XMM-Newton Calibration Updates

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Recent Calibration Files

- Astrometry: Time Variable Boresight Update
- Update of the RGS contamination correction
- Update of the RGS Gain and CTI
- RGS Bad Pixels
- Update of EPIC MOS Gain and CTI
- Refinement of the EPIC-MOS QE at the Si Edge
- CORRAREA: Estimate of Aeff EPIC Inter-Calibration Uncertainties
- Time-Dependent Width of the EPIC-pn Spectral Response
- EPIC-pn Long-Term CTI and Energy Scale
- EPIC MOS HK GTI Selection
- X-ray Loading and Rate-Dependent CTI Correction for EPIC-pn Burst Mode

November 2014: **SAS13.5 -> SAS 14.0**
Astrometry: Time-Variable Boresight Update

A. Talavera and P. Rodríguez, 2014, XMM-CCF-REL-315

- Time-dependent boresight implemented in 2012 in order to address variability in star-tracker and instrument alignments.

- Recent observations show slight deviations of measured astrometry offsets with respect to model predictions.

- Deviations of the order of:
  - 0.5 arcsec for OM, and
  - 1-2 arcsec for EPIC and RGS corrected in new CCF: XMM_BORESIGHT_0024.
Updated values of the EPIC-MOS gain and CTI parameters based on recent sets of cal source data.

Gain and CTI parameters are defined on an epoch-wise basis. The changes affect the most recent epoch.

Overall, the EPIC-MOS Full Frame mode energy reconstruction accuracy is 5 eV at 2 keV, and within 10 eV elsewhere.
Empirical correction driven by reported prominent emission-like feature in EPIC-MOS spectra not seen in EPIC-pn.

Feature could be caused by residual inaccuracies of the MOS $A_{\text{eff}}$ calibration at the Si photoelectric absorption edge.

Correction derived from targets with featureless spectra in the band of interest, and include blazars and the Vela pulsar.

Data fit with absorbed powerlaw models in the 0.85 – 4 keV band.

Data-to-model residuals were stacked, and fit with a spline.
EPIC-MOS: Refinement of the QE at the Si Edge


- Resulting spline fits used to empirically adjust the EPIC-MOS quantum efficiency in the 0.8 – 2.2 keV band:
  \[ \text{EMOS1/2}_{\text{QUANTUMEF}_{0020/21}} \]

- Calibration files validated on
  - a sample of blazars from the XMM-Newton cross calibration database
  - a sample of non-piled-up on-axis sources

- Residuals around the Si edge reduced from ~ 5% to ~ 2% dynamical range.
Analysis of on-board calibration source and celestial sources indicates a gradual widening of the EPIC-pn spectral response, mainly due to the degrading CTE.

Implementation of a time-dependent width of the response function is implemented in SAS 14.0.

The calibration was mainly based on two on-axis observations of the the Circinus Galaxy in 2001 and 2014.

New calibration contained in EPN_REDIST_0012.
EPIC-pn: Time-Dependent Width of the Response


SAS 13.5

2001

singles

doubles

2014

Mn–Kα Line Sigma (ADU)
EPIC-pn: Time-Dependent Width of the Response


SAS 14.0

2001

singles
doubles

2014
SAS 14.0 contains two major modifications to the EPIC-pn energy scale correction methods:

- E-dependent long-term CTI correction:
  - Previously, LTCTI calibrated at Mn-Kα
  - Now, trend at Al-Kα also taken into account
EPIC-pn: Long-Term CTI and Energy Scale


- SAS 14.0 contains two major modifications to the EPIC-pn energy scale correction methods:
  - E-dependent long-term CTI correction:
    - Previously, LTCTI calibrated at Mn-Kα
    - Now, trend at Al-Kα also taken into account
  - Doubles-to-singles energy offset:
    - Double-pixel event energies were known to be overcorrected with respect to singles.
    - The discrepancies were increasing in time.
    - Issue mitigated through the introduction of empirical doubles-to-singles energy offsets, together with E-dependent LTCTI.

SAS 13.5

SAS 14.0
double events @ Mn-Kα
New calibration in \texttt{EPN\_CTI\_0045}.

Validated on Circinus Galaxy:

And on SNR 1E 0102.2-7219 (38 observations) using the IACHEC model (Plucinsky, P.P., et al., 2012, SPIE, 8443, 12)
Rate-dependent CTI parameters have been recalibrated for Burst Mode after including a correction for X-ray loading: EPN_CTI_0046, EPN_REJECT_0008.

57 Burst Mode exposures were used for the RDPHA calibration.

The empirical calibration is based on measuring gain shifts as function of shifted electron rate at the instrumental Si edge (1.8 keV) and telescope Au edge (2.2 keV).

Additional validation at higher energies (5-8 keV) was performed using sources with prominent Fe transition features.
As of SAS14.0 a new non-default option (applyxcaladjustment) is available in the arfgen task to empirically correct the EPIC effective areas by an energy-dependent multiplicative factor.

This so-called “CORRAREA” correction tool can be used to evaluate the impact that the current relative EPIC $A_{\text{eff}}$ uncertainties have on astrophysical parameters derived from spectral fitting.

The correction is empirical and somewhat arbitrary, and currently should not be used as replacement of the nominal calibration.
The CORRAREA calibration is based on spectral analysis of 46 bright non-piled-up sources.

The 0.7 – 7 keV EPIC-MOS stacked residuals against the EPIC-pn best-fit models were derived.

This data was fit with a combination of a constant and Gompertz functions:

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

giving the MOS to pn empirical correction factors.

The EPIC-pn correction factor is E-independent, its value motivated by the fact that EPIC-pn yields the lowest 2 – 10 keV flux of all operational CCD instruments.
The self-consistent implementation of the CORRAREA calibration has been verified on the set of 46 bright non-piled up sources.

However, further validation is required before this correction will be implemented as default.

After CORRAREA correction
- Derived from the RX J1856 count rate at 35 Å

- Assuming that the contaminant is a type of Hydrocarbon (C₈H₈) coming from the carbon-fibre structures of the telescope tube.
51 observations of PKS 2155-304, 3C 273 and H 1426+428 processed with SASv14 and calibrations available in November 2014

Work in progress. Should lead to an update of the RGS-pn rectification parameters contained in the RGSn_EFFAREACORR CCFs

<table>
<thead>
<tr>
<th>Wavelength Range</th>
<th>Flux Ratio RGS/EPIC-pn</th>
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<tbody>
<tr>
<td>7 - 23.5 Å</td>
<td>0.98 ± 0.02</td>
</tr>
<tr>
<td></td>
<td>1.03 ± 0.01</td>
</tr>
<tr>
<td>23.5 - 38.5 Å</td>
<td>0.99 ± 0.01</td>
</tr>
<tr>
<td></td>
<td>1.03 ± 0.02</td>
</tr>
</tbody>
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(R. González-Riestra)
XMM-Newton Cross Calibration Status

- Instrumental flux ratios derived from a set of ≈ 120 observations in the XMM-Newton Cross-Cal Database.
  - MOS1 / pn:
    - ≈ 0.98 (E < 0.54 keV)
    - ≈ 1.04 (E > 0.54 keV)
  - MOS2 / pn:
    - ≈ 1.00 (E < 0.54 keV)
    - ≈ 1.06 (E > 0.54 keV)
  - MOS / pn above > 3 keV under investigation.
  - RGS / pn: From 1.01 to 0.95 with increasing E (using $\chi^2$ statistic)

(M. Stuhlinger)