XMM-Newton Calibration Technical Note

XMM-SOC-CAL-TN-0084

Evaluation of pile-up thresholds in the EPIC-MOS camera

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History

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1 Scope

This report aims at giving an assessment of the count rate thresholds, above which pile-up can affect the quality of scientific observations with the EPIC-MOS cameras (Turner et al. 2001, A&A, 365, L27). Pile-up is defined as the reconstruction of independent events as a single one during a read-out cycle. The registered events are erroneously interpreted as one single event, whose energy is the sum of the individual incoming event energies. Pile-up distorts the spectral shape is three main ways, not necessarily exclusive:

1. by "hardening" the observed spectrum with respect to the intrinsic source (because events are shifter to higher energies)
2. by suppressing flux, if the sum of the incoming event energies is higher than the on board energy rejection threshold, the corresponding events are lost
3. by "joining" separate mono-pixel events into a single multi-pixel event ("pattern migration")

Pile-up can be mitigated in affected observation by extracting spectra of single events only (see, *e.g.*, Molendi & Sembay, XMM-SOC-CAL-TN-0036, available at: `http://xmm2.esac.esa.int/docs/documents/CAL-TN-0036-1-0.ps.gz`). A software library to correct spectra affected by pile-up is under implementation in the SAS.

The reference pile-up thresholds are reported in Tab. 3 (Sect. 3.3.2) of the XMM-Newton Users Handbook (Piconcelli et al. 2012; available at: `http://xmm.esac.esa.int/external/xmm_user_support/documentation/uhb/index.html`). For what said above, it is of paramount importance that XMM-Newton proposers take them into account when they choose the optimal instrumental configuration for their observation.

2 Methodology

2.1 The samples

The results of this study make use of the *Cross-calibration database* (XCAL hereafter), a compilation of over 250 observation performed over the mission and routinely used for calibration and cross-calibration purposes (Stuhlinger et al. 2010, XMM-SOC-CAL-TN-0052, available at: `http://xmm2.esac.esa.int/docs/documents/CAL-TN-0052.ps.gz`). They are mainly bright sources with astrophysically well defined (albeit not necessarily fully understood) astrophysical models. They have been mainly observed in "windowed" (*i.e.* Large or Small Window) EPIC instrumental modes to mitigate pile-up. Nonetheless many of them are still affected by pile-up. This makes of the XCAL an ideal sample for our study.

Table 1: Best-fit parameters of the P_f versus R function for different modes

Mode	a	b	c
MOS1-FF	-1.52 ± 0.08	0.6 ± 0.2	0.0 ± 0.2
MOS1-SW	-2.74 ± 0.09	1.55 ± 0.13	-0.34 ± 0.13
MOS1-LW	-1.99 ± 0.15	0.8 ± 0.2	0.0 ± 0.2
MOS2-FF	-1.48 ± 0.07	0.49 ± 0.16	-0.05 ± 0.16
MOS2-SW	-3.01 ± 0.09	2.00 ± 0.13	-0.50 ± 0.13
MOS2-LW	-1.83 ± 0.15	0.4 ± 0.4	0.0 ± 0.4

2.2 Pile-up estimation

The largest fraction of events affected by pile-up in a given XCAL spectral extraction region is estimated as follows: the PSF-weighted mean of the image obtained by dividing an image of diagonal events (`PATTERN` = 25–29; `selectlib` expression: `(FLAG & 0x1)!=0 && (FLAG & 0x766ba000)==0`) by an image extracted from *bona fide* X-ray events (`PATTERN`s from 0 to 12, both included). The image is smoothed with a 2-pixels side boxcar function to avoid the maximum intensity peak being significantly affected by pixel-to-pixel fluctuations. The statistical errors are calculating by propagating the Poissonian error on each pixel of the diagonal image using the Gehrels' prescription: $\sigma_C = (C + 0.75)^{1/2} + 1.0$ (Gehrels, 1986, ApJ, 303, 336), where C is the number of counts in a pixel.

3 Results

In Fig. 1 we present the pile-up fraction as a function of the full band energy band (0.2-12 keV) count rate, R. The *dotted lines* represent the best-fit with a the function:

$$P_f = 10^{a + b\log(R) + c\log(R)^2}$$

where a, b and c are fit parameters. In Tab. 1 we report the values of these parameters for the main MOS instrumental modes.

4 Comparison with the existing estimates

In Fig. 1 we compare the pile-up fraction as defined in Sect. 2.2 with the prediction by the software used during the evaluation of user proposals (already known as `PHSTools`: *dashed lines*), as well as in the XMM-Newton User's Handbook (UH). While there is a good agreement between the predicted and calculated level of pile-up fr Small Window, the pile-up level is underestimated by about 50% in Full Frame and large Window. Updated thresholds will be published in the UH Release for AO-13.

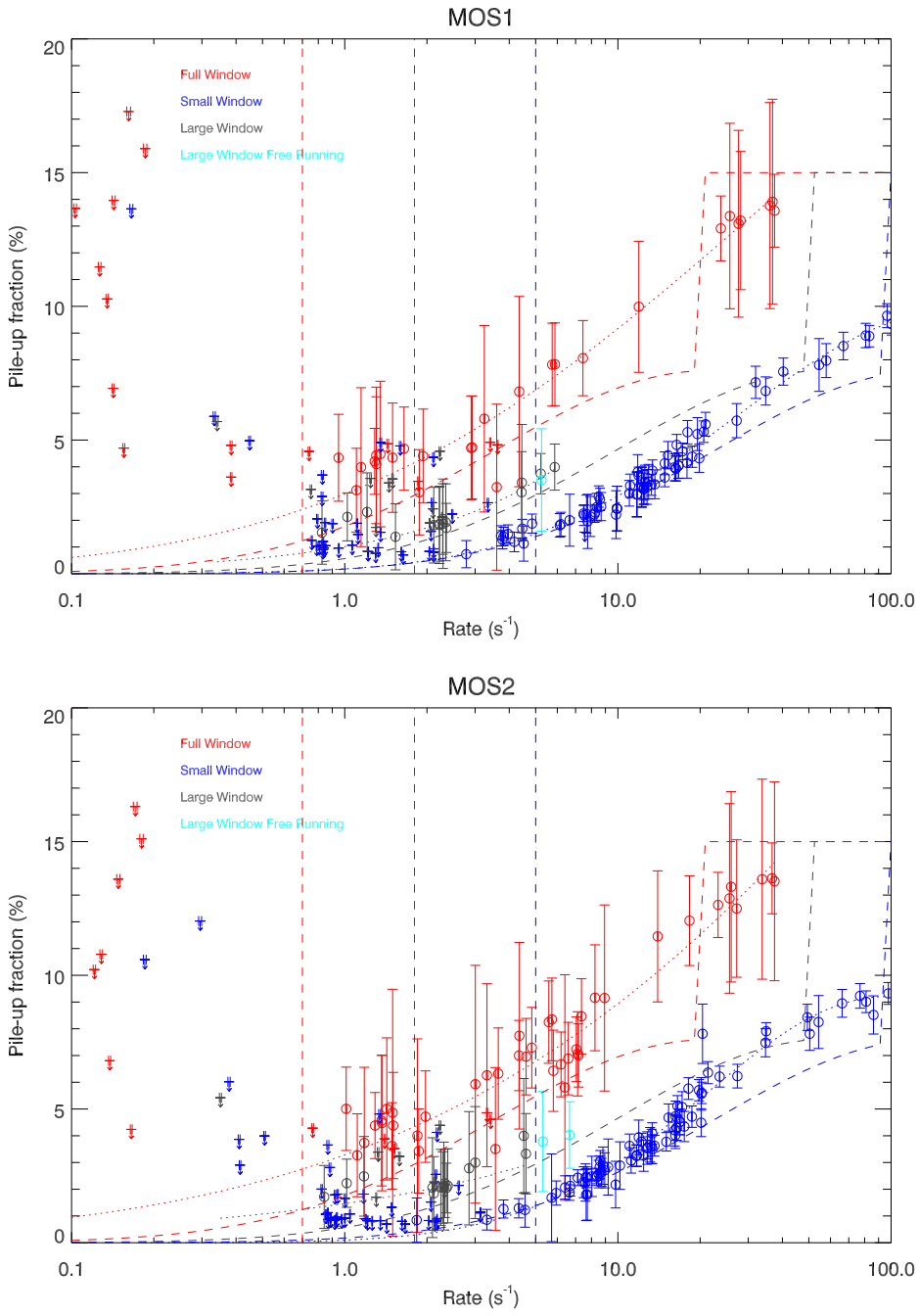

Figure 1: MOS pile-up fraction as a function of the full band count rate for the MOS1 (*top panel*) and the MOS2 (*bottom panel*) cameras. The instrumental modes are *colour coded*. The *dotted lines* represent the best-fit of the data (details in text). *Arrows* indicate upper limits. The *dashed vertical lines* indicate the nominal thresholds according to the XMM-Newton User Hand-Book. *Dashed lines* indicate the current model predictions as implemented in the `PHSTools` (silently called by XMM-Newton proposers when the run the technical evaluation of their proposals).