FIXING THE HARD X-RAY EPIC CROSS-CALIBRATION THROUGH THE XRT[12] EFFECTIVE AREA

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Talk outline

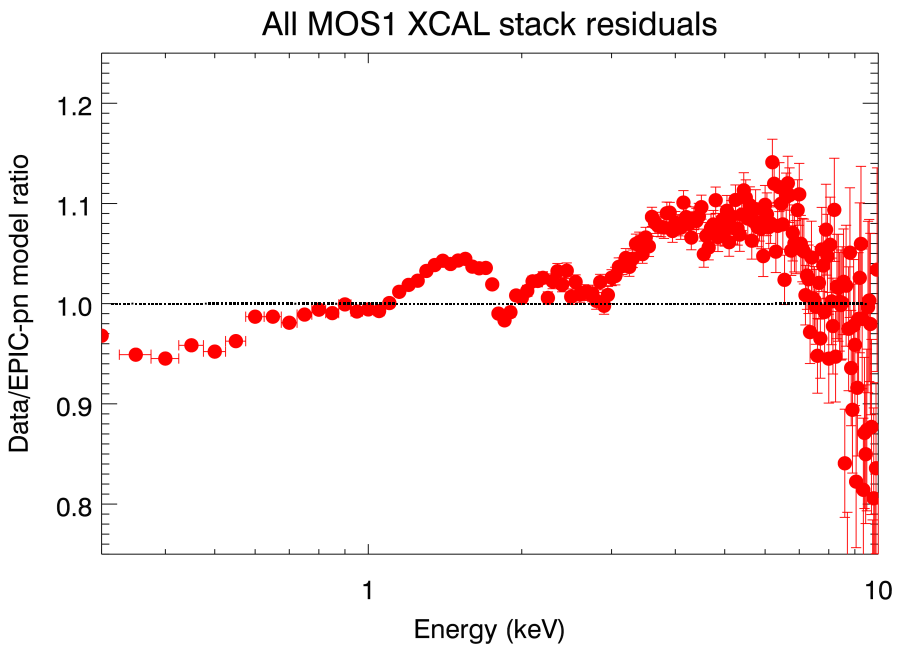
- Another way of visualising the energy-dependent cross-calibration status: **stacked residuals**
- The effect of the PSF choice on the XCAL cross-calibration status
- Proposed XRT CCF modification
- Tests on a sample of XCAL blazars (piled-up sources, PSF core excision, EEF correction ...)
- Tests on a sample of non-thermal, non piled-up 2XMM sources
- Tests on a sample of galaxy cluster (*talk by J.Nevalainen*)
- Conclusions, and next step

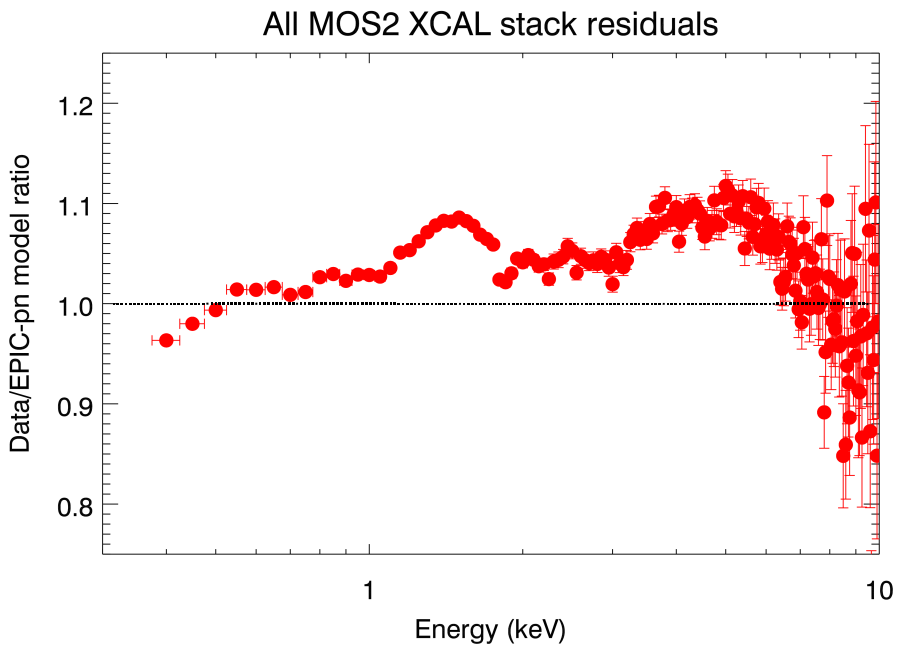
“Stacked residuals” algorithm

- Fit the EPIC-pn spectrum in the 0.3-10 keV energy band with the current XCAL model
- Create the residuals of the EPIC-pn unbinned spectrum against this best-fit model
  - “*unbinned*” here means: “*extracted with the intrinsic SAS PI binning*”: `specchannelmin=0, specchannelmax=20479, spectralbinsize=5`
- Create the residuals of the EPIC-MOS unbinned spectra against the EPIC-pn best-fit model
  - “unbinned” here means the EPIC-MOS equivalent of the definition above
- Bin the residuals created in Steps#2 and #3 on the same energy grid (e.g.: 50 eV in the 0.3-10 keV energy range)
- Stack the residuals obtained on the *same source*, observed with the *same instrumental configuration* in all cameras
- Divide the EPIC-MOS residuals by the EPIC-pn ones
- [It goes without saying that *using EPIC-pn as reference is arbitrary*]
- The results of this exercise as presented during the cross-calibration Workshop at MPE follow:

EMOS/EPN stack'd residuals

Stack of 25 XCAL sources (all AGN) covering the whole mission after MOS cooling





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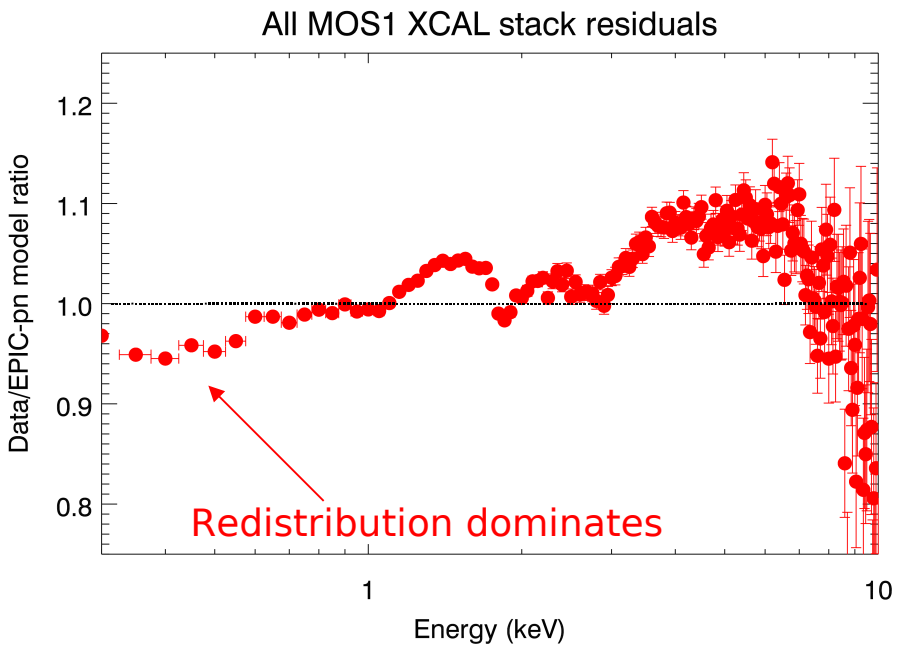

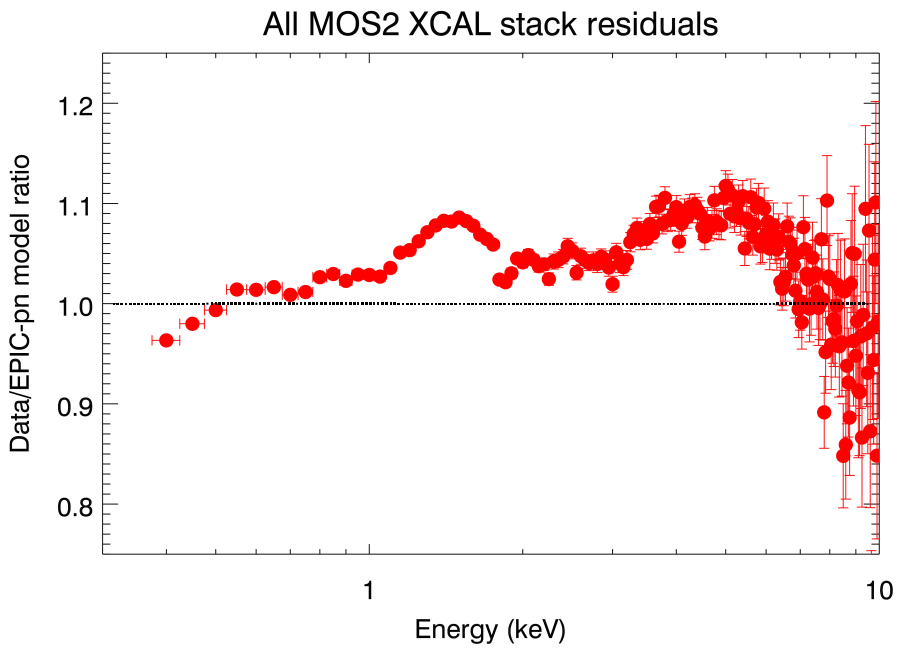

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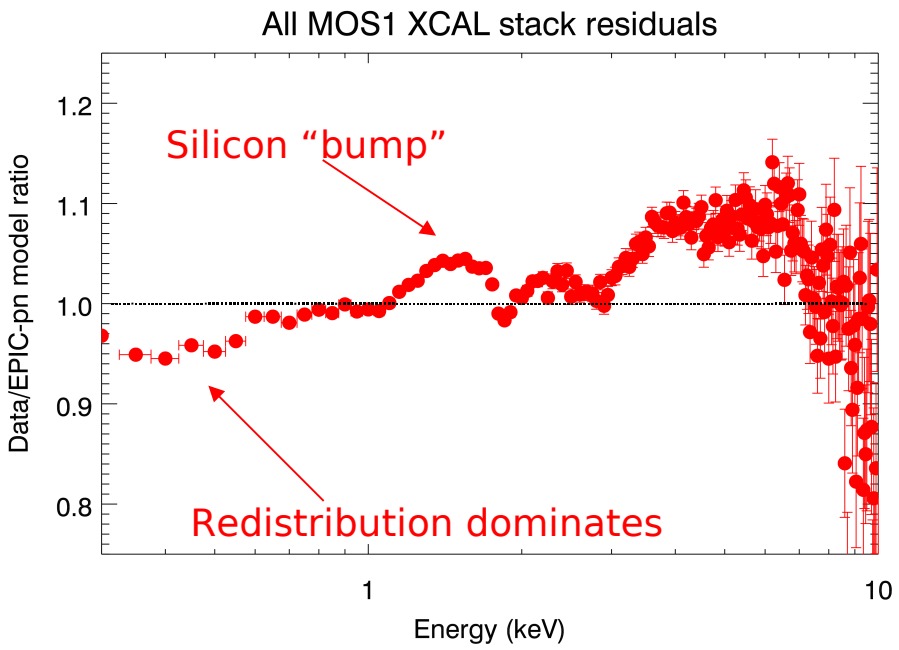

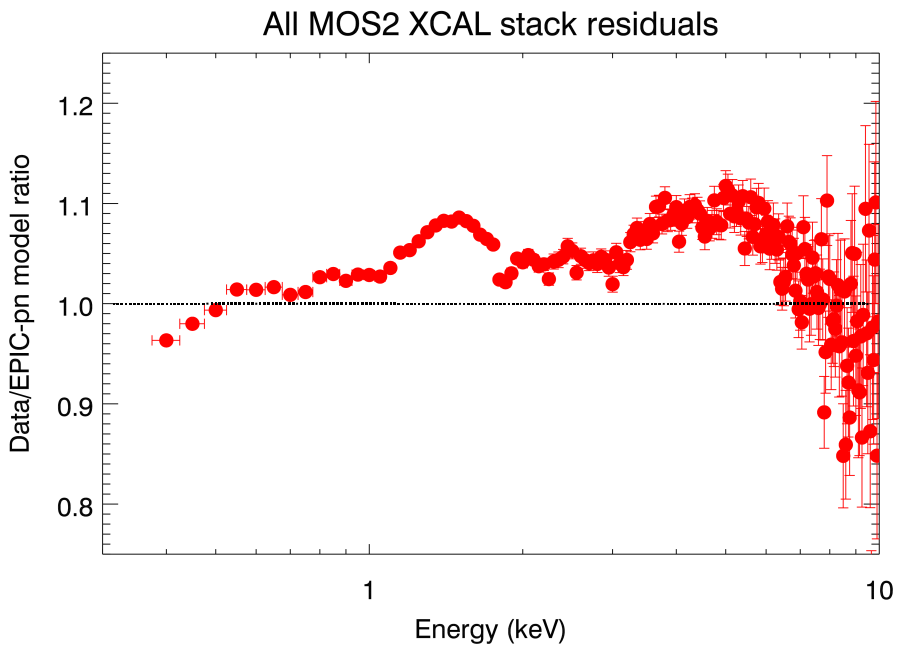

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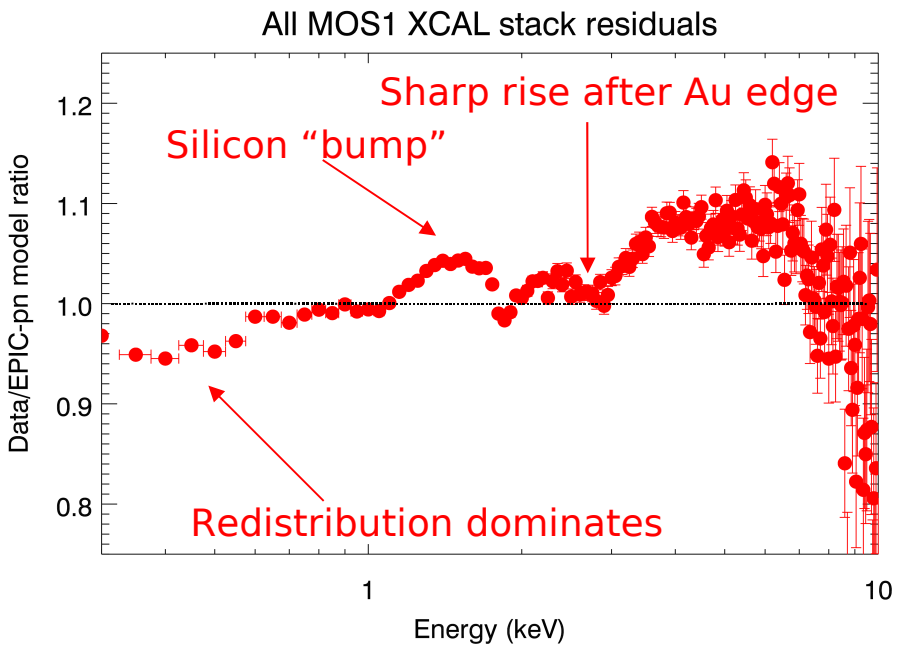

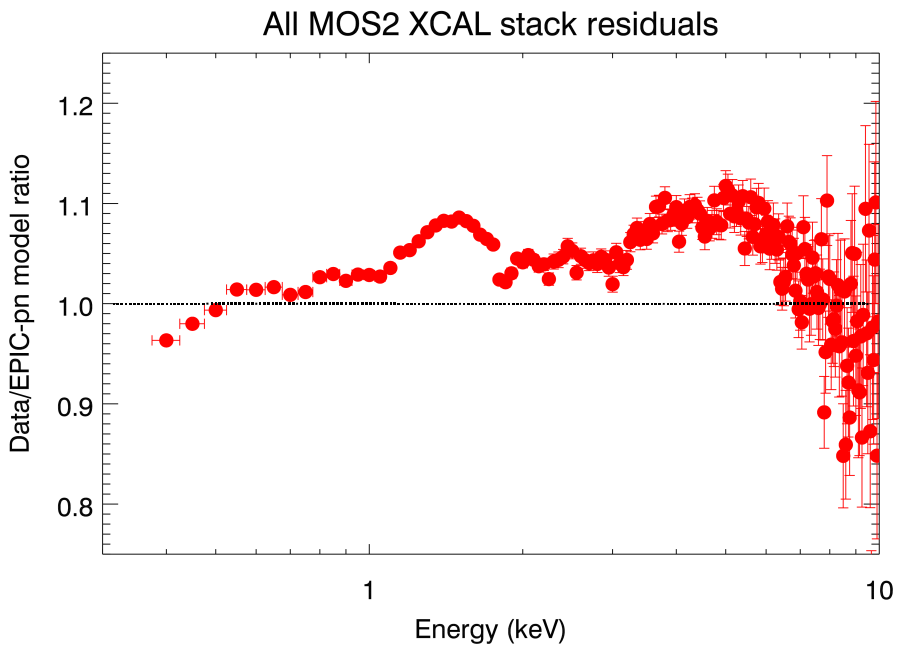

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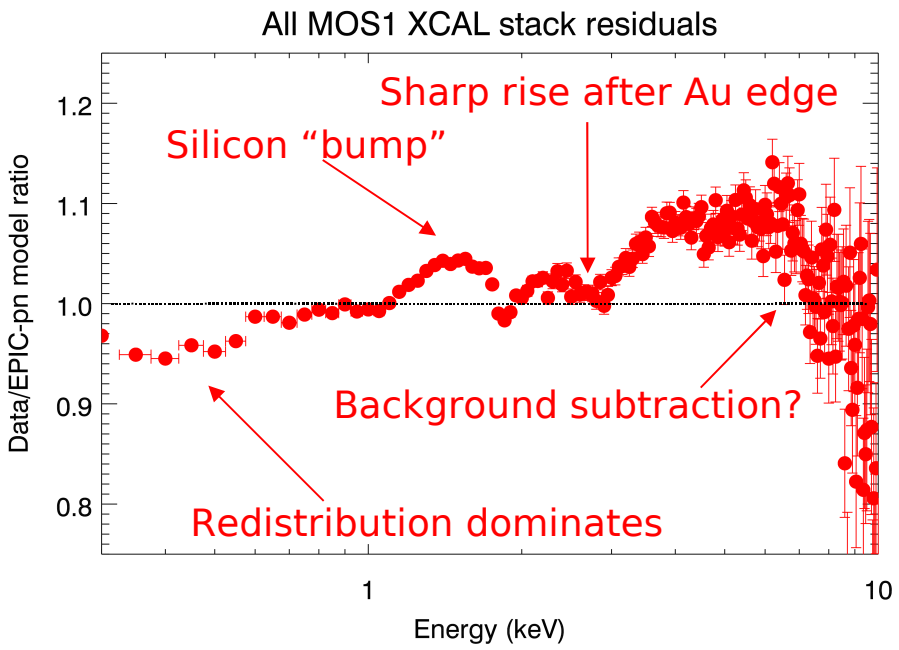
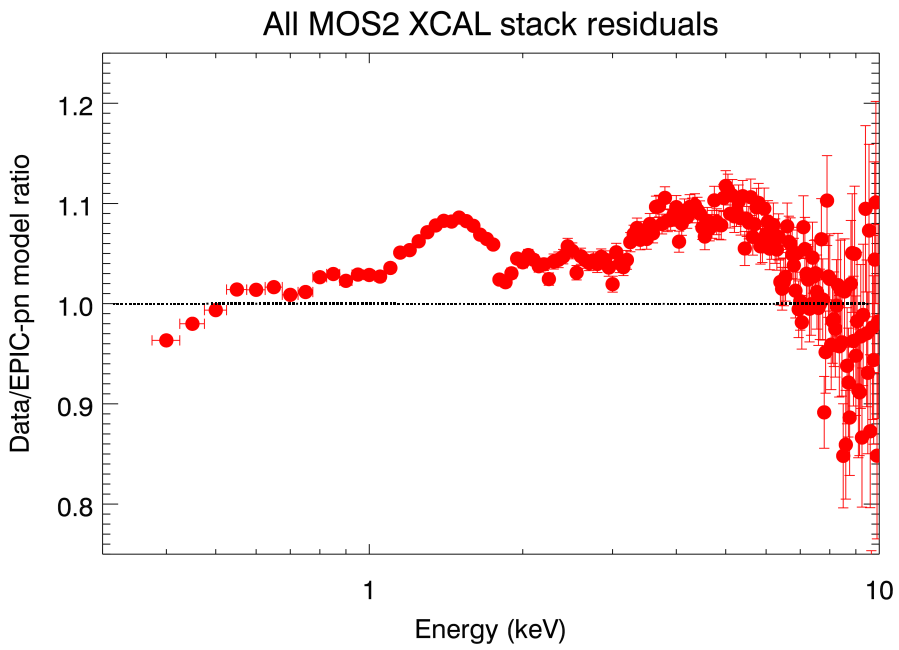
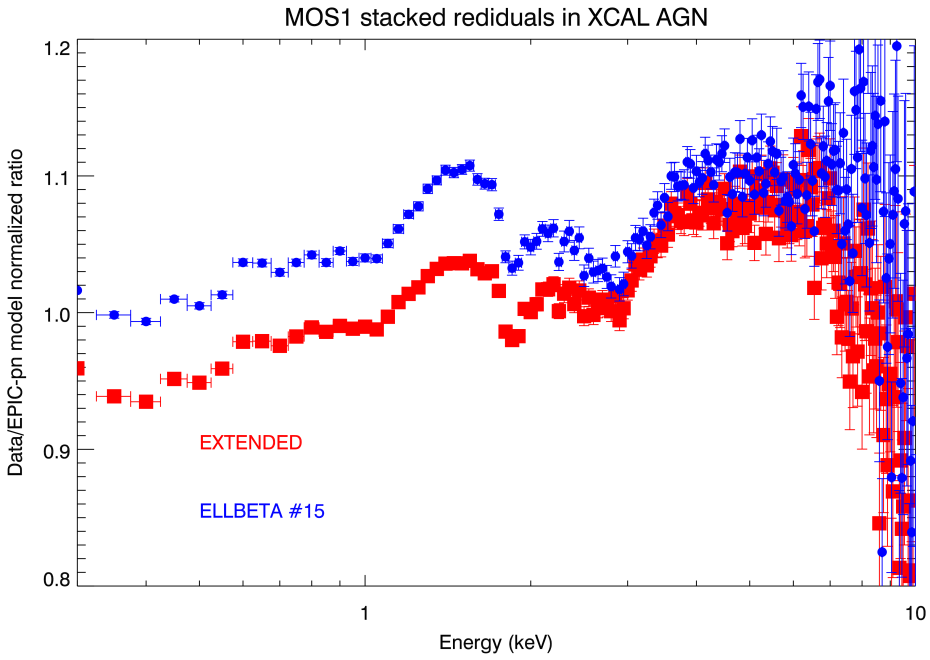


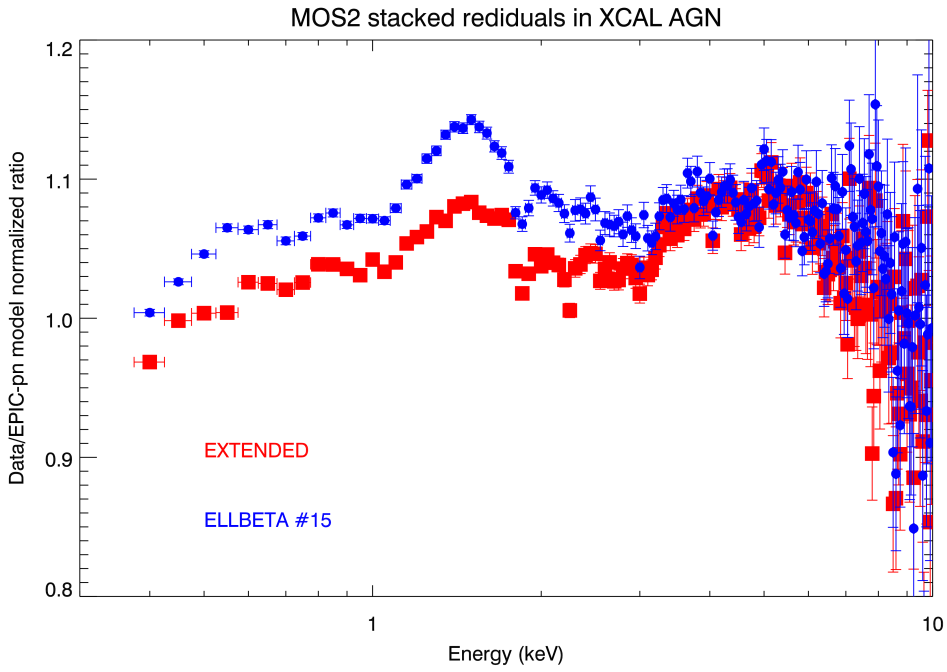


Rationale behind XRT as a working hypothesis

- The sharp rise above ≃2 keV may indicate that the cross-calibration mis-alignment originates in the calibration of the optics effective area
- *Working hypothesis*: we can improve the cross-calibration between MOS and PN above 2 keV by **multiplying the effective area of the MOS optics by the energy-dependent cross-calibration ratio between MOS and PN**
- Why changing the area of the optics behind the MOS cameras?
  - Ground-based calibration results suggest a difference of ≃3% between the MOS1 and MOS2 XRT effective areas. However, the calibration files contain the same numbers
  - The XRT effective area behind MOS1 and MOS2 has remained untouched over the mission (except a small tweak due to D.Willingale at the edges to account for improved atomic constants), while the XRT effective area behind the PN has been tweaked three times using results on astrophysical sources

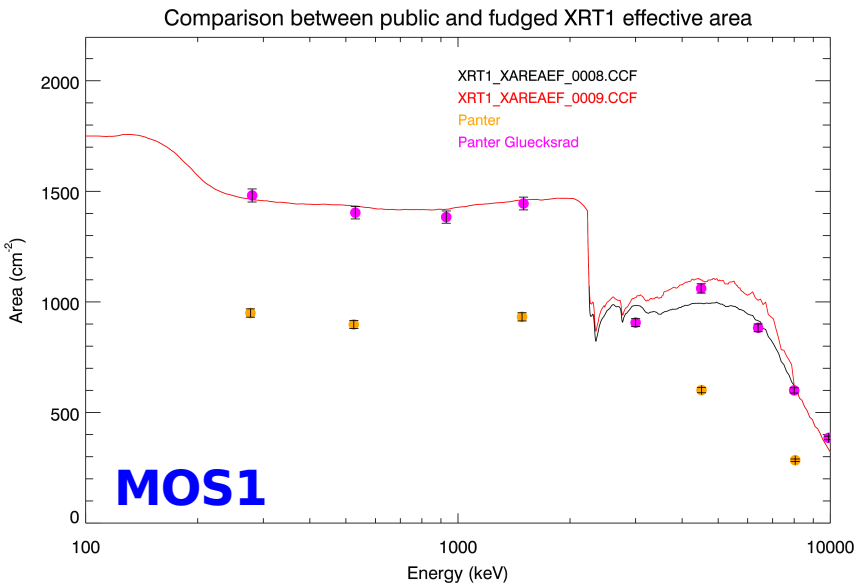
The effect of the 2-D PSF on the XCAL

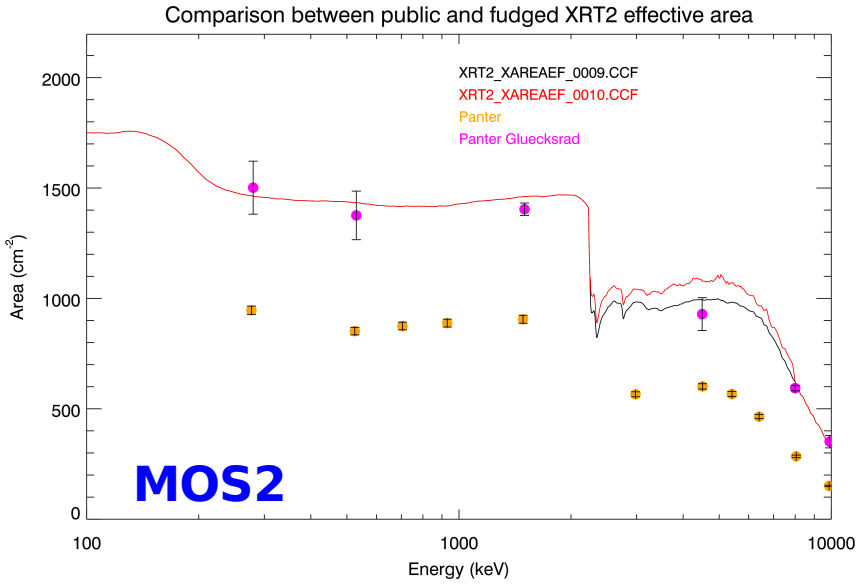




The PSF choice affects the cross-calibration results on the XCAL blazars (although only marginally above 2 keV) ⇒ the results shown hereafter are obtained with: **SASv11**, **`XRT*_PSF_0014.CCF`**, and **`psftype=ELLBETA`** in `arfgen`

Optics effective area tuning vs. ground calibration

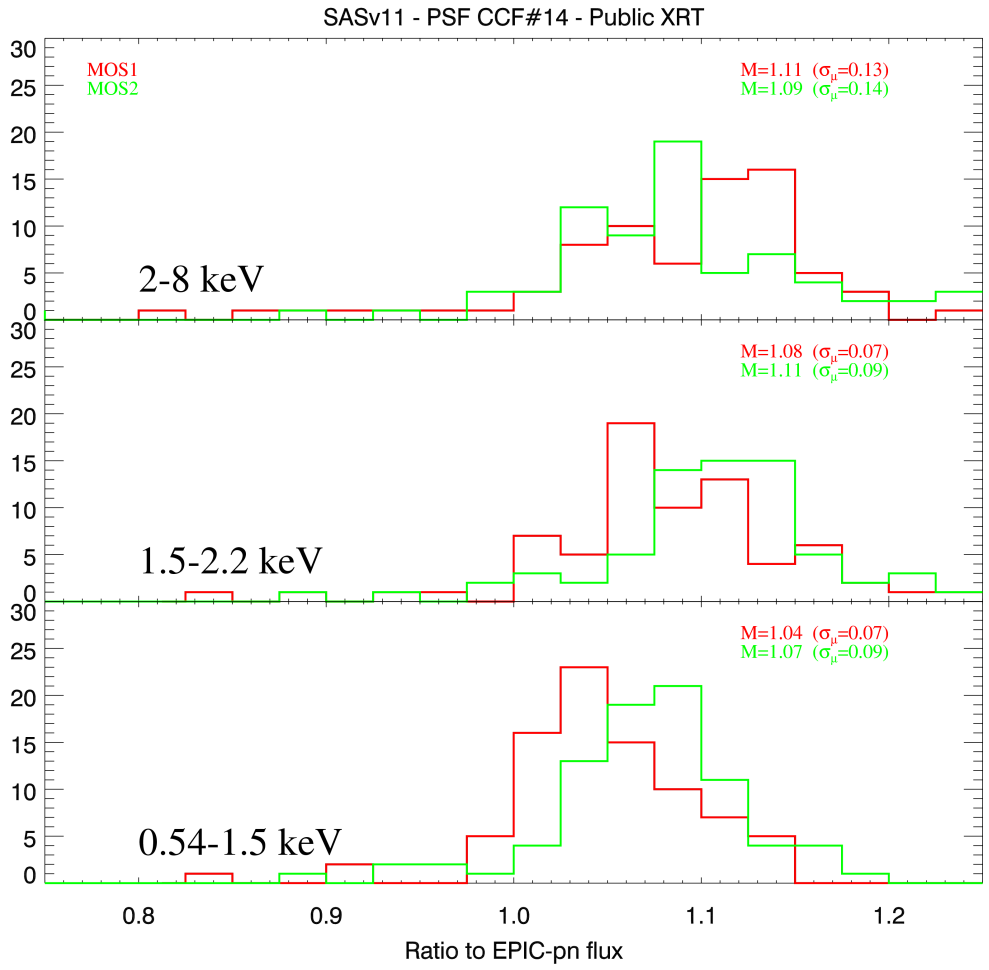


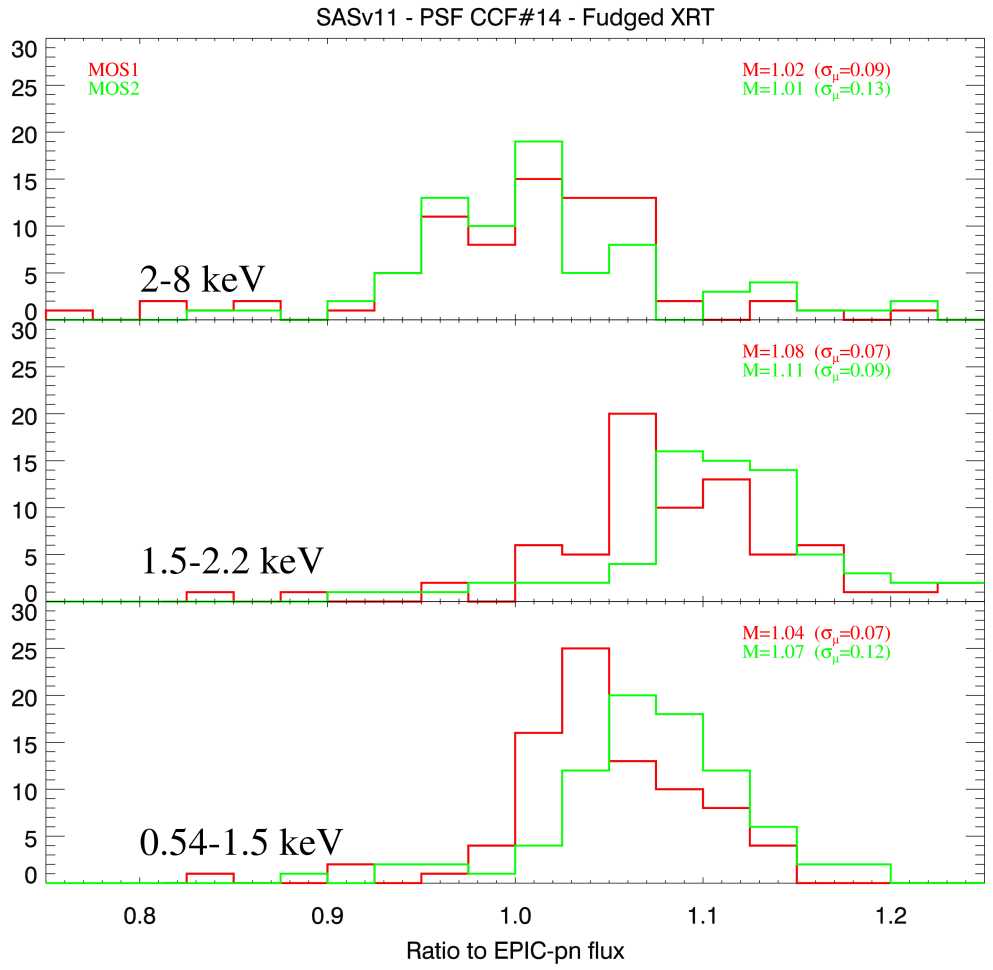


- Data points are flight module effective area measurements at Panter
  - [only the **magenta points** with tiny error bars are reliable]

- The **red curve** is the effective area corrected by the XCAL average (**black curve** is the public CCF)
  - Tweak applied only in the 2.5-8 keV band (elsewhere the effective area is unchanged)
  - In worse agreement with MOS1 ground-based measurements for $E \simeq E_{\text{Au edge}}$
  - In better agreement with MOS1 ground-based measurements for $E \simeq 4.5$ keV
  - (no reliable MOS2 measurements above 2 keV)

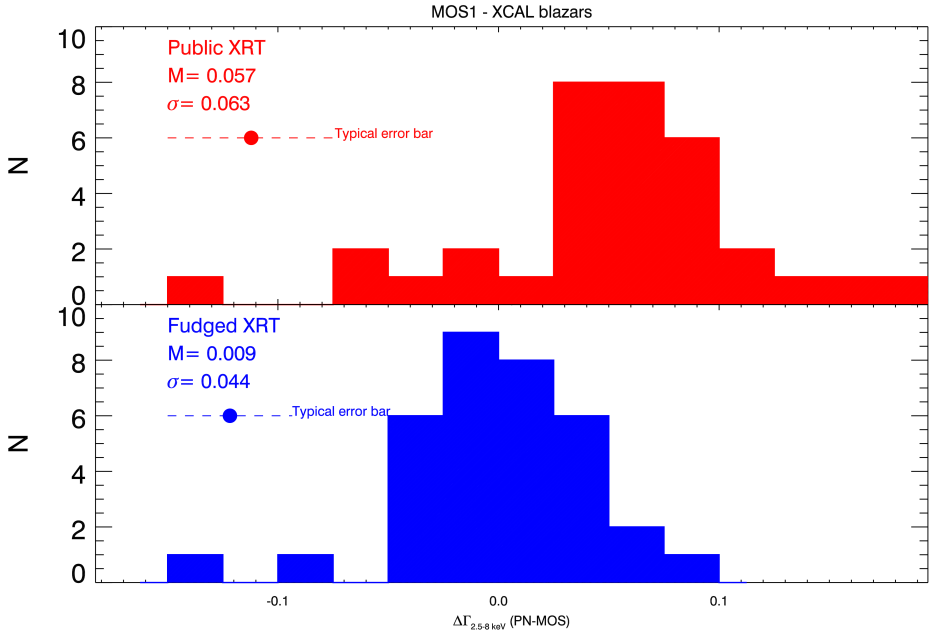
Test on XCAL blazars: fluxes

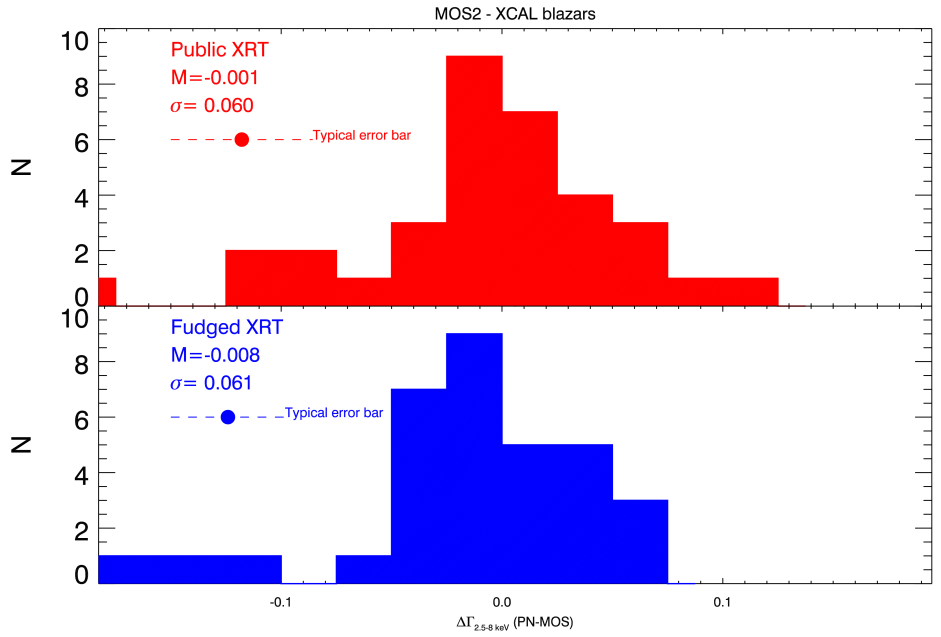




Test on XCAL blazars: slopes (I)

Comparison between the power-law spectral index (Γ_{PN}-Γ_{MOS}) of independent fits on the 2-5-8 keV energy band – Red:public XRT, Blue:"fudged" XRT

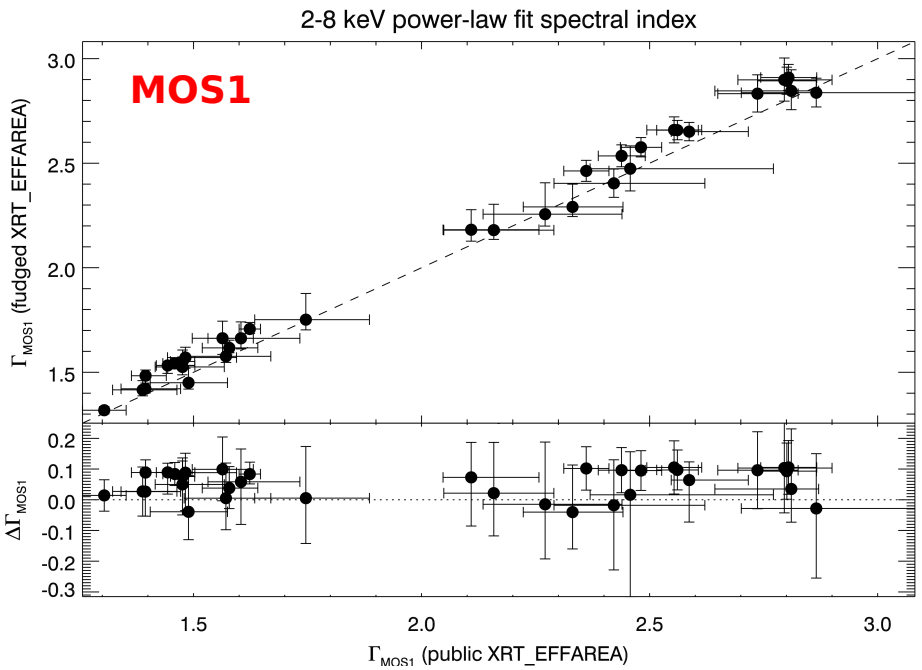


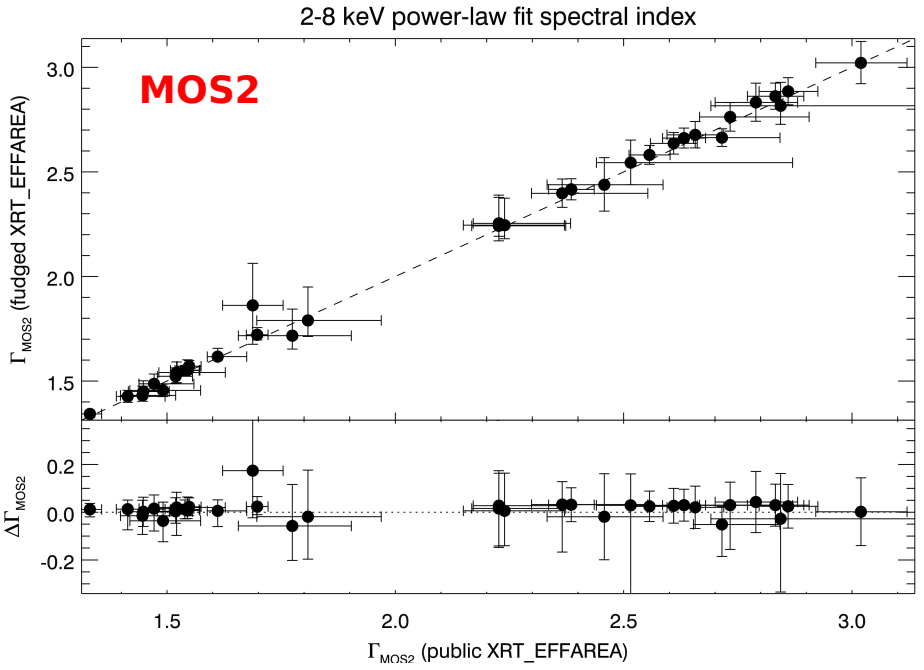


Post-fudge slopes in agreement between MOS and PN within **±0.01** (median)

Test on XCAL blazars: slopes (II)

Comparison of 2-8 power-law slopes with the public and the “fudged” XRT

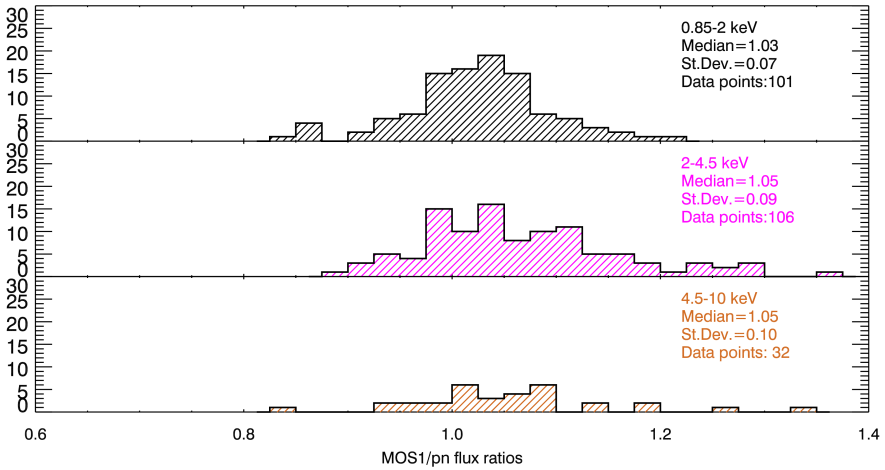




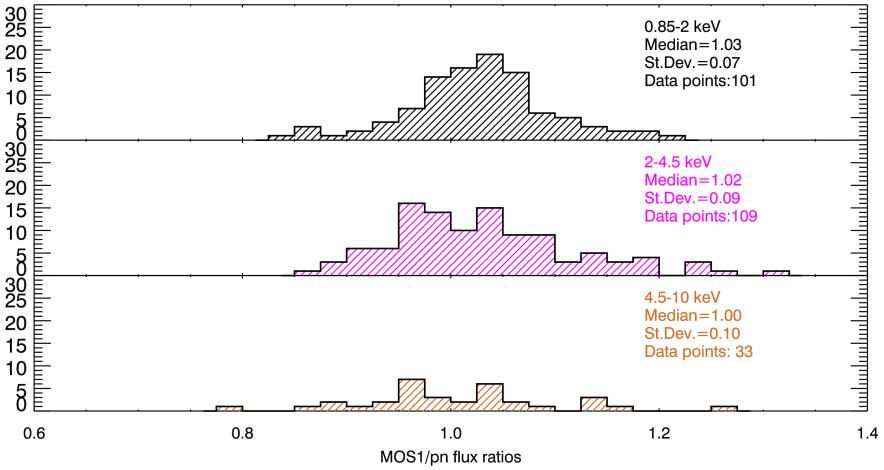
Test on 2XMM sources: MOS1/PN flux ratios

247 on-axis (<2') 2XMM sources, fit with simple power-laws in small energy ranges
[*N.B.*: only sources with a certain χ^2 and statistical quality (i.e., relative error on flux) are shown]

Public XRT



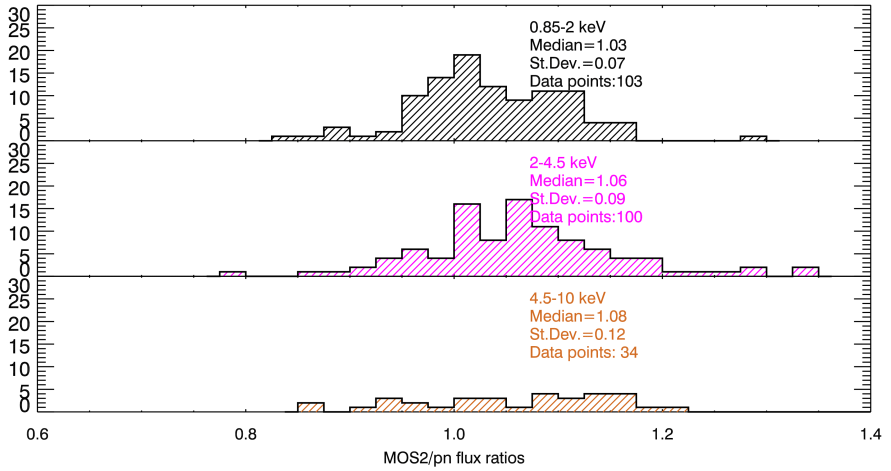
"Fudged" XRT



Test on 2XMM sources: MOS2/PN flux ratios

247 on-axis (<2') 2XMM sources, fit with simple power-laws in small energy ranges
[*N.B.*: only sources with a certain χ^2 and statistical quality (i.e., relative error on flux) are shown]

Public XRT



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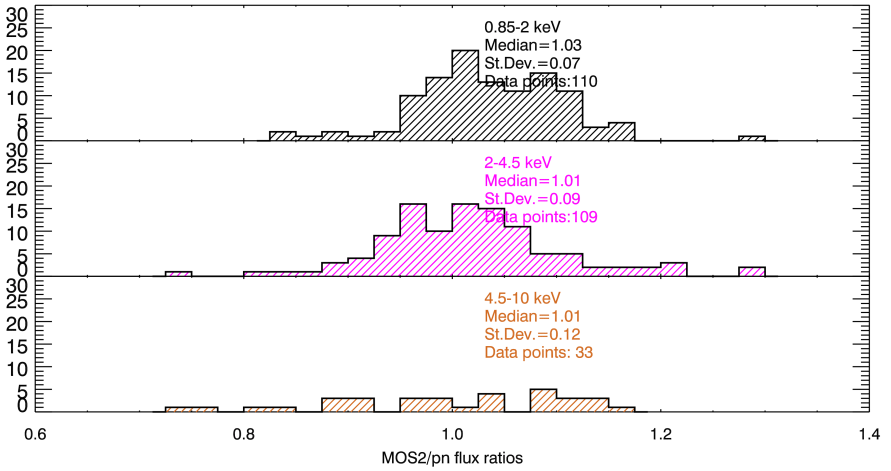

Test on 2XMM sources: MOS1-PN slope difference

247 on-axis (<2') 2XMM sources, fit with simple power-laws in small energy ranges
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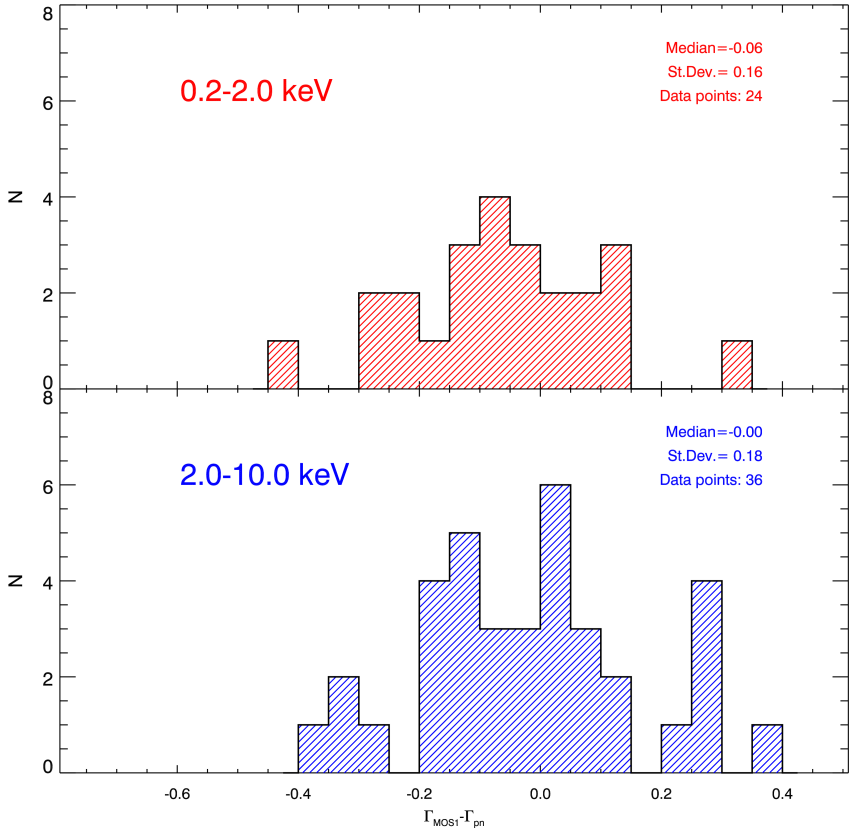
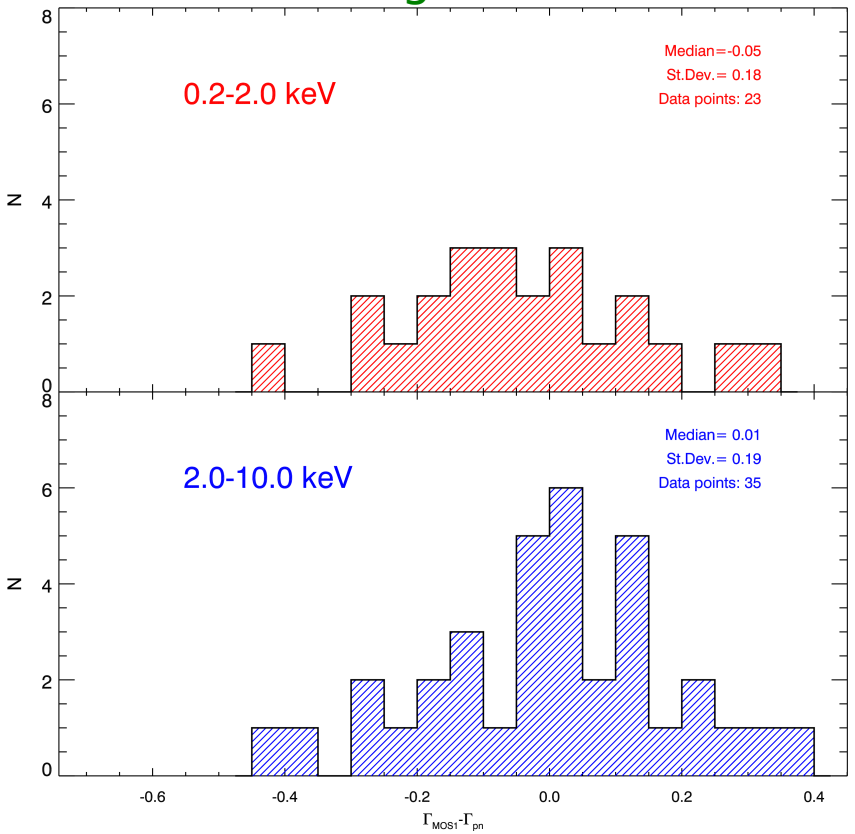
Public XRT



"Fudged" XRT



Test on 2XMM sources: MOS2-PN slope difference

247 on-axis (<2') 2XMM sources, fit with simple power-laws in small energy ranges
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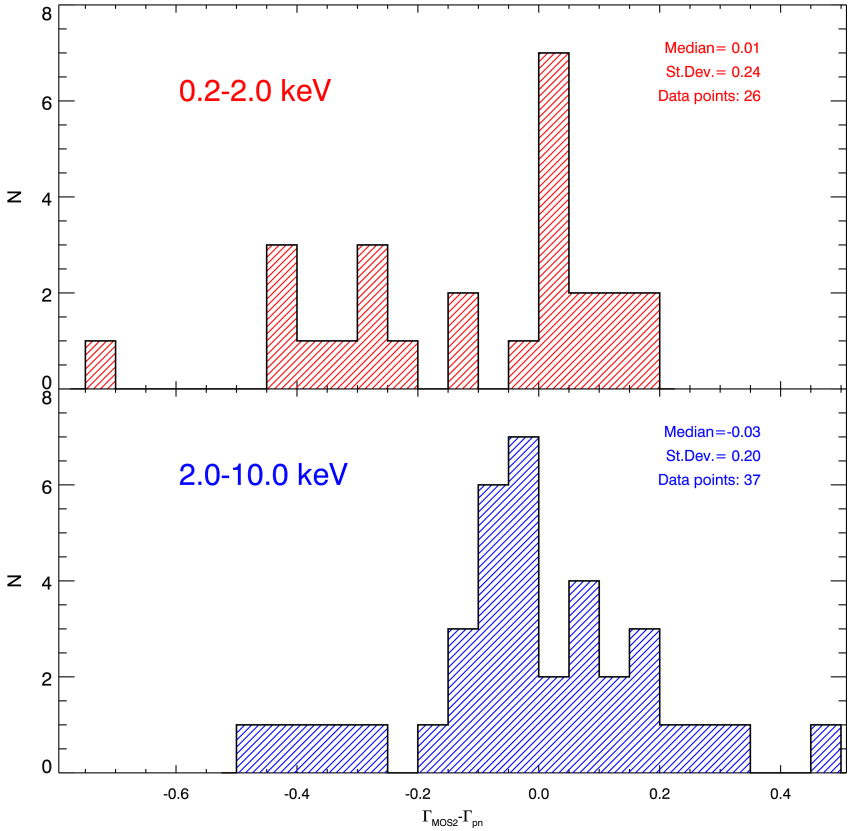
Public XRT



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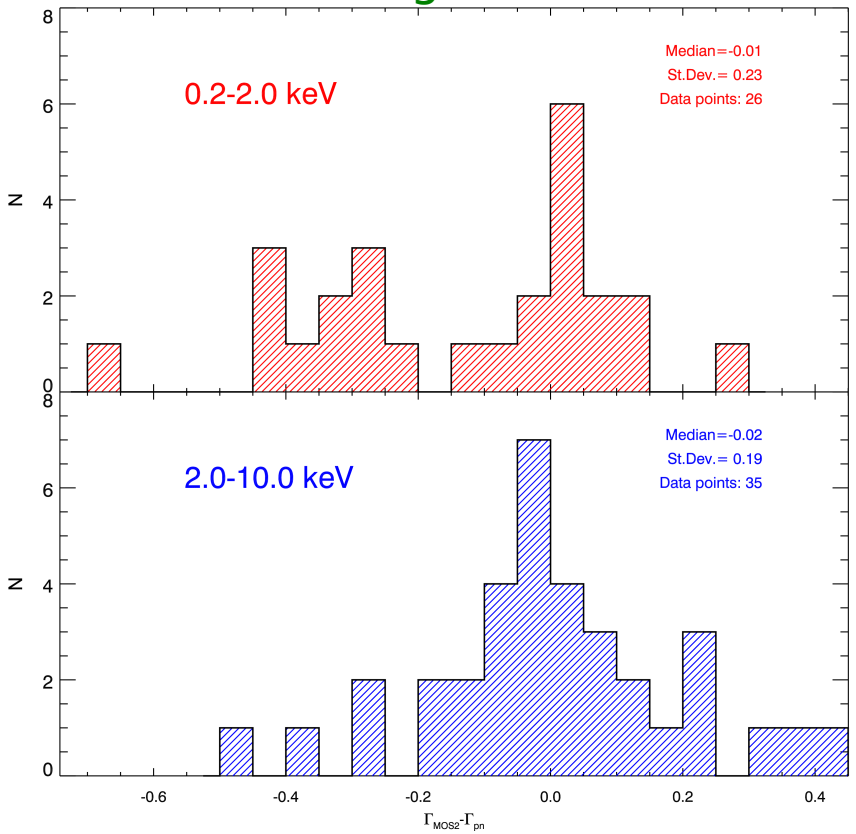

Conclusions

- We have presented a working hypothesis on how to improve the EPIC cross-calibration in the high-energy band: **adjusting the 2.5-8 keV XRT effective area on the basis of the average cross-calibration status** (as measured on the XCAL blazars)
- The proposed adjustment yields a substantial improvement of the MOS/PN flux ratios on an independent sample of on-axis, non piled-up non-thermal, 2XMM sources
- The MOS vs. PN high-energy spectral shape improves as well on the XCAL blazars sample with the "fudged XRT"
- The impact on the galaxy cluster sample is far less clear (cf. *talk by J.Nevavalinen*)
- The choice of the PN XRT optics as reference is, in principle, arbitrary. Should we consider the spectral impact on a wider (i.e., IACHEC) context?
- The cross-calibration status is *dependent on the PSF choice* (primarily below 2.5 keV) ⇨ cross-calibration comparisons require a common choice of SAS version and `XRT*_PSF` CCFs
- Next step: "de-structuring" the spectral fits on a small XCAL-blazar and galaxy cluster sub-sample during the cross-calibration Workshop, Thursday March 8, 10:00.