XMM-Newton Calibration Updates

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10th IACHEC, Beijing

20-23 April 2015

Recent Calibration Files

❖ Astrometry: Time Variable Boresight Update	XMM_BORESIGHT_0024
❖ Update of the RGS contamination correction	RGS1_EFFAREACORR_0009, RGS2_EFFAREACORR_0009
❖ Update of the RGS Gain and CTI	RGS1_ADUCONV_0025, RGS1_CTI_0013,
❖ RGS Bad Pixels	RGS2_BADPIX_0033
❖ Update of EPIC MOS Gain and CTI	EMOS1_ADUCONV_0086, EMOS1_CTI_0074, EMOS2_ADUCONV_0087, EMOS2_CTI_0075
❖ Refinement of the EPIC-MOS QE at the Si Edge	EMOS1_QUANTUMEF_0020, EMOS1_QUANTUMEF_0021, EMOS2_QUANTUMEF_0020, EMOS2_QUANTUMEF_0021
	RGS2_ADUCONV_0028, RGS2_CTI_0014
❖ CORRAREA: Estimate of Aeff EPIC Inter-Calibration Uncertainties	XRT1_XAEREAEF_0009, XRT2_XAEREAEF_0010,
❖ Time-Dependent Width of the EPIC-pn Spectral Response	EPN_REDIST_0012
❖ EPIC-pn Long-Term CTI and Energy Scale	EPN_CTI_0045
❖ EPIC MOS HK GTI Selection	EMOS1_HKPARMINT_0011, EMOS2_HKPARMINT_0010
❖ X-ray Loading and Rate-Dependent CTI Correction for EPIC-pn Burst Mode	EPN_REJECT_0008, PN_CTI_0046

November 2014: **SAS13.5 -> SAS 14.0**

Astrometry: Time-Variable Boresight Update

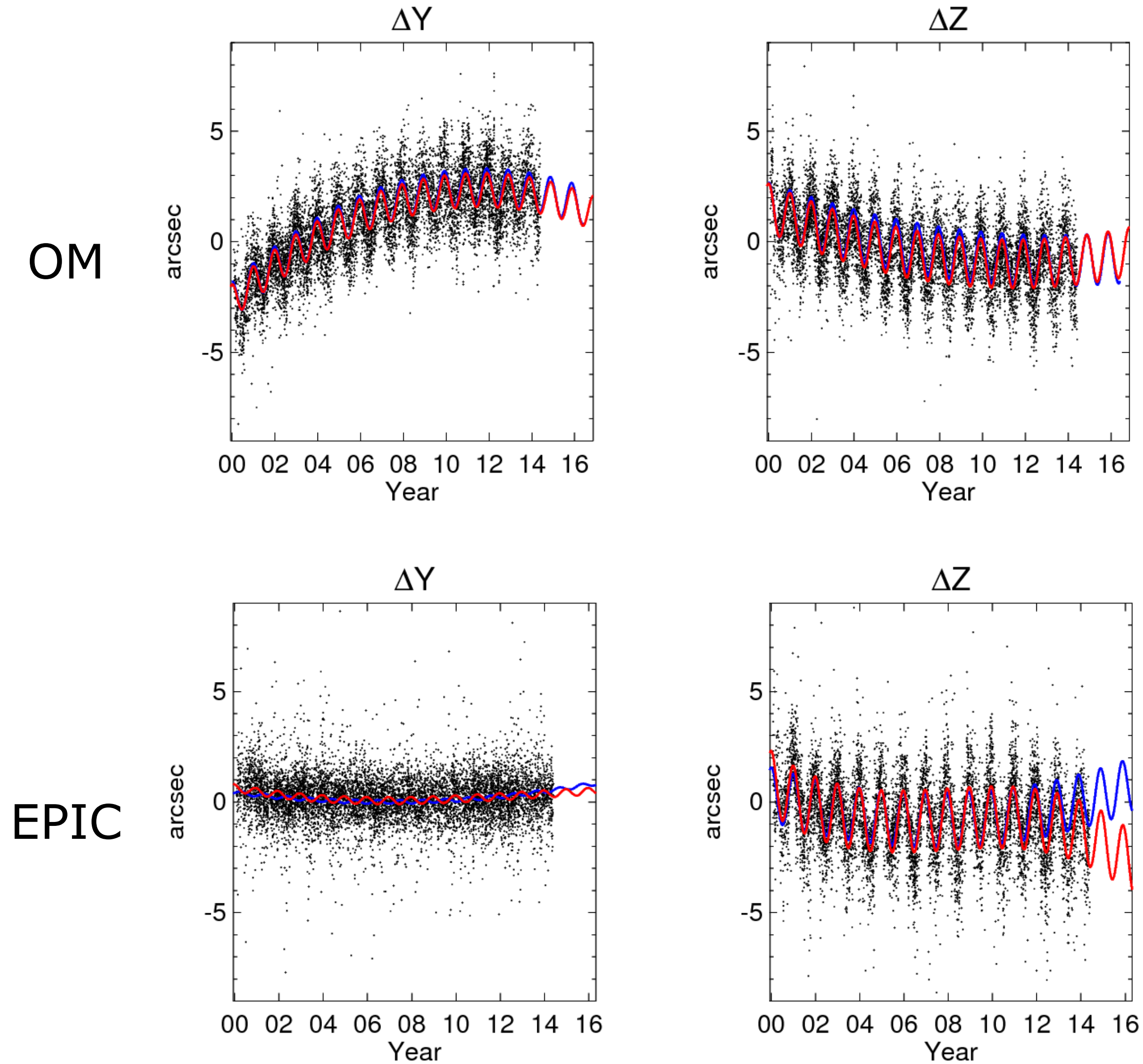
A. Talavera and P. Rodríguez, 2014, XMM-CCF-REL-315

- Time-dependent boresight implemented in 2012 in order to address variability in star-tracker and instrument alignments.

- Recent observations show slight deviations of measured astrometry offsets with respect to model predictions.

- Deviations of the order of:
  - 0.5 arcsec for OM, and
  - 1-2 arcsec for EPIC and RGS

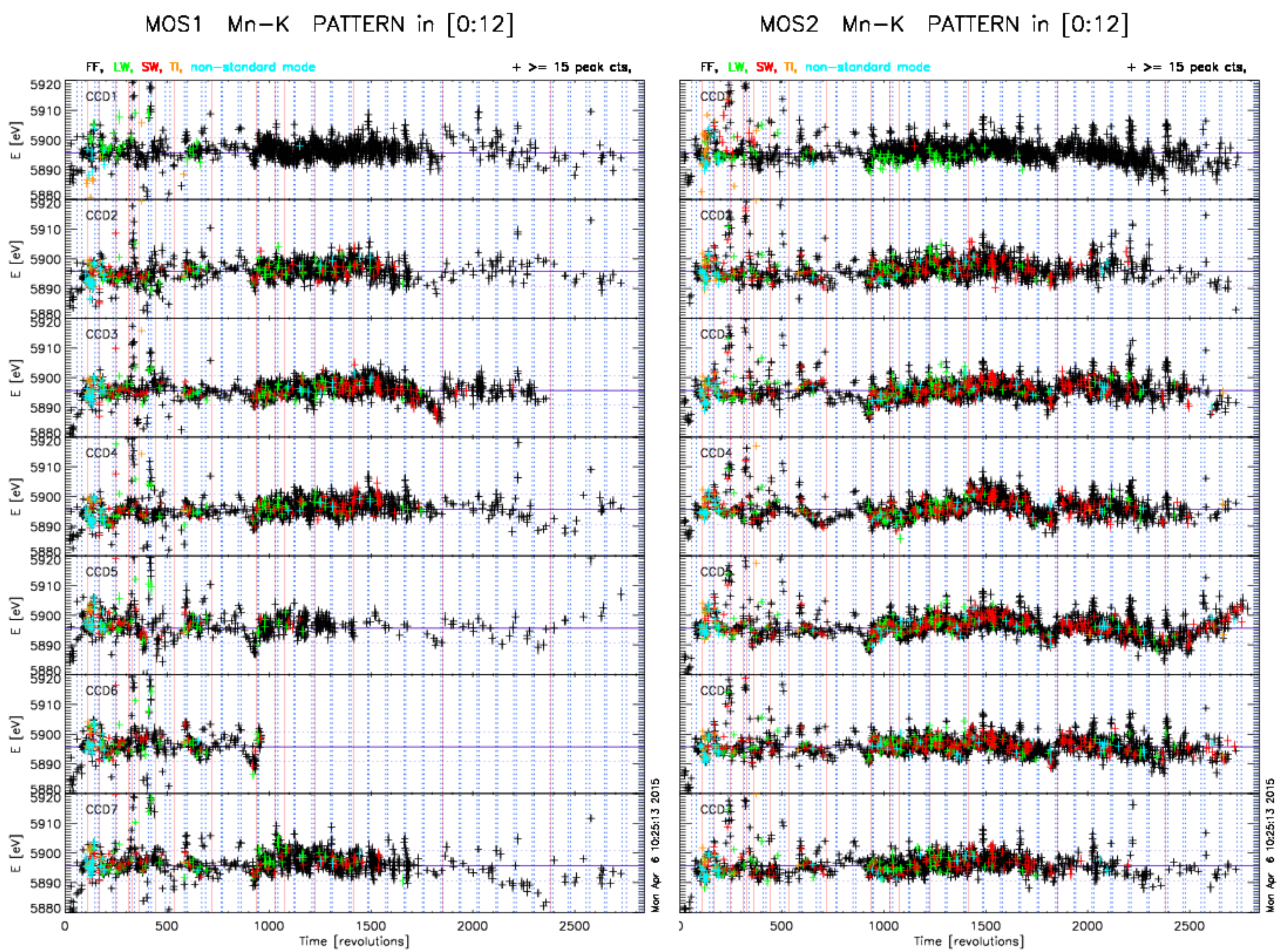
  corrected in new CCF: **`XMM_BORESIGHT_0024`**.



EPIC-MOS: Update of Gain and CTI

M. Stuhlinger, 2014, XMM-CCF-REL-316 / 317

- Updated values of the EPIC-MOS gain and CTI parameters based on recent sets of cal source data.
- Gain and CTI parameters are defined on an epoch-wise basis. The changes affect the most recent epoch.
- Overall, the EPIC-MOS Full Frame mode energy reconstruction accuracy is 5 eV at 2 keV, and within 10 eV elsewhere.

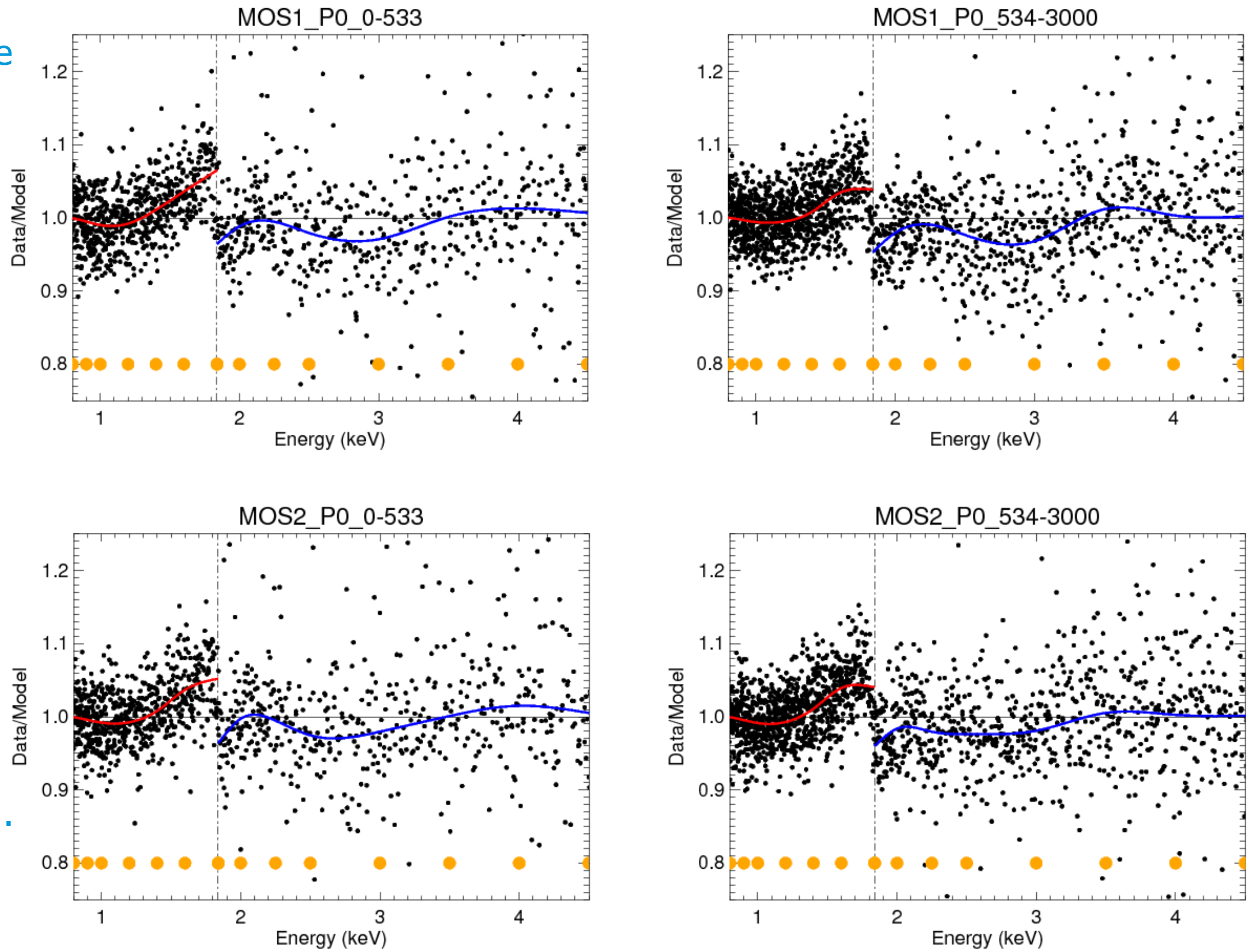


European Space Agency

EPIC-MOS: Refinement of the QE at the Si Edge

S. Sembay, M. Guainazzi, R. Saxton, M. Stuhlinger, 2014, XMM-CCF-REL-318

- Empirical correction driven by reported prominent emission-like feature in EPIC-MOS spectra not seen in EPIC-pn. (e.g. Read et al. 2014 , A&A 564, 75)
- Feature could be caused by residual inaccuracies of the MOS A_{eff} calibration at the Si photoelectric absorption edge.
- Correction derived from targets with featureless spectra in the band of interest, and include blazars and the Vela pulsar.
- Data fit with absorbed powerlaw models in the 0.85 – 4 keV band.
- Data-to-model residuals were stacked, and fit with a spline.



European Space Agency

EPIC-MOS: Refinement of the QE at the Si Edge

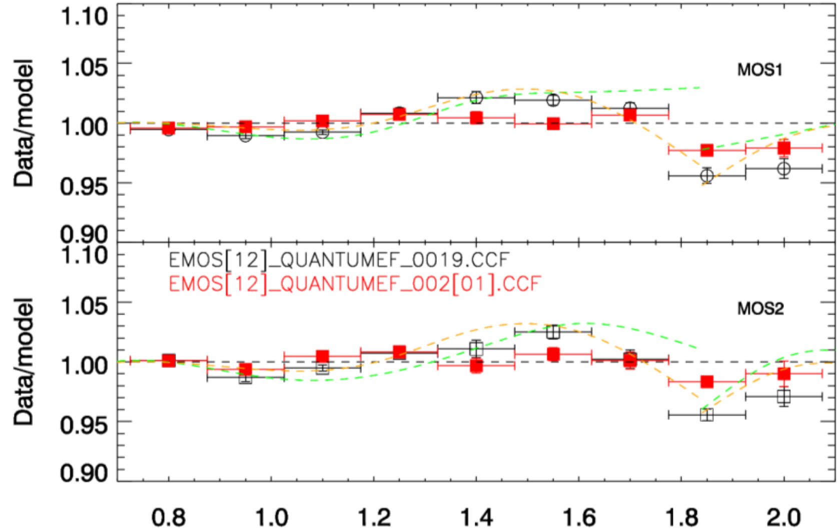
S. Sembay, M. Guainazzi, R. Saxton, M. Stuhlinger, 2014, XMM-CCF-REL-318

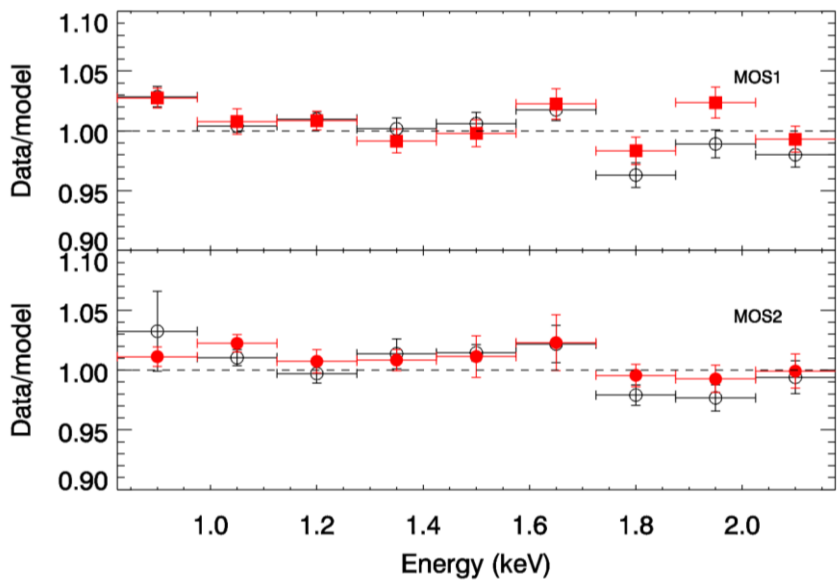
- Resulting spline fits used to empirically adjust the EPIC-MOS quantum efficiency in the 0.8 – 2.2 keV band:

  `EMOS1/2_QUANTUMEF_0020/21`

- Calibration files validated on
  - ✓ a sample of blazars from the XMM-Newton cross calibration database
  - ✓ a sample of non-piled-up on-axis sources

- Residuals around the Si edge reduced from ~ 5% to ~ 2% dynamical range.





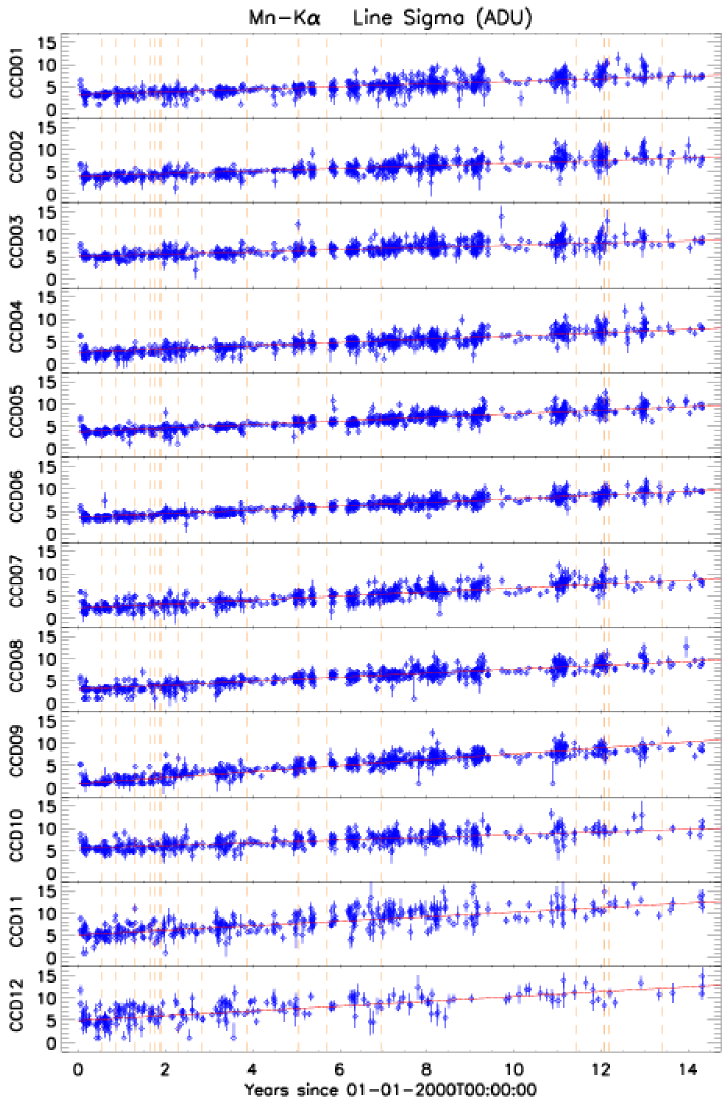
EPIC-pn: Time-Dependent Width of the Response

R. Saxton, F. Haberl, M. Smith, 2014, XMM-CCF-REL-322

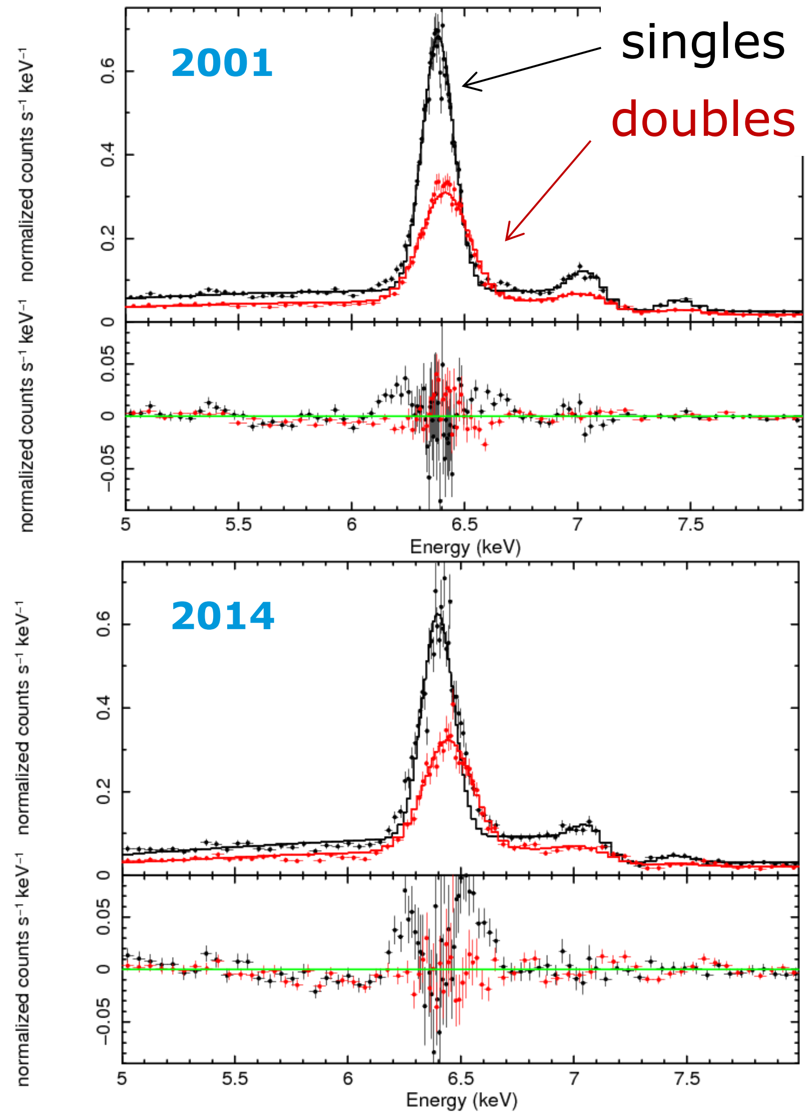
- Analysis of on-board calibration source and celestial sources indicates a gradual widening of the EPIC-pn spectral response, mainly due to the degrading CTE.
- Implementation of a time-dependent width of the response function is implemented in SAS 14.0
- The calibration was mainly based on two on-axis observations of the the Circinus Galaxy in 2001 and 2014.
- New calibration contained in **`EPN_REDIST_0012`**.

EPIC-pn: Time-Dependent Width of the Response

R. Saxton, F. Haberl, M. Smith, 2014, XMM-CCF-REL-322



SAS 13.5



EPIC-pn: Time-Dependent Width of the Response

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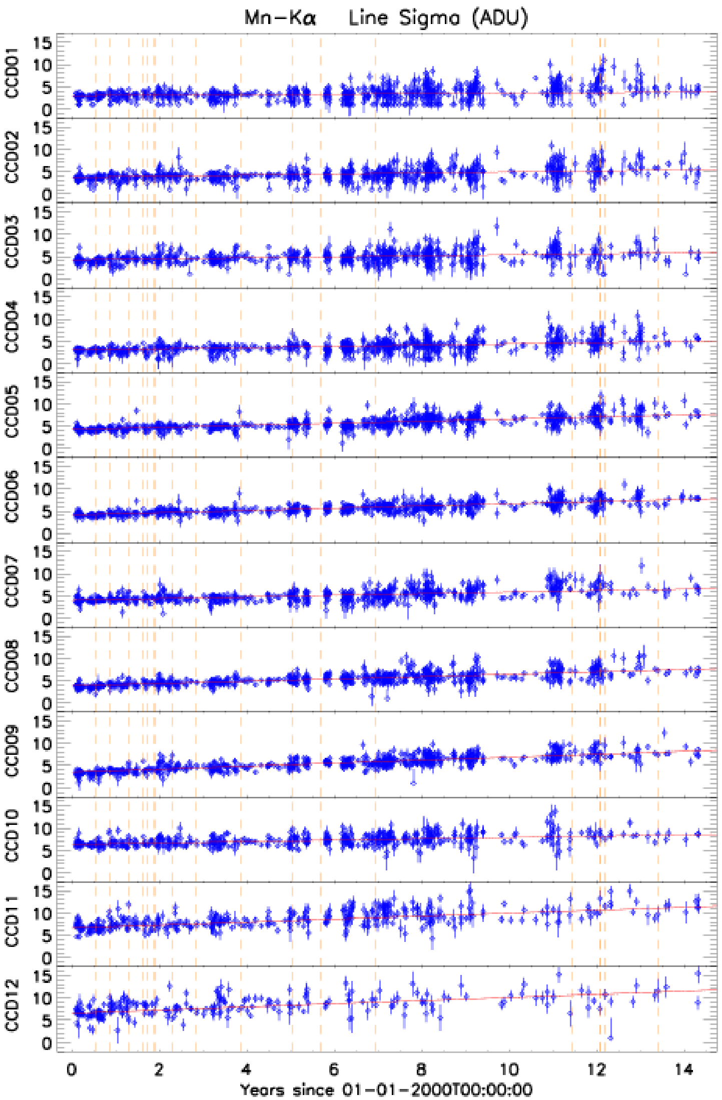
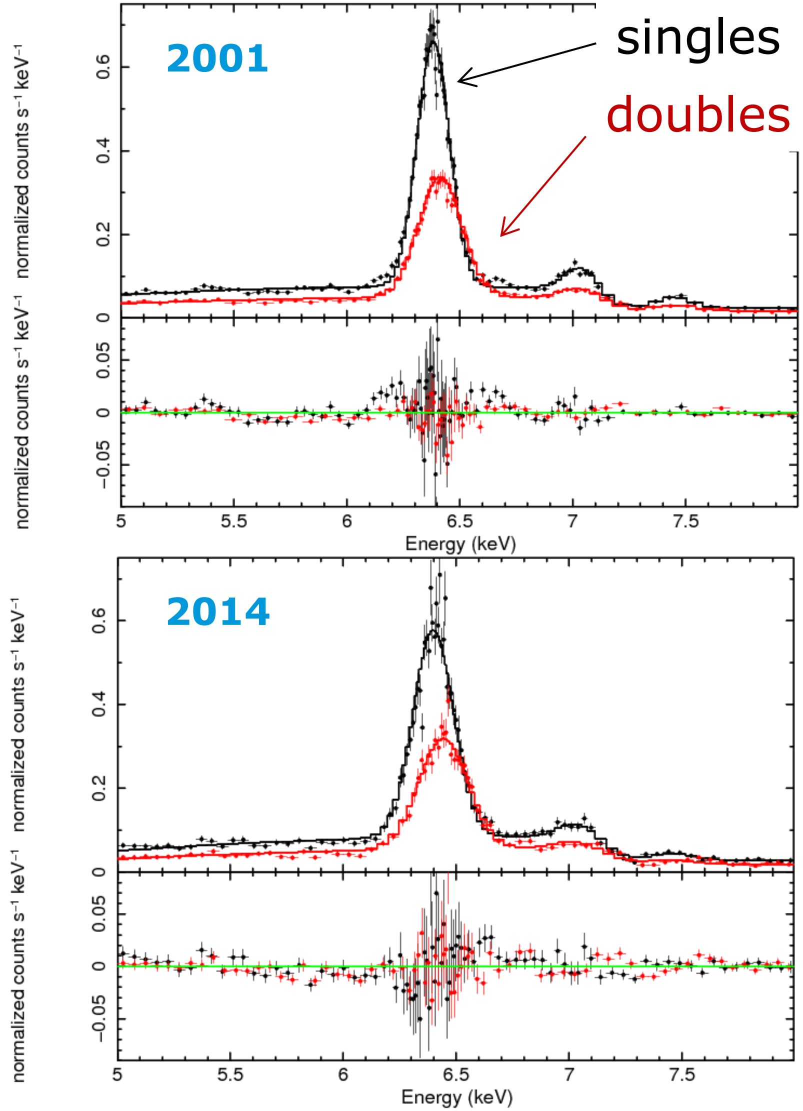


SAS 14.0

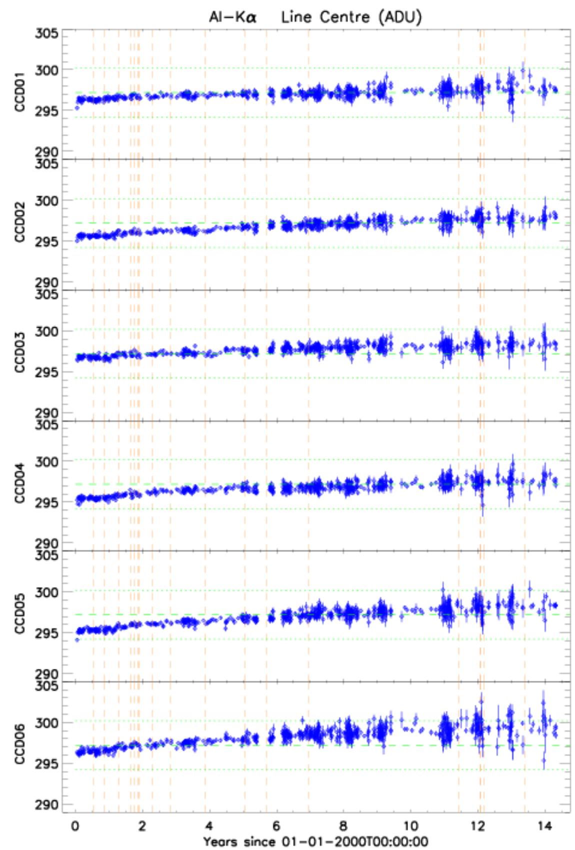


EPIC-pn: Long-Term CTI and Energy Scale

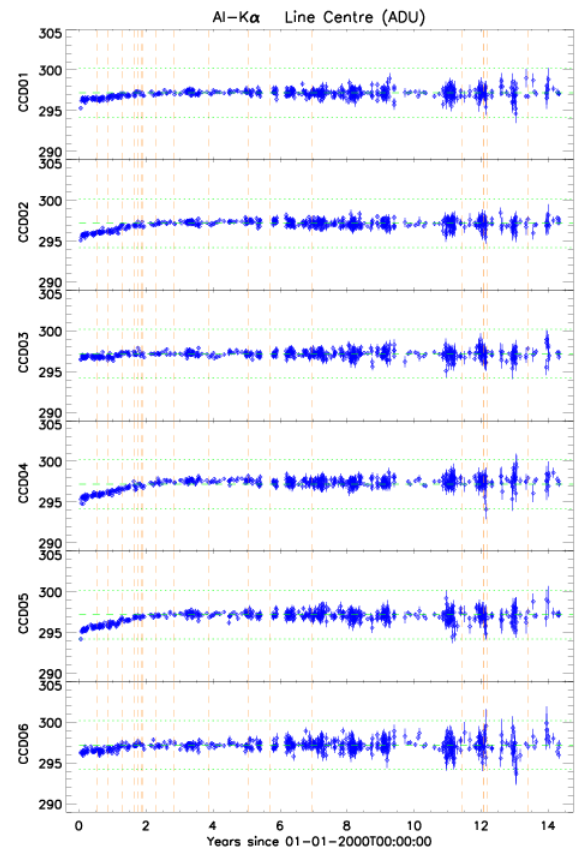
M. Smith, M. Stuhlinger, R. Saxton, M. Freyberg, 2014, XMM-CCF-REL-323

- SAS 14.0 contains two major modifications to the EPIC-pn energy scale correction methods:

- E-dependent long-term CTI correction:
  - Previously, LTCTI calibrated at Mn-Kα
  - Now, trend at Al-Kα also taken into account



SAS 13.5



SAS 14.0

single events @ Al-Kα

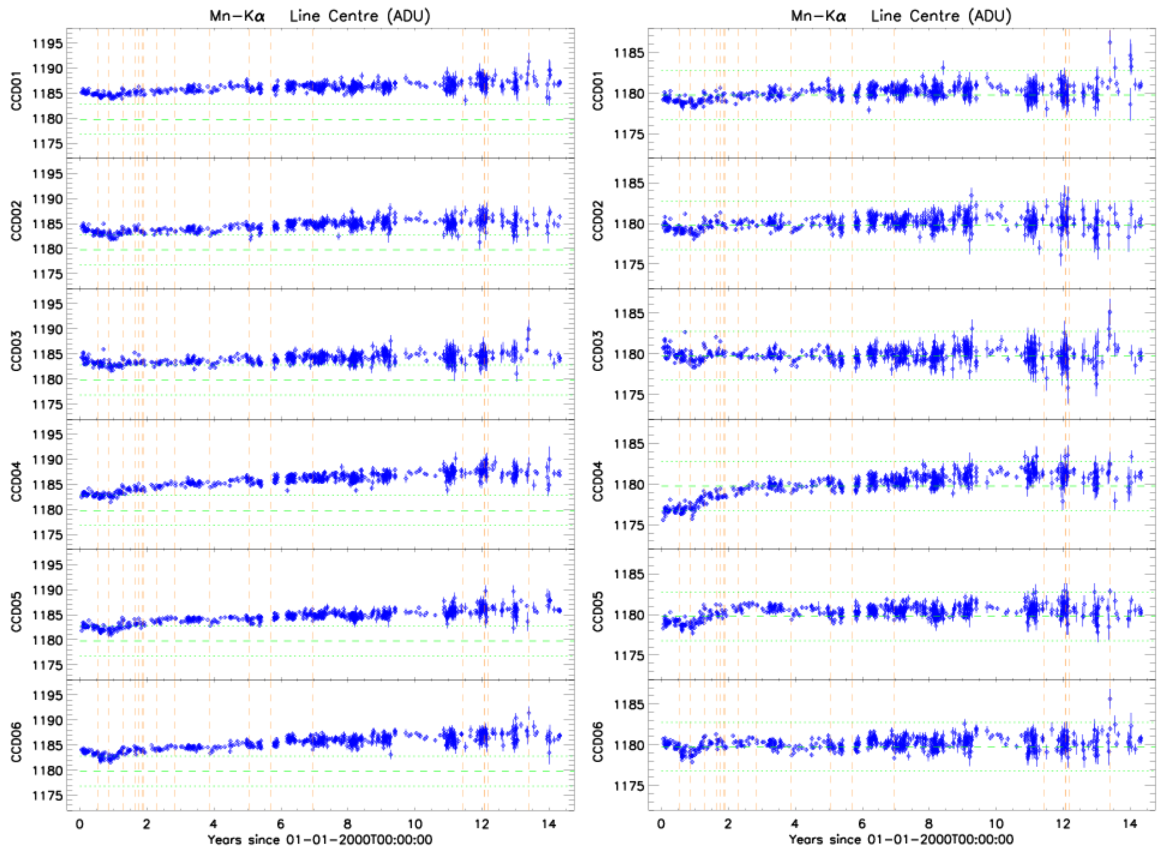
EPIC-pn: Long-Term CTI and Energy Scale

M. Smith, M. Stuhlinger, R. Saxton, M. Freyberg, 2014, XMM-CCF-REL-323

- SAS 14.0 contains two major modifications to the EPIC-pn energy scale correction methods:

- E-dependent long-term CTI correction:
    - Previously, LTCTI calibrated at Mn-Kα
    - Now, trend at Al-Kα also taken into account

- Doubles-to-singles energy offset:
    - Double-pixel event energies were known to be overcorrected with respect to singles.
    - The discrepancies were increasing in time.
    - Issue mitigated through the introduction of empirical doubles-to-singles energy offsets, together with E-dependent LTCTI.



SAS 13.5 **SAS 14.0**

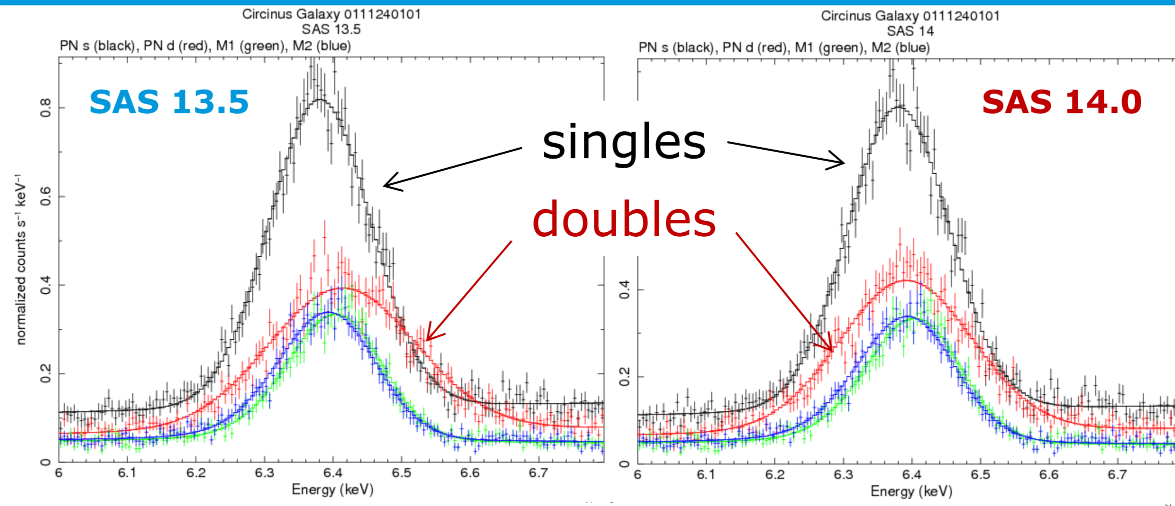
double events @ Mn-Kα

EPIC-pn: Long-Term CTI and Energy Scale

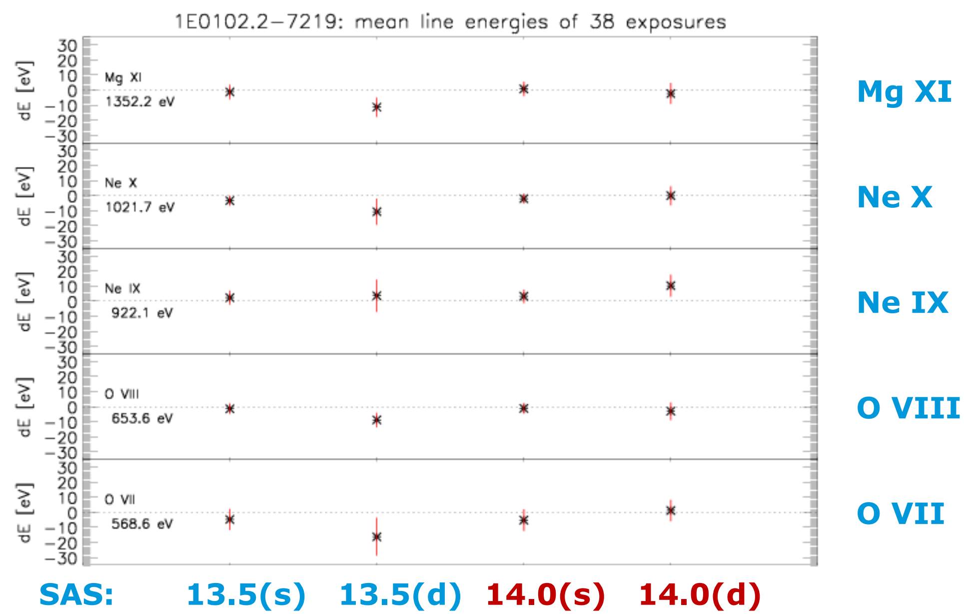
M. Smith, M. Stuhlinger, R. Saxton, M. Freyberg, 2014, XMM-CCF-REL-323

- New calibration in `EPN_CTI_0045`.

- Validated on Circinus Galaxy:



- And on SNR 1E 0102.2-7219 (38 observations) using the IACHEC model (Plucinsky, P.P., et al., 2012, SPIE, 8443, 12)

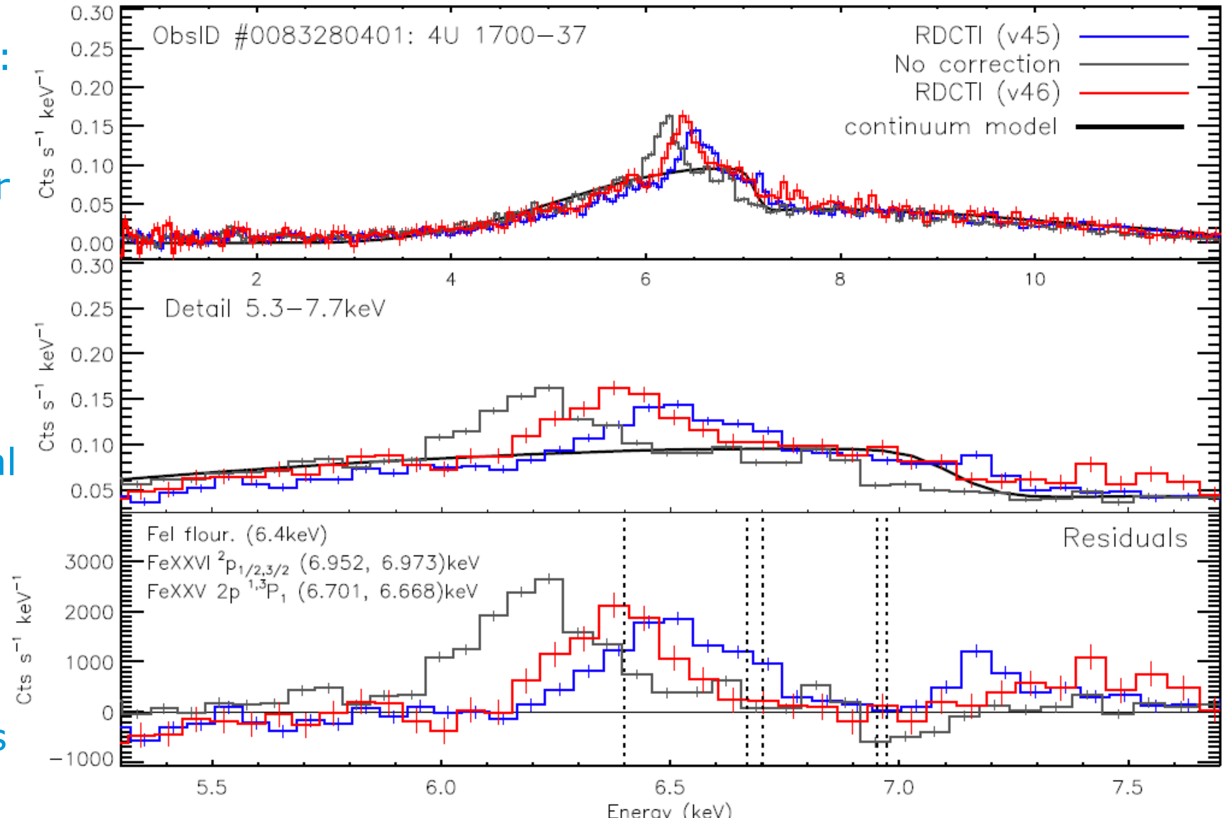


EPIC-pn: XRL & RDCTI Correction for Burst Mode

J.-U. Ness, M. Guainazzi, M. Smith, 2015, XMM-CCF-REL-326

- Rate-dependent CTI parameters have been recalibrated for Burst Mode after including a correction for X-ray loading:
  EPN_CTI_0046, EPN_REJECT_0008
- 57 Burst Mode exposures were used for the RDPHA calibration.
- The empirical calibration is based on measuring gain shifts as function of shifted electron rate at the instrumental Si edge (1.8 keV) and telescope Au edge (2.2 keV).
- Additional validation at higher energies (5-8 keV) was performed using sources with prominent Fe transition features.

4U 1700-37



old calibration

new calibration

EPIC: Tool to Estimate Effect of A_{eff} Uncertainties

Guainazzi et al., 2014, XMM-CCF-REL-321

- As of SAS14.0 a new **non-default** option (**`applyxcaladjustment`**) is available in the **`arfgen`** task to empirically correct the EPIC effective areas by an energy-dependent multiplicative factor.

- This so-called "**`CORRAREA`**" correction tool can be used to evaluate the impact that the current relative EPIC A_{eff} uncertainties have on astrophysical parameters derived from spectral fitting.

- The correction is empirical and somewhat arbitrary, and currently should not be used as replacement of the nominal calibration.

EPIC: Tool to Estimate Effect of A_{eff} Uncertainties

Guainazzi et al., 2014, XMM-CCF-REL-321

- The **CORRAREA** calibration is based on spectral analysis of 46 bright non-piled-up sources.

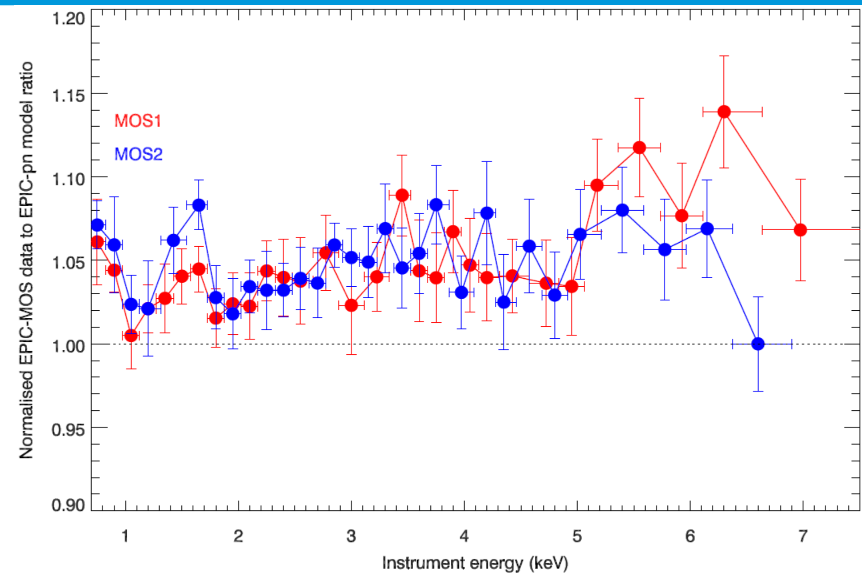
- The 0.7 – 7 keV EPIC-MOS stacked residuals against the EPIC-pn best-fit models were derived.

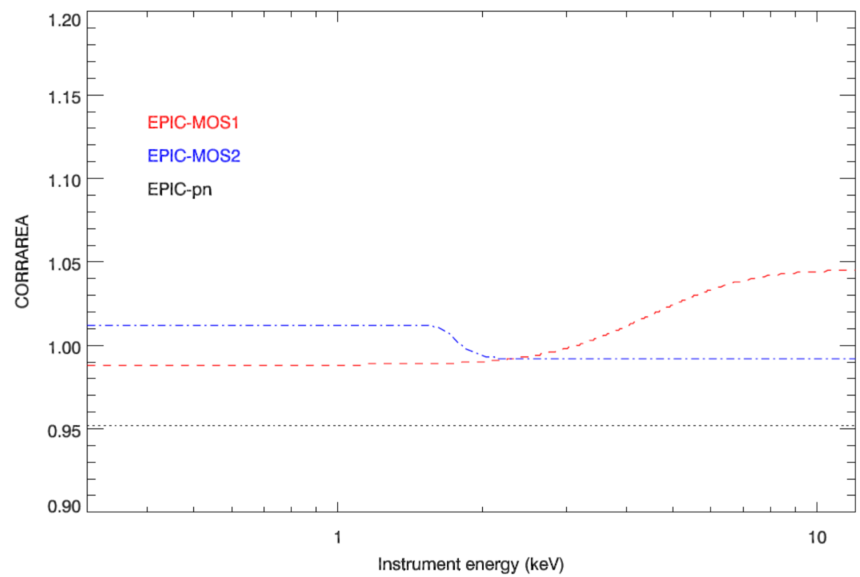
- This data was fit with a combination of a constant and Gompertz functions:

$$R_i(E) = a_i + a_{pn} + b_i \times e^{-c_i \times e^{-d_i \times E}}$$

giving the MOS to pn empirical correction factors.

- The EPIC-pn correction factor is E-independent, its value motivated by the fact that EPIC-pn yields the lowest 2 – 10 keV flux of all operational CCD instruments.





EPIC: Tool to Estimate Effect of A_{eff} Uncertainties

Guainazzi et al., 2014, XMM-CCF-REL-321

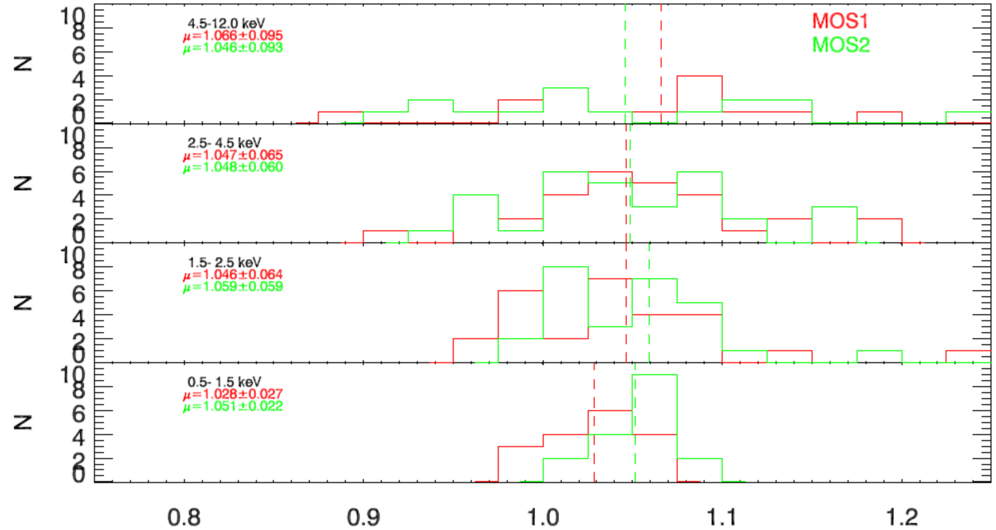
- The self-consistent implementation of the **CORRAREA** calibration has been verified on the set of 46 bright non-piled up sources.

4.5-12 keV

2.5-4.5 keV

1.5-2.5 keV

0.5-1.5 keV



- However, further validation is required before this correction will be implemented as default.

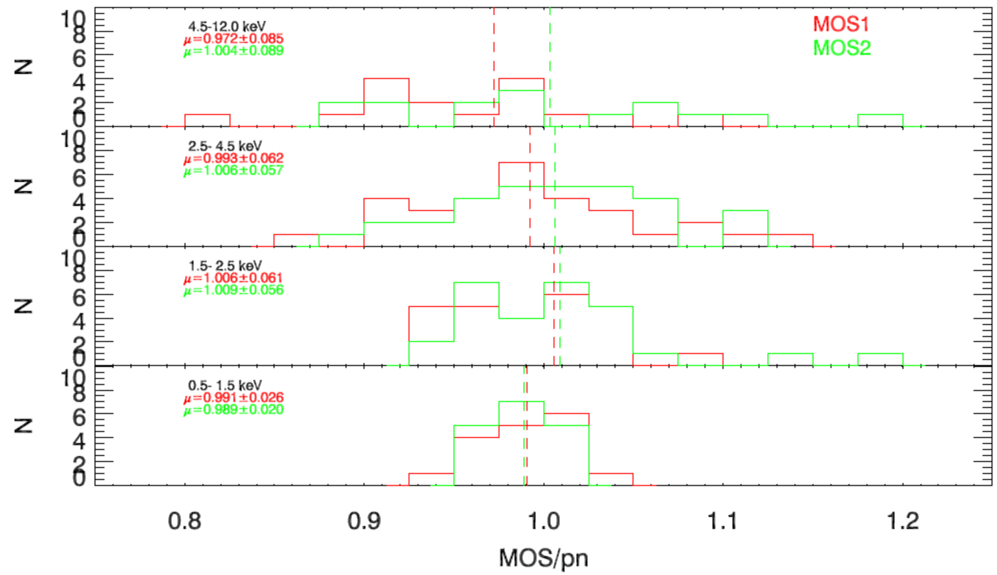
After **CORRAREA** correction

4.5-12 keV

2.5-4.5 keV

1.5-2.5 keV

0.5-1.5 keV



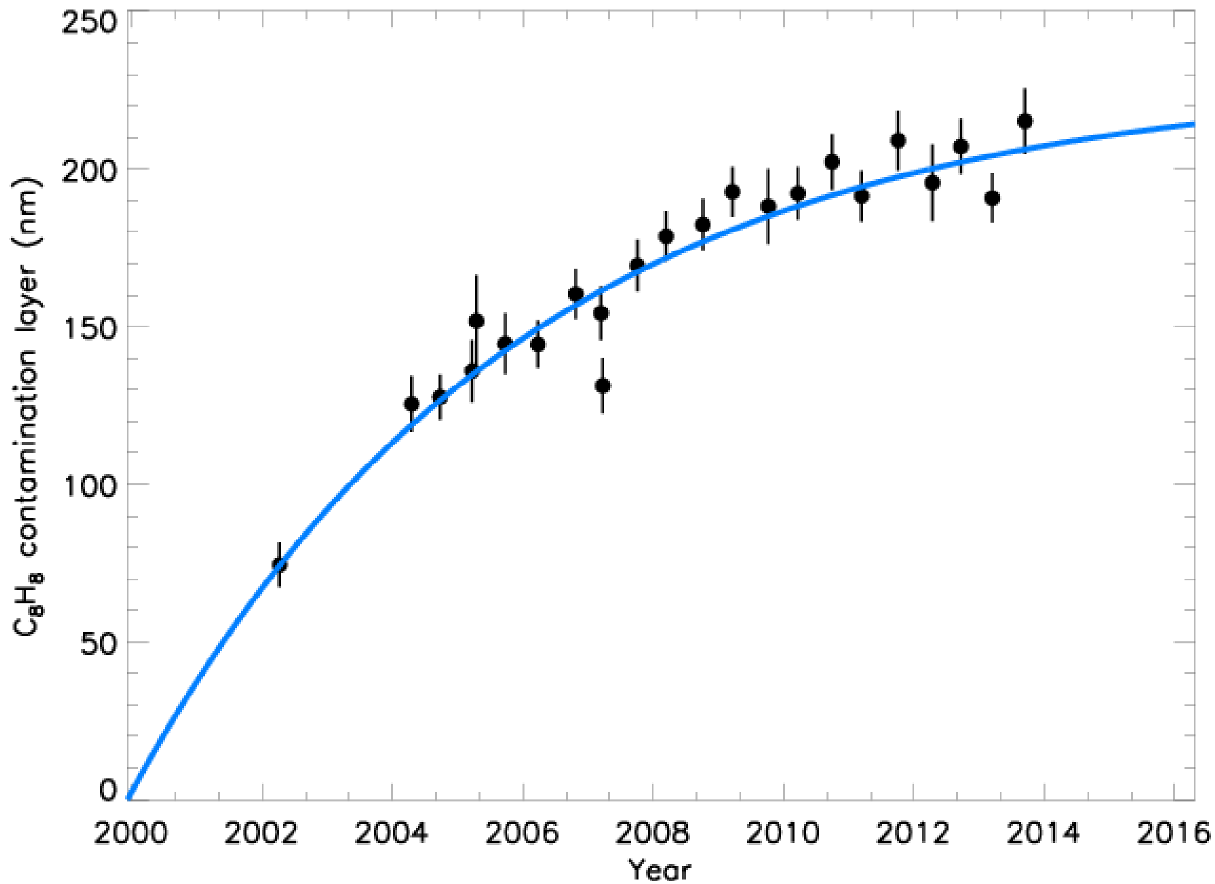
European Space Agency

RGS: Contamination Model Update

R. González-Riestra, 2014, XMM-CCF-REL-314

- Derived from the RX J1856 count rate at 35 Å

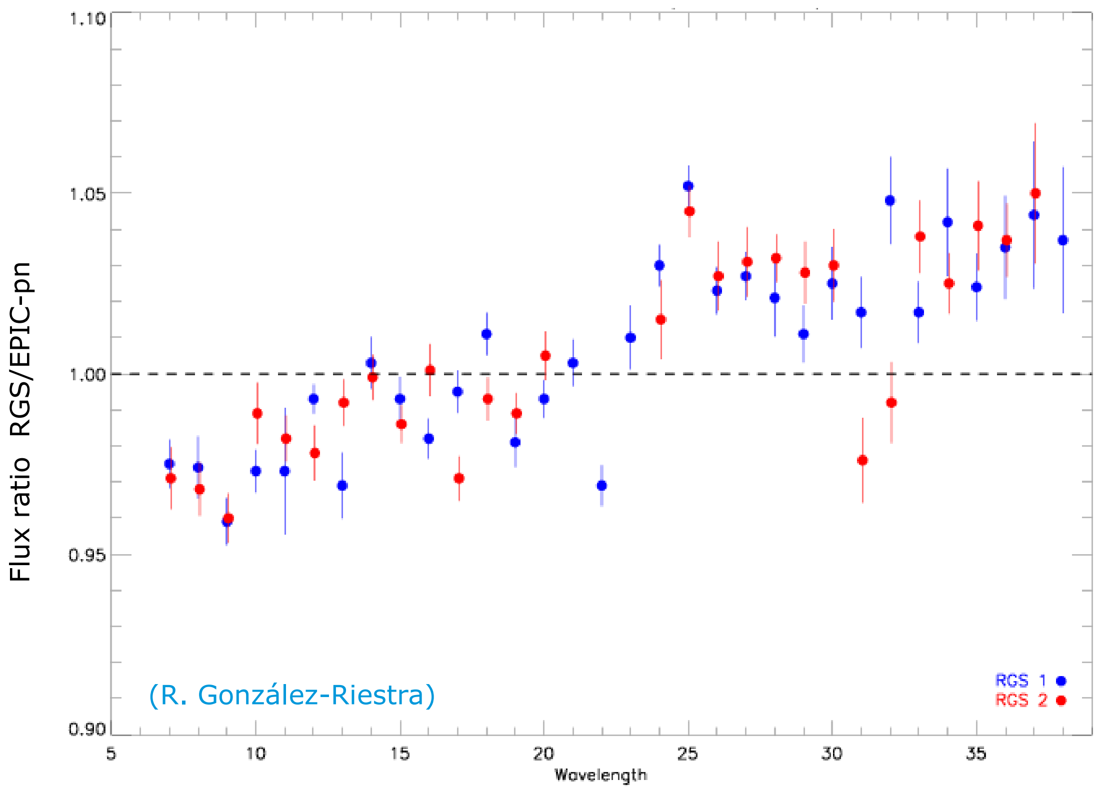
- Assuming that the contaminant is a type of Hydrocarbon (C_8H_8) coming from the carbon-fibre structures of the telescope tube.



RGS: Comparison with EPIC-pn Fluxes

- 51 observations of PKS 2155-304, 3C 273 and H 1426+428 processed with SASv14 and calibrations available in November 2014

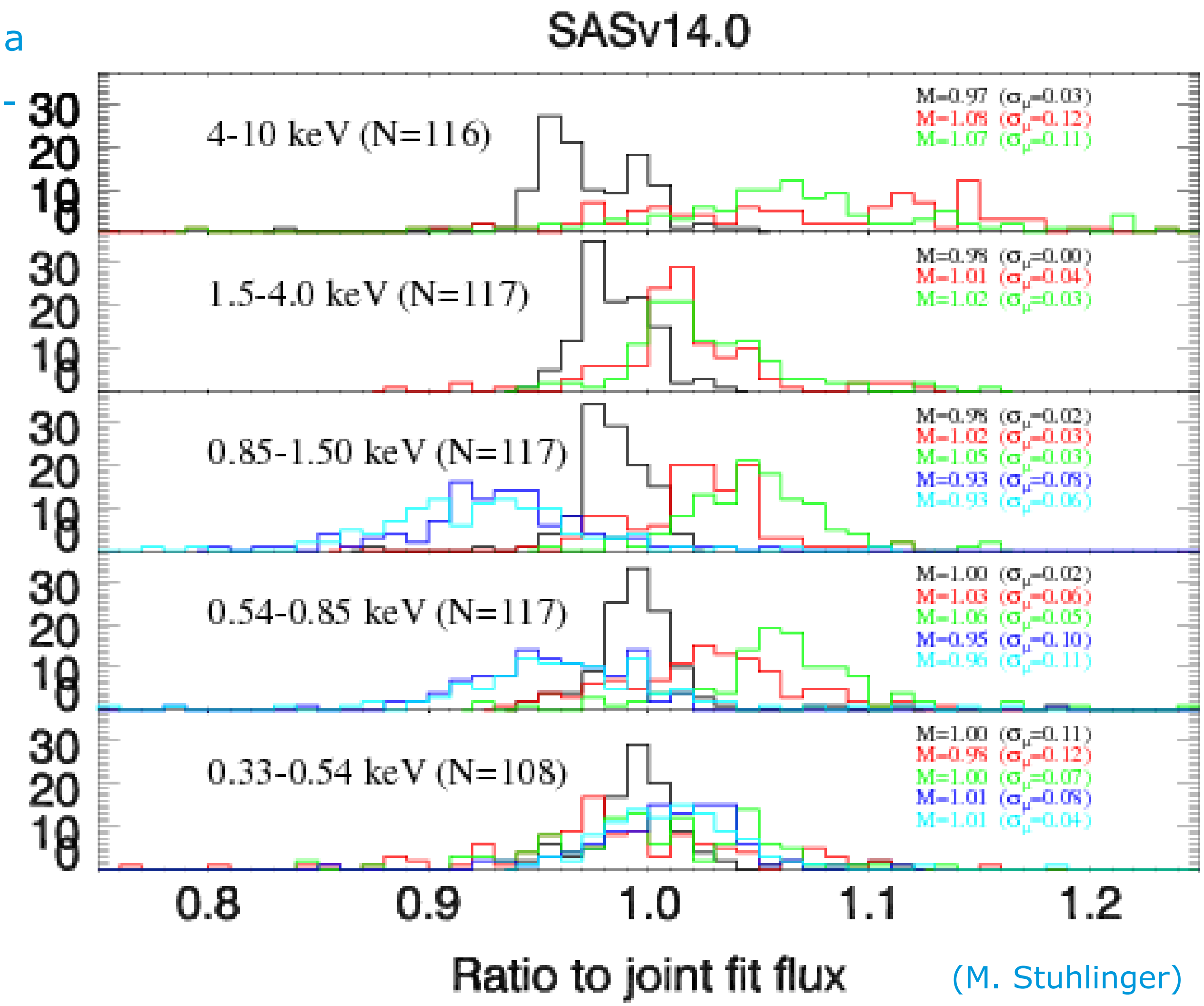
	7 - 23.5 Å	23.5 - 38.5 Å
RGS1 / pn	0.98 ± 0.02	1.03 ± 0.01
RGS2 / pn	0.99 ± 0.01	1.03 ± 0.02



- Work in progress. Should lead to an update of the RGS-pn rectification parameters contained in the **RGSn_EFFAREACORR** CCFs

XMM-Newton Cross Calibration Status

- Instrumental flux ratios derived from a set of ≈ 120 observations in the XMM-Newton Cross-Cal Database.
- MOS1 / pn:
  - ≈ 0.98 (E < 0.54 keV)
  - ≈ 1.04 (E > 0.54 keV)
- MOS2 / pn:
  - ≈ 1.00 (E < 0.54 keV)
  - ≈ 1.06 (E > 0.54 keV)
- MOS / pn above > 3 keV under investigation.
- RGS / pn: From 1.01 to 0.95 with increasing E (using χ^2 statistic)



(M. Stuhlinger)