XMM-Newton CCF Release Note

XMM-CAL-SRN-0321

CORRAREA: a new tool to estimate the impact of effective area EPIC inter-calibration uncertainties

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1 CCF components

Name of CCF	VALDATE	EVALDATE	Blocks changed	XSCS flag
XRT1_XAREAEF_0009.CCF	2001-01-13		CORRAREA	No
XRT2_XAREAEF_0010.CCF	2001-01-13		CORRAREA	No
XRT3_XAREAEF_0012.CCF	2001-01-13		CORRAREA	No

As of SASv.14 a new non-default option (`applyxcaladjustment`) is available in `arfgen` to empirically correct the EPIC effective areas by an energy-dependent multiplicative factor. In this Release Note (RN) we present the first calibration of this empirical correction, embedded in the `CORRAREA` extension of the `XAREAEF` CCF constituents. This calibration can be used to evaluate the impact that the current relative uncertainties on the calibration of the XMM-Newton telescopes' effective areas yield on astrophysical parameters derived from spectral fitting. Because an absolute calibrator of the effective area is still missing (see the discussion in, *e.g.*, Sembay et al. 2010), users are warmly recommended not to use this correction as a replacement of the nominal calibration. While a significant improvement of the formal quality of spectral fits is expected using the `applyxcaladjustment` option, this will not reduce the unavoidable true systematic errors on the spectral fit parameters. However, this new tool permits - if applied with scientific common sense - to get an estimate of the importance of these systematic errors for each specific astronomical case.

2 Changes

The `CORRAREA` calibration presented in this RN is based on an extensive cross-calibration study of 46 non-piled up sources extracted from the 2XMM EPIC Serendipitous Source Catalogue (Watson et al. 2009). The sources were used by Read et al. (2014) to estimate the status of the EPIC effective area cross-calibration with SASv12.0 (and associated

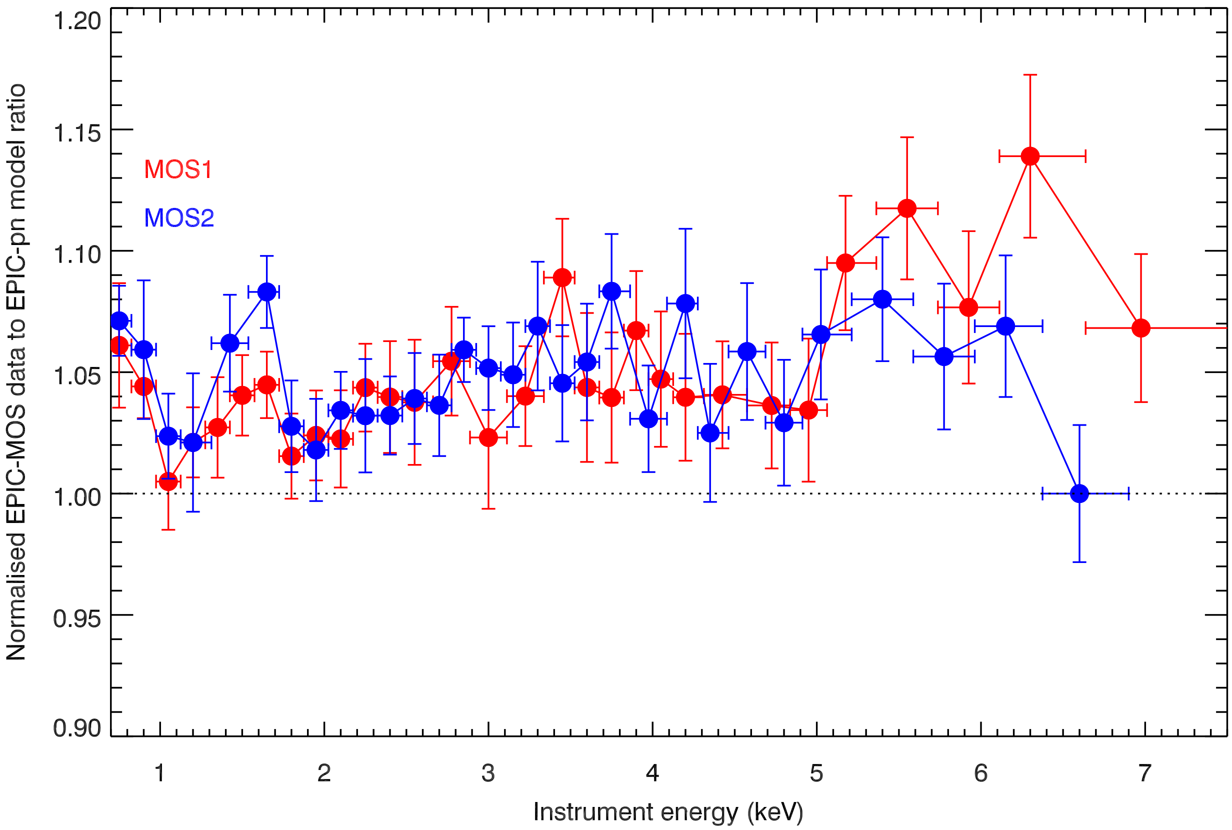

Figure 1: EPIC-MOS vs. EPIC-pn stacked residuals spectrum based on the 2XMM EPIC sources after Read et al. (2014) with SASv13.5 and calibration files publicly available at the date of this RN.

CCFs). For the sake of the analysis presented in this RN, the spectra of the 2XMM sources were re-extracted using SASv13.5. The main differences with respect to the original reduction in Read et al. (2014) are the calibration of the contamination in the EPIC-MOS cameras (Sembay & Saxton 2013), and a recent refinement of the EPIC-MOS Quantum Efficiency at the energies of the Si edge (Sembay et al., 2014, RN to be publicly released). The procedure for data screening, spectral extraction and spectral analysis is described in Read et al. (2014). We discuss here only the aspects of the data reduction and analysis pertinent to this RN, and refer to Read et al. (2014) for a more detailed discussion.

The EPIC cross-calibration status was evaluated using the stacked residual method (Longinotti et al. 2008; Kettula et al. 2013; Schellenberger et al. 2014) in the "stack and fit" flavour described in Read et al. (2014). The 0.7–7 keV EPIC-MOS stacked residual spectra against the EPIC-pn best-fit model are shown in Fig. 1. The experimental points were fit with a combination of constant and Gompertz functions:

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

where $R_i(E)$ is the energy-dependent (E) EPIC-MOS to EPIC-pn empirical correction factor, and the indices i = 1,2 correspond to each EPIC-MOS camera. The non cap-

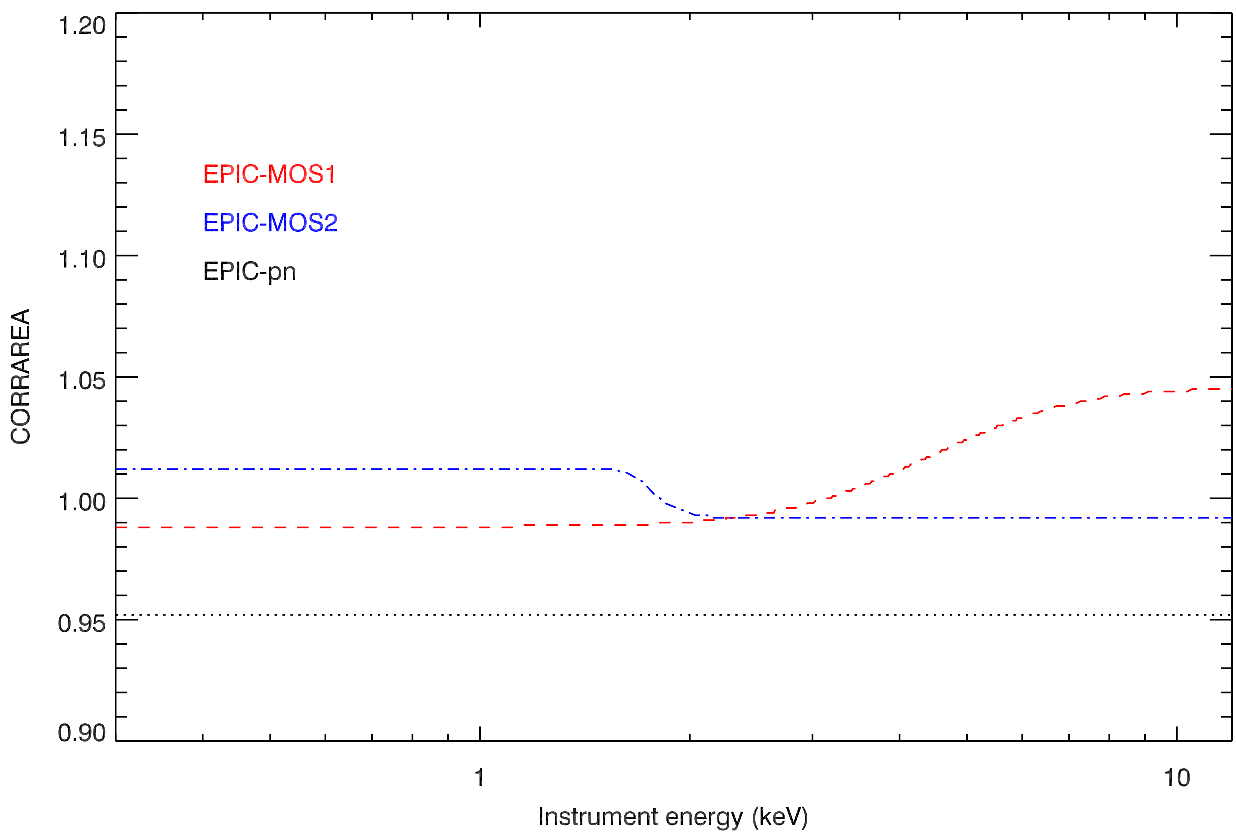

Figure 2: CORRAREA functions for XRT1 (MOS1; *red curve*), XRT2 (MOS2; *blue curve*), and XRT3 (pn; *black curve*).

ital letters a_i to d_i indicate the best-fit parameters. With the above parametrisation, the EPIC-pn CORRAREA correction factor is energy-independent [*i.e.*, $a_{pn} \neq a_{pn}(E)$], and absorbs most of the constant part of the offset among the EPIC cameras fluxes. This means that the CORRAREA correction does not change the shape of the EPIC-pn telescope's effective area. We stress that this assumption is *arbitrary*, as the source(s) of the effective area systematic uncertainties is still under investigation. Empirically, EPIC-pn yields the lowest fluxes in the 2–10 keV energy band among all the currently operational CCDs, whereas the EPIC-MOS cameras are closer to the mean (Nevalainen at al. 2010; Tsujimoto et al. 2011; Ishida et al. 2011).

The CORRAREA functions in the CCF constituents released with this RN are shown in Fig. 2.

We stress once again that the calibration of the CORRAREA extension embedded in the new CCF constituents is not unique. The CORRAREA extension shall be used exclusively as a tool to estimate the impact of systematic uncertainties on the EPIC effective area-intercalibration.

3 Scientific Impact of this Update

The goal of the CORRAREA extension (with the associated applyxcaladjustment option in arfgen) is providing XMM-Newton users with a tool to estimate the astrophysical impact of systematic uncertainties due to effective area inter-calibration inaccuracies. The nominal effective area in the new CCF constituents is identically equal to that of the previous CCF version. No change in the spectral results is expected if the new CCFs are used with the default SAS data analysis and reduction options, because the parameter applyxcaladjustment in arfgen is set to no by default in SASv14.

4 Estimated Scientific Quality

If the nominal empirical correction embedded in the CORRAREA extension is employed, the fluxes measured by all the EPIC cameras shall be consistent within $\pm 1\%$ over the whole sensitive EPIC cameras energy band (cf. Sect 5). This evidently does not imply that the fluxes obtained by using the option applyxcaladjustment option in arfgen are more correct that those obtained by extracting the EPIC effective areas with the default SAS!

5 Test procedures and results

In Fig. 3 we compare the EPIC-MOS to EPIC-pn flux ratio distributions when the effective area are extracted with the nominal arfgen parameters and with applyxcaladjustment and the CCF constituents described in this CCF RN, respectively. The flux ratio distribution in the latter case are much closer to 1. The standard deviation of the distributions is $\simeq 2\%$ below 1.5 keV and $\simeq 5\%$ above 1.5 keV. This is simply a verification of the self-consistency between the CORRAREA calibration and SAS implementation of the corresponding corrections.

6 Expected updates

A recalibration of the XMM-Newton telescope effective area based on a detailed re-analysis of the ground based calibration results and error budget is ongoing (Lumb et al., in preparation). The recalibration is expected to reduce the dynamical range of the CORRAREA empirical correction to $\pm 2\%$ at most. We stress that the dynamical range of the empirical correction in CORRAREA is inconsistent (because larger) with this accurate error budget. New effective area files based on this recalibration are expected to be released by the end of 2014.

The impact of applying the applyxcaladjustment option in arfgen together with the CORRAREA empirical correction presented in this RN will be tested during the scientific

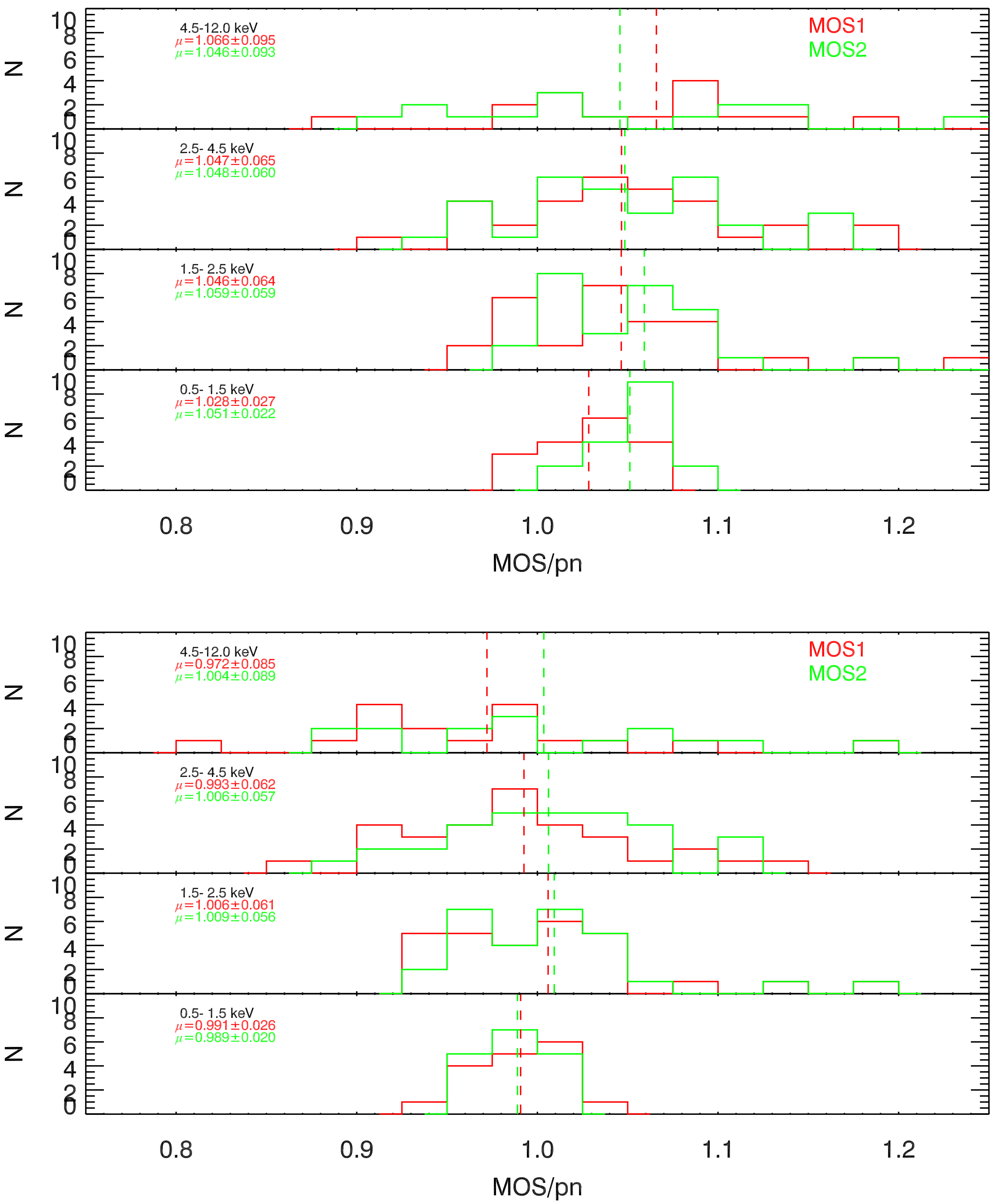

Figure 3: Distribution of EPIC-MOS to EPIC-pn flux ratios in different energy range on the 2XMM source sample if effective areas are calculated with the public SAS(v13.5) and calibrations (*top*, and with the `CORRAREA` calibration presented in this RN (*bottom*

validation of SASv14 on additional source samples, such as the radio-load AGN sample in the XMM-Newton cross-calibration database (XCAL; Stuhlinger et al., 2010), and the galaxy cluster sample discussed in Nevalainen et al. (2010). The corresponding results will be published in the SAS Scientific Validation Report for SASv14[1].

References

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[1]SAS Scientific Validation Reports are available at: http://xmm.esac.esa.int/external/xmm_data_analysis/sas_validation/index.shtml