EPIC Calibration

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

19th XMM-Newton Users' Group Meeting, ESAC, 17 May 2018

Outline

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

2. EPIC calibration monitoring and improvements over the last year

3. Summary of EPIC calibration plans and activities

2017 UG Recommendations

Recommendation 2016-06-08/01:

- […] implement an iterative adjustment to the parameters for the 2-D PSF. […] This activity needs to be considered as of the highest priority because of its impact on many other aspects of the calibration.

Recommendation 2015-05-22/02: The UG identifies the following tasks in order of priority;

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2. Evidence for a shift in gain of the PN detectors, which is dependent on the quiescent background. This should be investigated and quantified, and a correction implemented.
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4. Complete the calibration of the PN Burst Mode, RDPHA correction.

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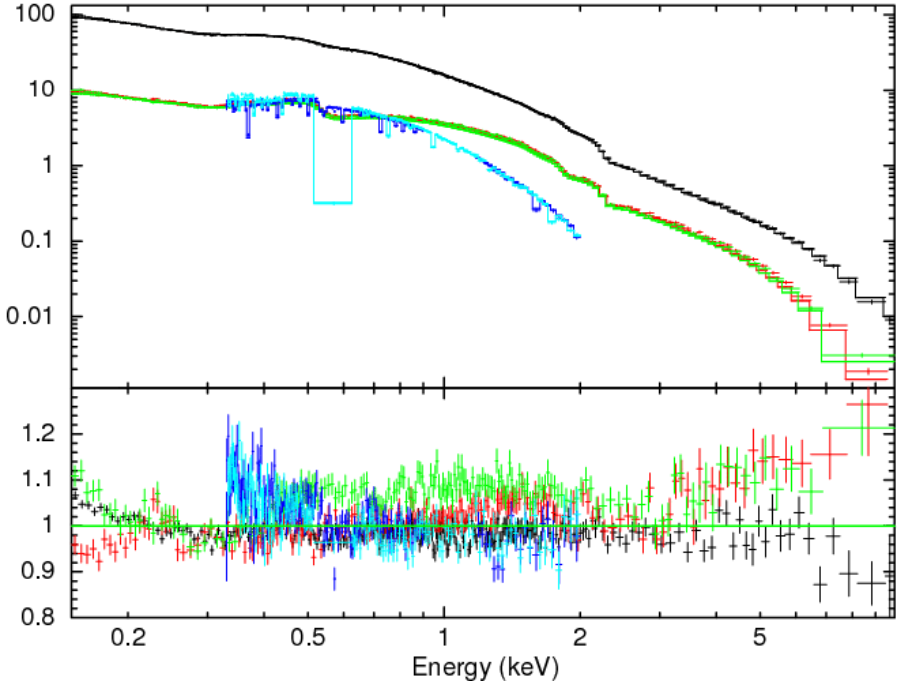
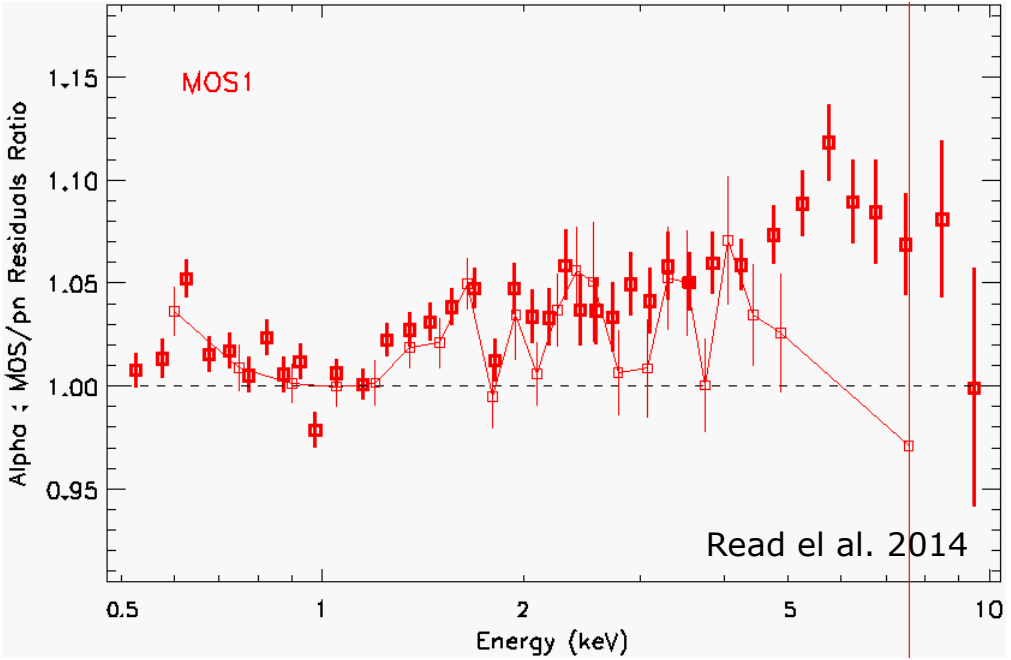
XRT PSF Modification

PKS 2155-304
- Piled-up
- Annular extraction regions for EPIC



Sample of non-piled-up
on-axis sources



XRT PSF Modification

Systematics in the PSF modelling for all 3 XRTs improved by iterative tuning of the on-axis PSF model parameters:

- Minimisation of annular spectral residuals w.r.t circular spectral model
- Source sample: 11 observations of bright non-piled-up point sources located at the nominal aim point
- Most relevant on-axis PSF parameters were investigated (r_0 and α)
- Main changes affect off-axis angles < 3'

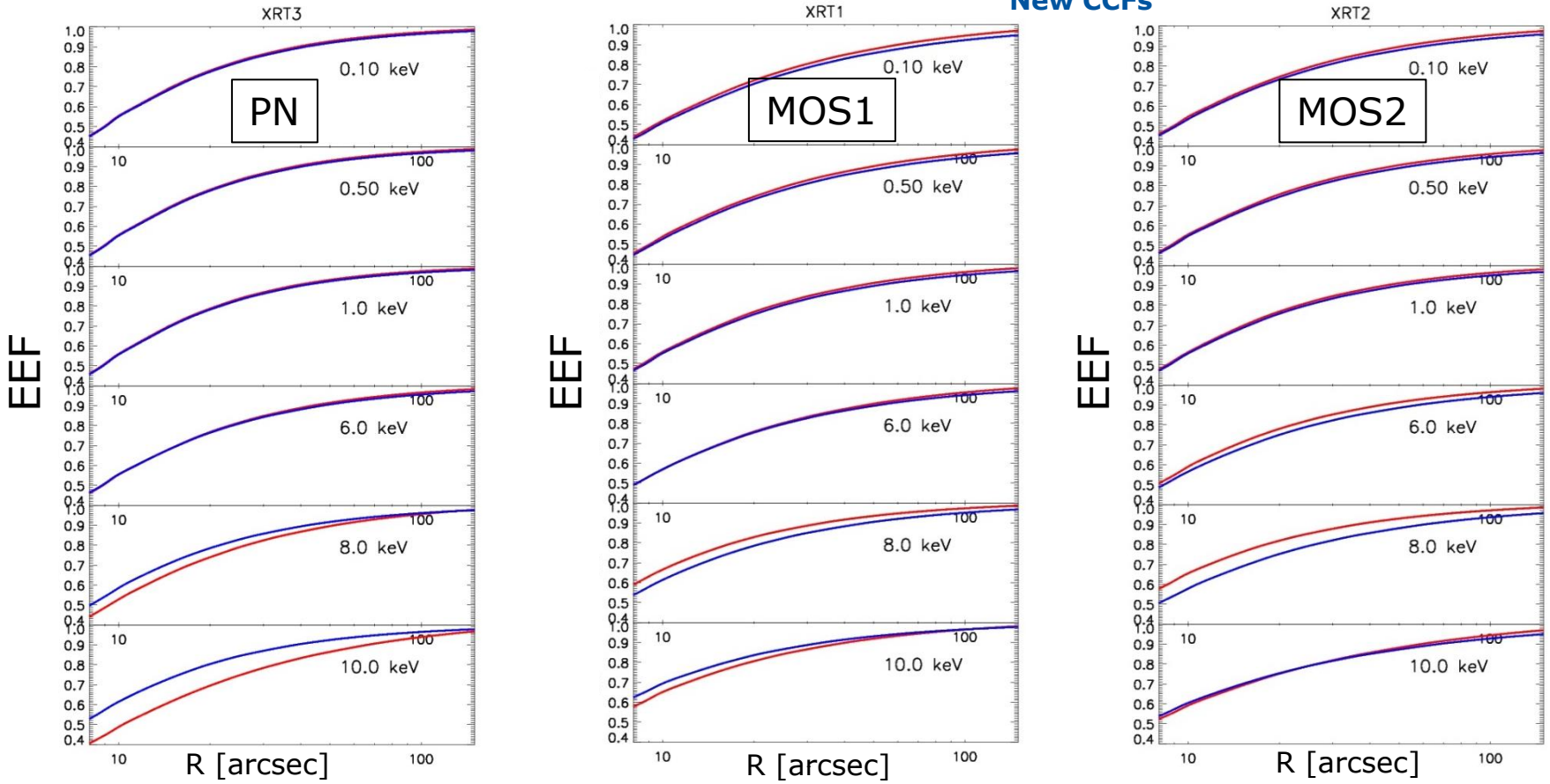
2-D King profile:

$$B(r) = \frac{A}{(1 + (r/r_0)^2)^{\alpha}}$$

➔ New XRTn_XPSF CCFs released: 08/2017 (Smith et al., XMM-CCF-REL-348)

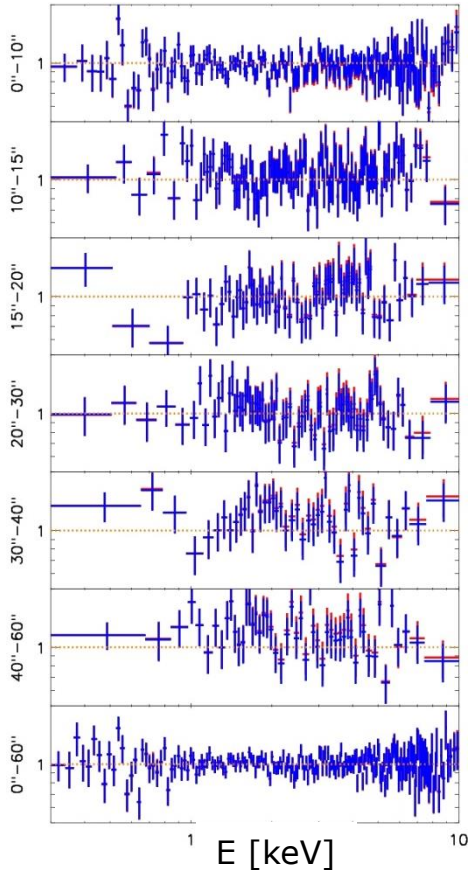
XRT PSF Modification

Old CCFs
New CCFs



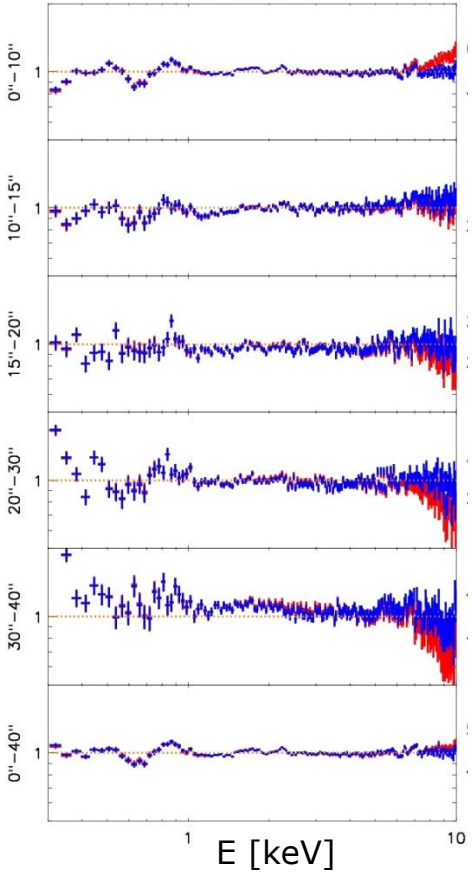
XRT PSF Modification

Annular spectral residuals:
old PSF v. new PSF



Markarian 6 (MOS1)

MCG-5-23-16 (PN)



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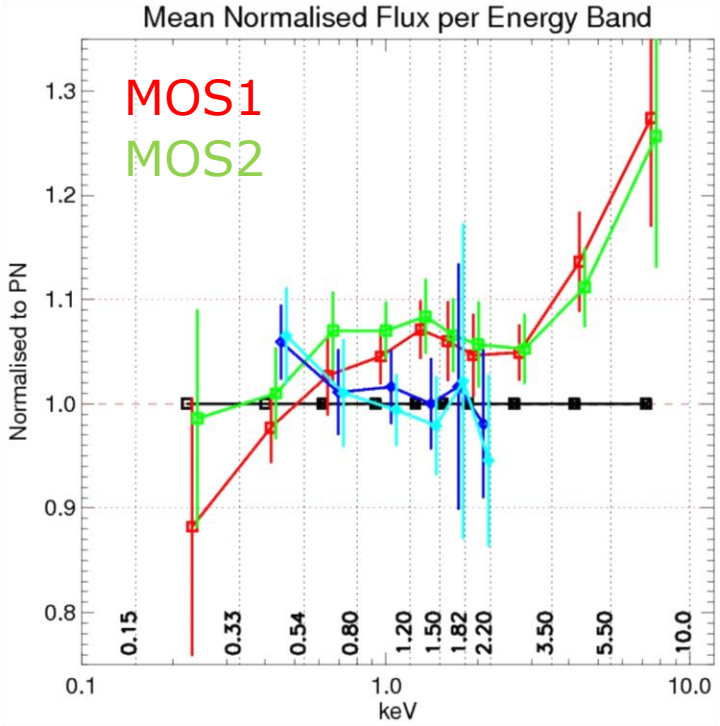
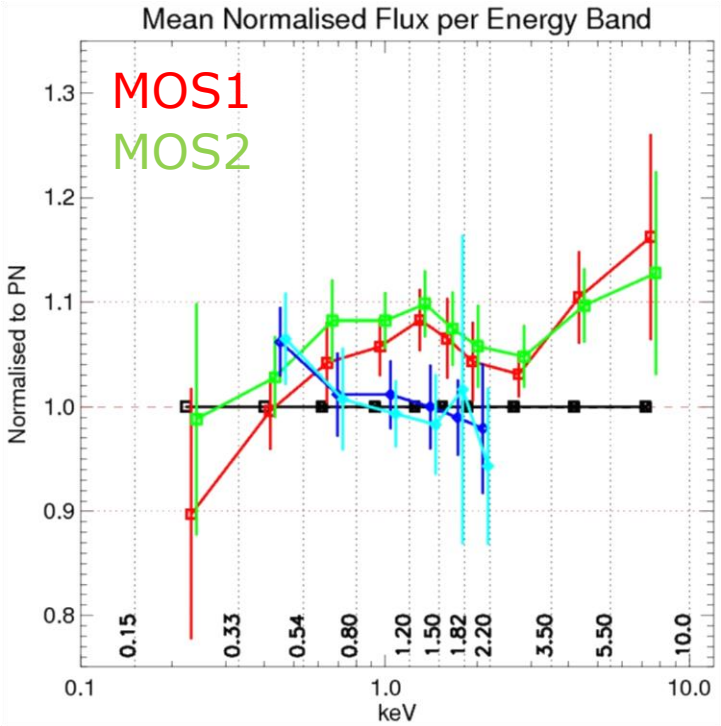


Old XRTn CCFs



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Update of the CORRAREA Correction

The **CORRAREA** tool was implemented in SAS 14 (autumn 2014):

- Applies an empirical correction to the EPIC effective areas.
- Can be used to evaluate the impact that the current relative EPIC A_{eff} uncertainties have on astrophysical parameters derived from spectral fitting.
- Derived from a sample of ~50 sources (FF and EFF modes only).
- Currently, a non-default SAS option.

A recalibration and full validation of the **CORRAREA** correction is currently being undertaken:

- Based on SAS 16.1, and current public CCFs.
- Larger source sample (~ 350 observations).
- More instrument modes (LW, SW) and filters (Thick).
- Revised screening: common GTIs, background selections, pile-up evaluation.
- Largely automated pipeline from data reduction to spectral and residual fitting.

⇨ To be released in summer 2018

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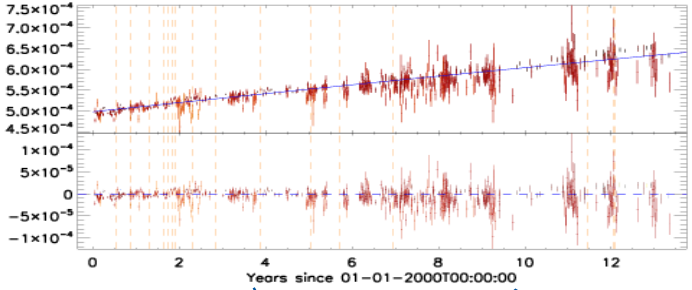
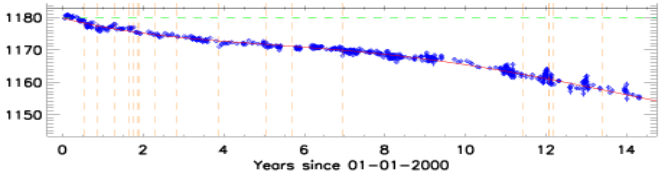
PN: Quiescent Background Gain Correction

Long-term CTI and model residuals



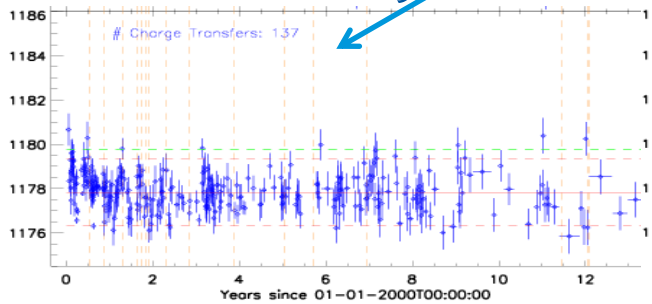
Line energy trend with **no correction** for the LTCTI

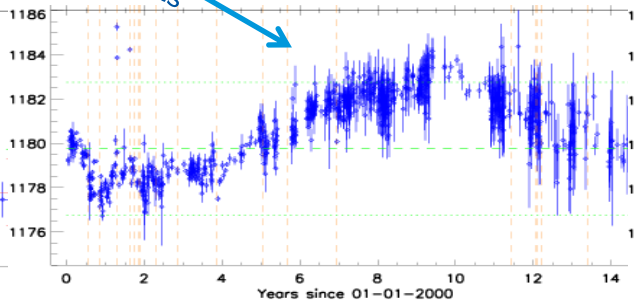


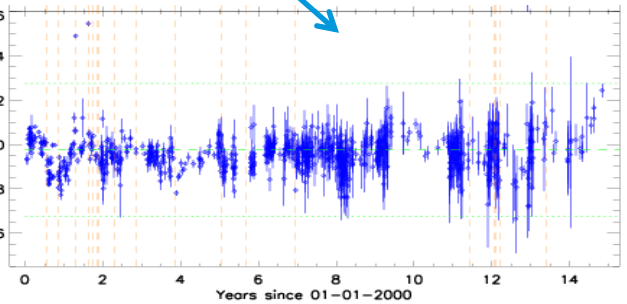
Simulated

Actual Results

Current Calibration





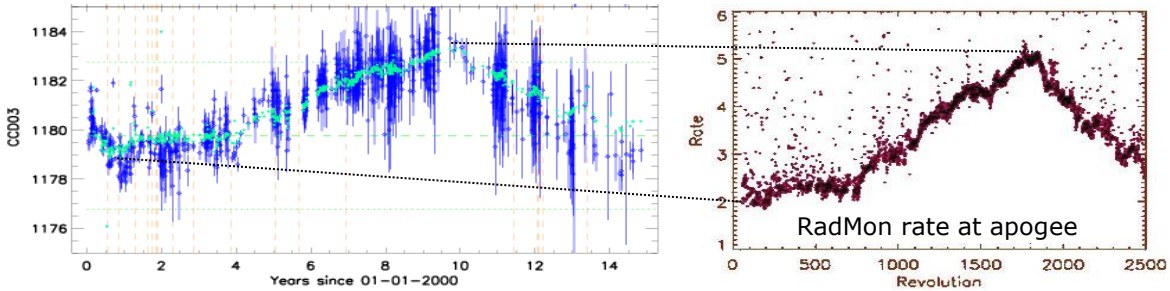


Simulated line energy trend after CTI correction using the LTCTI model based on LTCTI model residuals

Actual line energy trend after CTI correction using the LTCTI model

Actual line energy trend after applying the empirical LTCTI correction **Current calibration**

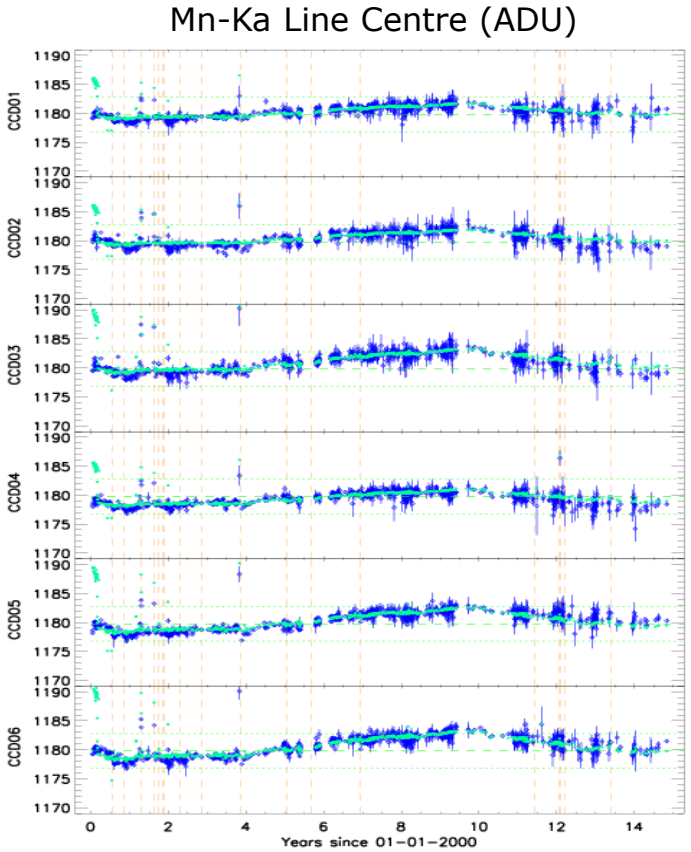
PN: Quiescent Background Gain Correction



After correcting for the long-term CTI:

- an additional **gain correction** is required
- residuals show correlation with quiescent background
- use the Discarded Line Counter (`NDISCLIN`) HK parameter as proxy for the QB

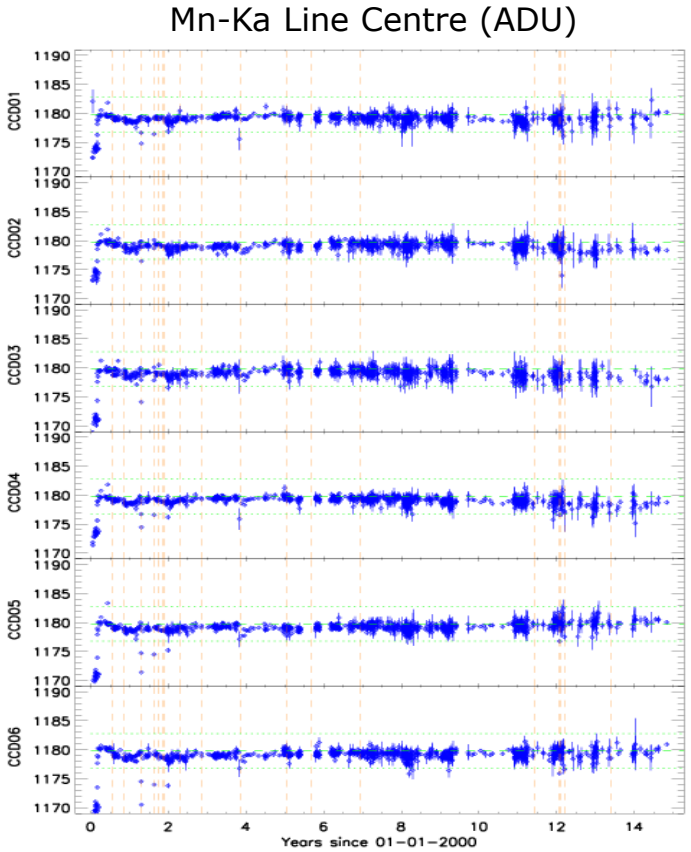
PN: Quiescent Background Gain Correction



Current SAS implementation:

- Correct energies for long-term CTI.
- Use the average discarded line rate, **NDISCLIN**, as proxy for the quiescent background.
- Determine mode / CCD dependent **NDISCLIN** rate scaling.

PN: Quiescent Background Gain Correction



Current SAS implementation:

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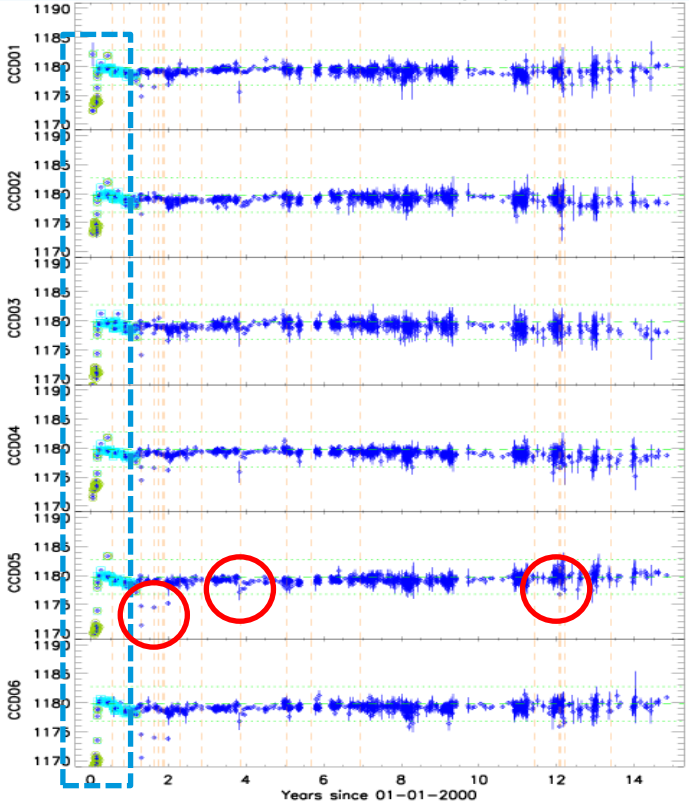
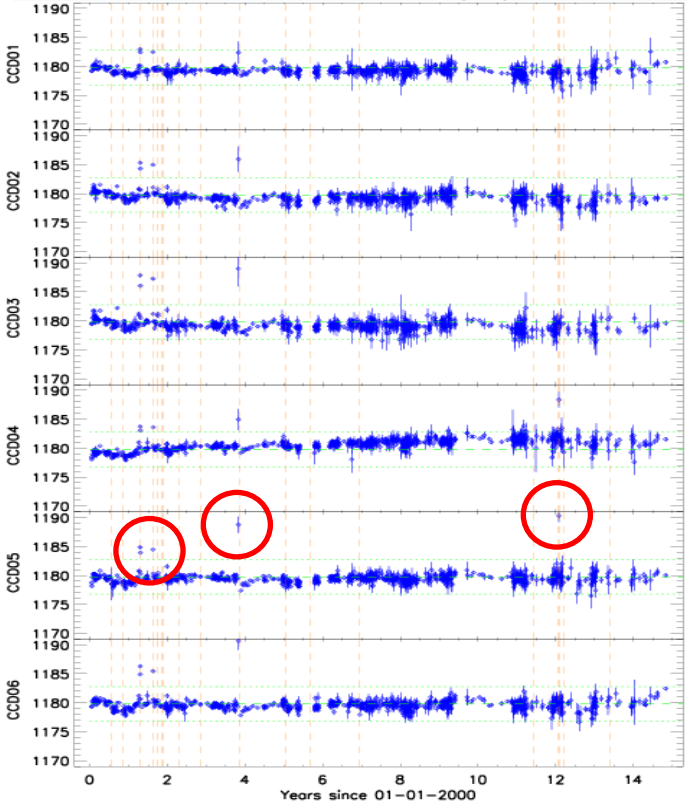
- Use the average discarded line rate, **NDISCLIN**, as proxy for the quiescent background.
- Determine mode / CCD dependent **NDISCLIN** rate scaling.
- Use this for an additional background-dependent gain correction.

PN: Quiescent Background Gain Correction

With Background Gain Correction



With Current Calibration



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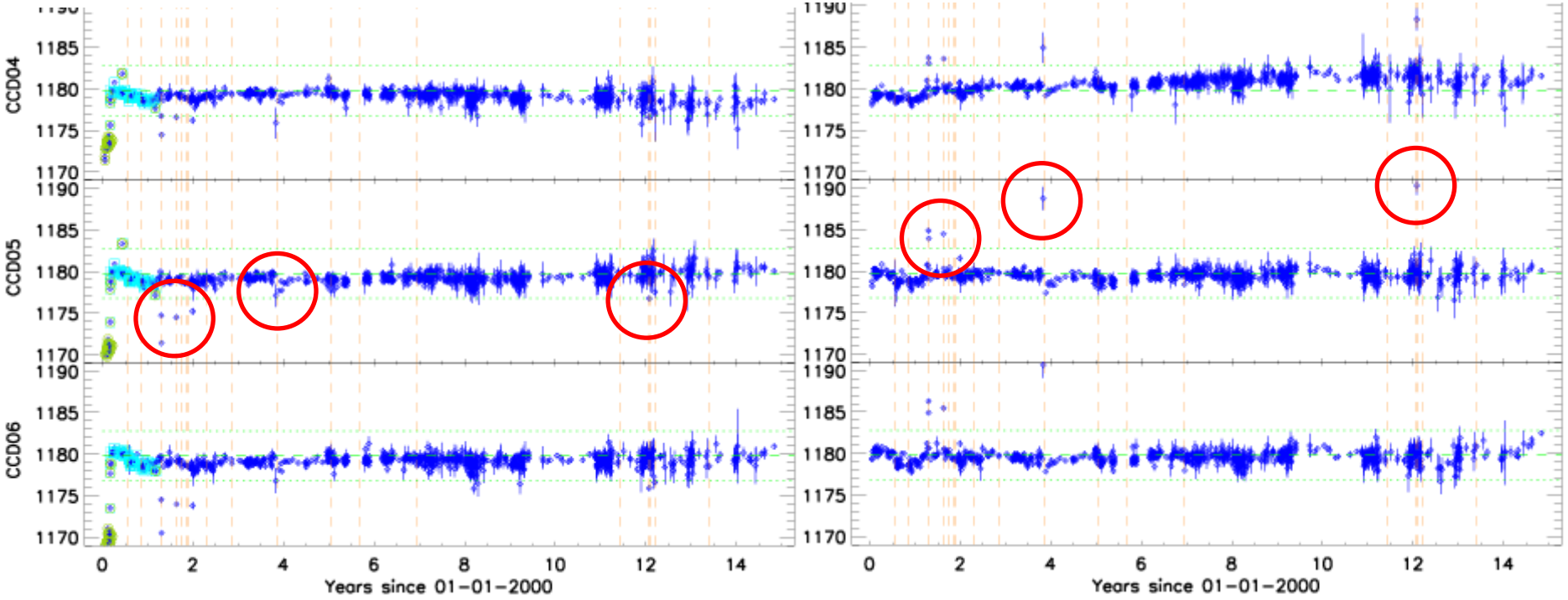
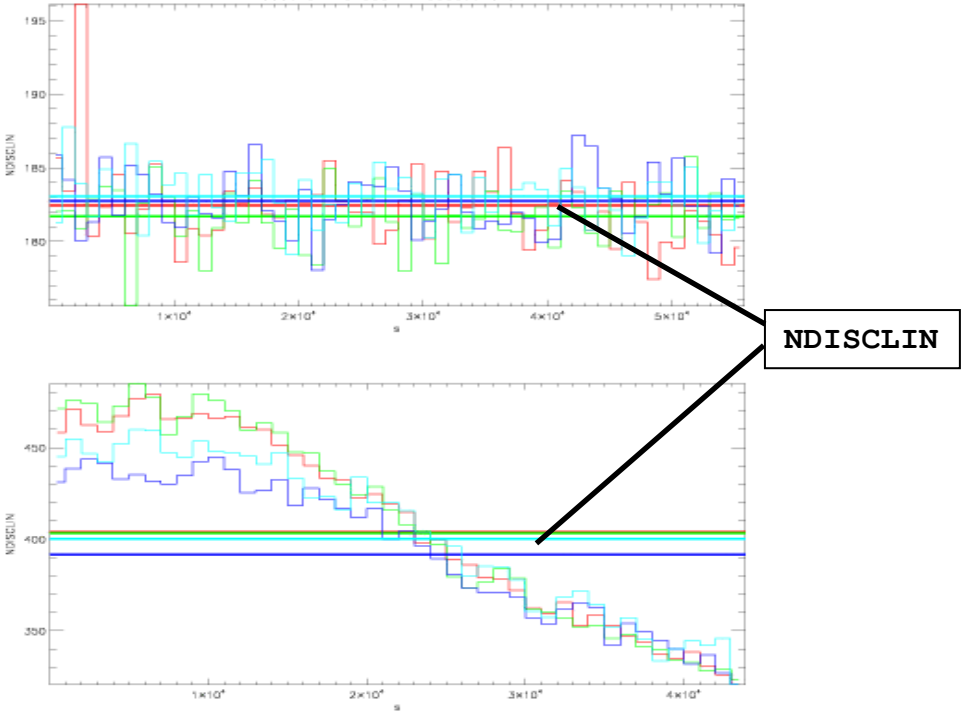


PN: Quiescent Background Gain Correction

Discarded line rate (per quadrant) v. Time



- The average discarded line rate, **NDISCLIN**, is not always representative of the actual quiescent background.
- Need to use the **instantaneous** discarded line rates (HK data).
- S/W change required: **implemented in SAS 17**
- Currently undergoing testing and calibration

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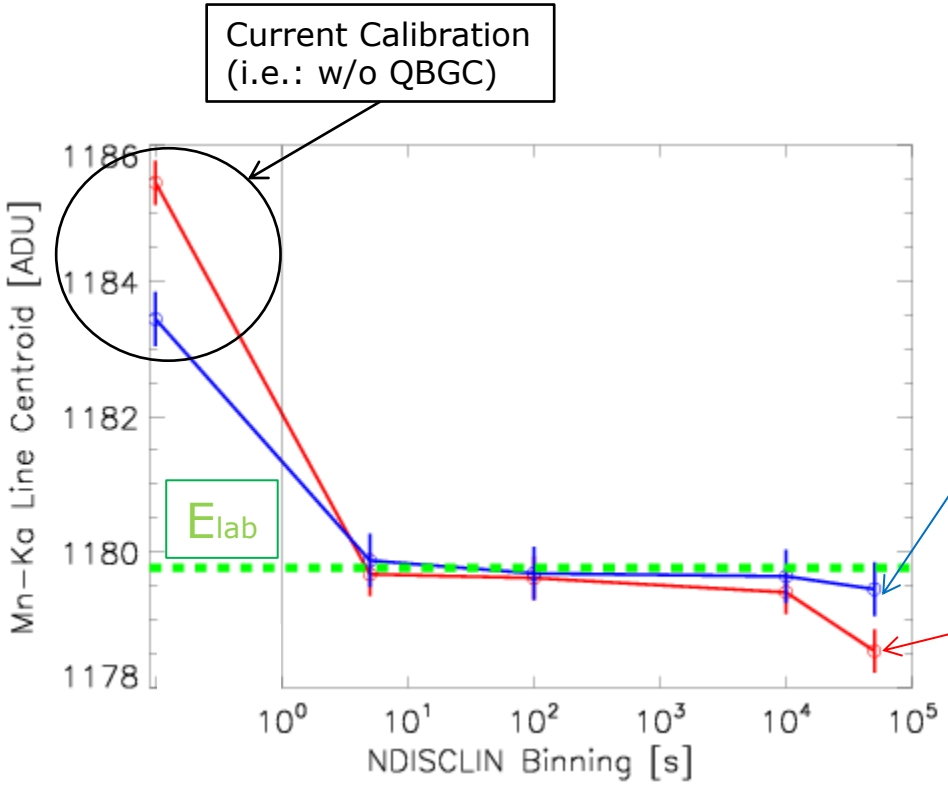
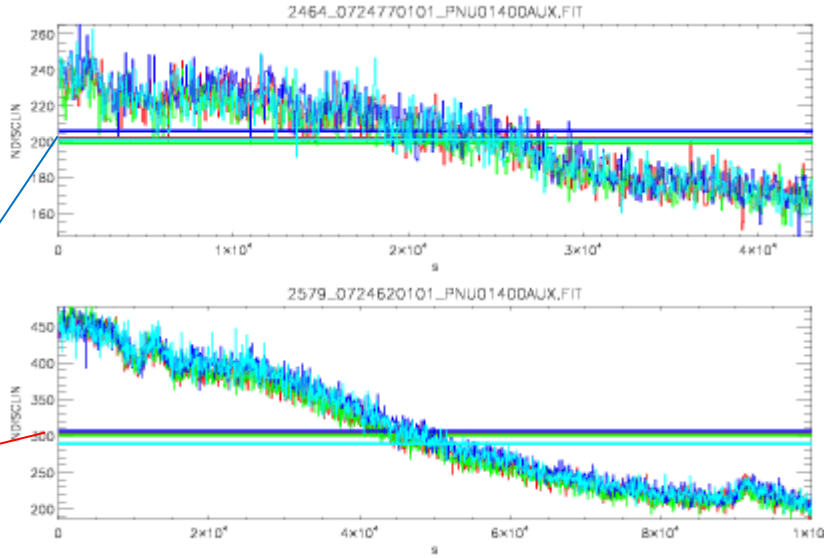


Discarded Line rate versus Time



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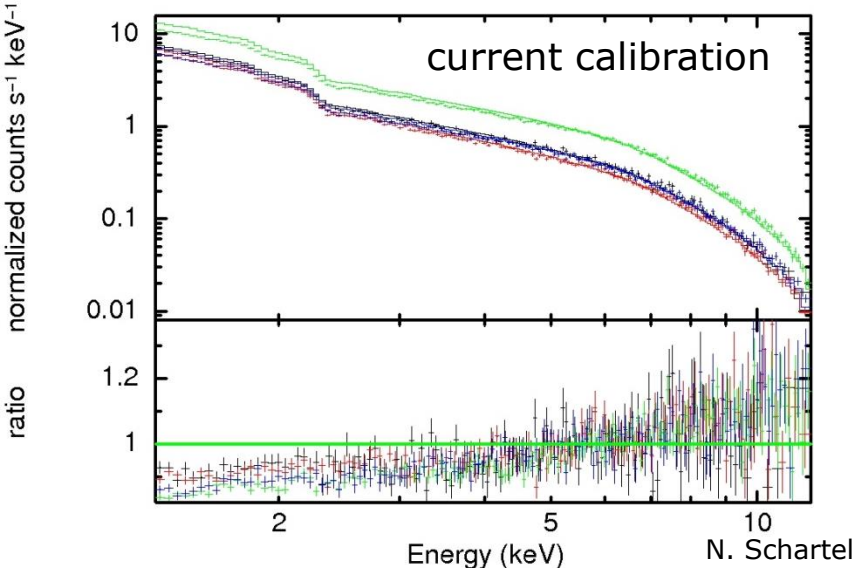
EPIC-pn / NuSTAR Comparison

Comparison of 4 observations of 3C 273:

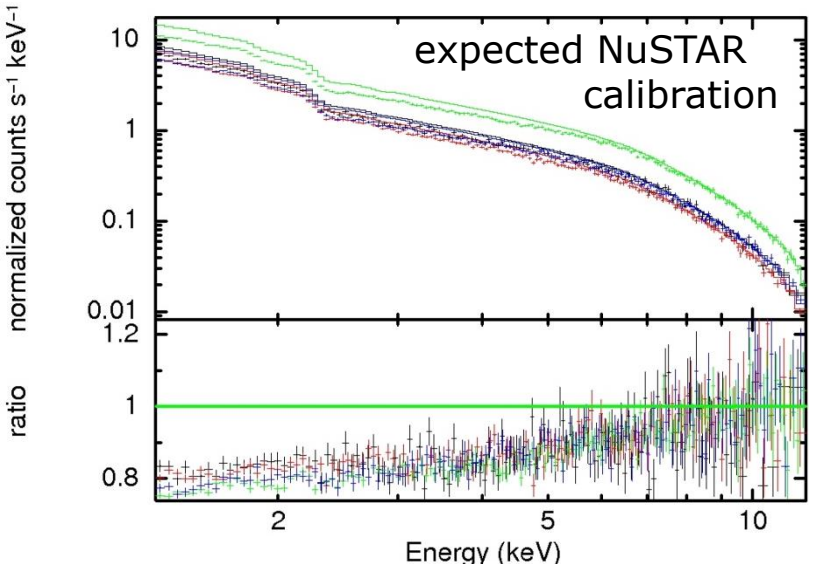
- PN imaging modes
- Strictly simultaneous PN-NuSTAR data
- Models fit to NuSTAR (extrapolated below 3 keV)

⇒ Systematic PN residuals: flux and spectral shape



- NuSTAR results comparing focused with stray-light measurements of the Crab confirm NuSTAR normalisation underestimated by ~ 12% (Madsen et al. 2017)

⇒ 15 – 20% PN flux deficit (> 3 keV)



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PN: Timing & Burst Mode Issues

PN Timing Mode observations show several cases of sources with:

- larger than expected residuals at instrumental edges
- significant differences in line E with respect to e.g. grating data (up to 70 eV at ~ 6 keV)

Sources are in the moderate count rate regime.

Possible issue with rate dependent correction in Timing Mode (and Burst Mode).

- ➢ The chain of corrections affecting the TI & BU mode energy scale is being systematically evaluated.
- ➢ Additional observations added to the calibration sample (150 v. 45)
- ➢ Possible additional calibration point at Au-L edge (11.93 keV)

Work in progress…

- Rate dependent correction (pattern recognition)
- Find event patterns
- Rate dependent correction (applied to charges)
- Gain correction
- Mode-specific gain correction
- CTI correction
- Long-term CTI correction
- CCD offset correction

2017 UG Recommendations: Summary of Status

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2. Evidence for a shift in gain of the PN detectors, which is dependent on the quiescent background. This should be investigated and quantified, and a correction implemented. **Implemented in SAS 17; undergoing validation**
3. Calibrated spectra from NuSTAR and XMM-Newton sometimes show a significant mis-match in spectral slope and offset above 3keV. This is a matter which the IACHEC should be encouraged to investigate. **Under investigation**
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EPIC: Instrument Operations

- Smooth EPIC instrument operations over the last year
- No major events to report
- In general, the instruments are functioning nominally

MOS: CTI and Gain Update

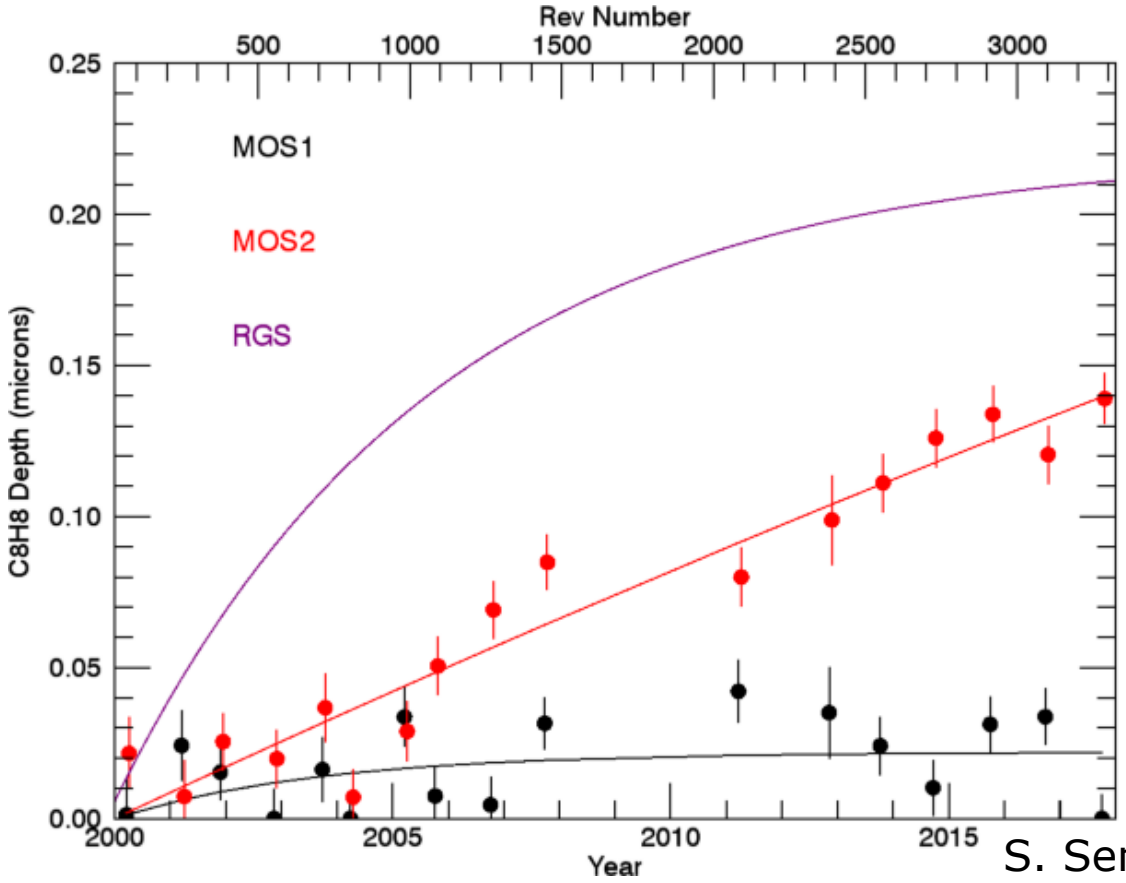
- New set of MOS CTI & Gain CCFs released in 02/2018
  (M. Stuhlinger, XMM-CCF-REL-354 / 355):
  - MOS1: 24 epochs
  - MOS2: 27 epochs

- Epoch conformity between MOS1 and MOS2 broken after rev. 1163 (04/2006), mainly due to evolving charge traps within CCD columns

➢ Improvement of energy reconstruction of up to 5 eV @ 1.5 keV and 15 eV @ 6 keV (for peripheral CCDs in latest epoch).

➢ Energy scale is now accurate to < 5 eV for all CCDs.

MOS: Contamination Monitoring



S. Sembay

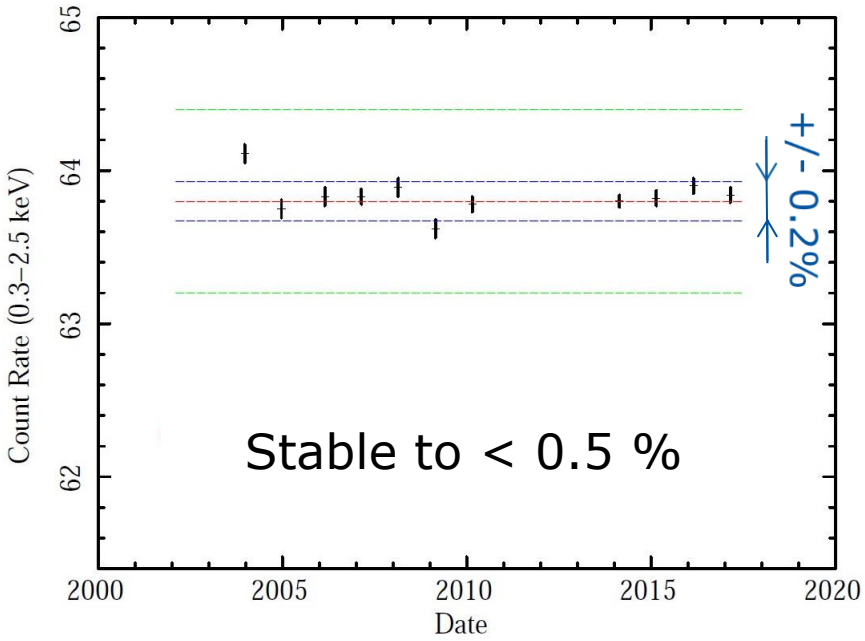
Primary monitoring source: SNR 1E0102

Contamination status shows no change in trend:

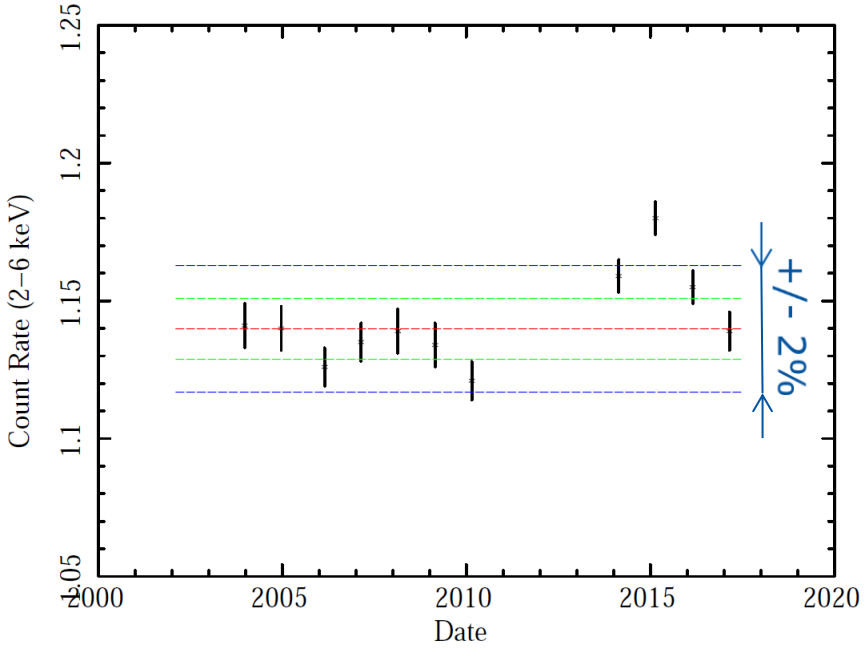
- MOS1 stable
- MOS2 steadily increasing (~ 14 % Aeff loss @ 0.5 keV in 2018)

PN: Stability Monitoring

N132D 0.3-2.5 keV



N132D 2.0-6.0 keV



R. Saxton, 2017, XMM-SOC-CAL-TN-0212

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Summary of Calibration Plans & Activities

EPIC CORRAREA: recalibration and extended validation	Summer 2018
EPIC-pn quiescent background gain correction:	
• in SAS 17	Imminent
• calibration	Summer 2018
Re-evaluation of EPIC-pn fast mode energy scale corrections	In progress
EPIC-pn empirical RMF modelling	In progress
EPIC-pn LTCTI correction for windowed modes (LW, SW)	In progress
Include Cu-Ka fluorescence emission (8.0 keV) in EPIC-pn long-term CTI modelling	Under investigation