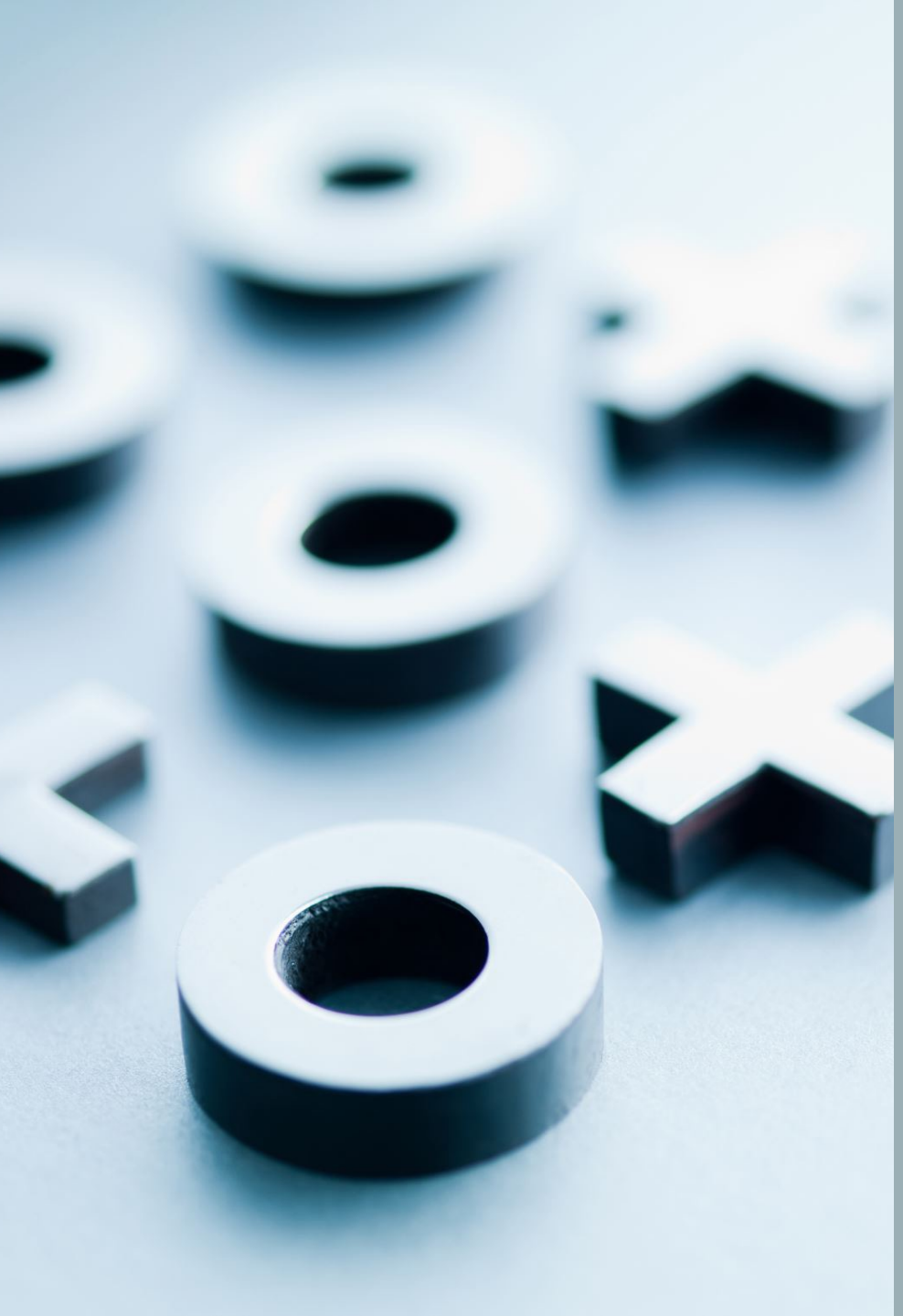

EMPIRICAL CROSS-CALIBRATION CORRECTIONS FOR XMM-NEWTON

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XMM-NEWTON CROSS-INSTRUMENT EMPIRICAL CORRECTIONS

XMM-Newton cross-instrument empirical corrections:

- RGS-to-PN rectification factors (since 2010)
- MOS-to-PN CORRAREA effective area correction (since 2014)
- PN-to-NuSTAR effective area correction (since 2022)

RGS-PN RECTIFICATION

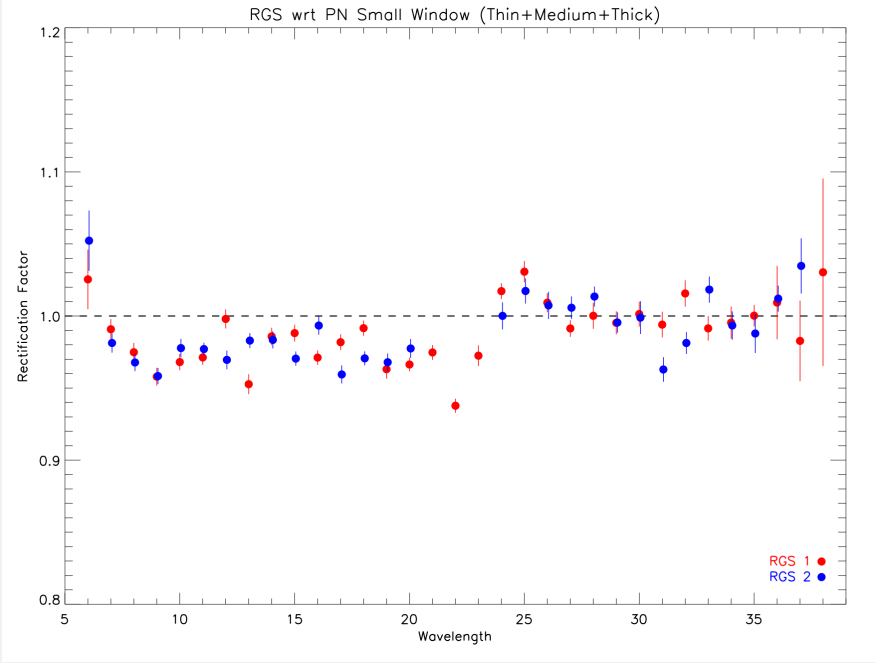
RGS-pn rectification is an empirical correction to eliminate significant systematic model inconsistencies between RGS and EPIC spectra

Implementation driven by user community's desire to have an option to allow joint fitting of pn and RGS

Originally implemented end of 2010, following UG recommendation in 2009:

https://xmm-tools.cosmos.esa.int/external/xmm_user_support/usersgroup/20090506/minutes.pdf

https://xmmweb.esac.esa.int/docs/documents/CAL-SRN-0269-2-0.pdf



	$7.5 < \lambda(\text{Å}) \leq 23.5$	$23.5 < \lambda(\text{Å}) \leq 37.5$
RGS1	0.9716	1.0021
RGS2	0.9753	1.0028

Between 6Å-7Å

RGS1	1.052
RGS2	1.065

RGS-PN RECTIFICATION

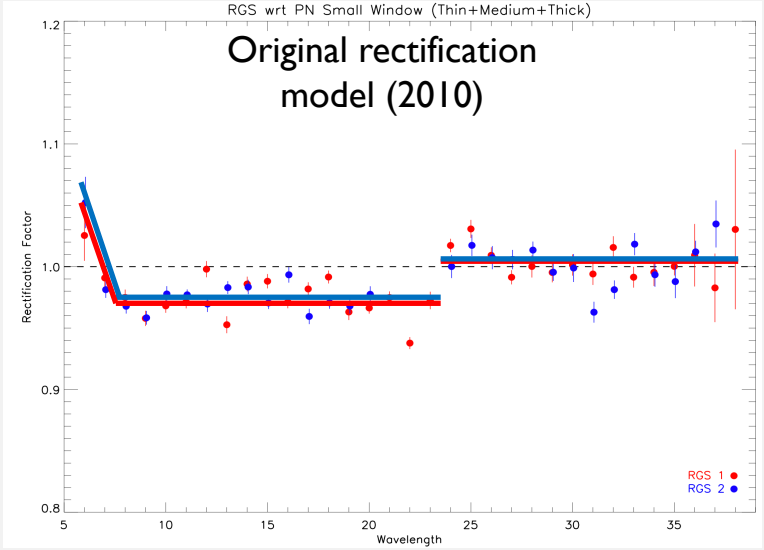
Derivation:

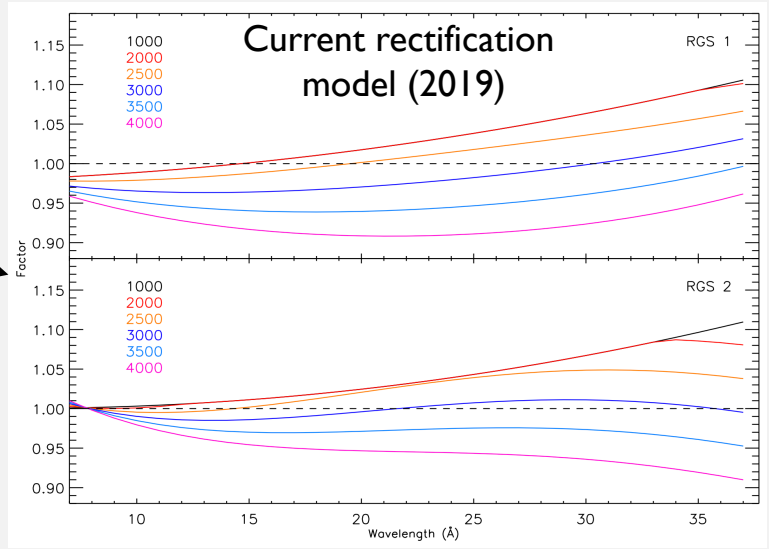
- based on a sample of observations of bright blazars (mainly PKS 2155-304, 3C 273)
- a set of wavelength dependent rectification factors is applied to the RGS model in simultaneous RGS/pn fits
- best-fit values of the rectification factors show discrepancies between instruments, which are then suitably modelled

Rectification was initially modelled as a step around the O-edge (23.5 Å, 0.5 keV)

Has been twice updated (2015 and 2019) – is now a more complex function with time dependency due to time-dependent in effective area.

https://xmmweb.esac.esa.int/docs/documents/CAL-SRN-0328-1-1.pdf
https://xmmweb.esac.esa.int/docs/documents/CAL-SRN-0372-1-0.pdf





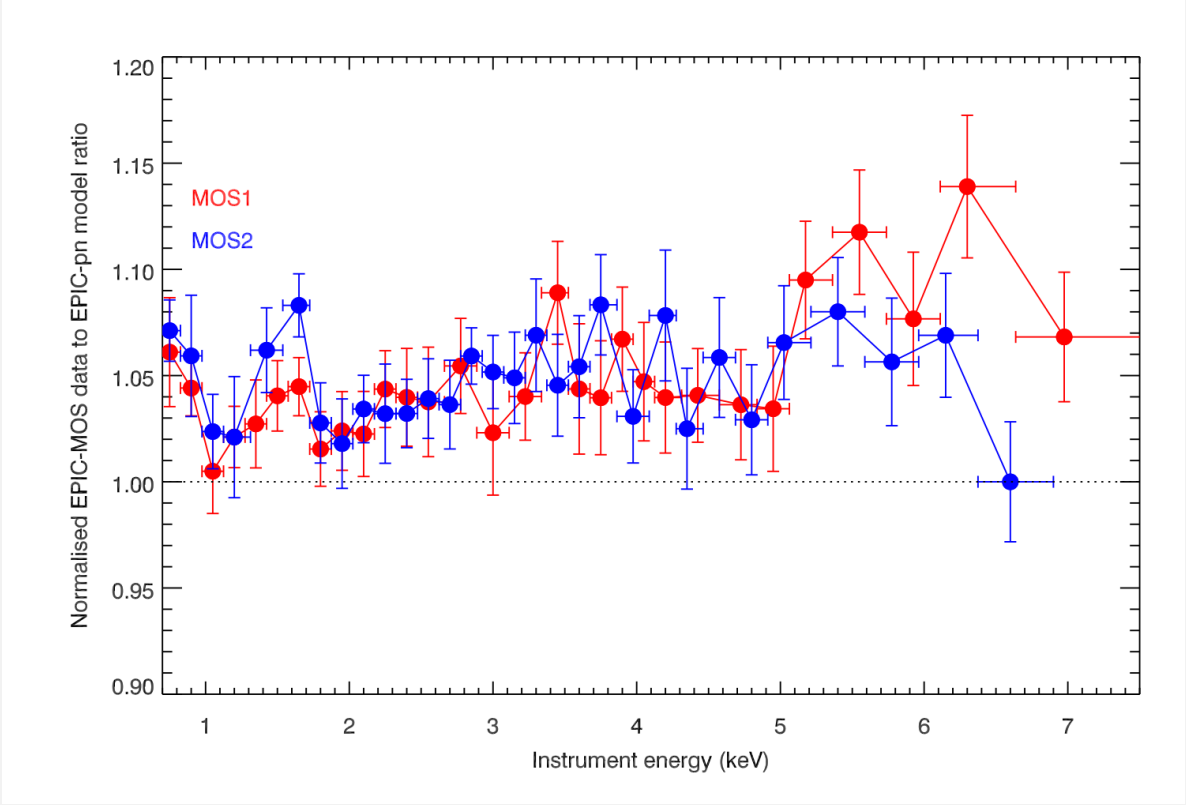
MOS-PN CORRAREA

CORRAREA is an empirical MOS-to-pn effective area correction of residual calibration issues affecting instrumental throughput

Not applied by default – must be explicitly invoked by user: `applyxcaladjustment=yes`.

Originally released in 2014, updated in 2021

https://xmmweb.esac.esa.int/docs/documents/CAL-SRN-0321-1-2.pdf



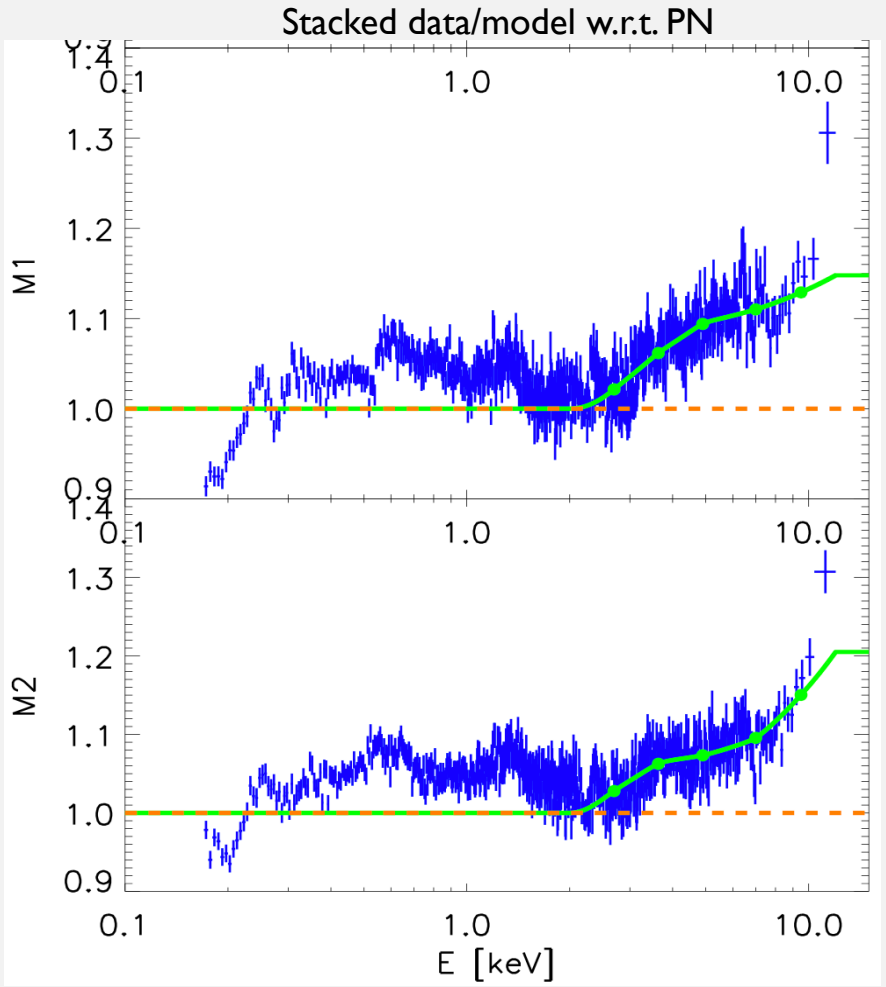
MOS-PN CORRAREA

Derivation:

- Based on a sample of ~ 120 non-piled-up on-axis point sources
- MOS effective area curves above 2.0 keV modified by a multiplicative spline function
- Spline node amplitudes derived by simultaneous fit to best-fit PN spectral models, in order to minimise MOS stacked data-to-model ratios

No correction below 2.0 keV, where calibration discrepancies will also be redistribution related.

https://xmmweb.esac.esa.int/docs/documents/CAL-SRN-0382-1-1.pdf



PN-NUSTAR CROSS-CALIBRATION

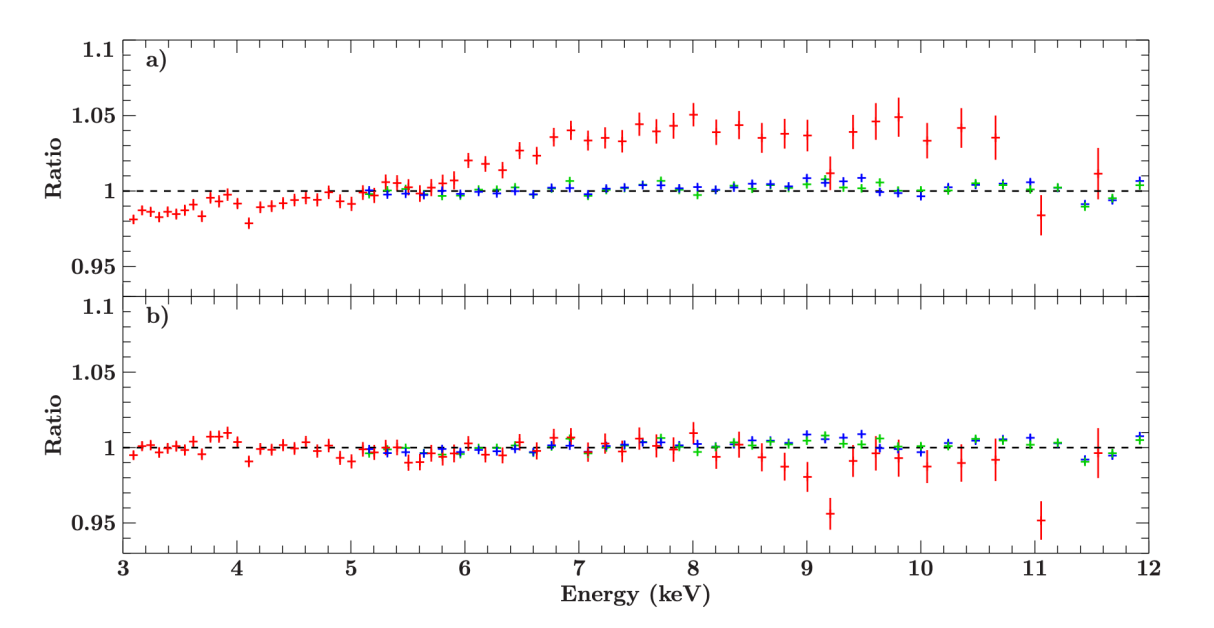
Triggered by large number of simultaneous observations between XMM-Newton.

Discrepancies in flux and photon-index (spectral slope) present

Corrections recommended by the UG.

Not applied by default, user must set the keyword in arfgen: `applyabsfluxcorr=yes`

Published in 2022.



https://xmmweb.esac.esa.int/docs/documents/CAL-SRN-0388-1-4.pdf

PN-NUSTAR CROSS-CALIBRATION

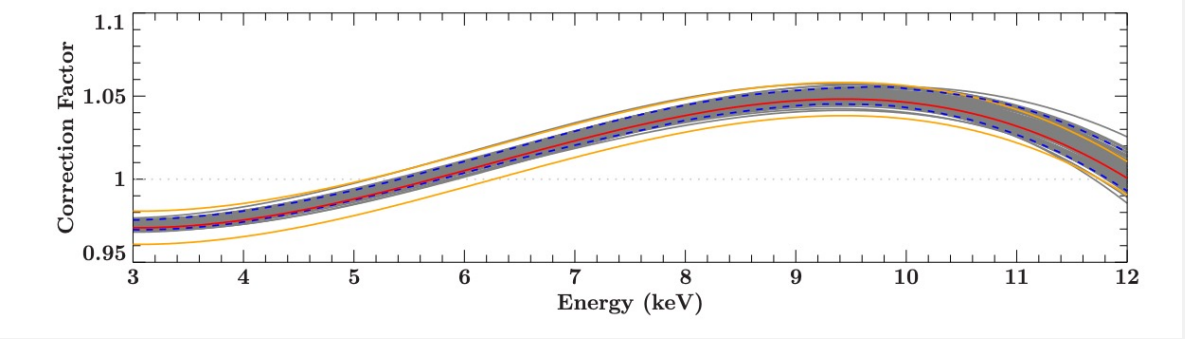
Based on observations of the Crab nebula (burst mode in pn).

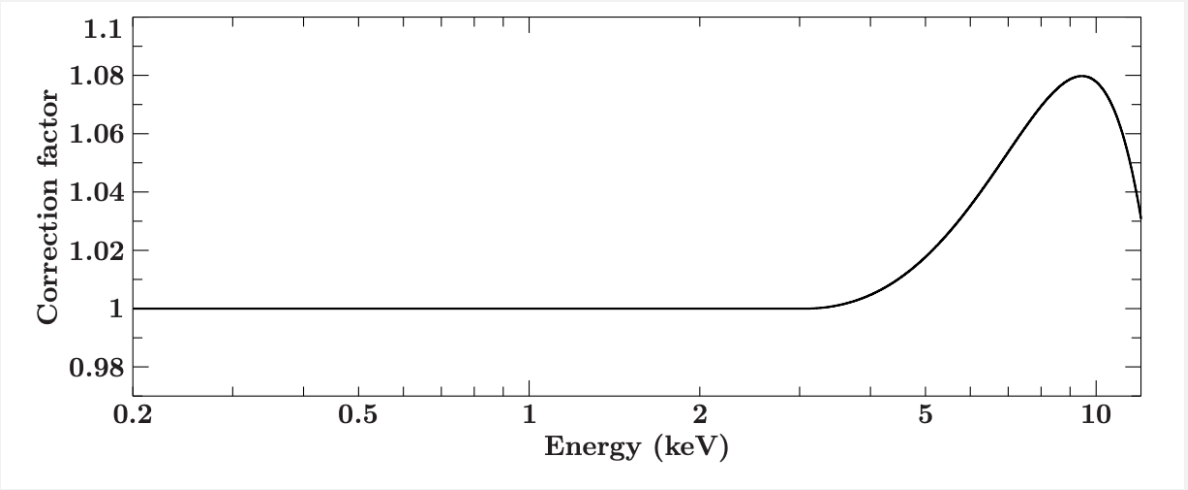
Tested with 3C273 cross-calibration observations and sample of non piled-up AGN in Small Window and Full Frame mode.

Splie correction to correct for the "bump".

No correction to absolute flux difference (factor fixed to 1 at 3keV): normalization cross-calibration is still ~0.82.

https://xmmweb.esac.esa.int/docs/documents/CAL-TN-0230-1-3.pdf





XMM-NEWTON EMPIRICAL CORRECTIONS

RGS-to-pn, MOS-to-pn, and pn-to-NuSTAR empirical corrections depend on

- Calibration of respective instruments
  - As calibration evolves this will entail re-evaluation of empirical corrections
- Details of spectral modelling, e.g.:
  - Data sample
  - Accuracy of assumed physical models
  - Statistical methods employed
- Choice of instrument to correct to
  - Choice of pn as anchor for RGS and MOS is essentially arbitrary – however, practical advantages due to effective area stability and widest band pass
  - Choice of NuSTAR as anchor for pn is based on convincing arguments from the NuSTAR team that their Crab spectrum is correct
- Choice of correction function
  - Some arbitrary choices will need to be made

XMM-NEWTON EMPIRICAL CORRECTIONS

Applying empirical cross-instrument corrections

- will yield a significant improvement in the formal consistency between instrumental spectral parameters
- will emphatically not necessarily result in reduced true systematic errors
- will tie the calibration of instruments together
- nevertheless, depending on the case, may allow better exploitation of the combined data