v5.3

CTI future

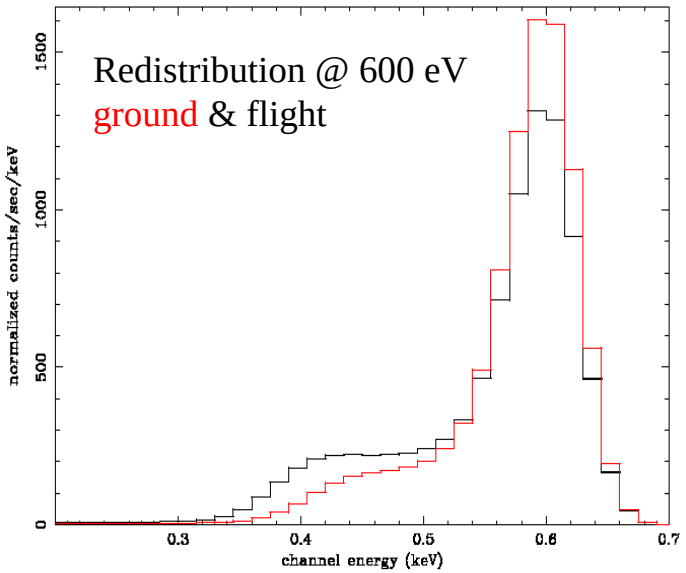
- Column to column variation of line centroid have been evidenced
- EPIC looks into ways of including that in data treatment (CTI per column, deviation maps)
- In any case, slight degradation of line resolution remains



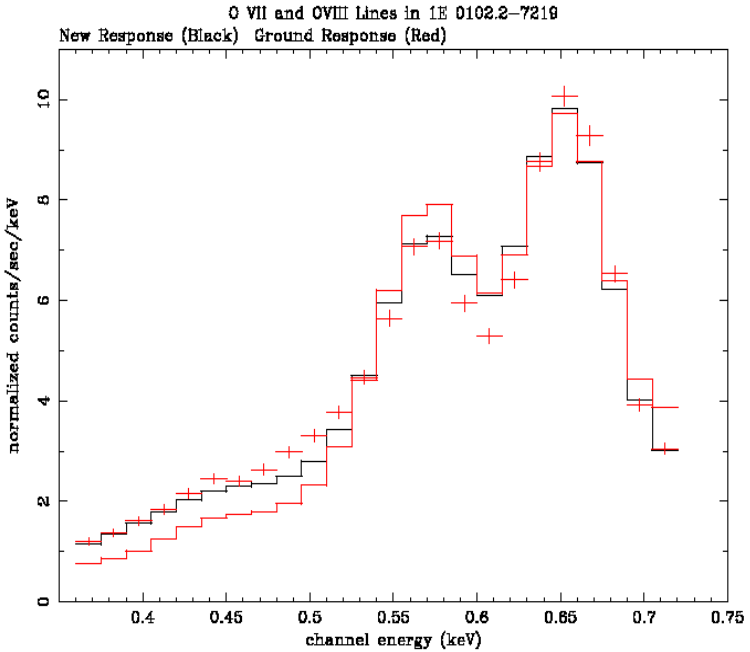
Unrecoverable degradation :
FWHM increase of ~ 4 eV / year
w.r.t. start at ~ 130 eV

Redistribution

(S. Sembay *et al.*, poster WA2-5)



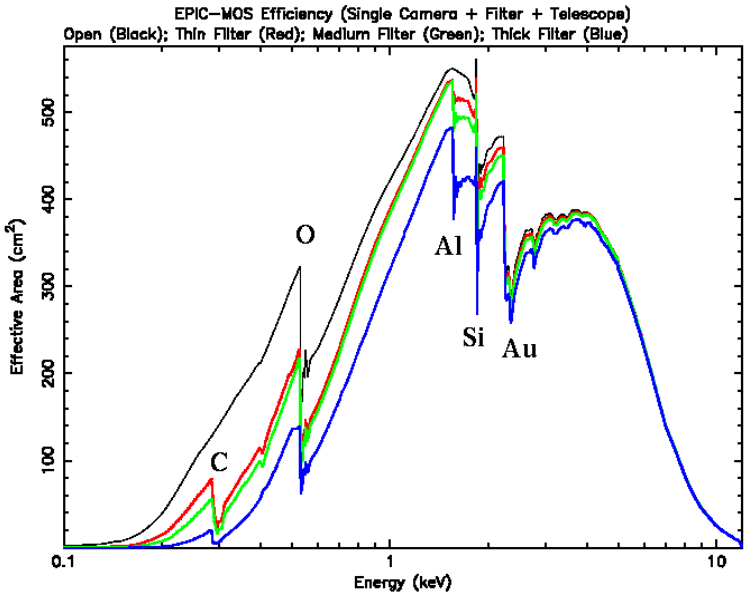
- Gaussian at high energy, with a strong shoulder at low energy (< 1 keV)
- Very well measured on ground, but definitely not good for flight

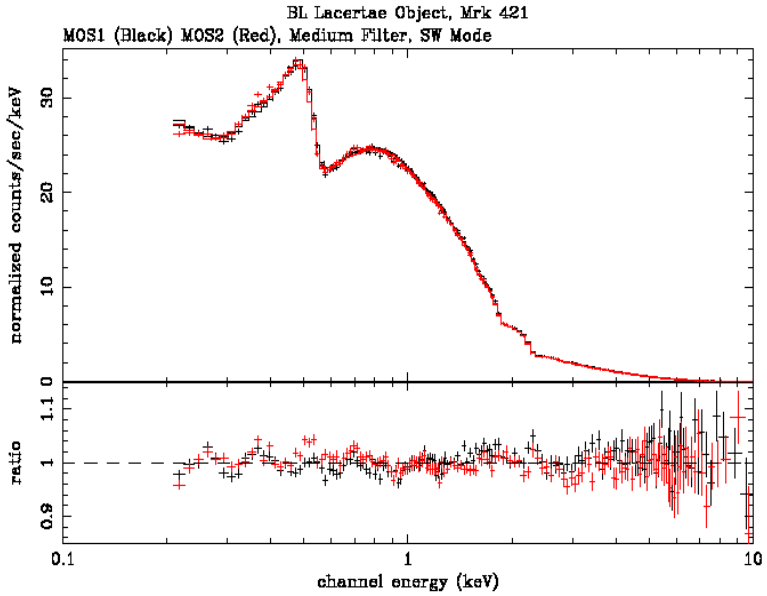


- New version for E < 0.7 keV in prep.
- Will be time dependent
- Same function for all imaging modes

On axis effective area

(S. Sembay *et al.*, poster WA2-5)





Telescope + RGA + filter + CCD

Residuals within 5 % from 0.2 to 10 keV

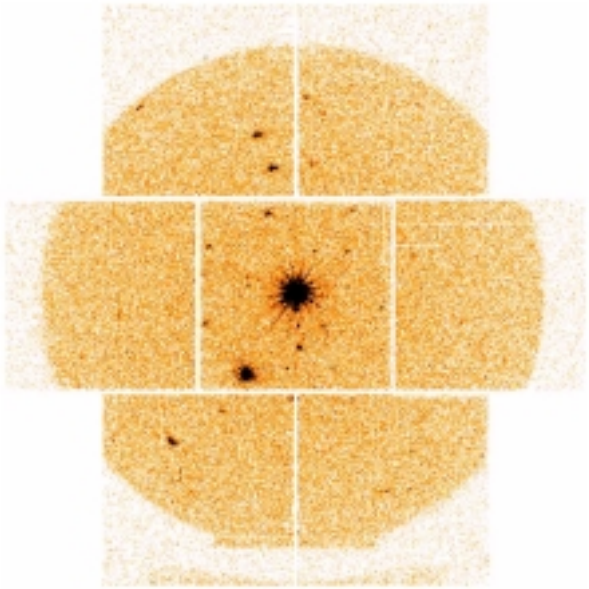
Background

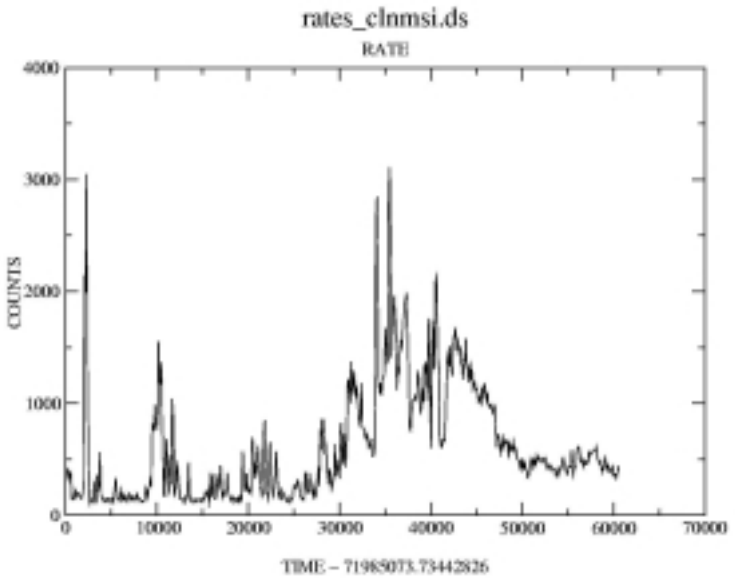
(2 posters WA2 : D. Lumb, and A. De Luca & S.Molendi, and an all EPIC work)

Background components :

1. Low energy electronic noise
2. Soft proton “flares”
3. Quiet time high energy proton induced
4. Astrophysical background

Background - Soft protons





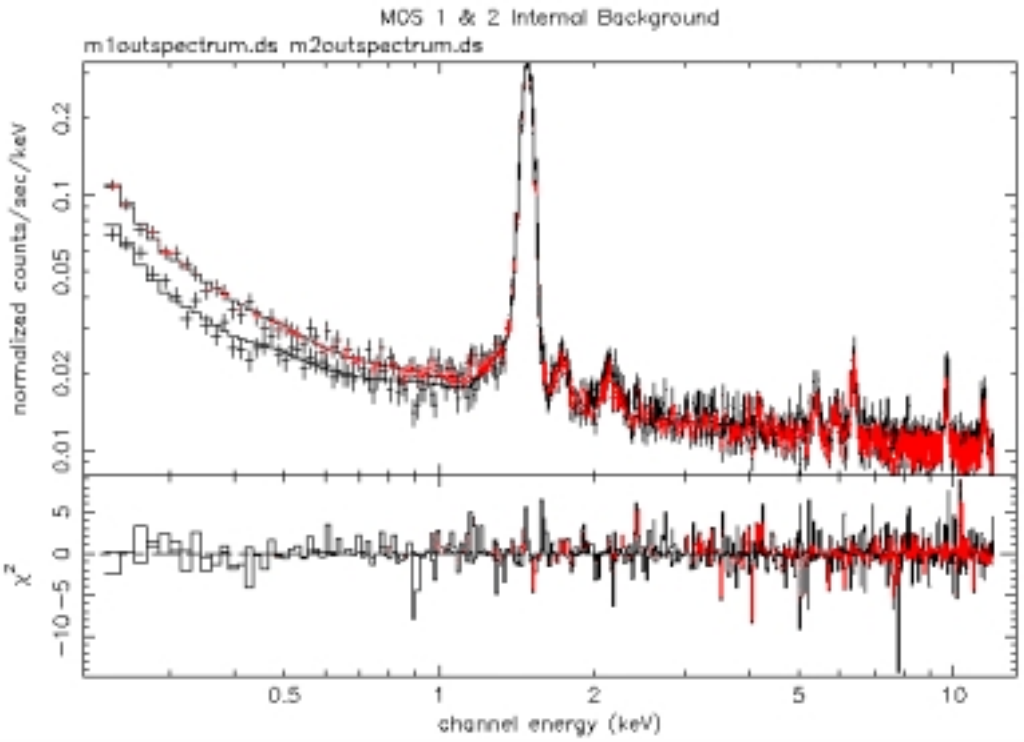
- Energy spectrum shape varying from flare to flare
- For weak or diffuse sources only solution is to select quiet time periods

Background - quiet time

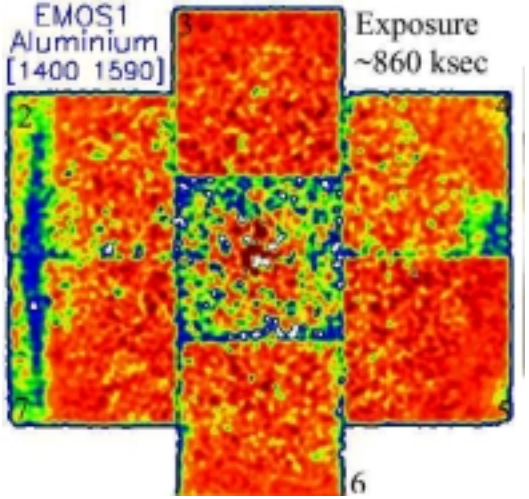
- Induced by high energy particles :
  - directly in the CCD
  - indirectly via fluorescent lines

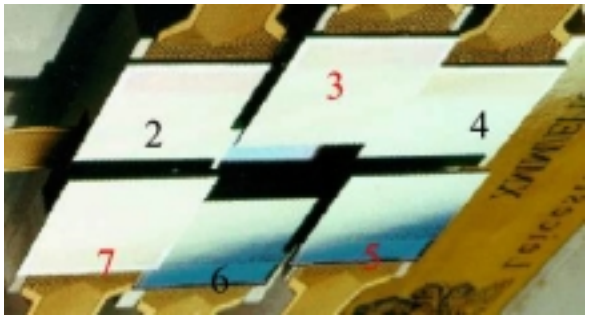
- Weakly variable with time

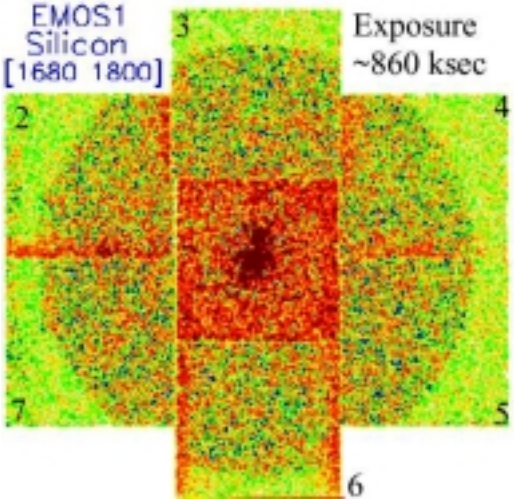
- Hard spectrum with lines

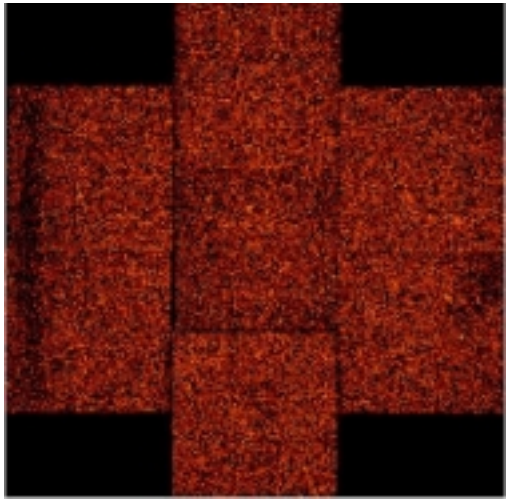


Background - quiet time - spatial variation

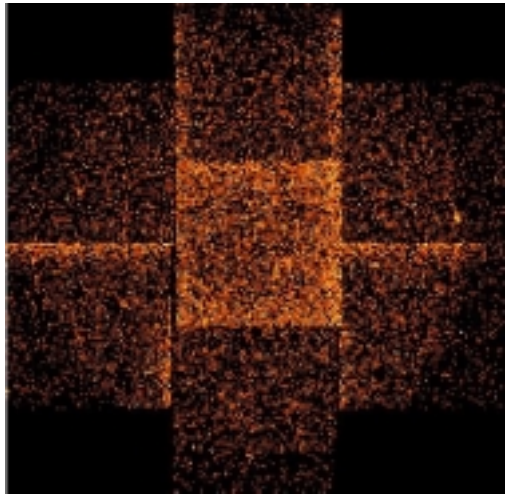








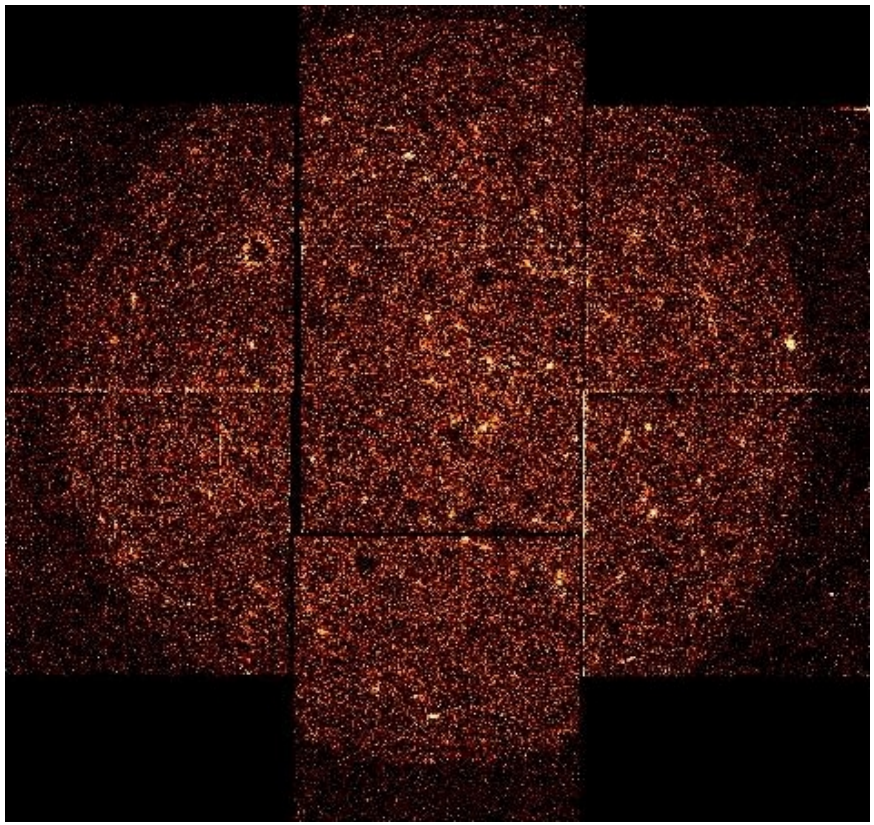
Spatial variability of :
~ 15 % for Al and Si Kα
≤ 10 % for E > 2 keV



Background - new template files

- Selection of THIN filter, high galactic latitude, low proton background, low N_H
- Removal of bright sources

- Duration now > 400 ks



Overall “first order” statements and to be done (I)

- Astrometry : “finished”
- PSF : “Very good”, high energy at large off-axis angles missing
- Vignetting : “Good” up to 10 arcmin, to be checked at larger angles
- CTI degradation : “Within predictions”, SAS to be updated
- On axis effective area and redistribution good to 5 % 0.2-10 keV
- Gain : good to 5 eV (relation with CTI ?)
- Background : “Characterized” and template files built
- Pile-up : “core exclusion” working - explore other alternatives

Overall “first order” statements and to be done (II)

- Lowest energies < 200 eV : variations not understood

- Off-axis :
  - CCD QE from ground implemented above > 1 keV
  - known inhomogeneities below 300 eV not implemented yet
  - redistribution difficult to check
  - implement known thick filter inhomogeneities below C edge

  - analysis of extended sources has however not revealed any strong deviation from on axis response

- Timing mode : timing aspect checked
  redistribution function to be worked out

More to come and to read !

- Next talks on cross-calibration will show quality of fits and level of consistency within EPIC and between EPIC and RGS.

- **Posters with all details are on display.**