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

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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 - MOS: > 5000 cts
   (0.2-12 keV) - pn: > 13500 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)
## Source Sample

<table>
<thead>
<tr>
<th>MOS1</th>
<th>MOS2</th>
<th>pn</th>
<th># obs. 3XMM-DR7</th>
</tr>
</thead>
<tbody>
<tr>
<td>LW</td>
<td>LW</td>
<td>FF</td>
<td>29</td>
</tr>
<tr>
<td>&quot;</td>
<td>&quot;</td>
<td>LW</td>
<td>50</td>
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<tr>
<td>&quot;</td>
<td>&quot;</td>
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<td>8</td>
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<tr>
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<td>FF</td>
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</tr>
<tr>
<td>LW</td>
<td>SW</td>
<td>FF</td>
<td>2</td>
</tr>
</tbody>
</table>

→ total: 347 observations
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:
   \[ \text{wabs} \times [\text{power} + \text{power} + \text{Gauss} + \text{Gauss} + \text{Gauss}] \times \text{edge} \]
7. reference model convolved with the instrument responses of MOS1 and MOS2

\[ \chi^2_{\text{red}} \text{ is 1.08 for 1888 degrees of freedom (calculated with SAS v13.5 and according calibrations)} \]

8. realignment of the residuals to a new, uniform energy grid

9. calculation of the residual ratio \( \alpha \)

\[
\alpha = \frac{\text{data}_i}{\text{model}_i \otimes \text{response}_i} \times \frac{\text{model}_\text{pn} \otimes \text{response}_\text{pn}}{\text{data}_\text{pn}}
\]

\( i: \) MOS indices (1, 2)
10. Fitting of the residual ratio

Current CORRAREA function:

\[ R_i(E) = a_i + a_{pn} + b_i \times e^{-c_i \times E} \]

Alternative:

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

Reproduced:

RN 0321:
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\[ i \]: MOS to pn empirical correction factor
\[ E \]: energy
\[ a \ldots d \]: best fit parameters
• 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
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
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:** \(SW \) 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

• 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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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!