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Cross-calibrating the XMM EPIC effective areas for a default empirical correction

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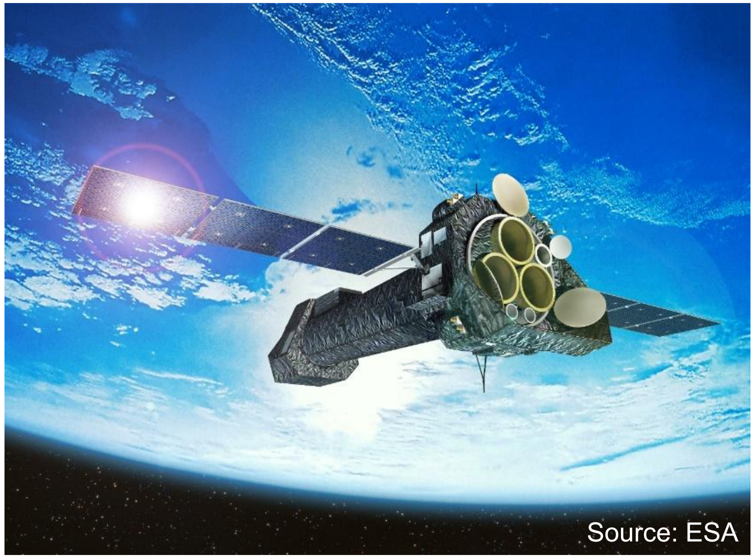
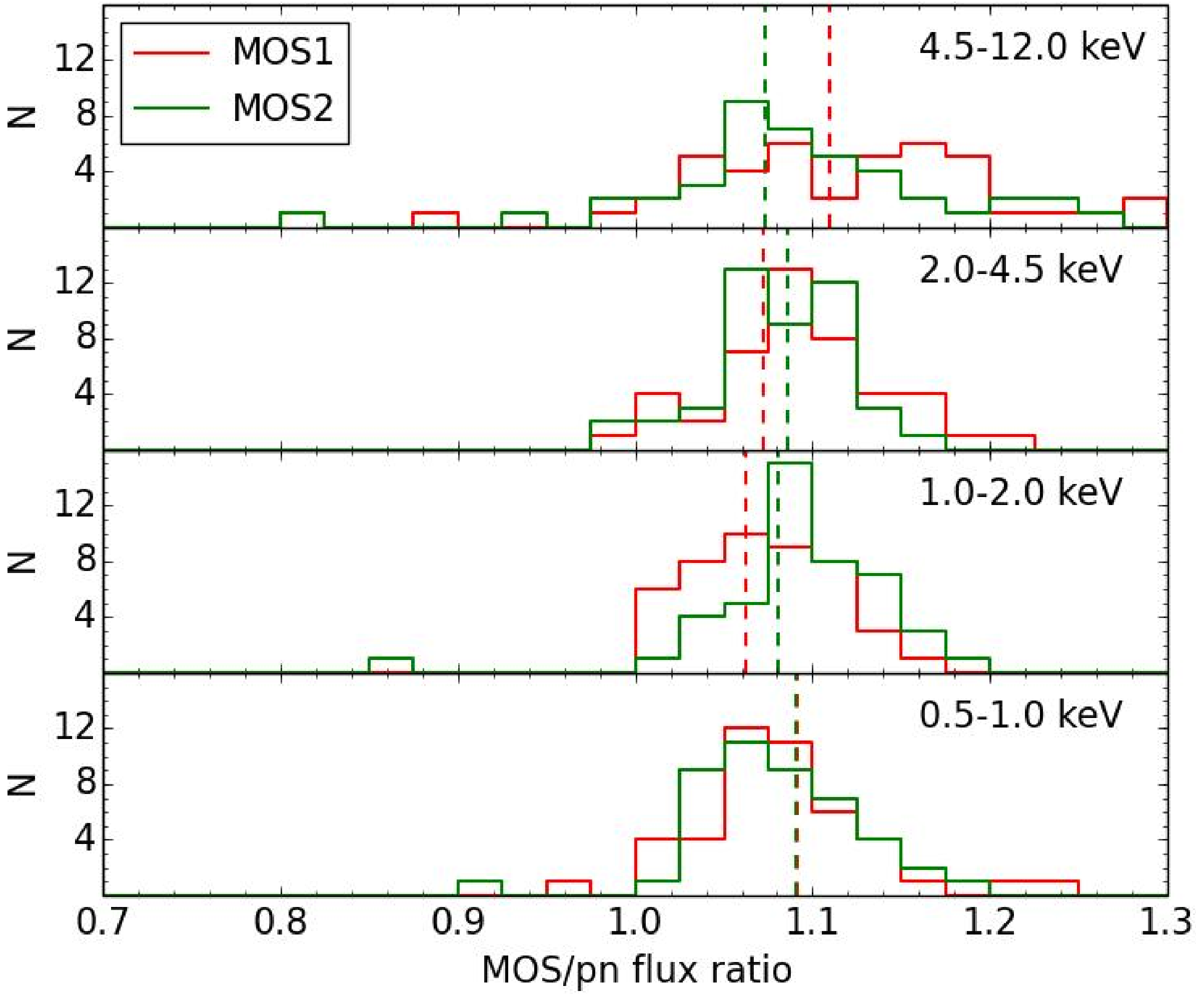
Outline



1 Introduction: CORRAREA



sample of 46 sources
fluxes taken from: XMM-Newton Serendipitous Source Catalogue (3XMM-DR7)

1 Introduction: CORRAREA

→ an **empirical correction** of the EPIC **on-axis effective areas** by an energy-dependent **multiplicative factor**, determined by **cross-calibration**

→ a non-default option since SAS v14.0 (Guainazzi et al., 2014): **CORRAREA** = extension of the according constituents in the current calibration files

residual ratio ⇒

- stacked residual method
- value for each energy bin would be unity if the cross-calibration of the effective areas was consistent
- reference instrument: pn

→ **GOALS:**

- make it a default empirical correction soon
- automation
- recalibration and further validation

2 Source Sample

- Original source selection, screening & stacking: Read et al. (2014)
- XMM-Newton Serendipitous Source Catalogue used (3XMM-DR7)

Selection criteria:

1.) point-like

2.) modes: Full Frame, Large Window, Small Window

3.) filters: Thin, Medium, Thick

4.) # of counts (0.2 - 12 keV) - MOS: > 5000 cts
- pn: > 13 500 cts

5.) count rates - MOS: < 0.7 (FF), < 1.5 (LW), < 4.5 (SW)
- pn: < 6 (FF), < 0.3 (FFext), < 3 (LW), < 25 (SW)

6.) near on-axis (boresight-to-source distance < 2')

7.) out of the plane of the Galaxy (|galactic latitude| > 15 deg)

- observations with multiple results dismissed (crowded fields)

2 Source Sample

MOS1	MOS2	pn	# obs. 3XMM-DR7
LW	LW	FF	29
“	“	LW	50
“	“	SW	8
SW	SW	FF	15
“	“	LW	9
“	“	SW	55
FF	FF	FF	166
“	“	LW	6
FF	LW	FF	3
FF	SW	FF	2
LW	FF	FF	2
LW	SW	FF	2

→ total: 347 observations

3 Automated Steps

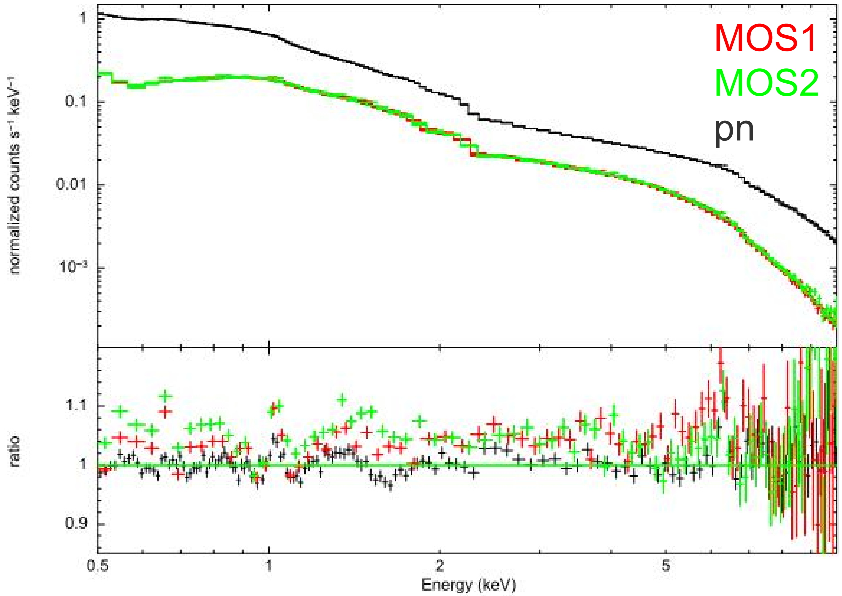
Mainly done via bash, python & idl scripts:

1. initial data processing
2. event files filtered with a **common GTI** file for each observation
3. images for visual screening & background region selection
4. source and background **spectra**, as well as the Redistribution Matrix and Ancillary Response Files (RMFs and ARFs)
5. **stacking** for each detector:
   - source & background spectra: summing up counts per bin, summing up exposures, exposure-weighting BACKSCAL values
   - exposure-weighted RMFs and ARFs
6. phenomenological **reference model** fit to **pn data**:

$$\boxed{wabs \times [power + power + Gauss + Gauss + Gauss] \times edge}$$

3 Automated Steps

7. reference model convolved with the instrument responses of MOS1 and MOS2



pn fit: χ^2_{red} is 1.08 for 1888 degrees of reedom (calculated with SAS v13.5 and according calibrations)

8. realignment of the residuals to a new, uniform energy grid
9. calculation of the residual ratio α

$$\boxed{\alpha = \frac{data_i}{model_{\mathrm{pn}} \otimes response_i} \times \frac{model_{\mathrm{pn}} \otimes response_{\mathrm{pn}}}{data_{\mathrm{pn}}}}$$

i: MOS indices (1, 2)

10. fitting of the residual ratio

current CORRAREA function:

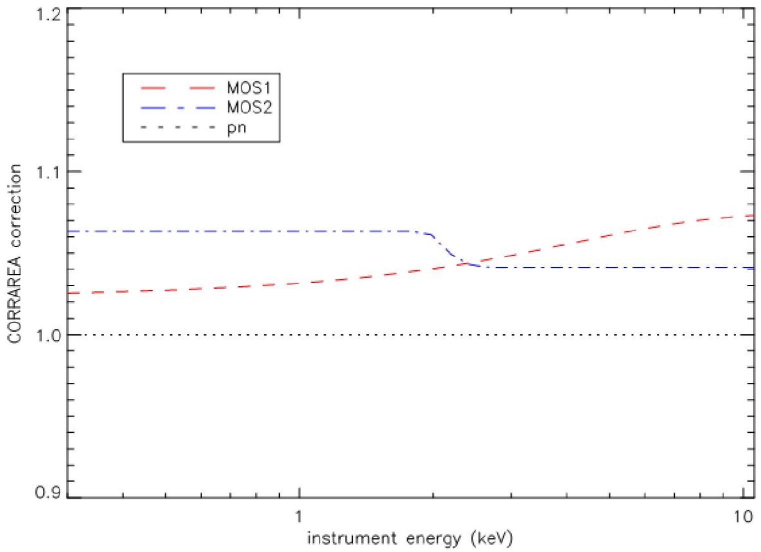
$$R_i(E) = a_i + a_{\mathrm{pn}} + b_i \times \mathrm{e}^{-c_i \times \mathrm{e}^{-d_i \times E}}$$

R_i: MOS to pn empirical correction factor
i: MOS indices (1, 2)
E: energy
$a \ldots d$: best fit parameters

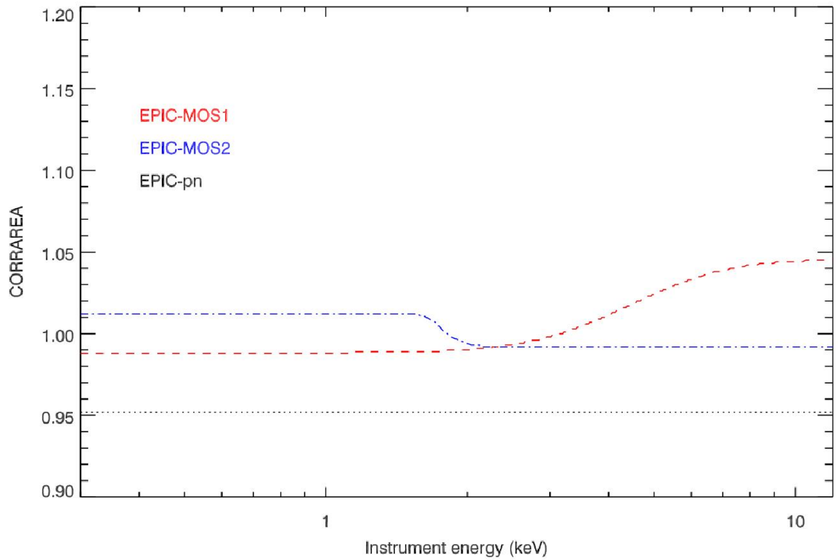
alternative:

$$R_i(E) = a_i + a_{\mathrm{pn}} + b_i \times \frac{1}{1 + \exp\left(\frac{-E + c_i}{d_i}\right)}$$

reproduced:



RN 0321:



3 Automated Steps

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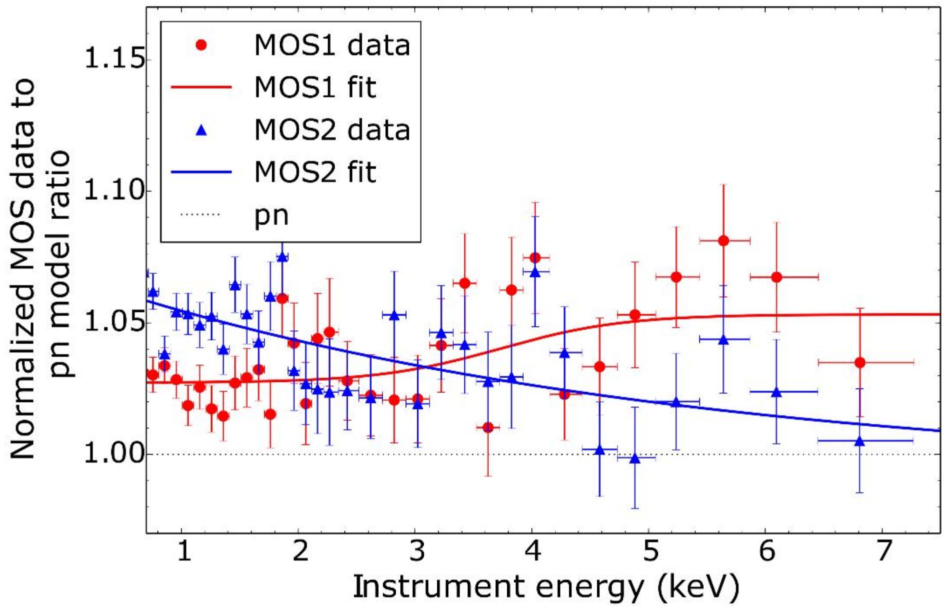
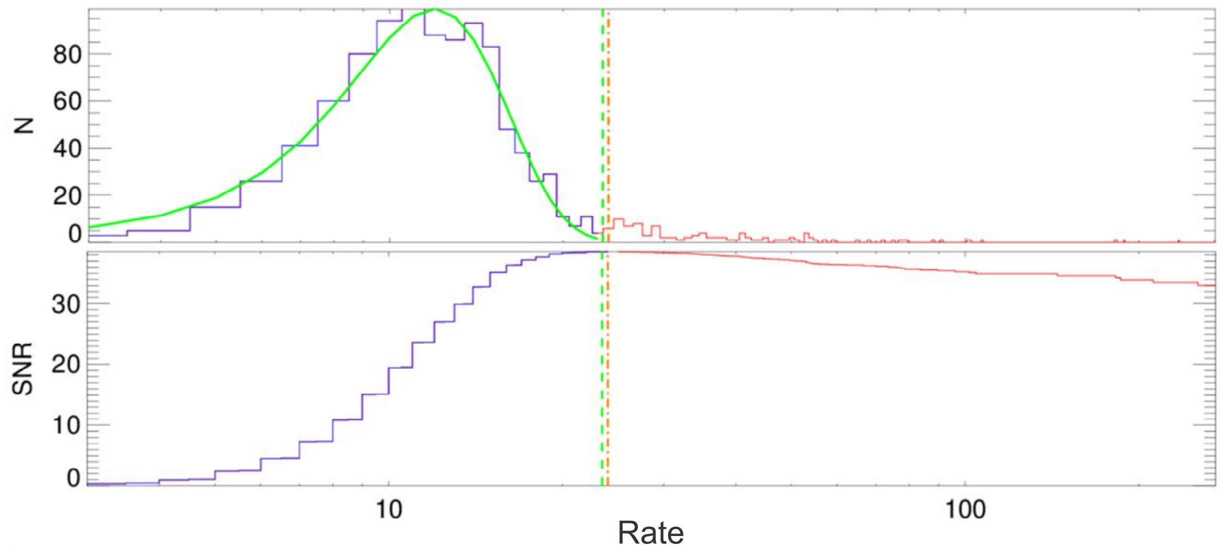


4 Screening

4.1 Good-Time-Intervals

- previously: GTIs uniformly defined as those bins containing less than 130 (pn) or 40 (MOS) counts per bin
- GTIs now individually defined for each observation:
  1. lightcurves with > 10 keV (MOS) or 10-12 keV (pn) are prepared
  2. histogramm → **gaussian threshold** at $\mu + 3\sigma$
  3. maximum signal-to-noise ratio (snr) → **snr threshold**
  4. the more conservative one of the thresholds is chosen

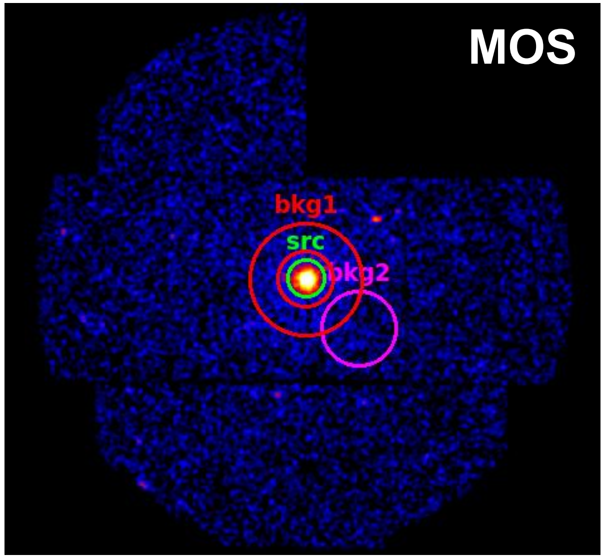


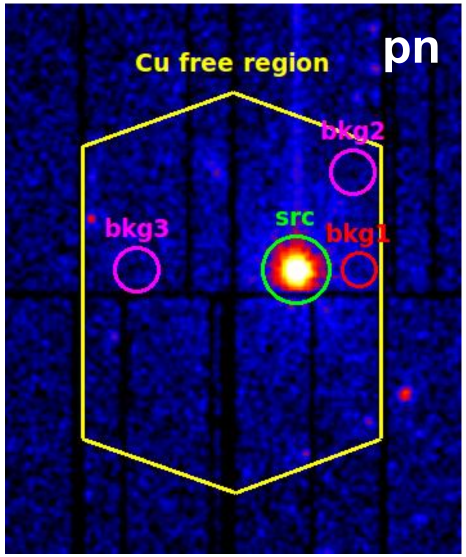
→ observations with < 1 ks GTI filtered common exposure time are excluded

Images have to be **screened for**:

- crowded fields
- chip gaps & bad CCD columns close to the source
- targets appearing extended or lying within extended emission
- a chip loss of an entire detector chip or quadrant
- maximum source extraction radius

Background selection: FF mode





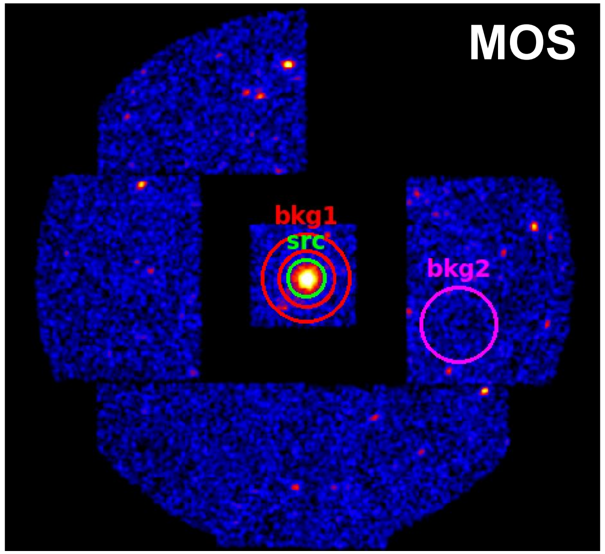
4 Screening

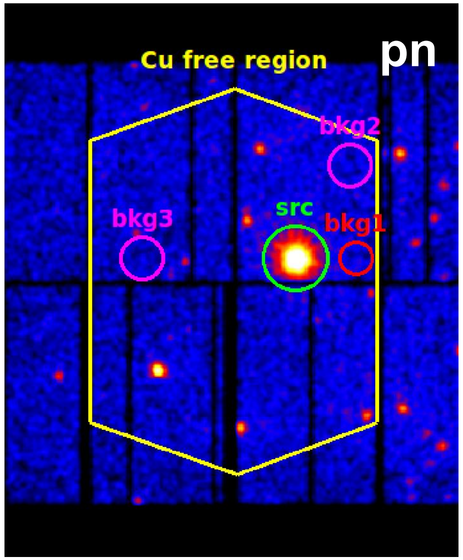
4.2 Image Screening & Background Selection

Images have to be **screened for**:

- crowded fields
- chip gaps & bad CCD columns close to the source
- targets appearing extended or lying within extended emission
- a chip loss of an entire detector chip or quadrant
- maximum source extraction radius

Background selection: LW mode





4 Screening

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Images have to be **screened for**:

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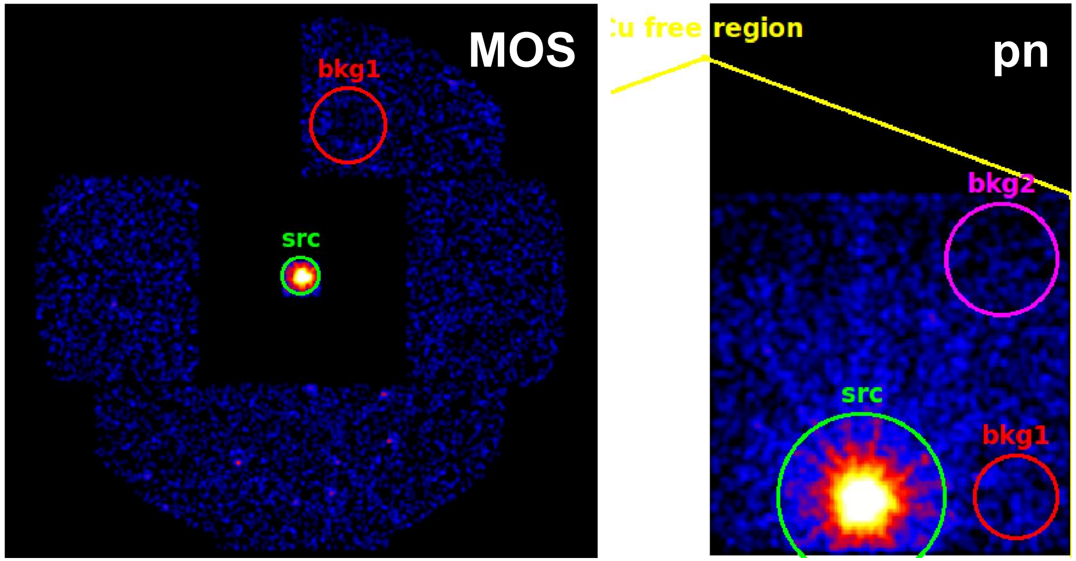
- targets appearing extended or lying within extended emission
- a chip loss of an entire detector chip or quadrant
- maximum source extraction radius

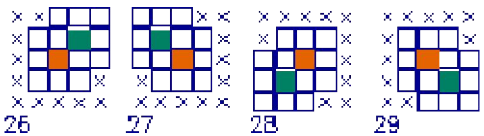
Background selection: SW mode



4 Screening

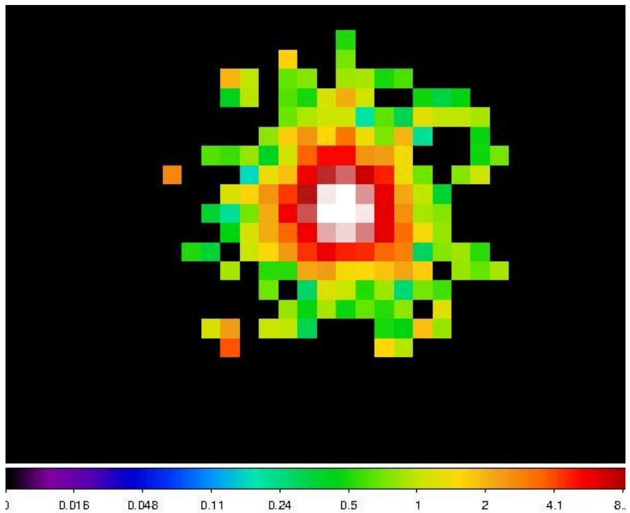
4.3 Pile-Up Check

- so far: maximum count rate (as in XMM-Newton Users Handbook v.2.10) given as a source selection criterium to limit pile-up
- more precise method: MOS diagonal events are produced almost exclusively from the pile-up of two single pixel events



Source:ESA

- fraction of diagonal events obtained by dividing an image of diagonal events by an image of 'clean' events
- not always a clear center; the maximum value is not necessarily in the center; which value to take as the pile-up limit



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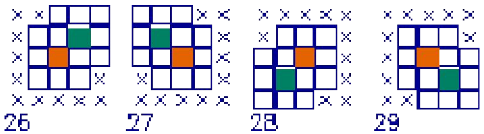

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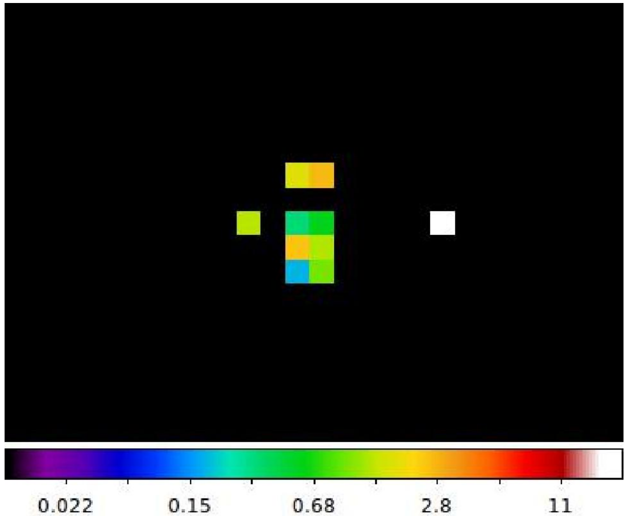

5 Summary & Outlook

- the **automation** to get the residual ratio and the correction function is **done to a large degree** ✓
- the **selection criteria & screening** have been revised ✓
- 3XMM-DR7 brought up **301 new potential observations** ✓
- **update** with SAS v16.1 and according calibration files:

  - initial data **reduction** ✓
  - **GTI** filtering ✓
  - **image screening** and **background region selection** (✓)
  - checking for **pile-up**
  - creating the spectra, stacking them & fitting the **stacked spectrum**
  - calculating the **residual ratio** & deciding on a **correction function** (compare different source extraction radii, pile-up levels, modes, filters)

Thank you!