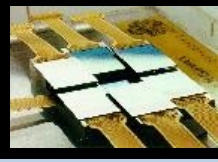
esa ESAC



Update on the status of the XMM-Newton calibrations

IACHEC Meeting, Ringberg Schloss
19 May 2008

Matteo Guainazzi, Andy Pollock, Martin Stuhlinger, Richard Saxton, Marcus Kirsch

with inputs of the whole EPIC and RGS consortia

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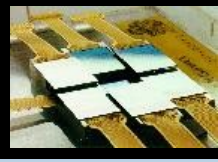

Outline

- Effective area improvements
  - MOS QE refinement
  - pn gain/CTI refinement
  - RGS effective area correction
  - RGS long-term contamination correction
- Status of cross-calibration among the XMM-Newton X-ray cameras
- The XMM-Newton SOC cross-calibration archive:
  - XMM-Newton vs. *Chandra*
  - XMM-Newton vs. *Suzaku*

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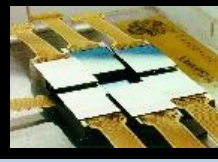
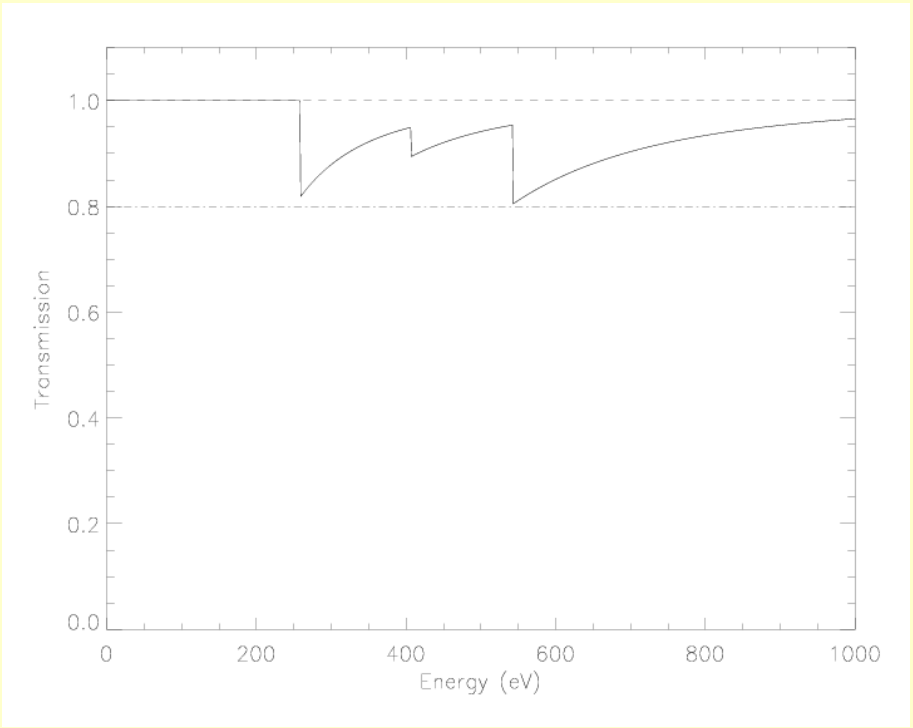
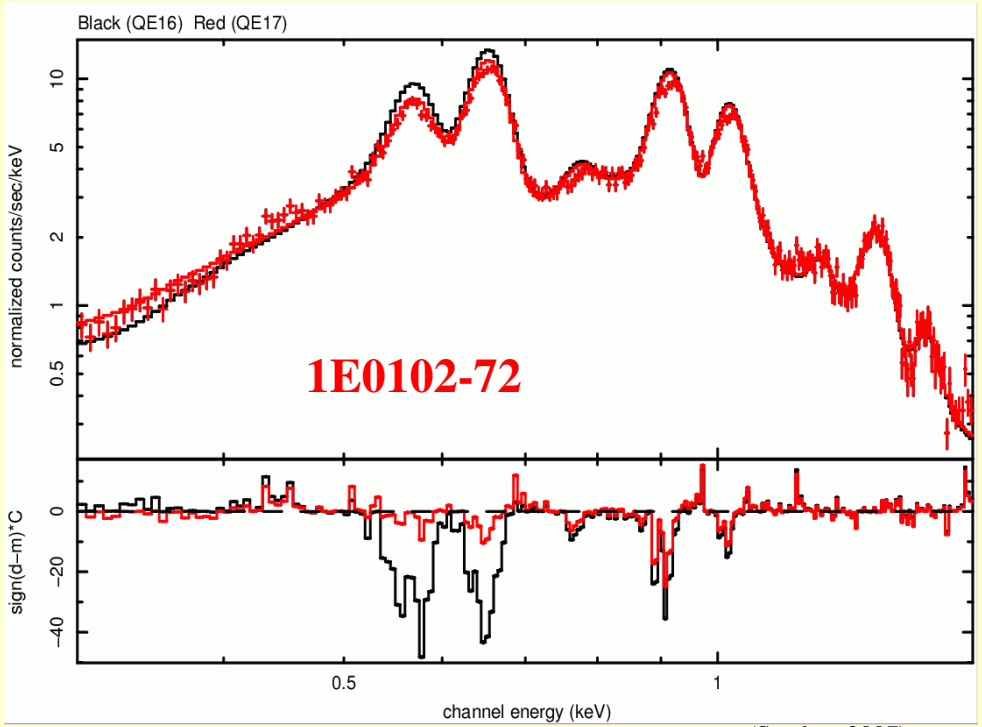


MOS QE

Adjustment of the MOS Quantum Efficiency at the C, N, O edges





(Sembay 2007)

Impact:

- Significant improvement at the Oxygen lines once compared with models based on high-resolution (RGS, HETG) data
- Better pn-MOS imaging mode cross-calibration

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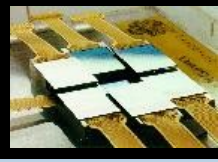
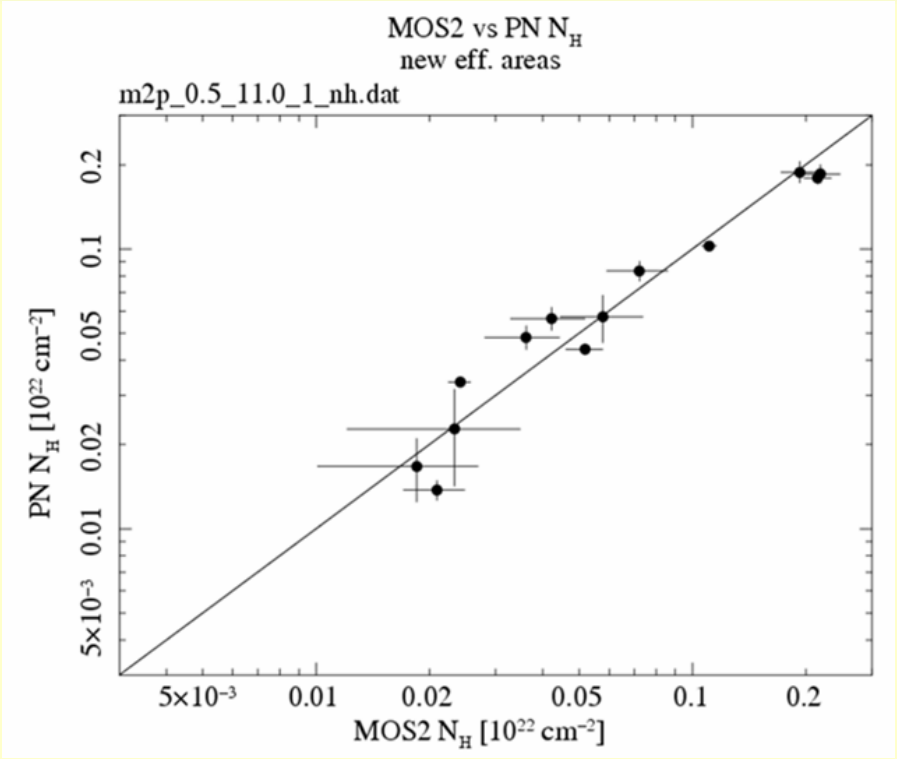
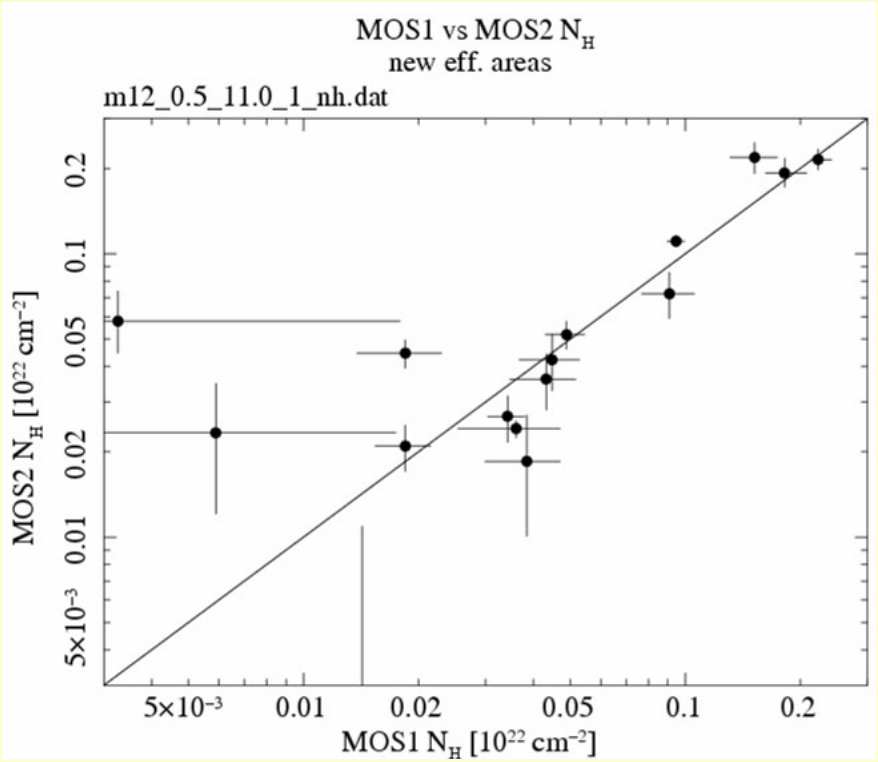


EPIC N_H comparison for 21 blazars





(Molendi, 2007)

After QE update:

- Very good agreement between MOS and pn
- Agreement between MOS1 and MOS2 remains good

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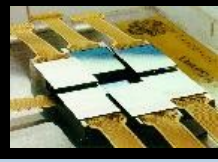
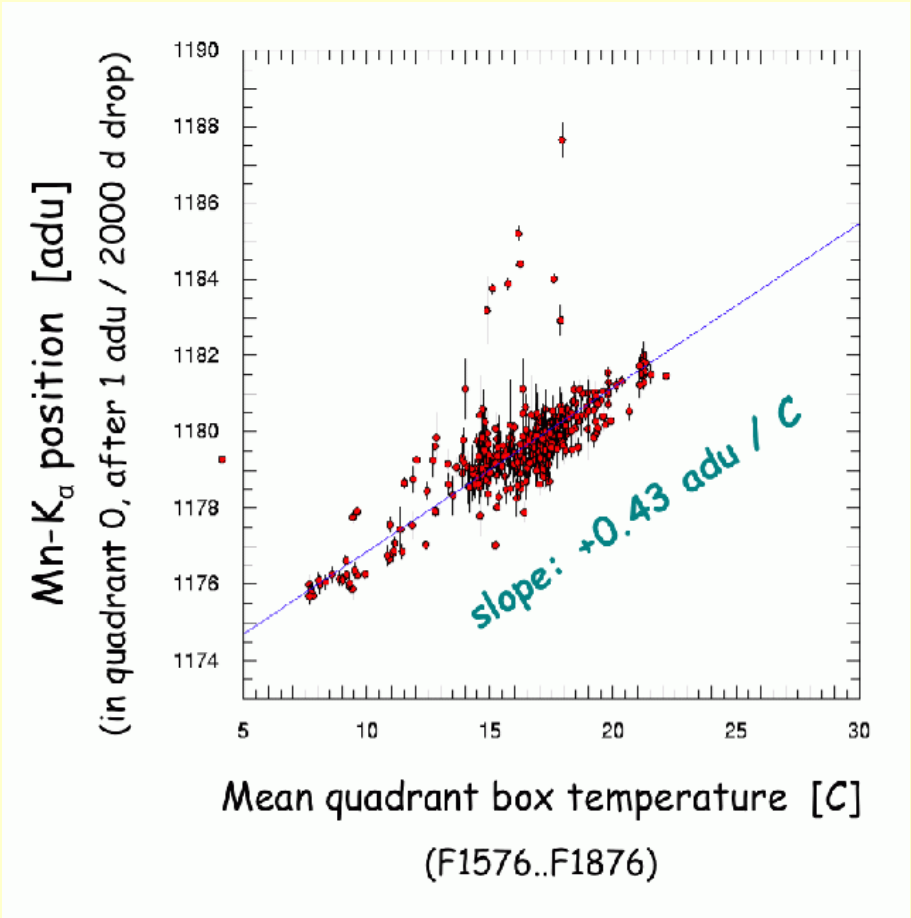


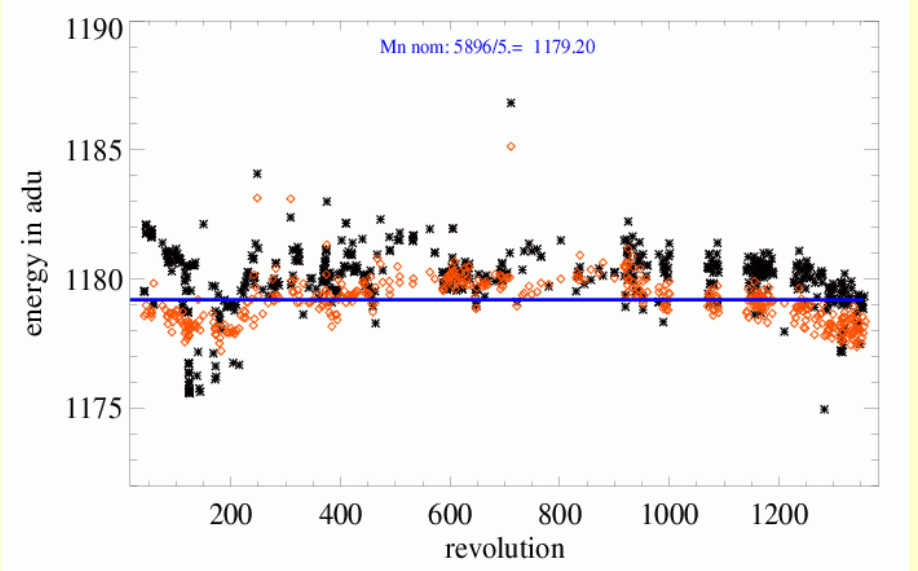
pn FF gain temperature-dependence



Without temperature correction

With temperature correction

(pn energy accuracy ≤5-10 eV)



(Kirsch, Haberl, Dennerl, Freyberg 2007)

Temperature-dependent gain correction is the default as of SASv7.1.2

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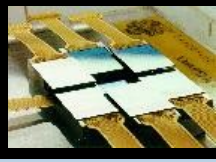
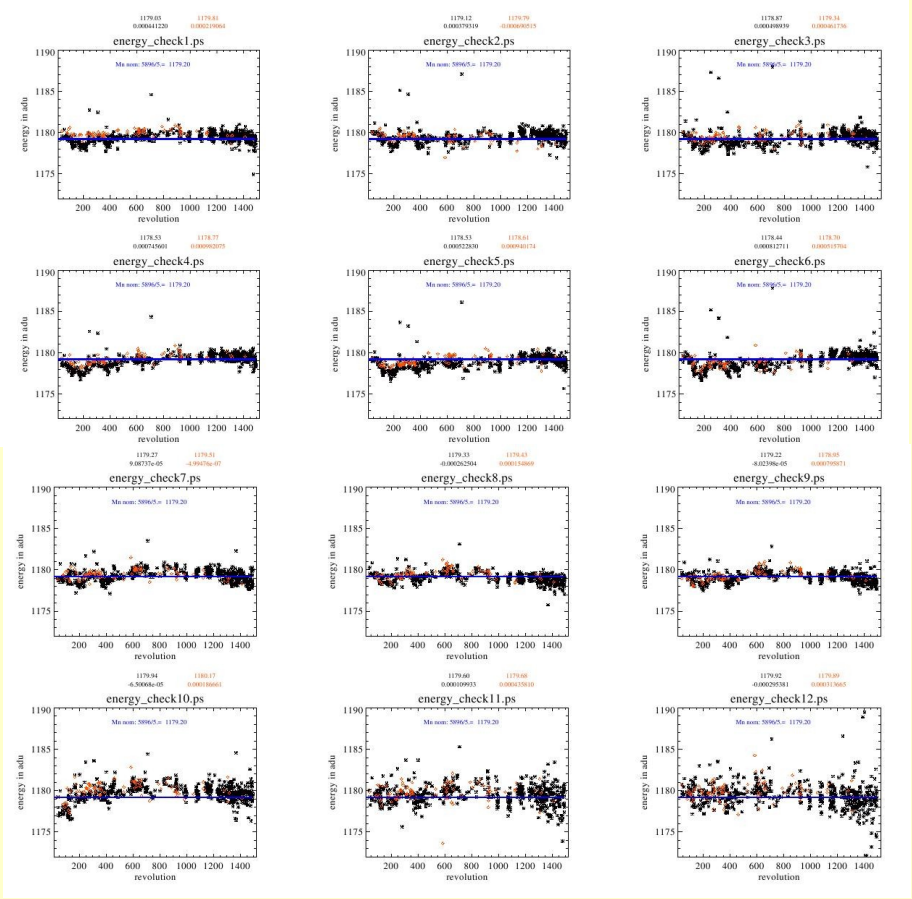


Refinement of CTI/gain

Refinement in pn long-term CTI



(Kirsch 2007)

Additionally:

- Refinement of Timing Mode gain (astrophysically-based)
- Refiniment of special CTI correction for pn Small Window (astrophysically-based)
- Refinement of CTI special correction for Large Window mode (PANTER measurement)

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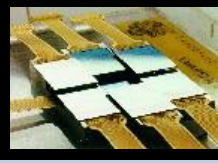
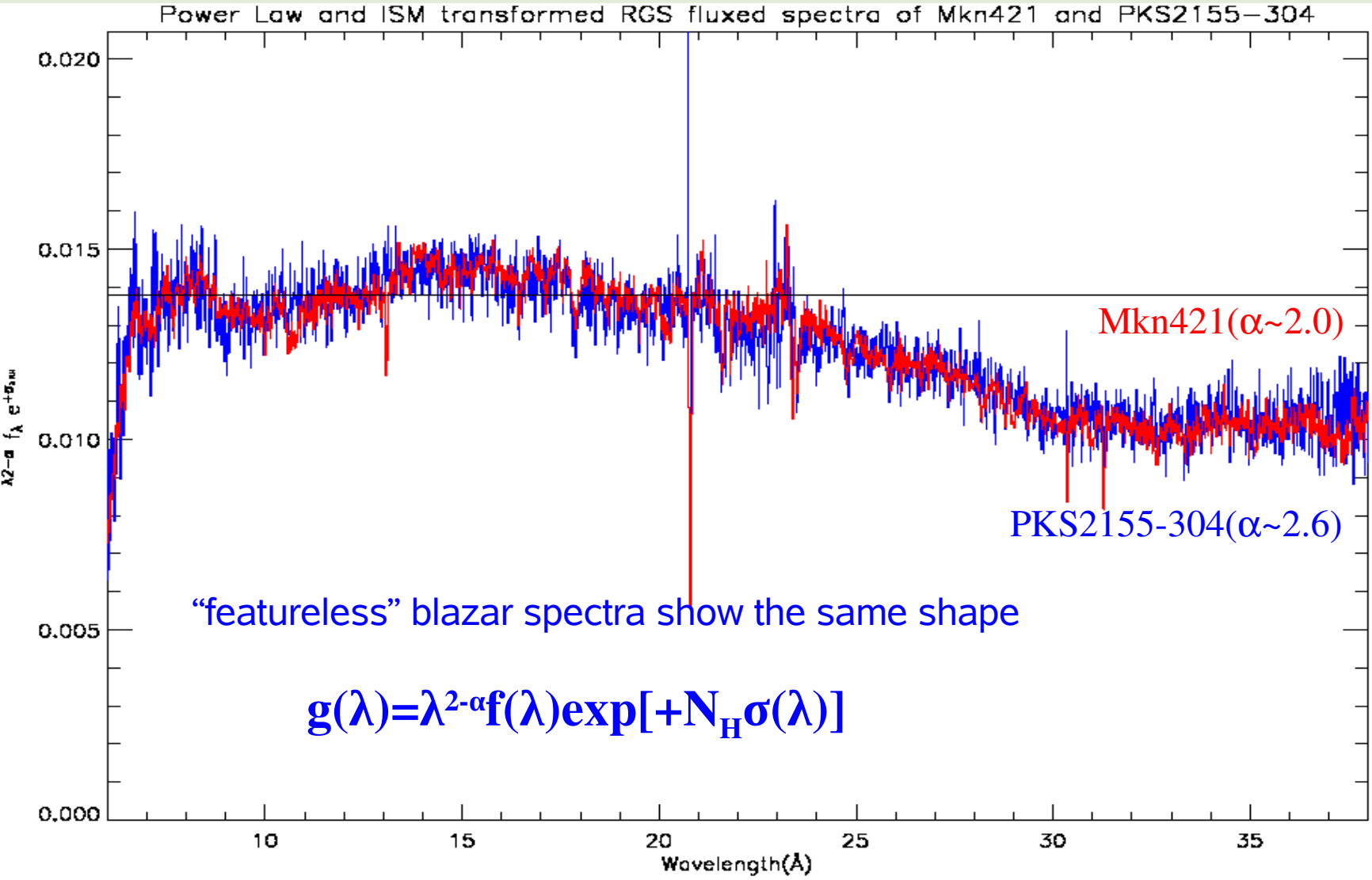
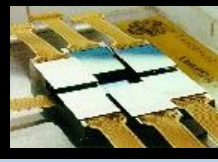


Basis of RGS effective-area corrections



"featureless" blazar spectra show the same shape

$$g(\lambda)=\lambda^{2-\alpha}f(\lambda)\exp[+N_H\sigma(\lambda)]$$



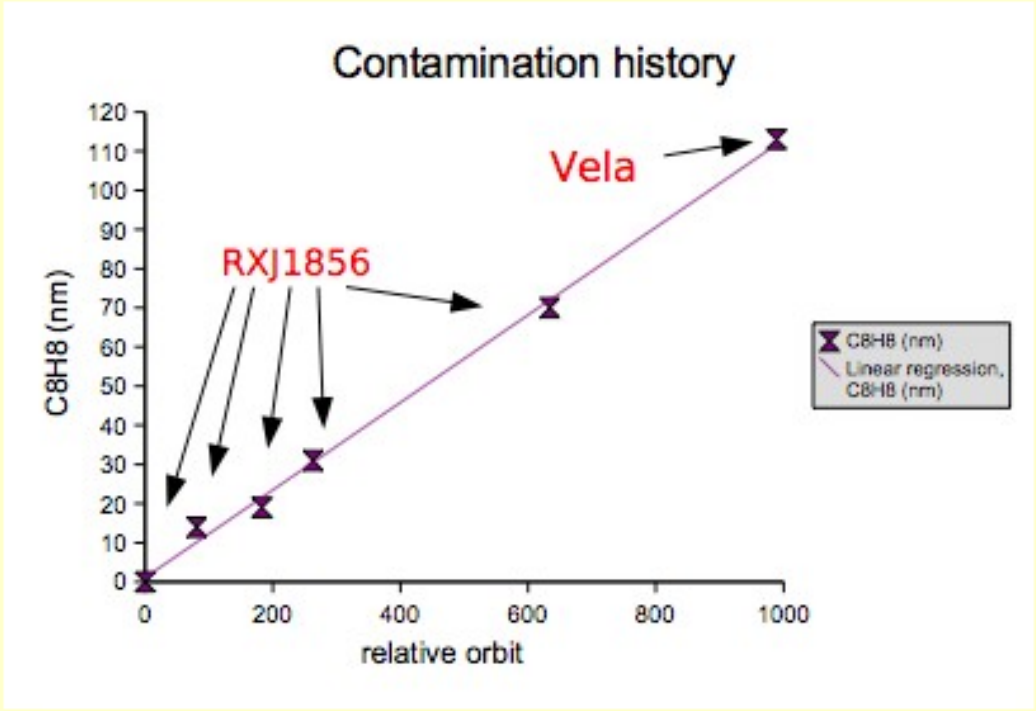
RGS effective-area corrections

- Δ(RXJ1856-3754) & Δ(Vela PWN)
  - ∀ ⇒ linear build-up of contamination by Carbon
- RGS EFFAREACORR CCF =
  - PolynomialCorrection(!t)×exp(-Ct)×CrabCorrection

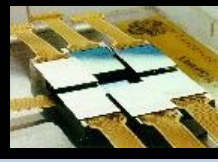
Ex: RXJ1856-3754 in RGS1

2002-04-08 : 0.171±0.002 cts/s

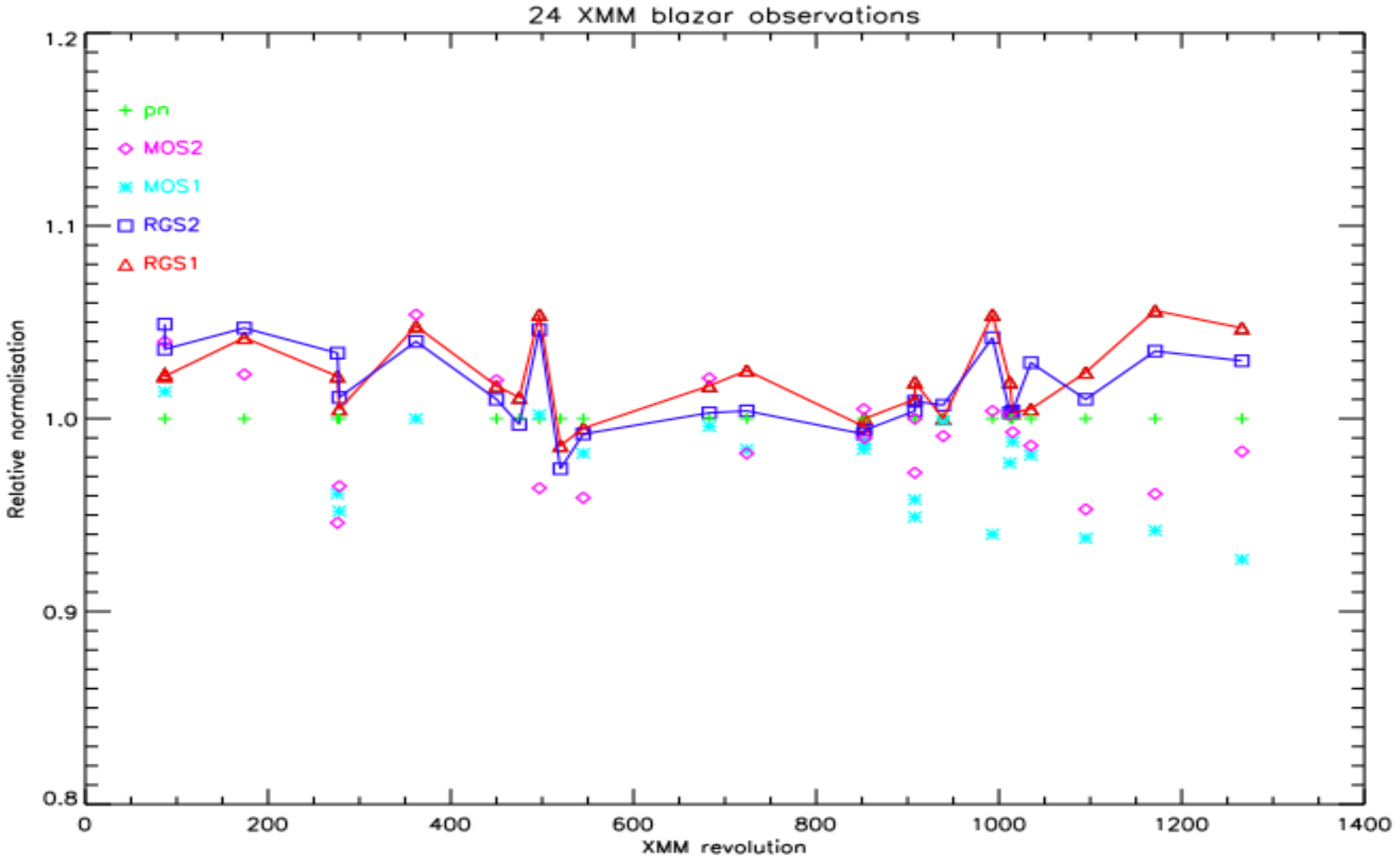
2008-03-14: 0.147±0.002 cts/s



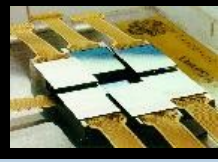
esa ESAC



RGS vs EPIC 2007-8 blazar statistics



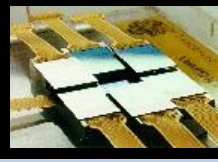
esa ESAC



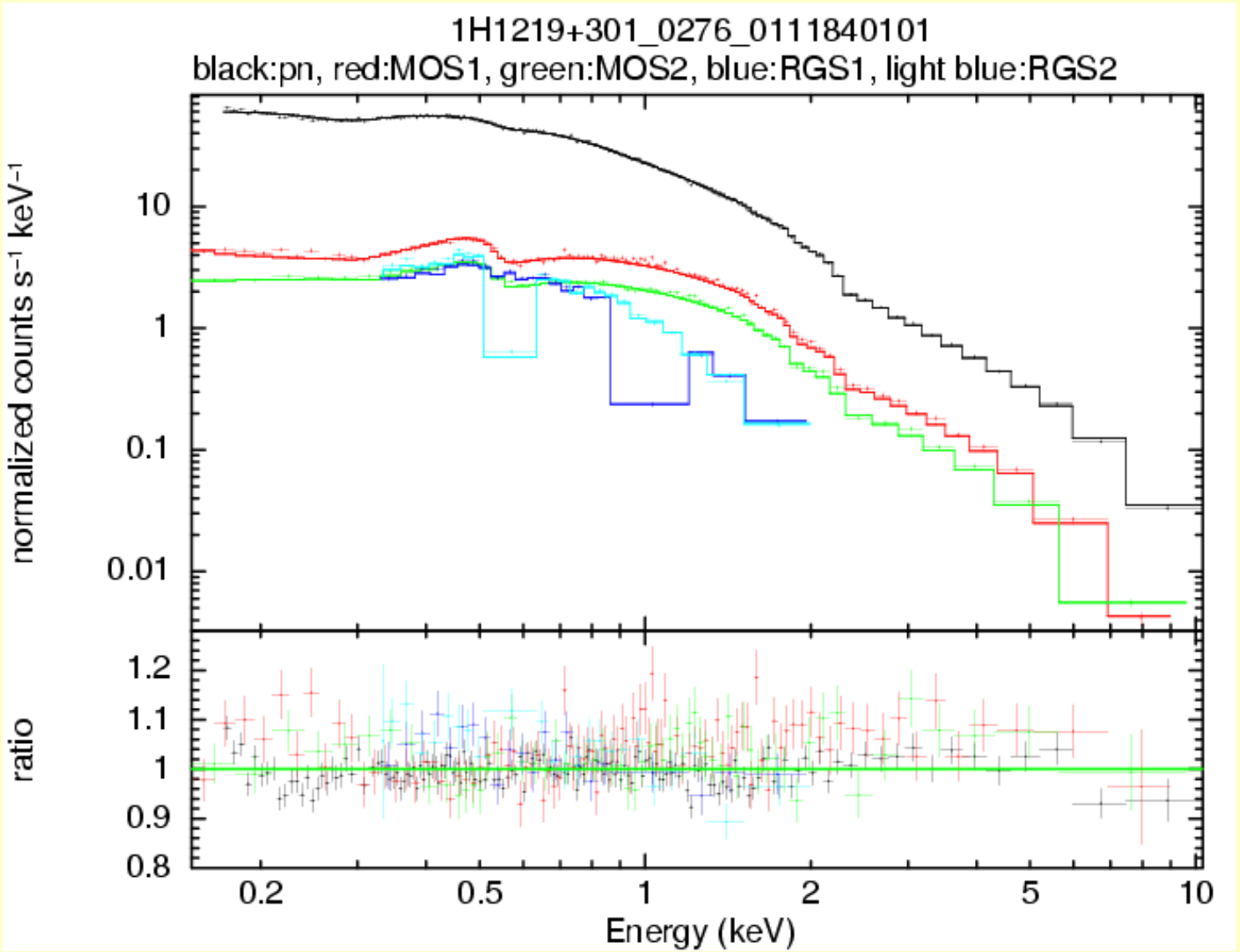
XMM-Newton cross-calibration archive

- 70 on-axis sources
- NEW: 24 off-axis sources (the brightest in the 2XMM catalog at off-axis angles *i:* 5'≤*i*≤12')
- Spectral fitting examples on various sources using SASv7.1 and the public CCFs
  - Comparison with previous calibration/SAS versions possible
- Statistical evaluation of fluxes measured in 5 energy bands
- Evolution of spectral parameters as a function of time for multiple-observations sources
- Cross-calibration with *Chandra* and *Suzaku:*
  - *Chandra:* 3C273, Mkn421, Mkn590, PKS2155-304
  - *Suzaku:* PKS2155-204
- `http://xmm2.esac.esa.int/cgi-bin/ept/preview.pl?`

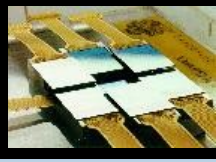
esa ESAC



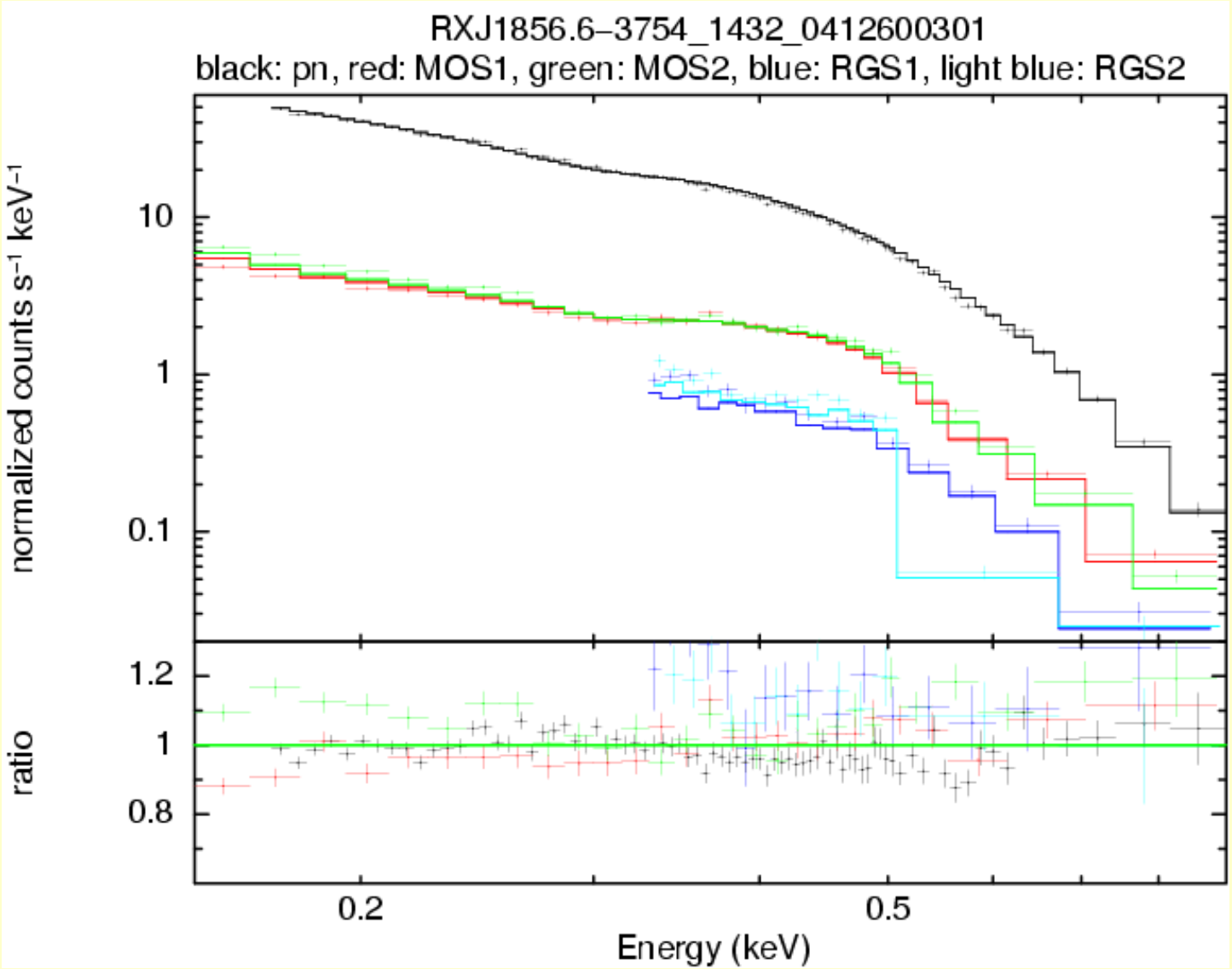
Representative examples: 1H1219+301



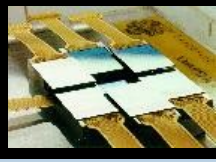
esa ESAC



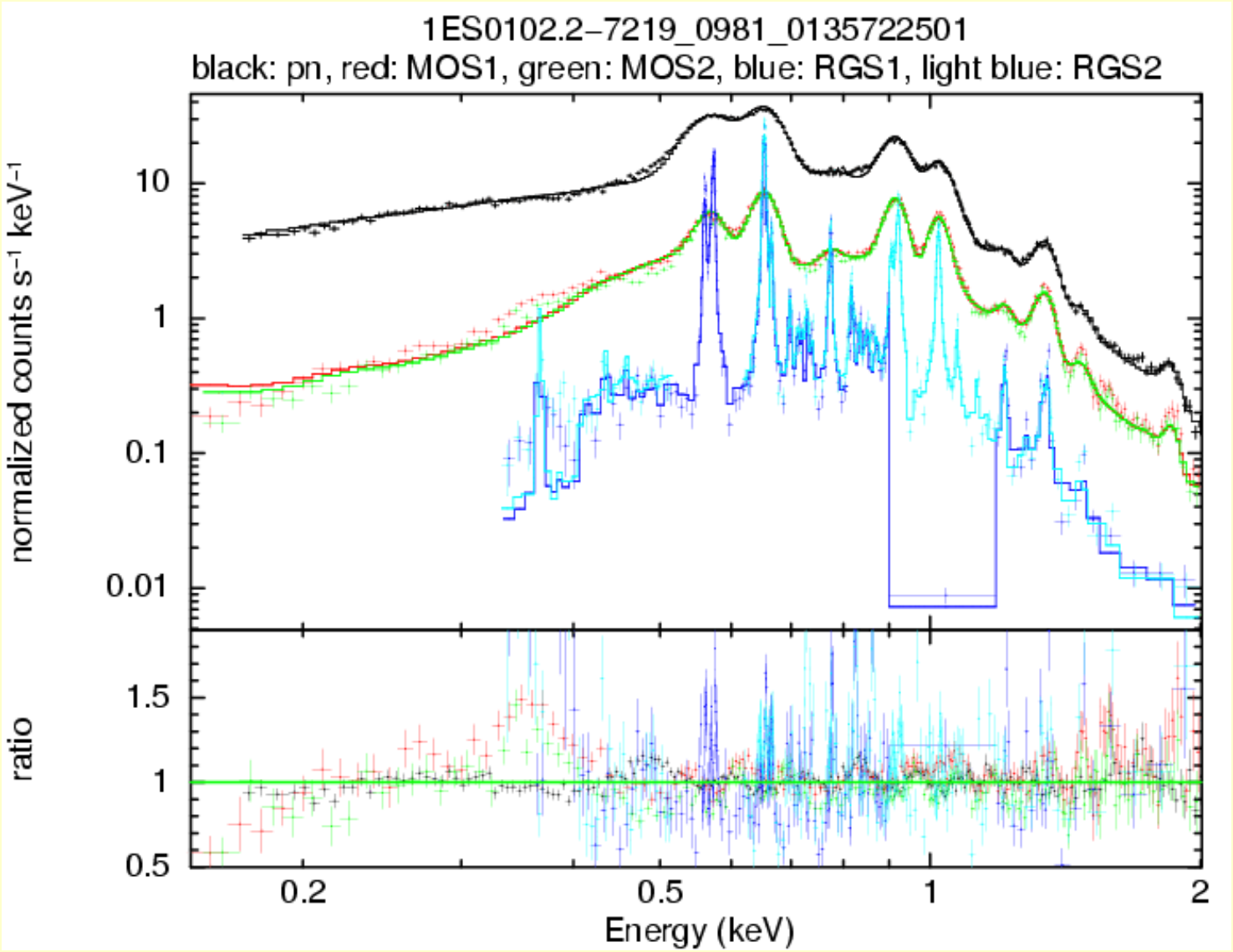
Low energy source: RXJ1856-3754



esa ESAC

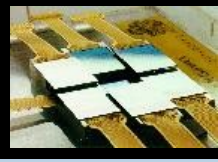


Line-rich source: 1ES0102-7219



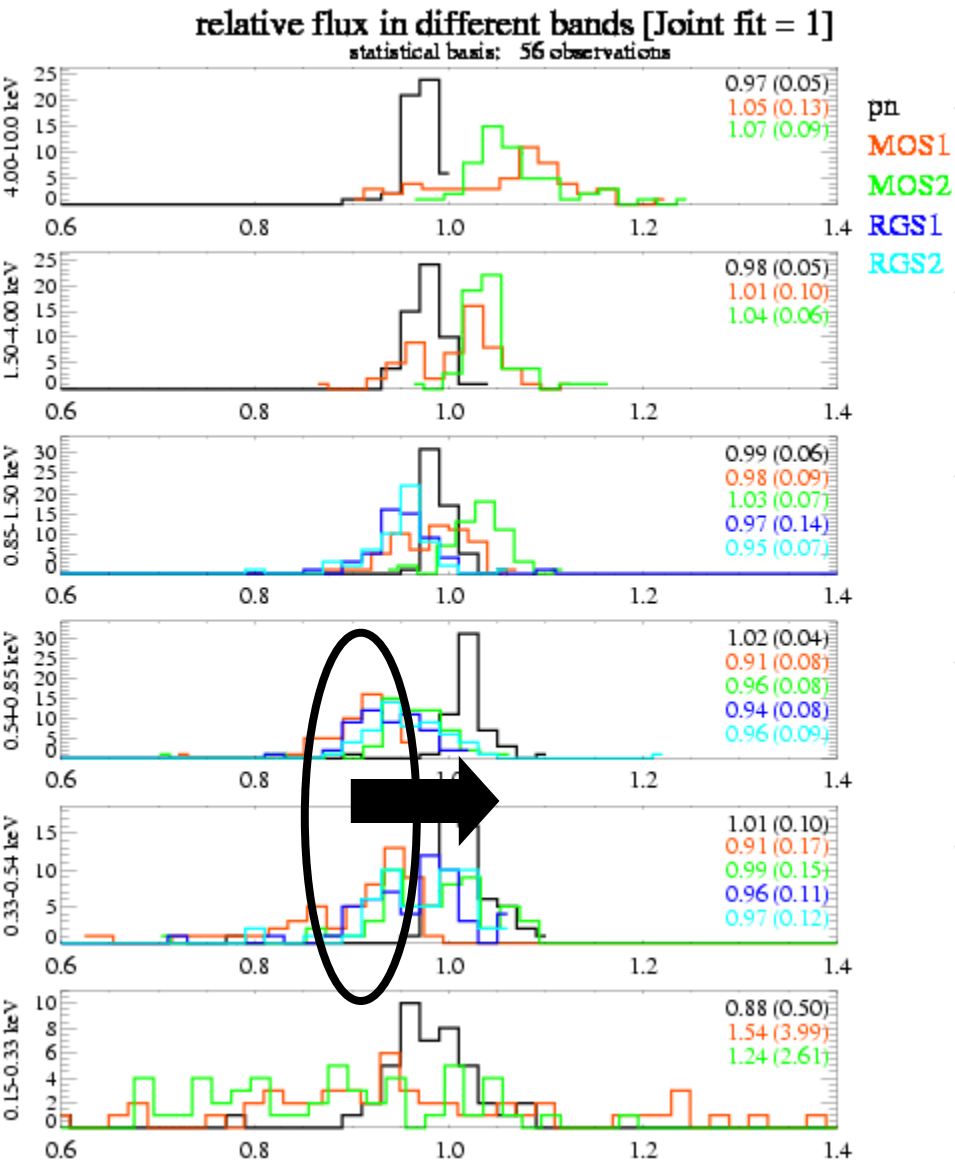
- 39 lines
- 6 recombination edges
- absorbed brems-strahlung
- joint fit to all instruments

esa ESAC

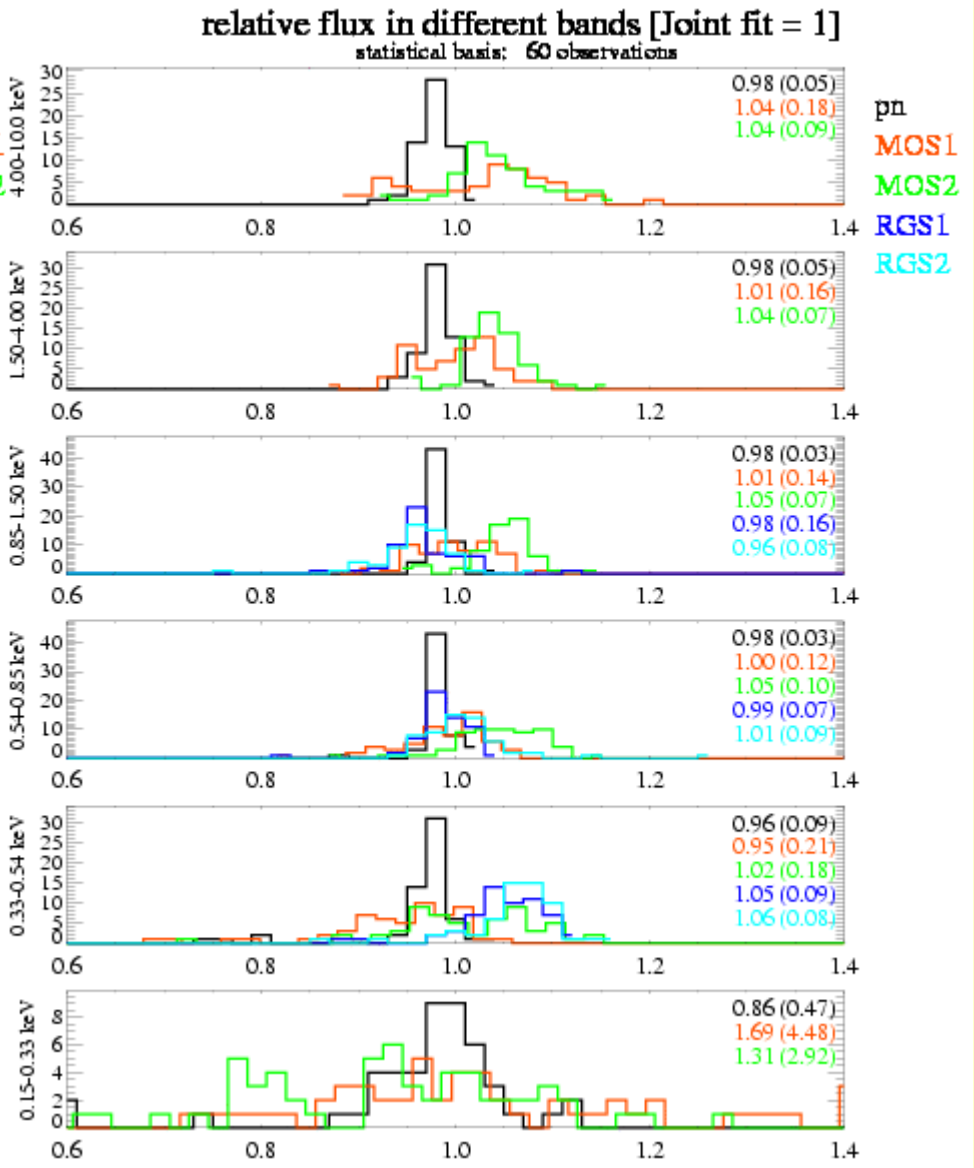


Statistical flux evaluation

SAS7.0



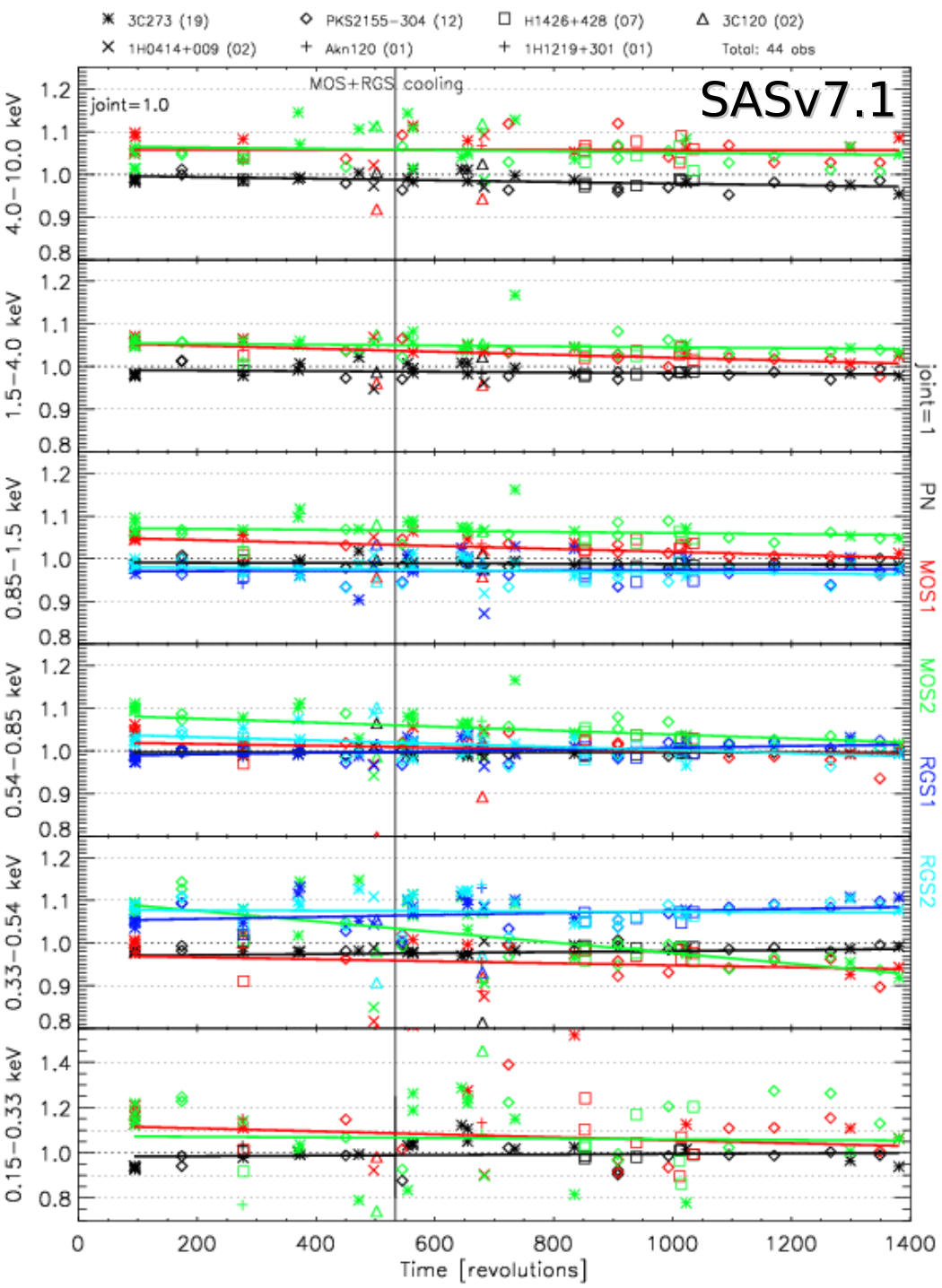
SAS7.1



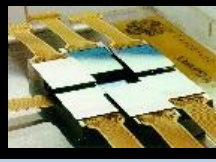
Flux ratio history

- Above ~0.8 keV, MOS fluxes are higher by on average 5-8% than pn.
- High deviations for MOS/pn flux ratios below 0.3 keV.
- Above O-edge RGS (up to 1.5 keV) and EPIC-pn agree to 2% on average.
- Below O-edge RGS fluxes are on average 5-10% higher than EPIC-pn.
- RGS flux ratios are stable for all energy bands.
- Possible trend with time in MOS/pn ratio being investigated

➡ **EPIC and RGS are consistent on average within 10%.**

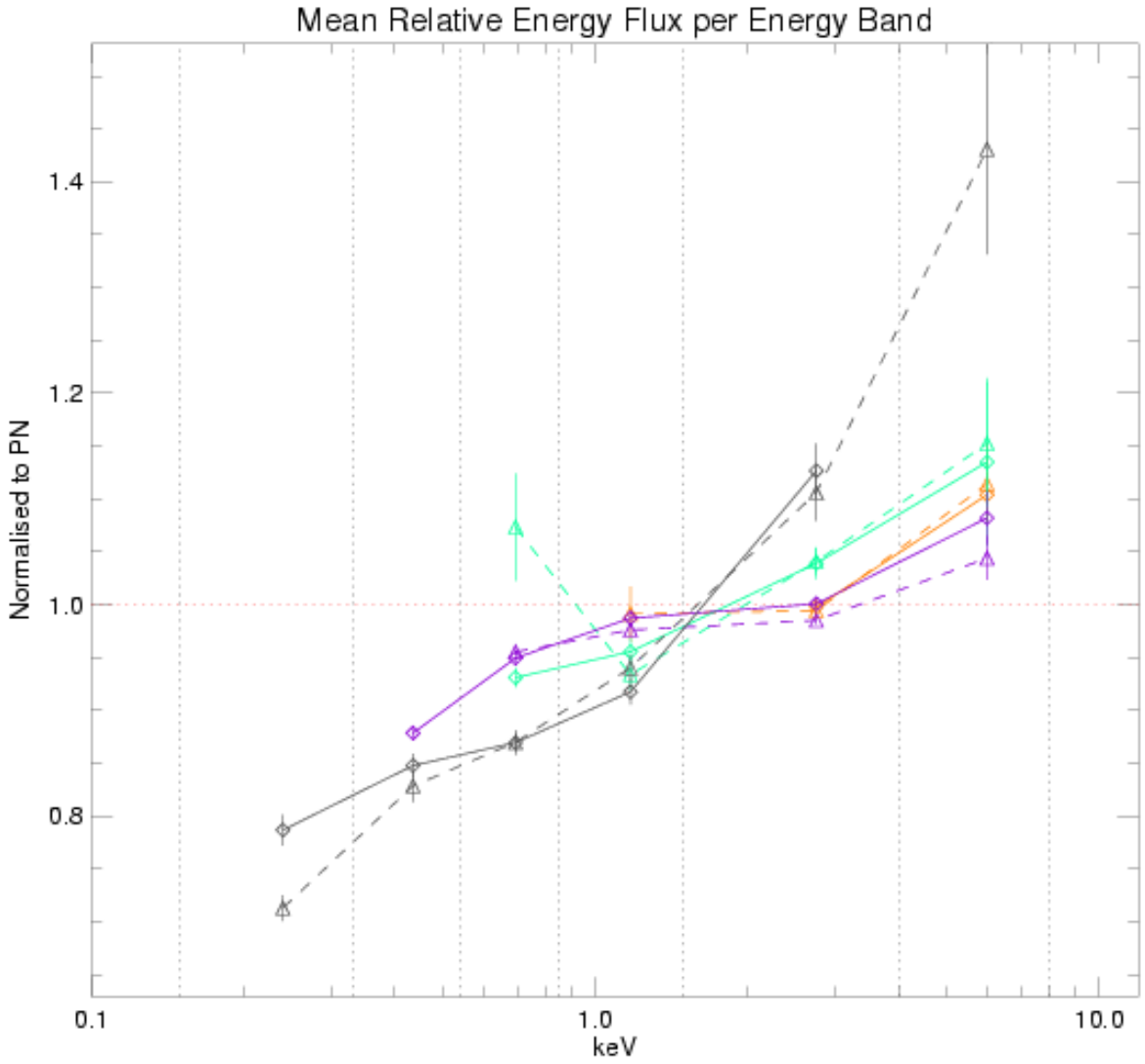


esa ESAC



XMM-Newton/Chandra comparison

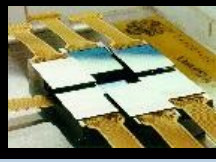
NEW: SOC XMM-Newton/Chandra cross-calibration archive



- 24 observations (Chandra)
- Mean flux ratio for different energy bands.
- [Error bars represent combined statistical errors of individual observations.]

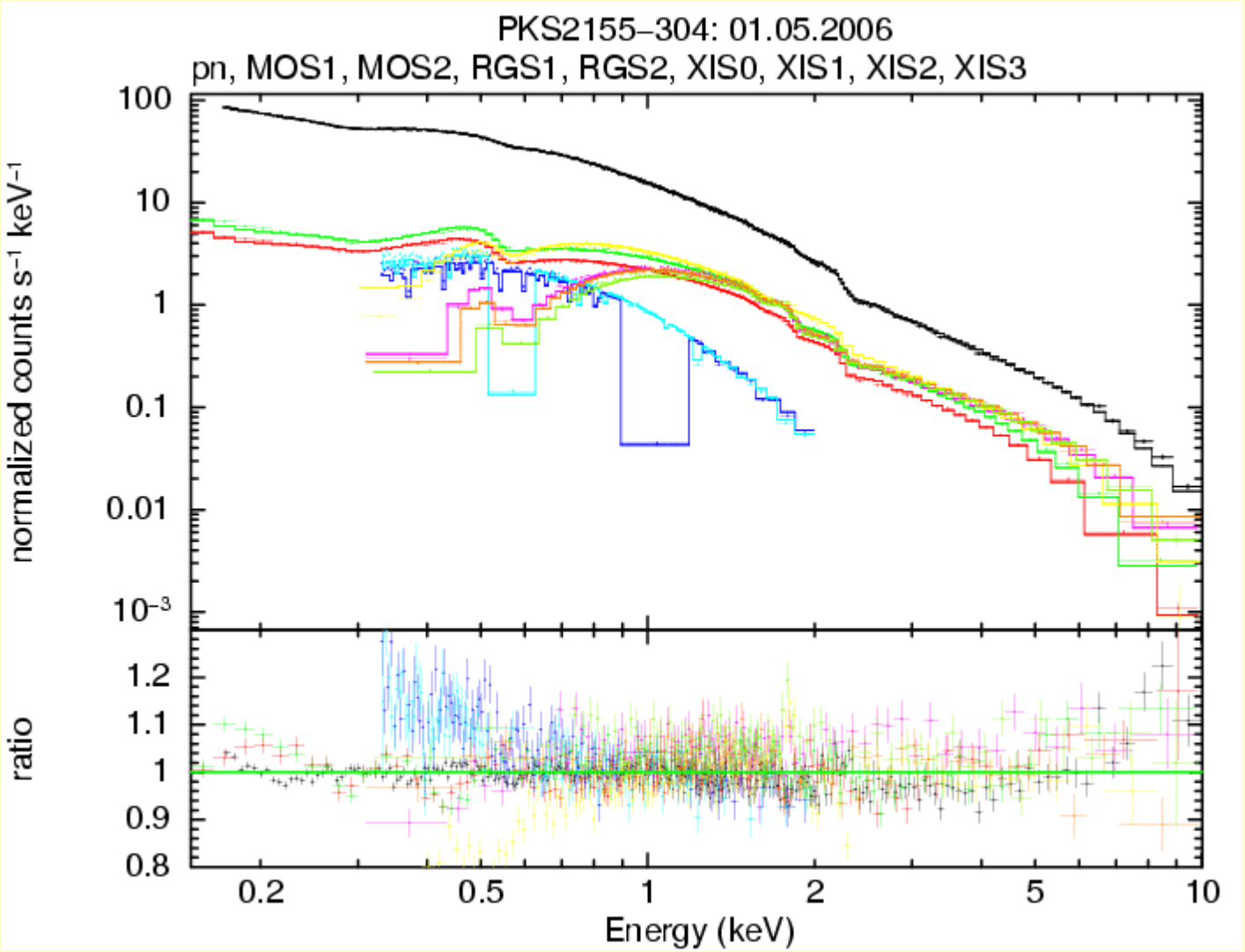
(courtesy of M.Smith)

esa ESAC



XMM-Newton versus Suzaku

NEW: SOC XMM-Newton/Suzaku cross-calibration archive



- PKS2155-304
- XMM rev. 1171

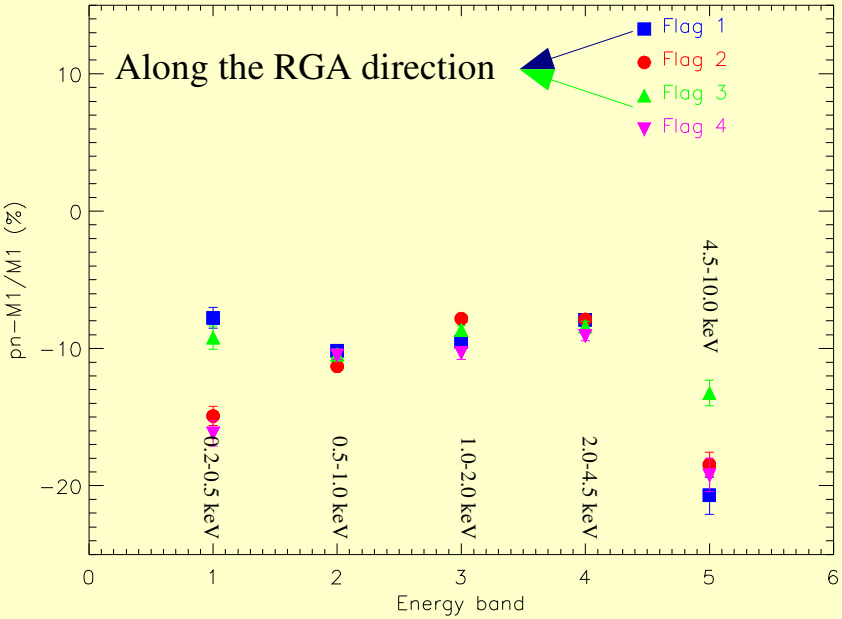
- FTOOLS 6.4
- Joint fit to all instruments.
- Absorbed single power law model
- $\chi_\nu^2 = 1.36/10439$ dof

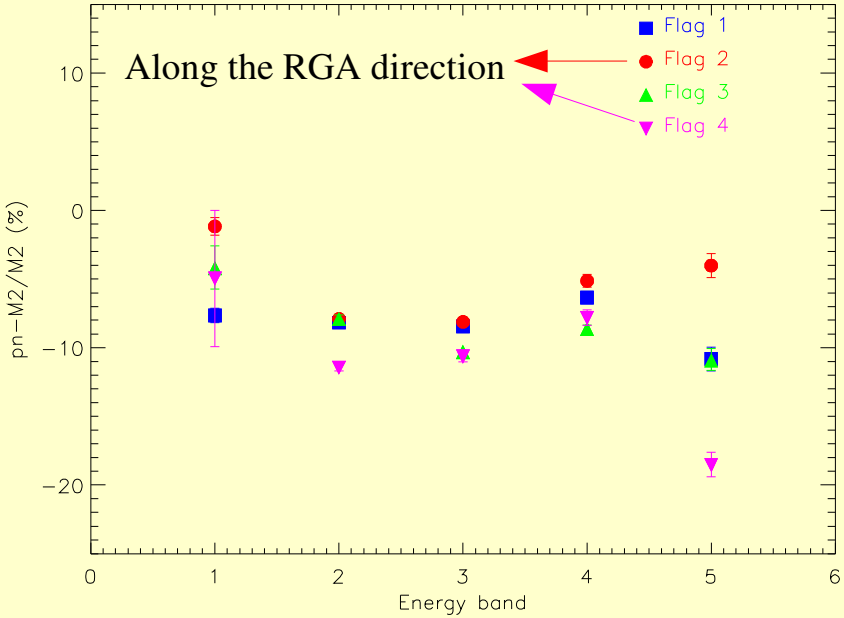
- Good general slope agreement.
- XIS fluxes slightly higher than EPICs.

Azimuth-dependence of camera fluxes in 2XMM

pn/MOS relative flux differences in 2XMM sources as a function of energy band

(colors code the quadrant in detector coordinates where the source is located)





(Mateos et al. 2008)

- In the 0.5-4.5 energy band average difference ≅8-10%
- Azimuth-dependence of pn/MOS flux differences in the **4.5-12 keV** band

(spread in the **0.2-0.5 keV** band mostly due to the usage of a non-patch redistribution in 2XMM)

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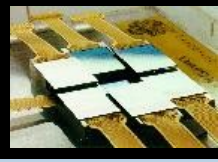
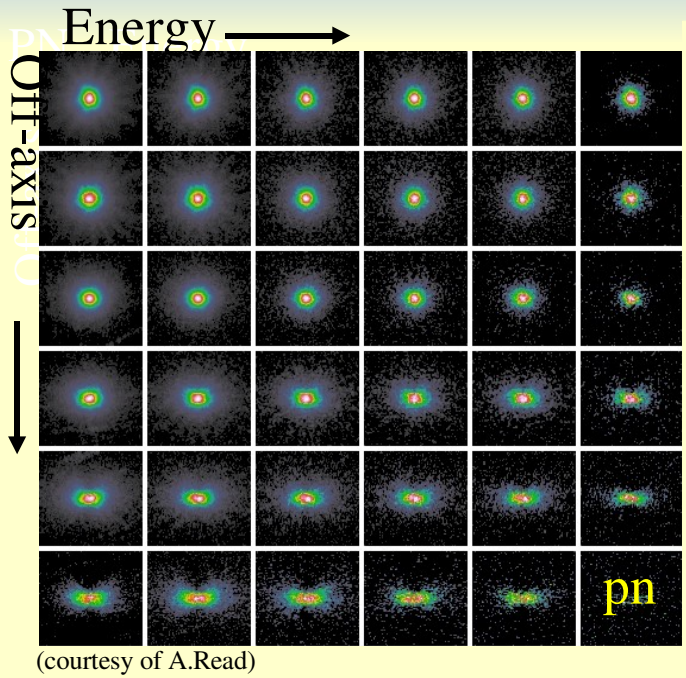
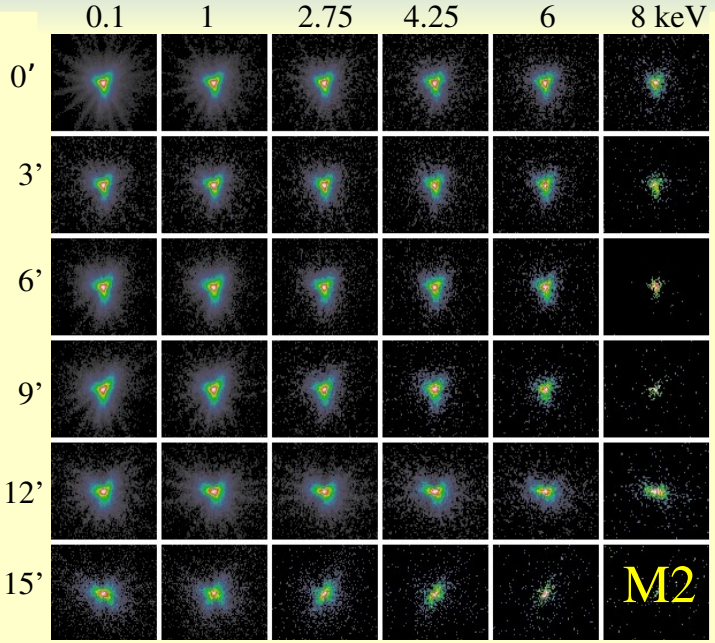


2-D parametrized EEF calculation



(courtesy of A.Read)



- Stacked images were fit with a "beta-model": $\{A/[1+(r/r_0)^2]^{\alpha}\}$
- New CCF PSFs [ELLBETA] were generated with core radius, ellipticity, and power-law index as a function of camera, energy, off-axis
- SASv8.0 `arfgen` will use this "2-D PSF" to calculate the encircled energy fraction

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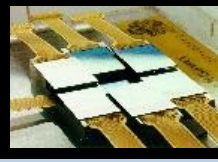
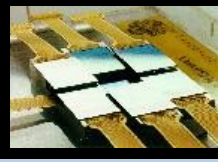


EPIC calibration accuracy status

Effect	Max. Error	Energy dependent	Off axis angle dependent
Accuracy of the XMM-Newton frame with reference to optical frame	1''(r.m.s.)	NO	NO
Relative Astrometry	1.5''(r.m.s)	NO	YES
Absolute Astrometry	2.0''(r.m.s)	NO	YES
Point Spread Function (PSF)	2 %	YES	YES
Relative Effective Area	± 5 %	YES	YES
Absolute Effective Area	± 10 %	YES	YES
Absolute Energy scale	± 10 eV	YES	YES
Relative Timing	$\Delta P/P<1E-8$	NO	NO
Absolute Timing	100 μs	NO	NO

http://xmm.esac.esa.int/document/CAL-TN-0018.pdf

esa ESAC



Cross-calibration status

- MOS flux above ~0.8 keV higher than pn by 5-8%.
- RGS and EPIC-pn flux ratios agree above O-edge to 2% on average.
- Current implementation of time-dependent RGS effective area model shows discrepancies below O-edge of 5-10%.
- RGS fluxes stable across the mission

EPIC and RGS are consistent on average within 10%.