EPIC Calibration

Michael Smith, on behalf of XMM-SOC and Instrument Teams

21st XMM-Newton Users' Group Meeting, ESAC, 17 June 2020

Outline

1. Status of EPIC calibration related to the Users' Group resolutions and recommendations

2. Additional EPIC calibration activities

2019 UG recommendations

Recommendation 2019-05-08/02: The UG strongly recommends to continue the ongoing efforts to cross-calibrate the responses between the XMM-Newton X-ray cameras and spectrometers. In addition, the UG also strongly recommends to continue the ongoing efforts to cross-calibrate the XMM-Newton EPIC detectors with the NuSTAR detectors to resolve the current discrepancies between the two different observatories in inferred spectral shape and normalizations.

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Update of the CORRAREA correction

CORRAREA: Empirical correction of the MOS-to-PN Aeff

- Introduced in 2014
- Based on a sample of 46 bright non-piled-up on-axis sources
- 0.7 -7 keV residuals of MOS v best fit model to the stacked PN data
- MOS-to-PN residual ratios fit with correction functions
- Correction is applied to the ARF:

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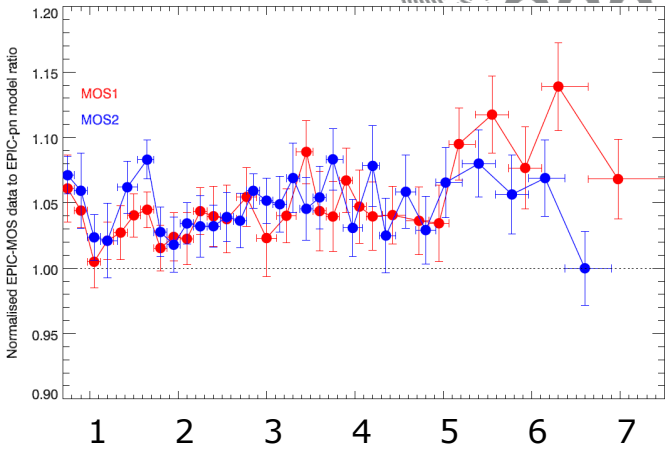
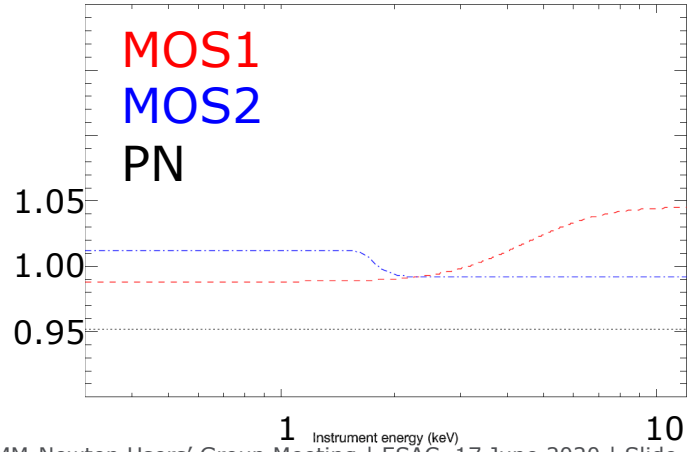


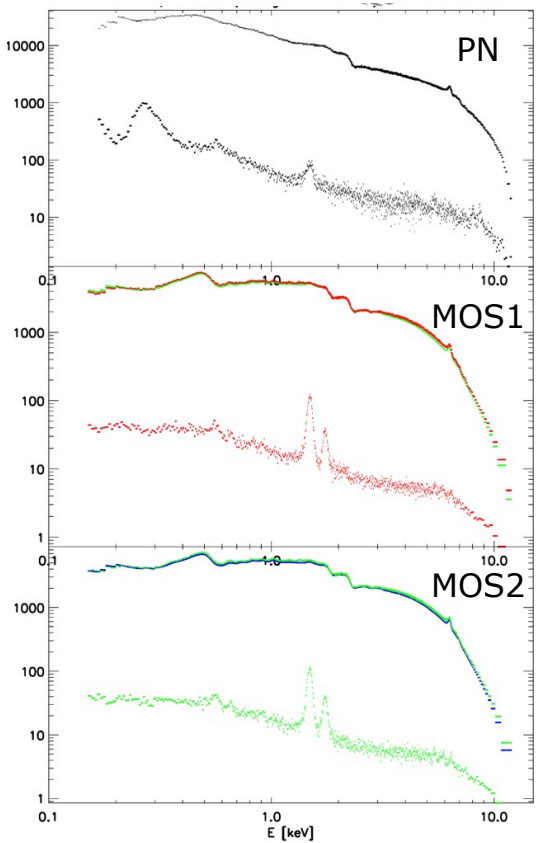


Update of the CORRAREA correction

A recalibration of the **CORRAREA** correction has been on-going:

- Combined effort of IAAT and SOC
- Larger source sample (262 observations)
- Additional instrument modes (LW, SW) and filters (Thick)
- Revised screening: background selections, pile-up evaluation
- Fit-and-stack (previously stack-and-fit)
- Largely automated pipeline from data reduction to spectral and residual modelling
- Extend modelling to full energy band

Stacked spectra (cts/bin)



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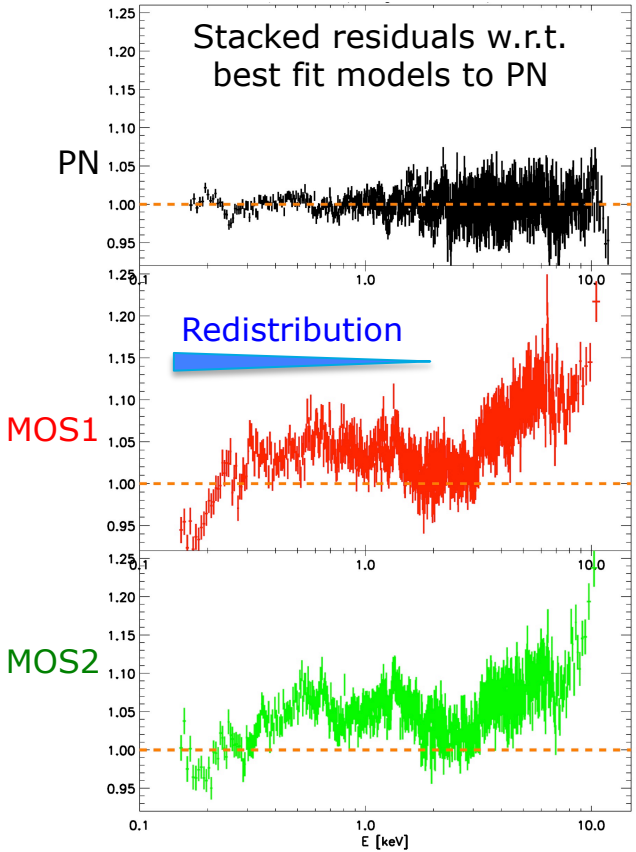


MOS-to-PN residuals:

> 2 keV: likely related to A_{eff}

< 2 keV: combination of A_{eff} and redistribution

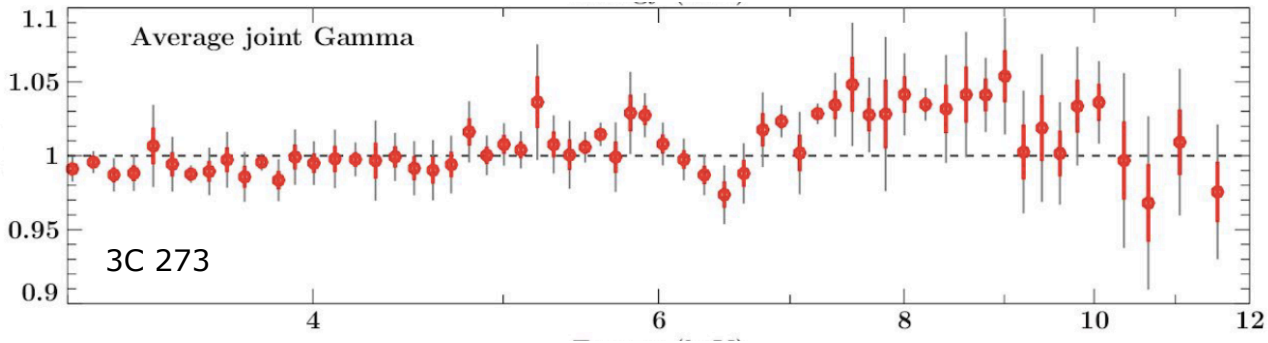
Empirical A_{eff} correction should not introduce features in spectra

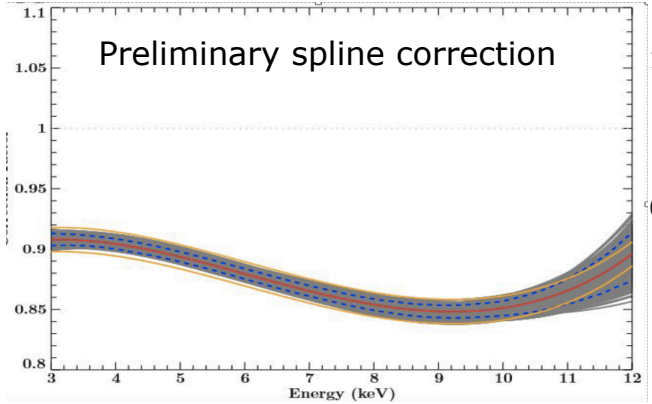
PN-NuSTAR cross-calibration

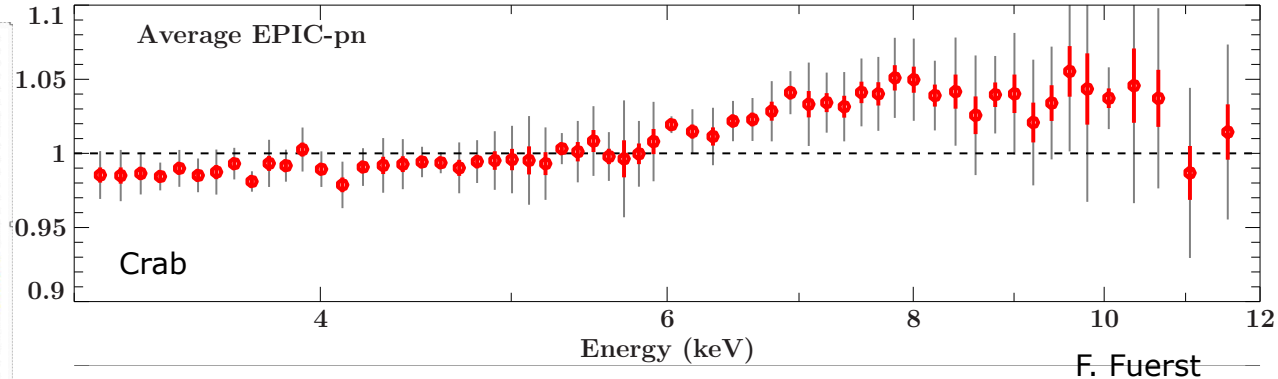
Spectral comparison between XMM (PN) and NuSTAR using simultaneous observations of:

- 3C 273 (5 observations)
- Crab (9 observations)
- AGN sample (30 observations)
- Additional problematic sources

Average ratios w.r.t. joint PN-NuSTAR fit







F. Fuerst

PN-NuSTAR cross-calibration

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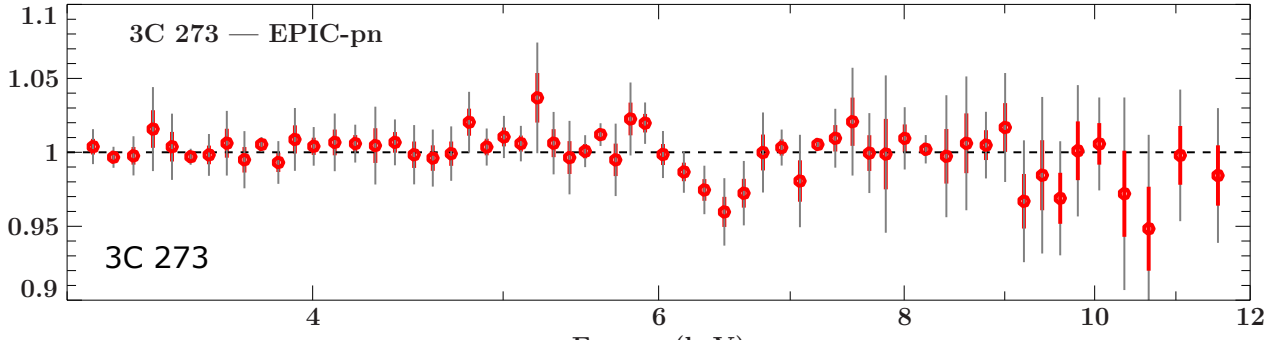
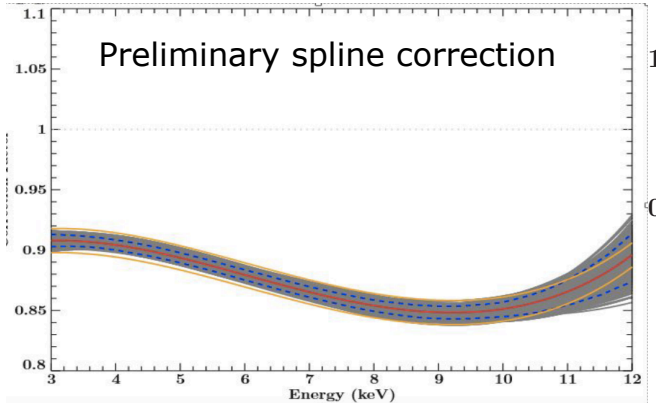
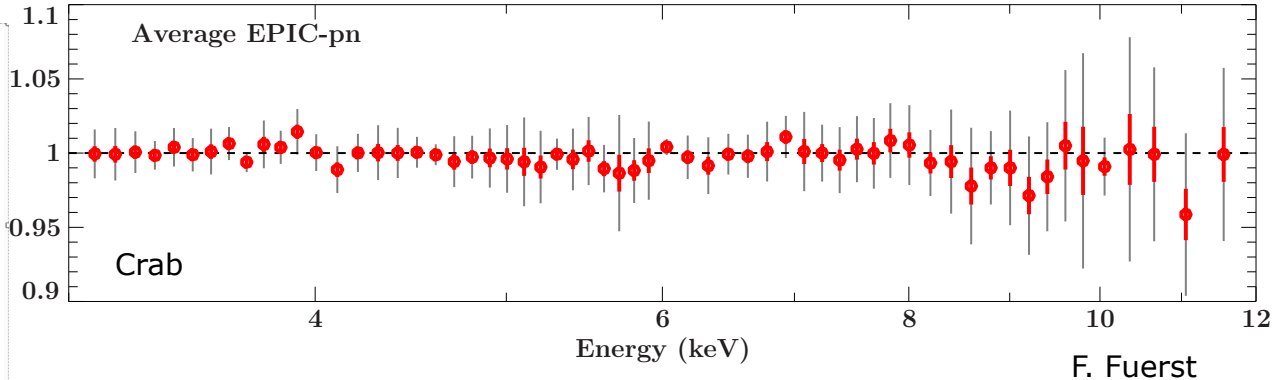
With Aeff correction applied







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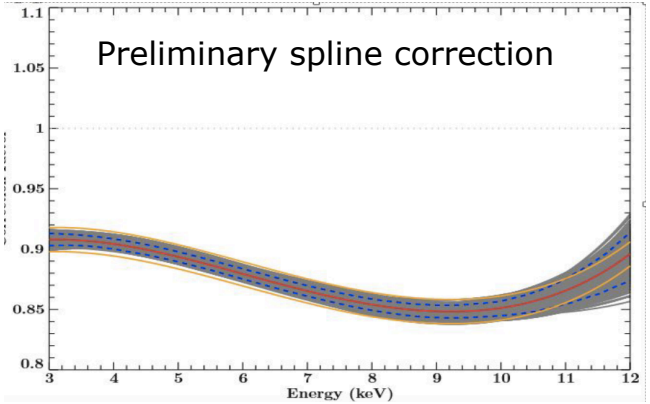
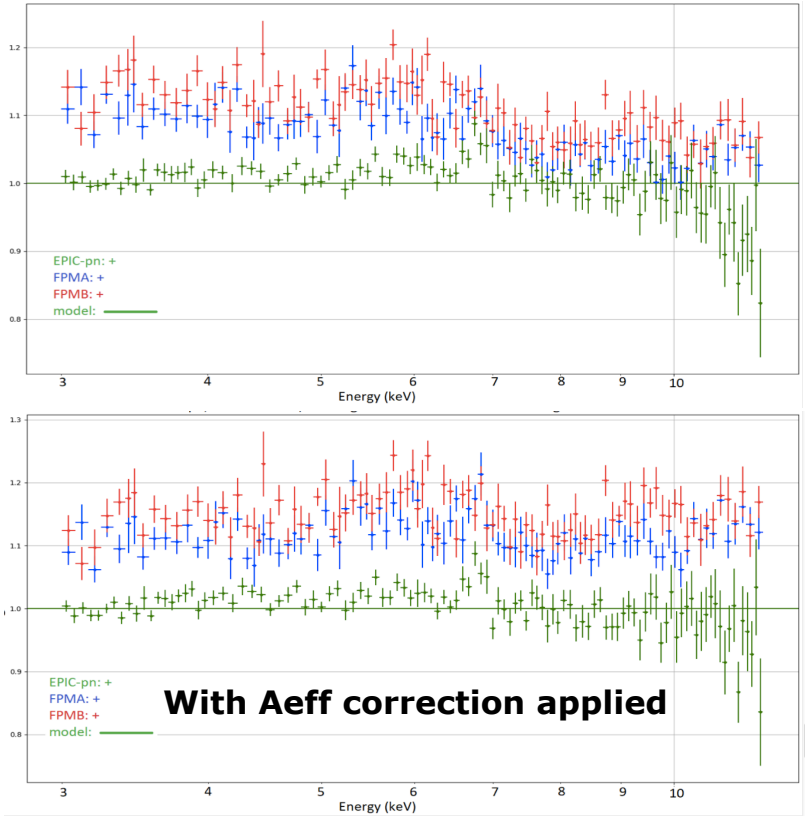


Average NuSTAR ratios w.r.t. PN fit



FPMA
FPMB
PN

A. Joyce

2019 UG recommendations

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Rate-dependent PHA correction

PN Timing and Burst mode energy scale shows a dependency on rate of shifted charge

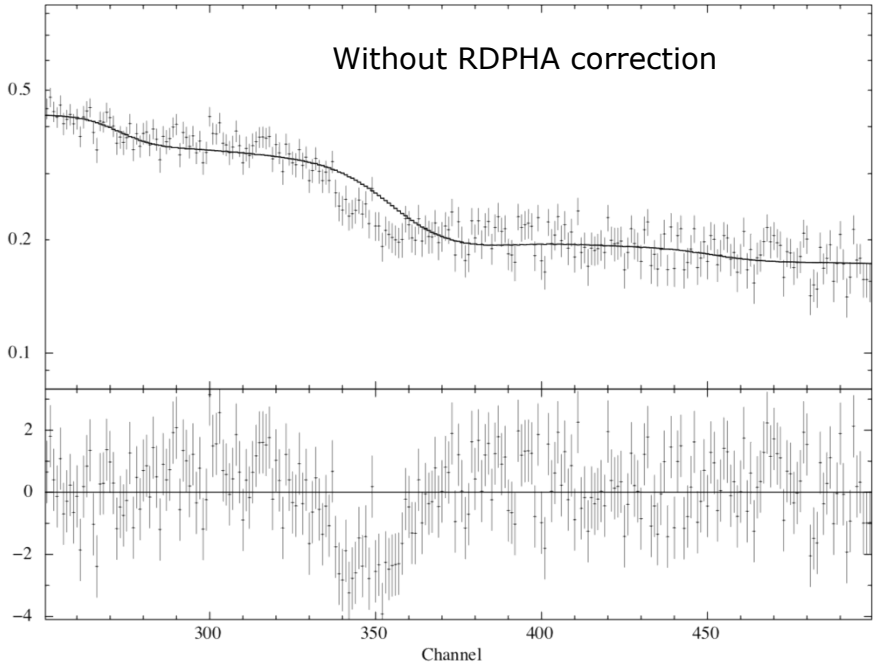
Corrected through the RDPHA correction

Calibrated at the Si K, Au M and Au L-edges

Timing mode RDPHA correction already available since 2013 (updated in 2019)

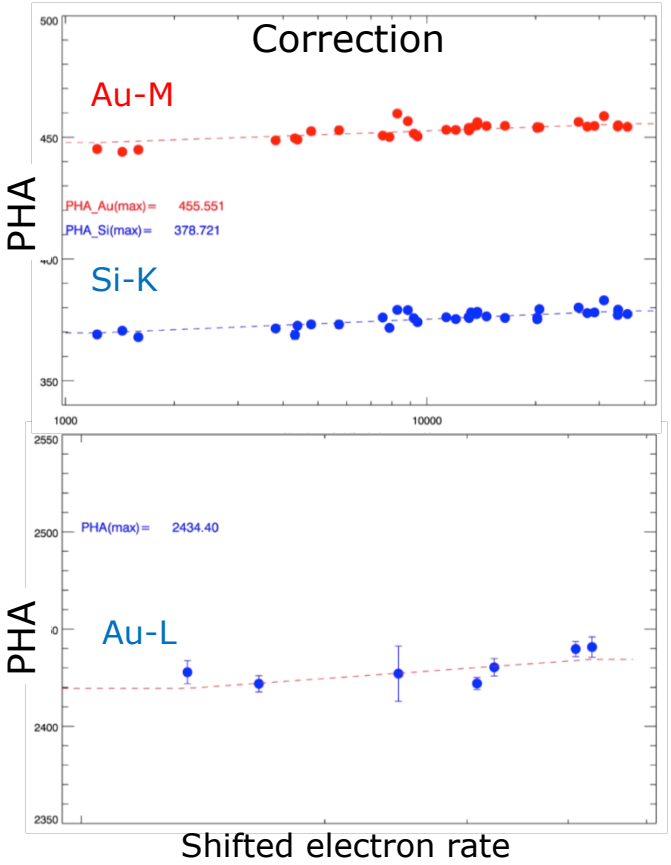
Burst mode RDPHA already presented at 2019 Users' Group meeting – was in validation stage

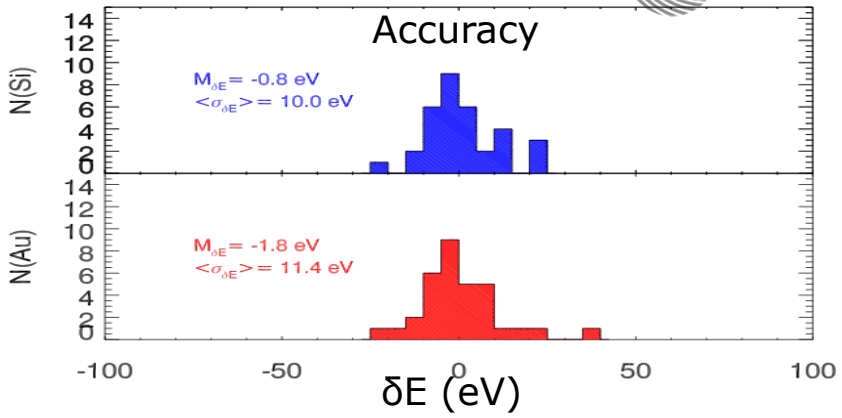
Burst mode RDPHA correction requires s/w change. Will be available as of SAS 19 (autumn 2020).



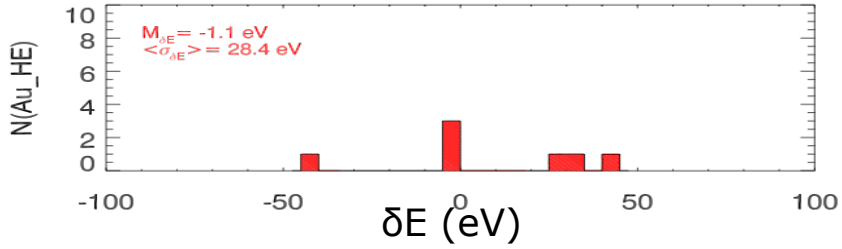
S. Migliari

Rate-dependent PHA correction





at ~2 keV: average systematics ~0.6%, tail to 40 eV (2%)



at ~12 keV: average systematics ~0.2%, tail to 50 eV (0.4%)

Rate-dependent PHA correction

Current RDPHA implementation uses a global rate of shifted charge.

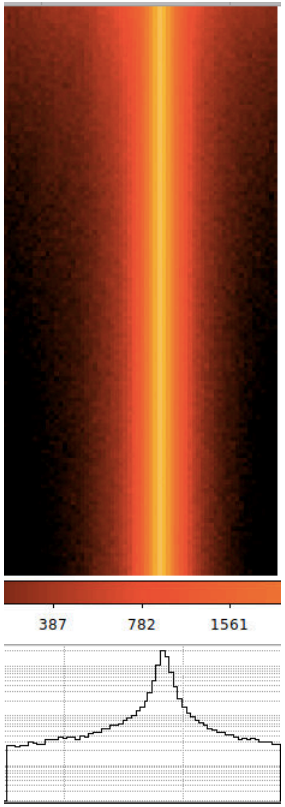
Does not take into account column dependency of the rate

-> blurring of energy scale across PSF

Implementation of column-dependent rate currently underway:

- Validation of rate dependency for wider range of rates
- Software change

Foreseen for SAS 20 (mid 2021)



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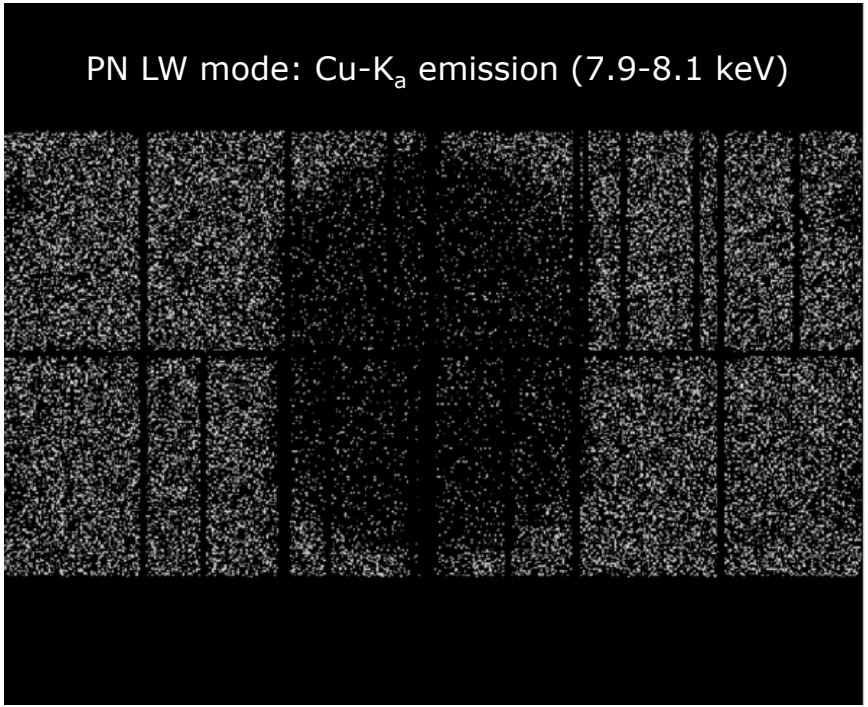
PN LW mode long-term CTI correction

PN LTCTI correction derived from:
- CalClosed exposures (Al K and Mn K)
- Suitable science exposures (Fe K) -> SW mode

For LW mode: too few of either for independent LTCTI derivation

Resort to use of fluorescent Cu Kα emission:
- Presented at last UG meeting
- Mentioned that "Cu hole" is problematic, esp. for energy scale @ B/S

Recent LW mode LTCTI recalibration:
- For Cu-Kα derive a per-quadrant LTCTI correction
- Drop the Mn Kα calibration point (derived from FF mode data)

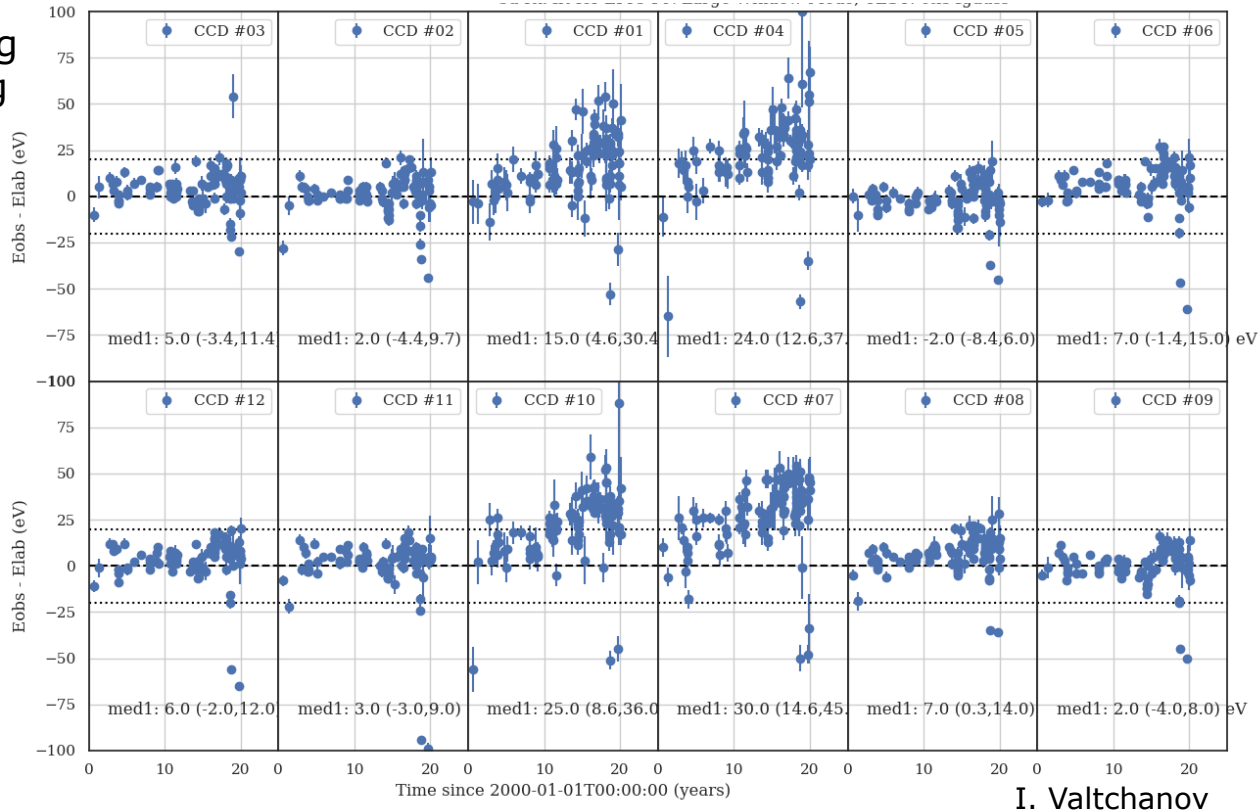


PN LW mode long-term CTI correction

Corrected energies at Cu Kα using the per-quadrant LTCTI modelling

Data in central CCDs are mainly OoT events

Some outliers clustered around ~ 2018 - 2019

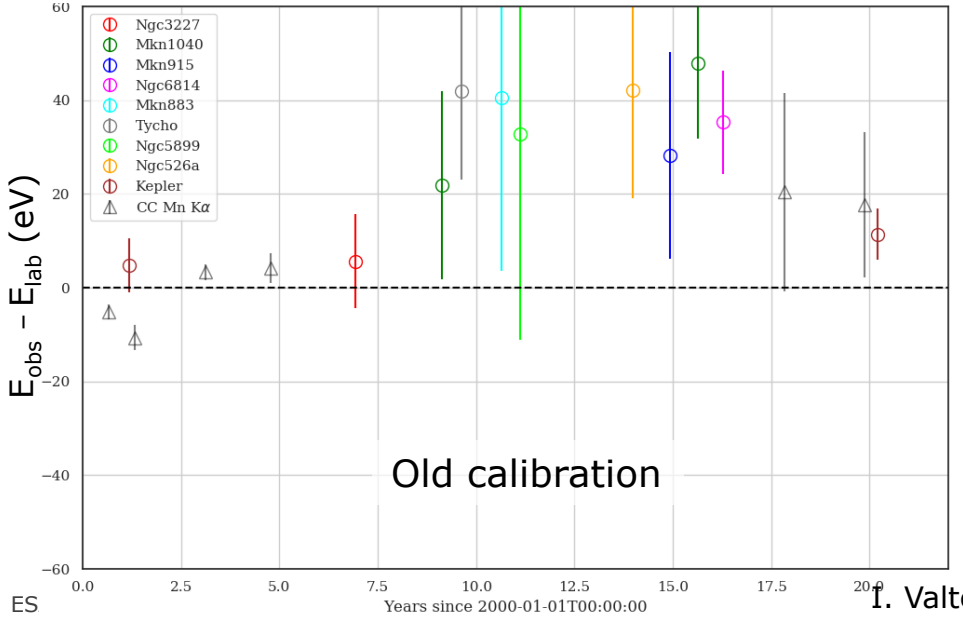


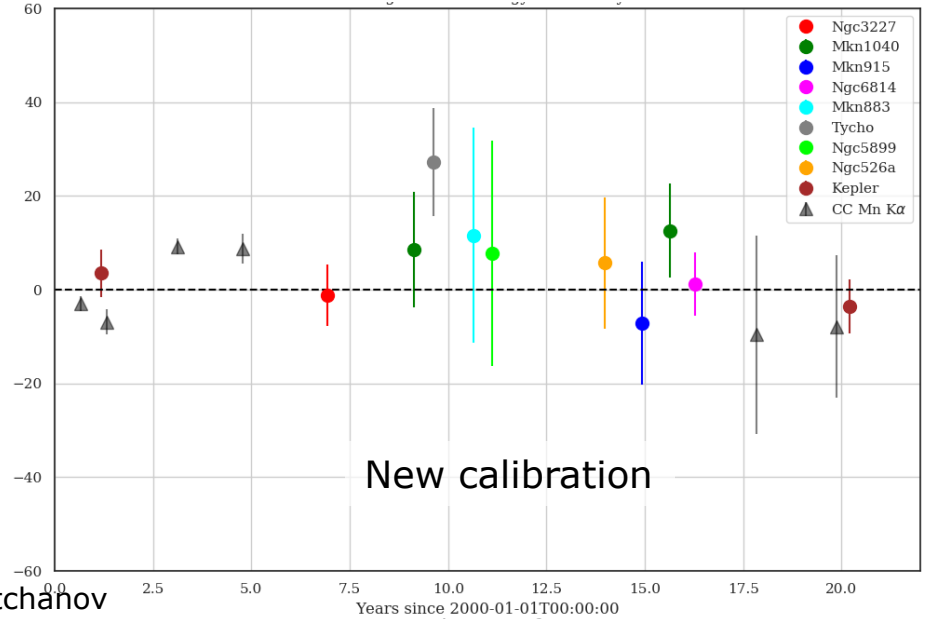
I. Valtchanov

PN LW mode long-term CTI correction

Corrected Mn Kα and Fe Kα energies at B/S, using the per-quadrant LTCTI modelling:

Improvement in general, esp. for the Fe Kα energy reconstruction





Additional EPIC calibration activities

EPIC PN empirical RMF modelling (K. Dennerl, MPE):
- So far work has concentrated on low E response, for SW mode data
- Expand beyond 1.7 keV, include other modes, epochs, spatial regions
- Adapt SAS and calibration products for RMF description

Spatial and temporal refinement of the PN energy scale (Sanders et al. A&A 633, 2020): increased accuracy to ~ 150 km/s (from ~ 550 km/s) @ Fe K
- Aim is to implement this as calibration product (in collaboration with the MPE group)
- Currently evaluating s/w requirements

Off-axis flux calibration:
Calibration issues reported, e.g.:
- Matteos et al., A&A 496 (2009)
- Lusso, Astron. Nachr. 340, 4 (2019)

Additional EPIC calibration activities

Off-axis flux calibration (*cont.*):

Analysis based on 2XMM / 3XMM EPIC flux comparisons:

- Show radial dependency of flux ratios
- Also, possible azimuthal dependency

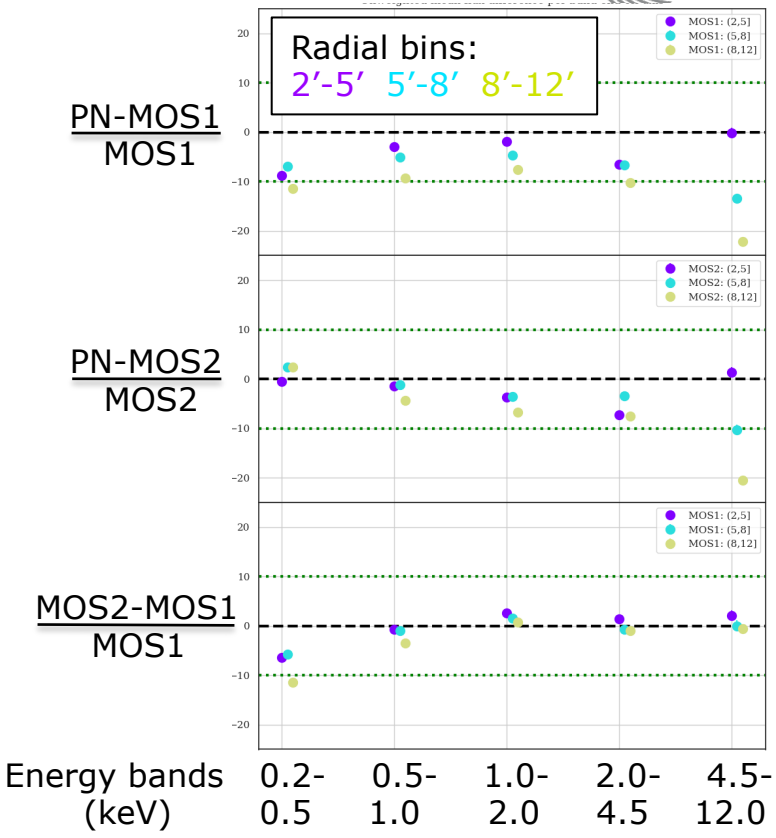
⇒ Vignetting calibration?

Results were reproduced with 4XMM, however interpretation not straightforward due to:

- Count rates – to – flux conversion
- Background
- Source variability

Investigation ongoing:

- Look at individual sources
- Revisit archival raster scan data



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BU mode RDPHA: available in SAS 19 (autumn 2020)
Column dependent correction: foreseen SAS 20 (mid 2021)

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Awaiting release