XMM-Newton Calibration Technical Note

PN Optical Loading

XMM-SOC-CAL-TN-0051 Issue 1.2

M.J.S. Smith

July 1, 2008

1 Abstract

An investigation into PN optical loading has been performed through analysis of PN offset maps. The extent of loading *versus* magnitude has been analysed and compared with the PHS Tools model output. Also, the PN optical PSF has been analysed using optical loading in offset maps.

2 Introduction

A description of EPIC optical loading is given in [1].

The offset map analysis, which makes use of residual offset maps and quantifies the extent of loading in terms of residual offset, is described in [2].

Although an offset map is nominally in energy space, as each optically generated photoelectron shifts the energy scale by 3.65 eV, the offset map can be considered as being in counts space for optical photons. Assuming an offset created *solely* by optical photons and a gain of 5 eV per ADU, the conversion from residual offset to optical counts per pixel is: 1 ADU $\approx$ 5/3.65 optical photons.

3 Analysis

Over 350 offset maps of imaging, non (cal)closed exposures were investigated for the presence of optical loading. Fig. 1 shows an example of optical loading cases in a PN residual offset map.

As far as possible, cases of X-ray loading were excluded by investigating the events image for excessive (*e.g.* near pile-up) count rate. The remaining cases of, presumed, optical loading were cross checked with catalogues. With very few exceptions a corresponding optical counterpart could be found, together with, in many cases, information on magnitude and spectral type.

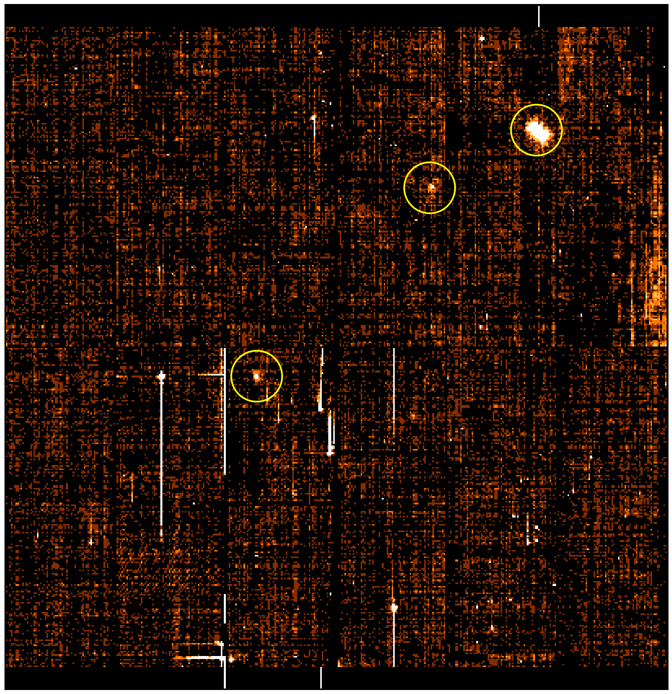

Figure 1: **PN Residual offset map showing cases of optical loading.** The bright object is of magnitude V ≈ 6.7, the two fainter objects are of magnitudes V ≈ 9; the mode is Full Frame.

Together with the above-mentioned conversion of residual offset energy to number of detected optical photons, this allows a comparison of detected optical flux with magnitude.

4 Results

As can be expected, optical loading cases were found mostly in thin filter exposures, with only a few cases in medium filter exposures. No cases of optical loading were found with thick filter in use. The faintest sources for which optical loading was detected is V ≈ 12 and V ≈ 6 for thin and medium filters respectively.

Fig. 2 shows the relationship between peak residual offset (*i.e.* the maximum residual offset found in the loaded region) and visual magnitude of optical loading cases. The data points follow quite closely the theoretical flux *versus* magnitude relationship. The main deviations are likely caused by the inclusion of various spectral types, uncertainty in visual magnitude due to possible optical variability of some sources, and the radial variation of the optical PSF with respect that on axis (discussed below).

For the optical loading cases for which the magnitude and spectral type is known, a comparison was made between the measured loading and the expected loading based on the PHS Tools model (see [1]). The model consists of a look-up table of the expected optical loading (expressed in photons/pixel/sec) for different spectral types and filters, and for a visual magnitude of 0. For PN, it assumes a fraction of 15% of light in the PSF central pixel. The results of the comparison are shown in Fig. 3; data and model are expressed in units of ADU/pixel/0.073 sec.

There is clearly a strong correlation between data and model, but the model systematically over-

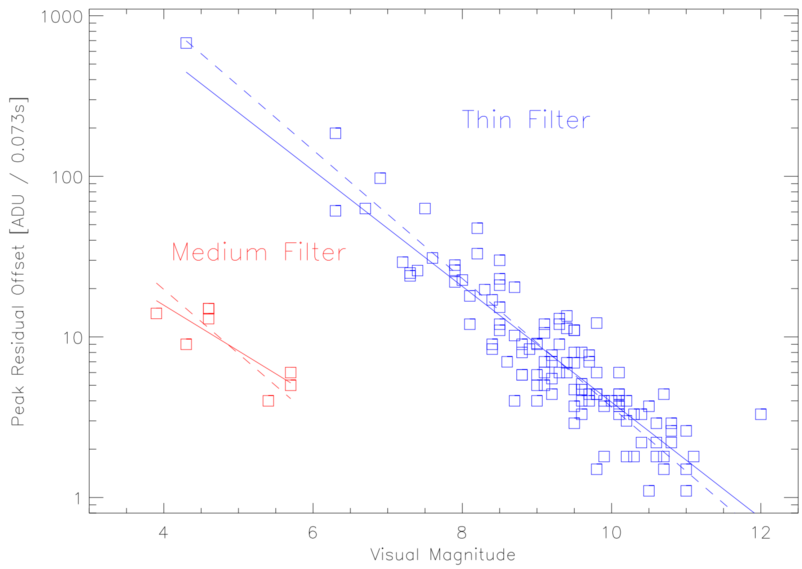

Figure 2: **Peak residual offset *versus* visual magnitude.** The peak residual offsets of the various modes have been normalised to the Full Frame integration time (0.073 s). Blue and red data points represent thin filter and medium filter exposures respectively. The theoretical flux *versus* magnitude relationship is shown with the dashed line. The drawn line represents a best fit exponential function.

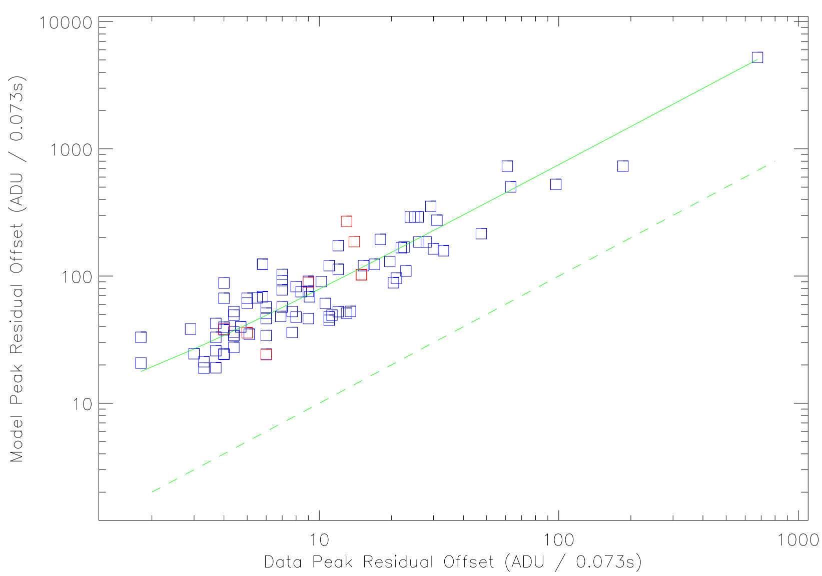

Figure 3: **Comparison of measured optical loading *versus* the PHS Tools prediction.** The data are shown in blue and red for thin and medium filter exposures respectively. A linear fit through the data is shown by the drawn line.

predicts the loading by a factor of ∼ 7 for the complete sample, with a minimum over-prediction by a factor of 4. A similar conclusion follows from the analysis of MOS optical loading described in [3].

The over-prediction could in part be explained by the fact that in the model the assumed fraction of detected light at the central PSF pixel appears to be too large (indeed it was expected to be a conservative estimate). This is illustrated in Fig. 4, which shows the PN optical and X-ray PSFs at various off-axis angles (unfortunately there are no cases of sufficiently strong optical loading on axis, so the top panel is indicative only.) The encircled energy fraction in the central pixel (*i.e.* radius up to $\sim 2''.5$) decreases with increasing off-axis angle, and is always less than ∼ 8% as compared to the assumed value of 15%. A similar finding for the MOS optical PSF is presented in [4].

It may be noted that while the optical PSF is similar to the X-ray PSF at small offset angles, it degrades much faster with increasing off-axis angles.

5 Impact on Science

The findings mentioned above have motivated a corresponding fourfold increase in the PHS Tools optical loading warning threshold from the original 25 photons/pixel/frame (based on a maximum of 5 photons/pixel/frame r.m.s. [5]) to 100 photons/pixel/frame. This should help avoid users unnecessarily opting for thicker filters or faster modes.

References

[1] PHS Tools - EPIC Optical Loading, XMM-SOC-CAL-TN-0001 , D. Lumb, 2000
[2] PN X-Ray Loading, XMM-SOC-CAL-TN-0050, M.J.S. Smith, 2004
[3] MOS optical loading, XMM-SOC-CAL-TN-0043, B. Altieri, 2003
[4] EPIC optical PSF, XMM-SOC-CAL-TN-0040, B. Altieri, 2003
[5] Interpretation of PHS Tool Output, XMM-PS-TN-36, C. Erd, D. Lumb and R. Much, 2000

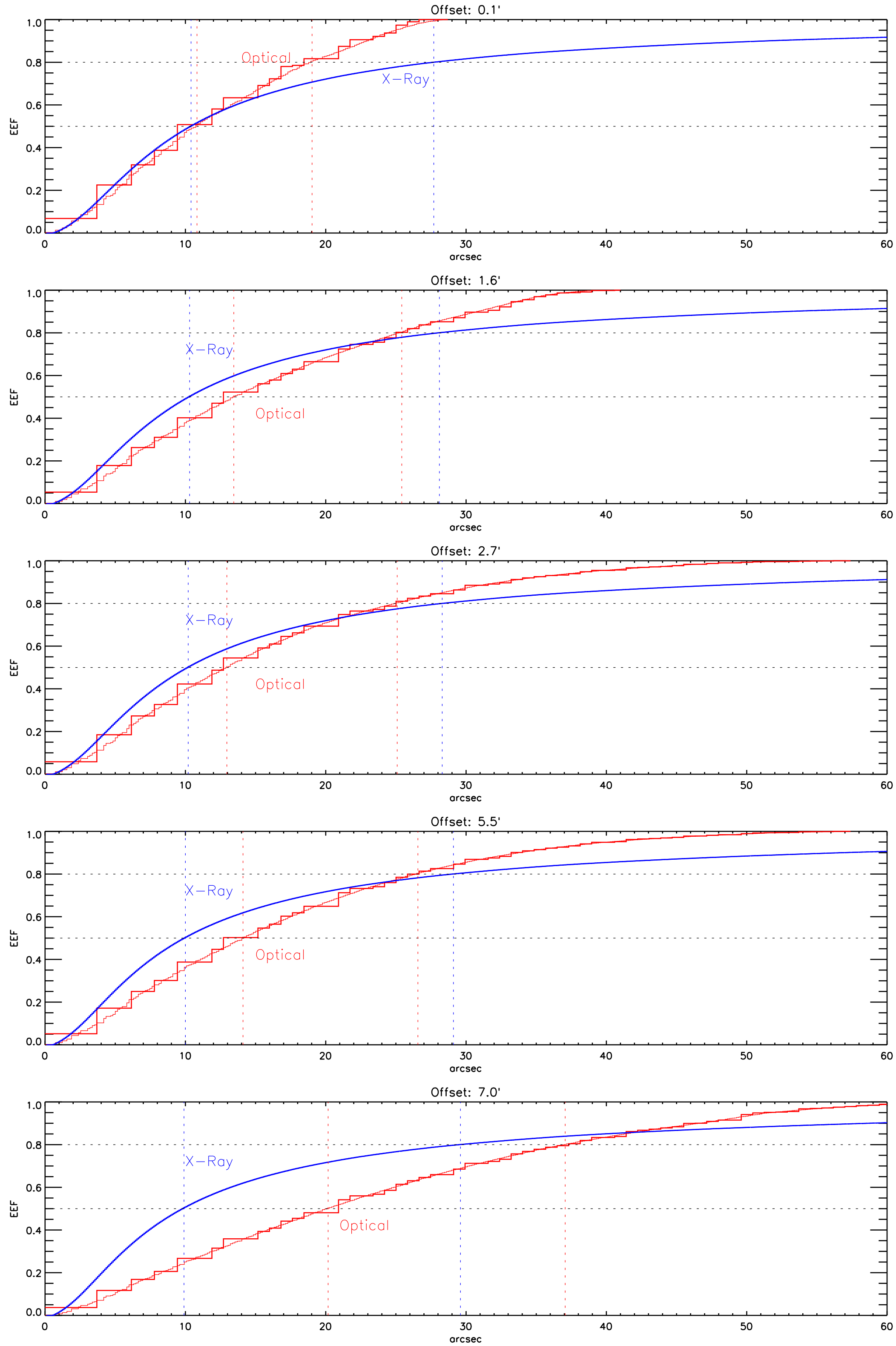

Figure 4: **Comparison of PN optical and X-ray PSFs for various off-axis angles** The encircled energy fraction is plotted *versus* radius. The optical PSF is shown in red (including a smoothing), the X-ray PSF is in blue.