# XMM-NEWTON SCIENTIFIC PAYLOAD CALIBRATION UPDATE

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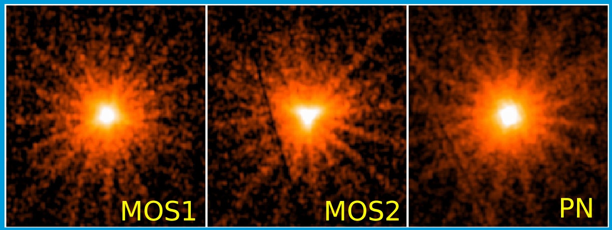
*on behalf of the XMM-Newton Instrument Teams and of the XMM-Newton SOC Instrument Dedicated Team*

# Outline

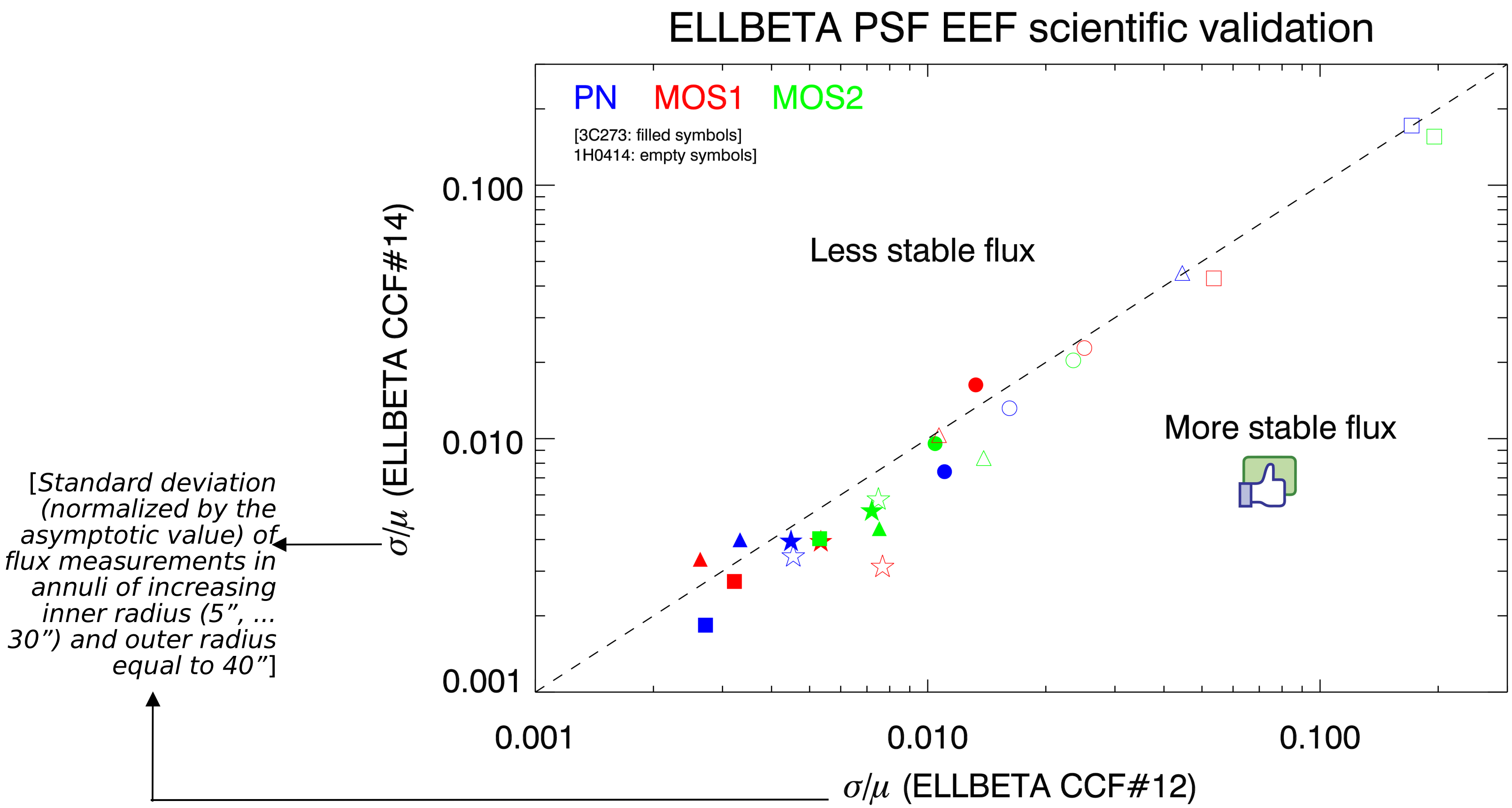
- 2-D PSF and astrometry
- RGS Line Spread Function (LSF)
- Energy- (wavelength-) scale updates in EPIC-MOS, EPIC-pn, RGS
- RGS contamination
- XMM-Newton cross-calibration status
- Future outlook

# EPIC 2-D PSF: parameterization




(Read et al., 2011, A&A, 534, A34; Read & Saxton, 2011, XMM-CCF-REL-280; Owen & Ballet, 2011, SSC-CEA-TN-1001)

The calibration of the 2-D PSF (ELLBETA) parameters has been improved to:
a) align the spoke intensity and radial profile to the observation of bright sources;
b) increase the stability of the measured fluxes as a function of excised core radius



# EPIC 2-D PSF: astrometry

(Summary courtesy of A.Read)

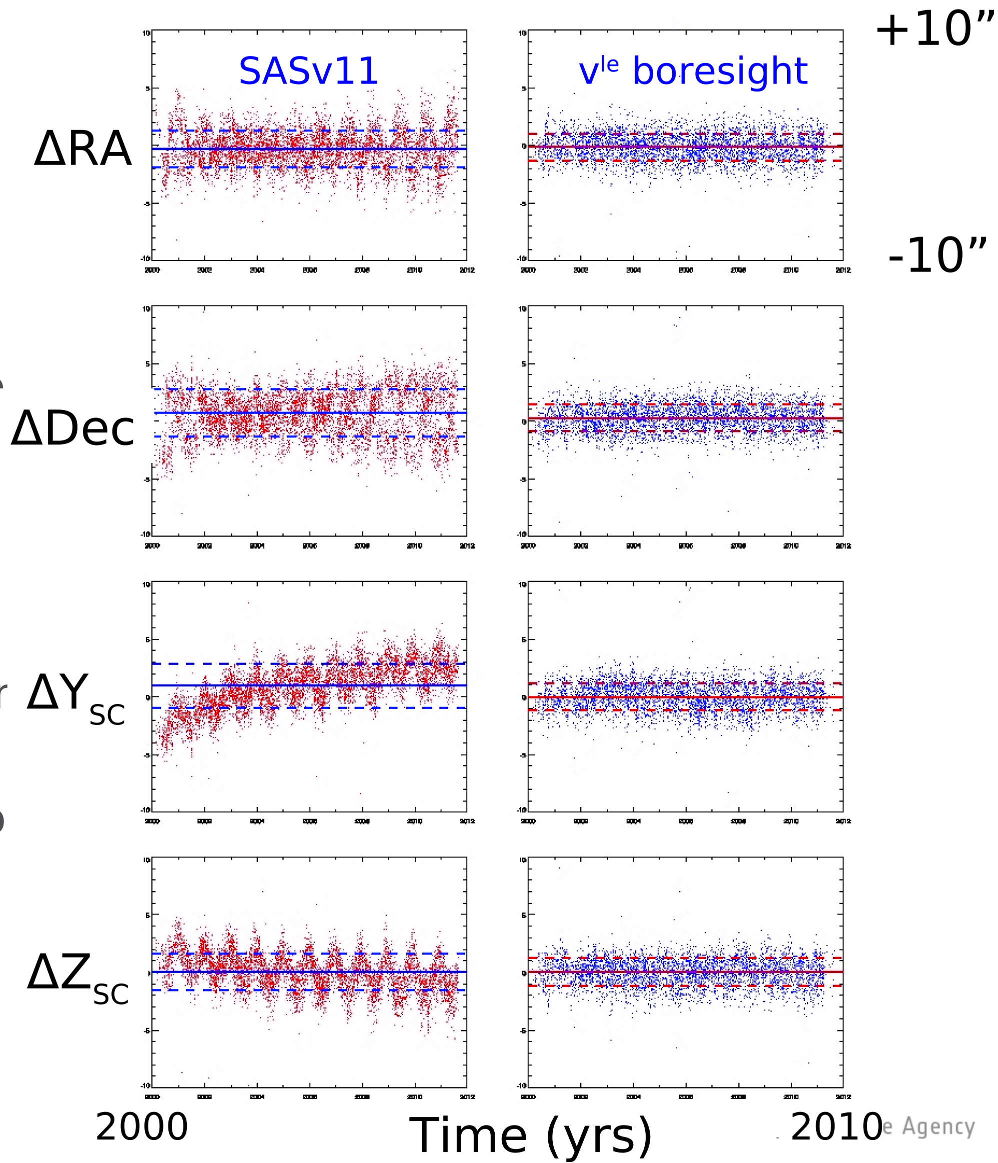
- Most of the 2-D PSF work has been focused on astrometry
- 3 issues have been discovered (and partly solved):
  - Sinusoidal behaviour as a function of position angle in the `MEDIUM` PSF
    - Due to: wrong centroiding (by about half a pixel) of the `MEDIUM` PSF
    - Solution: use the 2-D PSF (improves the astrometry in 70% of sources)
  - Systematic "offset" by about 1" between the `ELLBETA` and reference catalog positions
    - Shift seen when changing *only* the PSF type
    - Due to: software bug in `emldetect`
    - Solution: bug fixed in SASv12 – residual offset ±0.3-0.4"
  - Seasonal dependency (+ low-frequency trend in OM) of the "offset"
    - ±2" (dynamical range) wave-like dependence with time/PA/RA (correlated quantities)
    - Due to: cause unknown (errors in the code, systematics in the S/C boresight, thermal effect?)
    - Solution: "variable boresight" (see later)

- {(1+2 solved) + (previous slide)} = **2-D PSF the default as of *SASv12*** *(april 2012)*

# The OM "variable boresight"

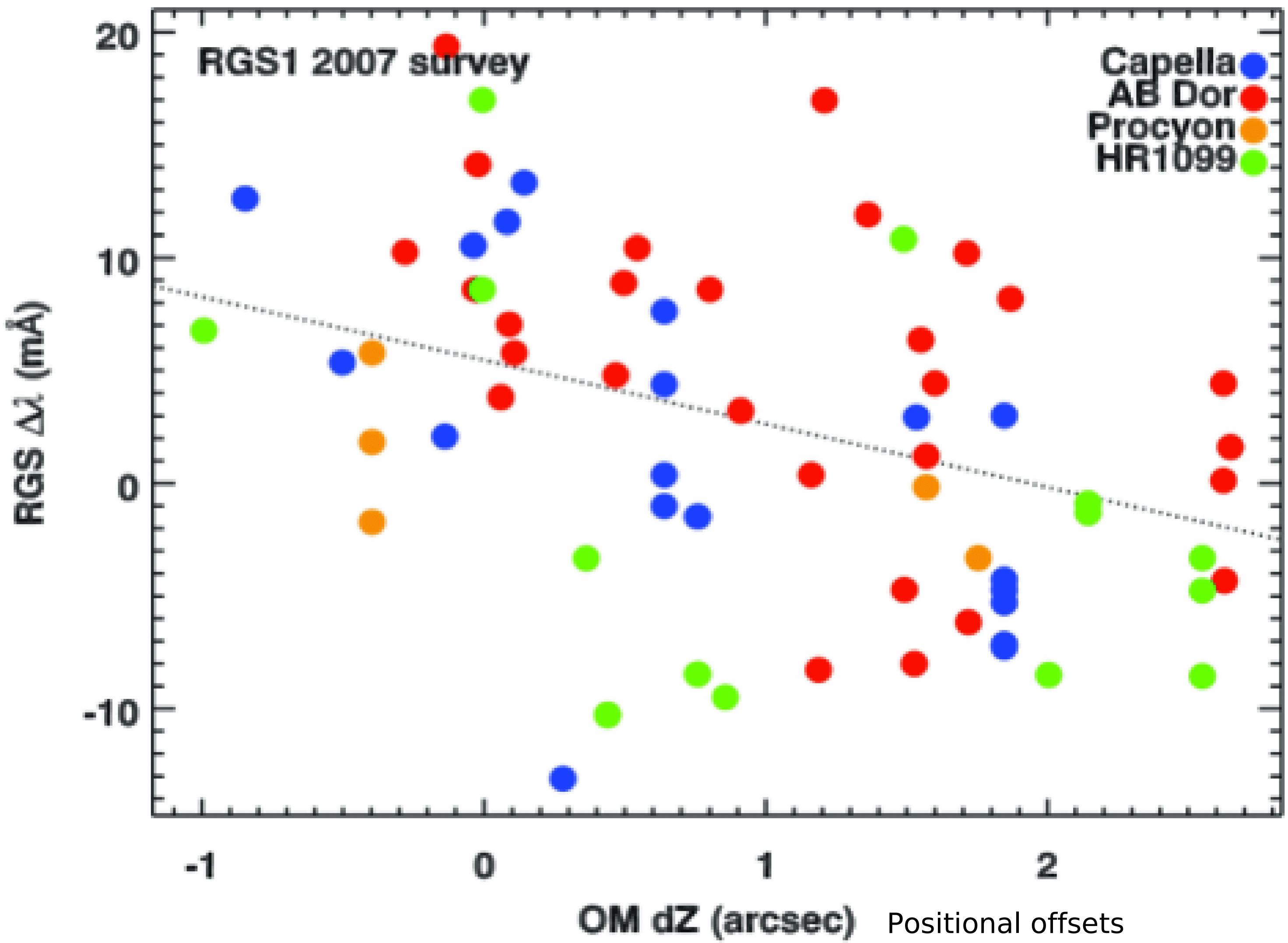
(Talavera & Rodriguez-Pascual, 2011, XMM-SOC-INST-TN-0041)

- The offset versus time relations are fit with a sinusoidal function + low-frequency envelope
- The function is translated into a correction table for the boresight Euler angles, sampled every 5 days
- The table is encoded in a new extension of the boresight CCF, and used in the processing
- This "variable boresight" leaves only a time-independent scatter of ≃1.5" (*i.e.* of the same order as the star tracker accuracy)
- The same approach is also being calibrated for the EPIC cameras
- The same approach will automatically apply to the RGS camera (astrometry inaccuracies could account for about half of the wavelength-scale systematics – under test)



# Impact of astrometry on the RGS λ-scale

(Courtesy of A.Pollock)



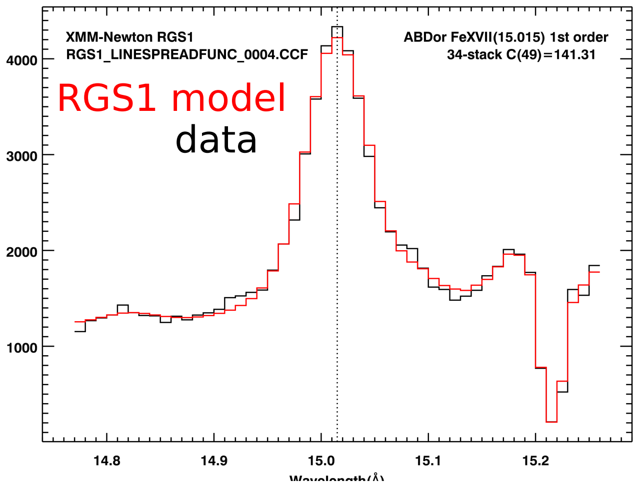

Positional offsets

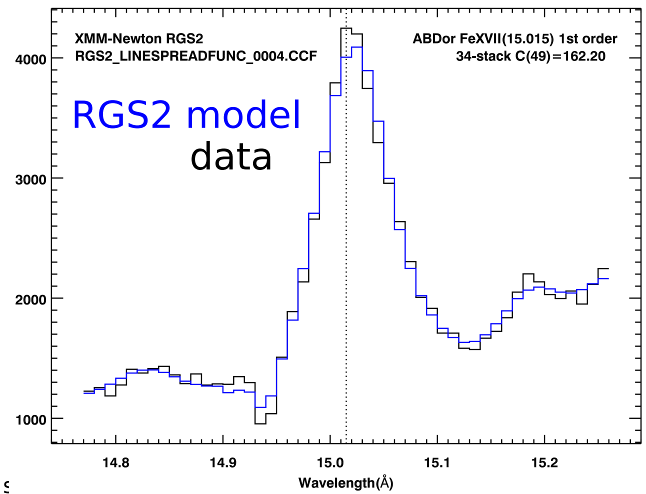
# RGS LSF

(Pollock, 2011, XMM-CCF-REL-275)

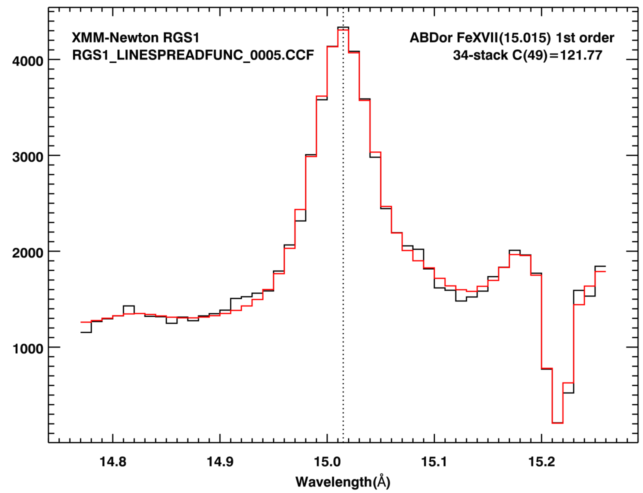
Outcome of an analysis of LSF parameter space by T.Raassen (SRON).
Post-LSF update wavelength accuracy for RGS1/RGS2: **7/5 mÅ**

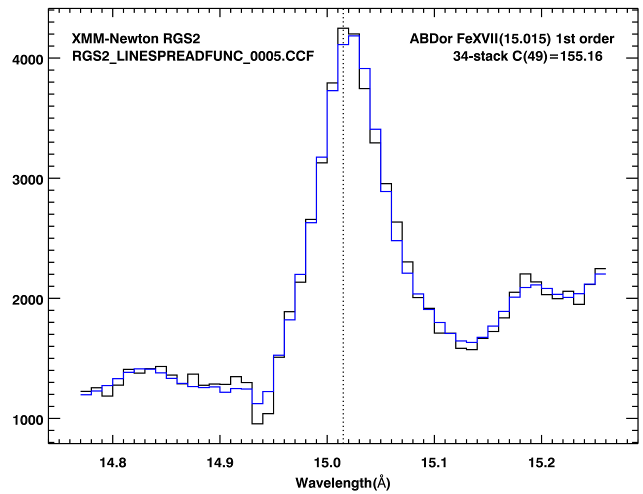
**Old CCF**




**New CCF**

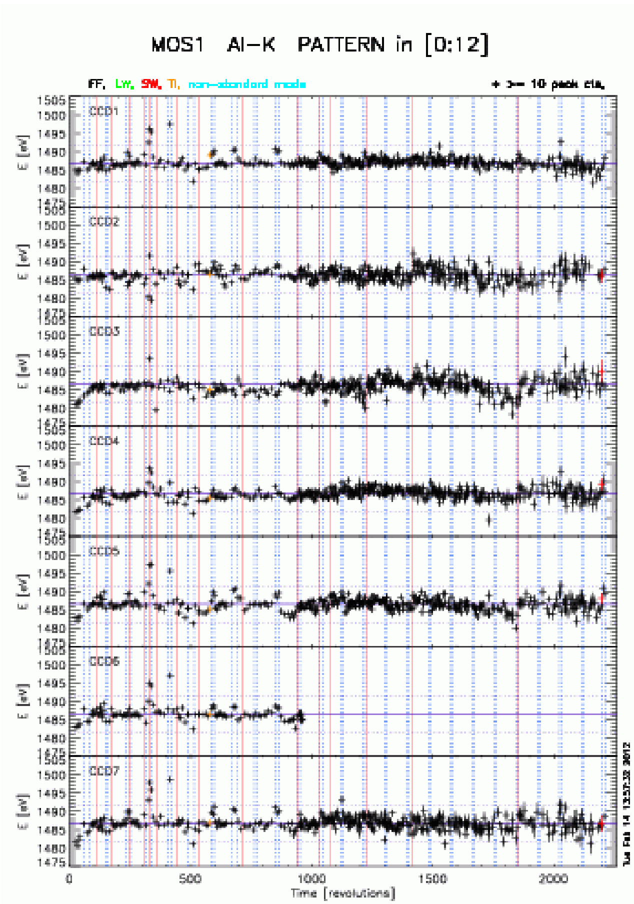


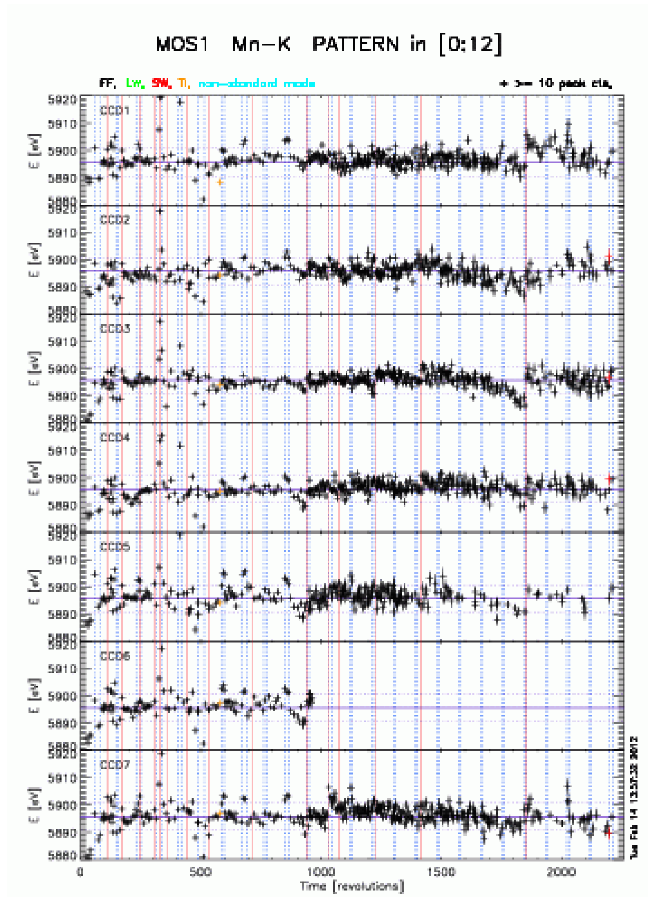



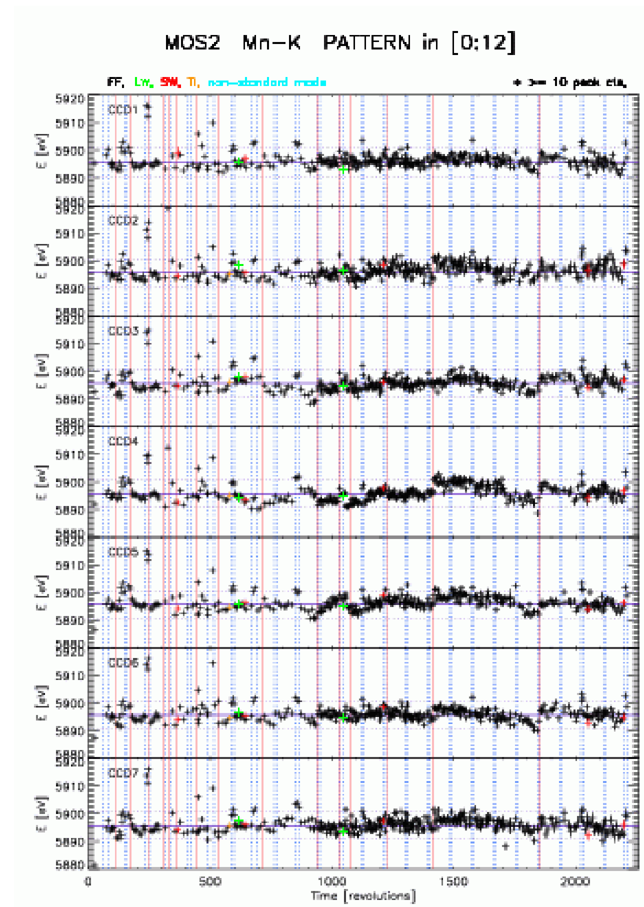
# MOS CTI/gain update

(Stuhlinger, 2011, XMM-CCF-REL-278, 279)

Periodic update of the CTI and gain (ADUCONV) in the MOS camera brings the accuracy of the calibration line energy reconstruction to **±5 eV** for all CCDs and epochs (from ≈-30 eV in the latest epochs with the old CCF)



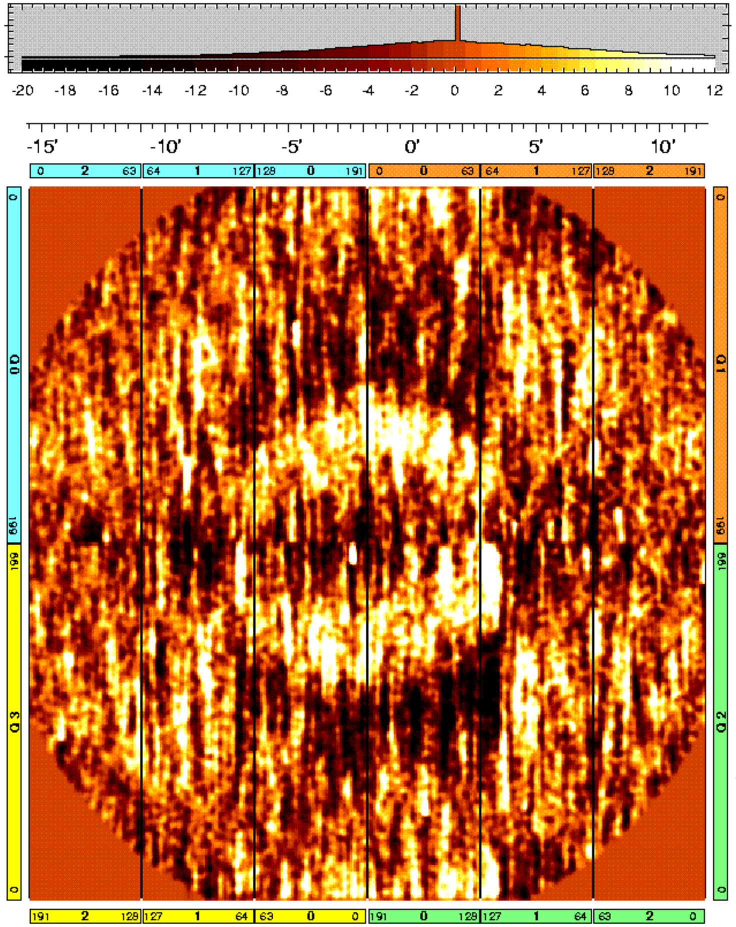



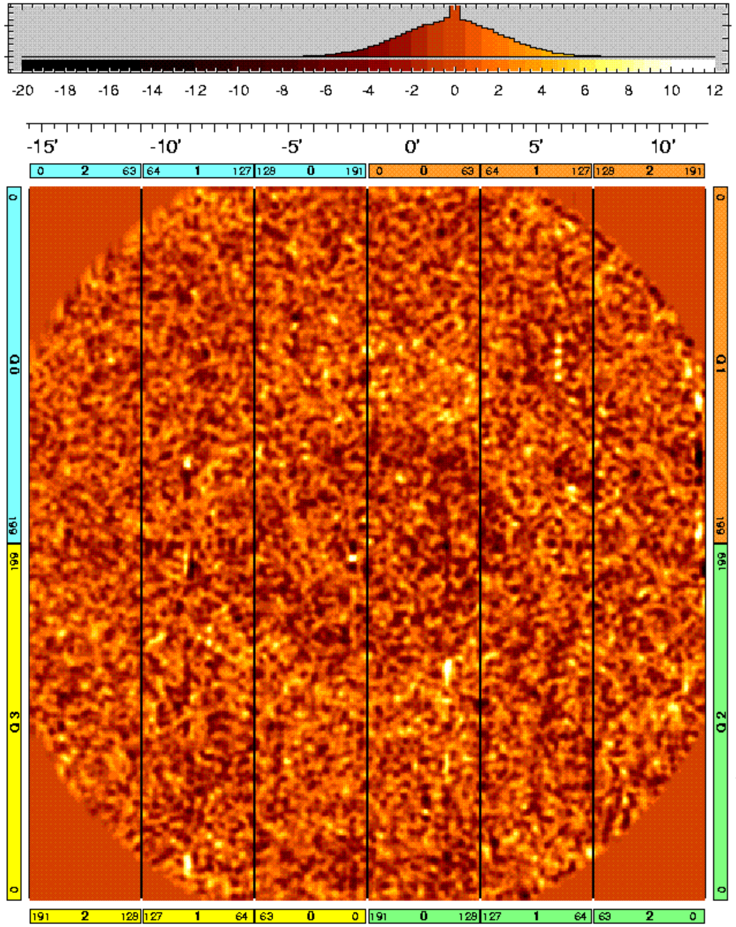
# EPIC-pn spatial gain correction for imaging modes

(Courtesy K.Dennerl)

Image of the Fe $K_{\alpha}$ band: measured versus nominal energy



SASv11 (now): ±10 eV (3σ)

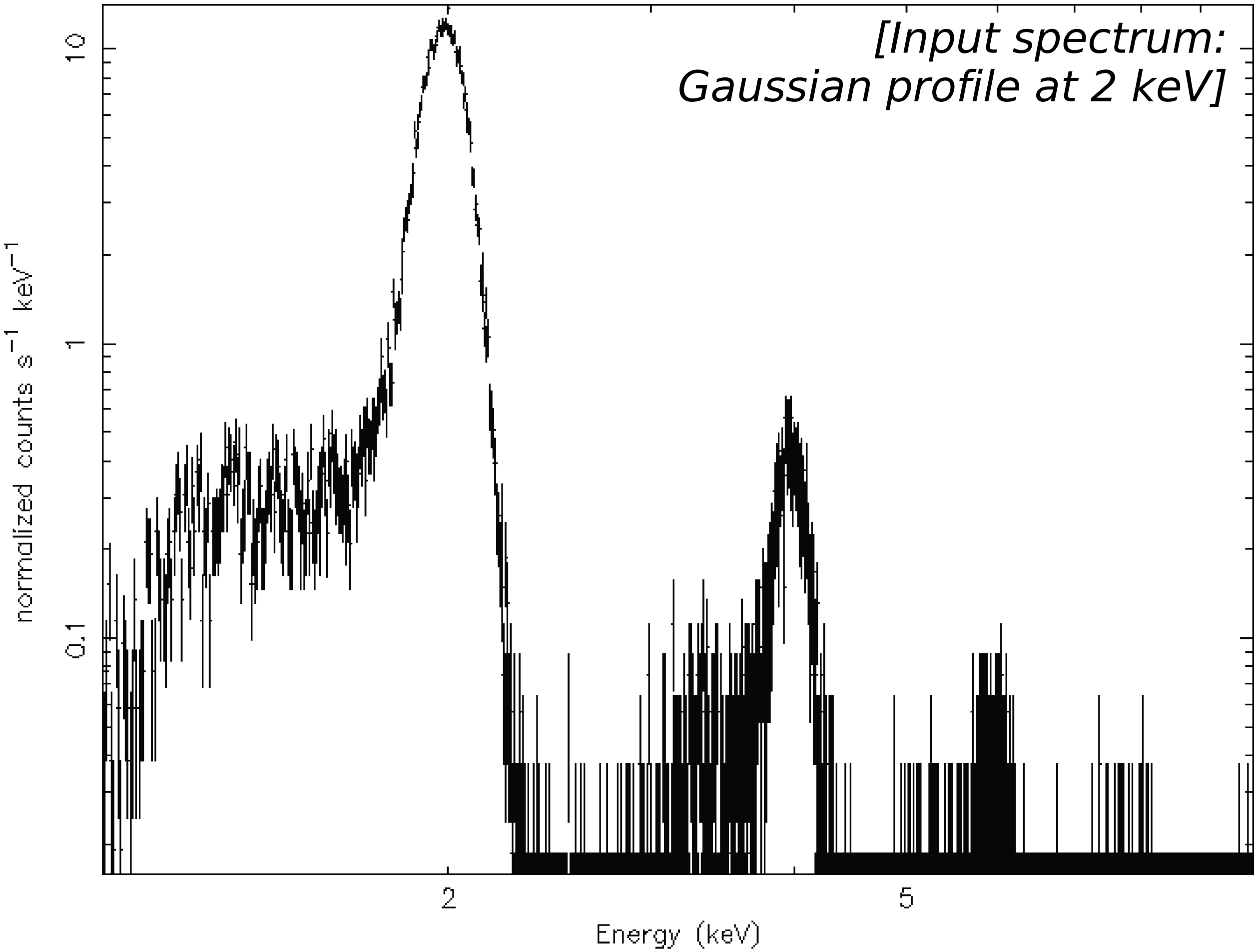


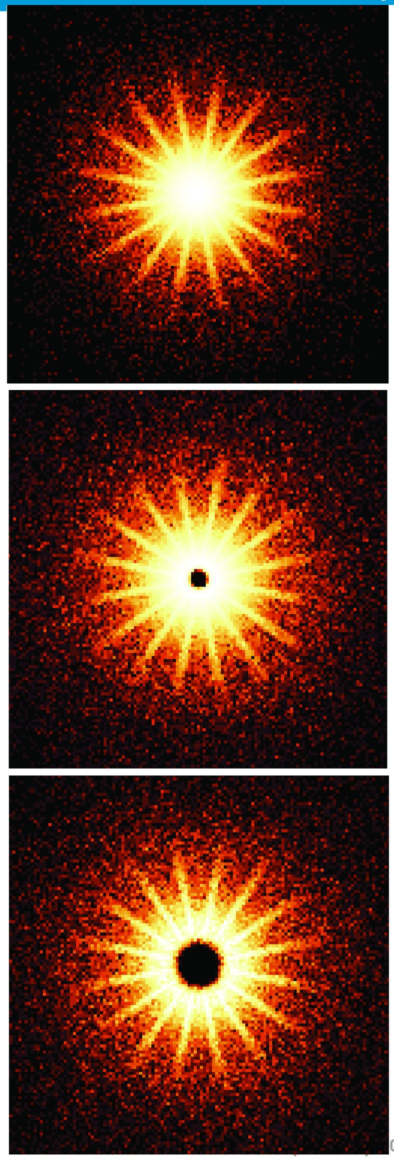
SASv12 (april 2012): ±5 eV (3σ)

# EPIC pile-up correction

(Cortesy P.Jethwa)

A novel event simulator is being developed at the SOC to investigate (and ultimately correct) for pile-up – more during the CCD Working Group meeting



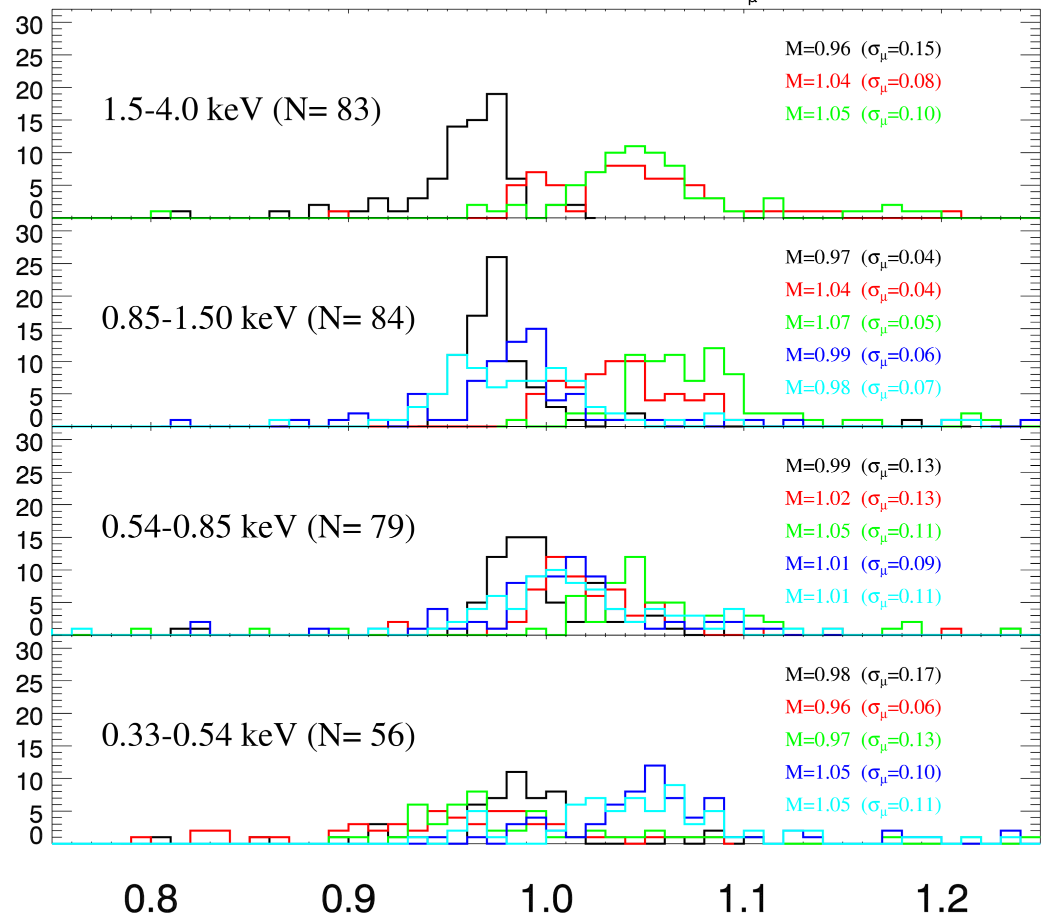
# Post-ELLBETA cross-calibration status

(Courtesy M.Stuhlinger)

*[Based on preliminary results on the SASv12 development track – (SASv11)]*

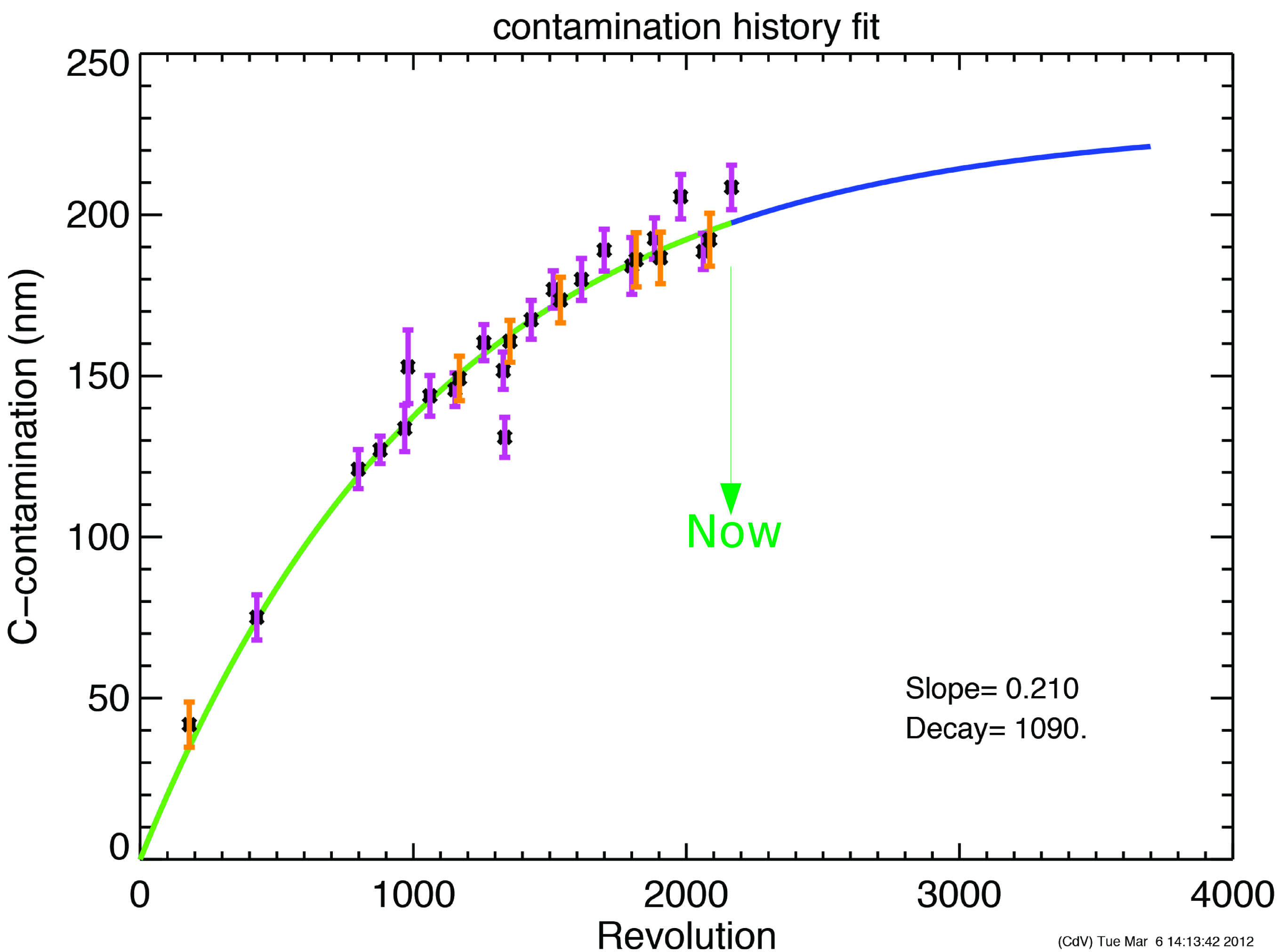
- RGS/pn (E<0.54 keV)≃1.07 (1.00)
- RGS/pn (E≥0.54 keV)≃1.02 (0.96)
- MOS/pn (E≤0.85 keV)≃0.98-1.06 (1.00)
- MOS/pn (E≳0.85 keV)≃1.07-1.10 (1.05)
- MOS1/MOS2 ≃ 1.00-1.03 (1.00)

[M=median; $\sigma_\mu$=standard deviation]



# RGS contamination

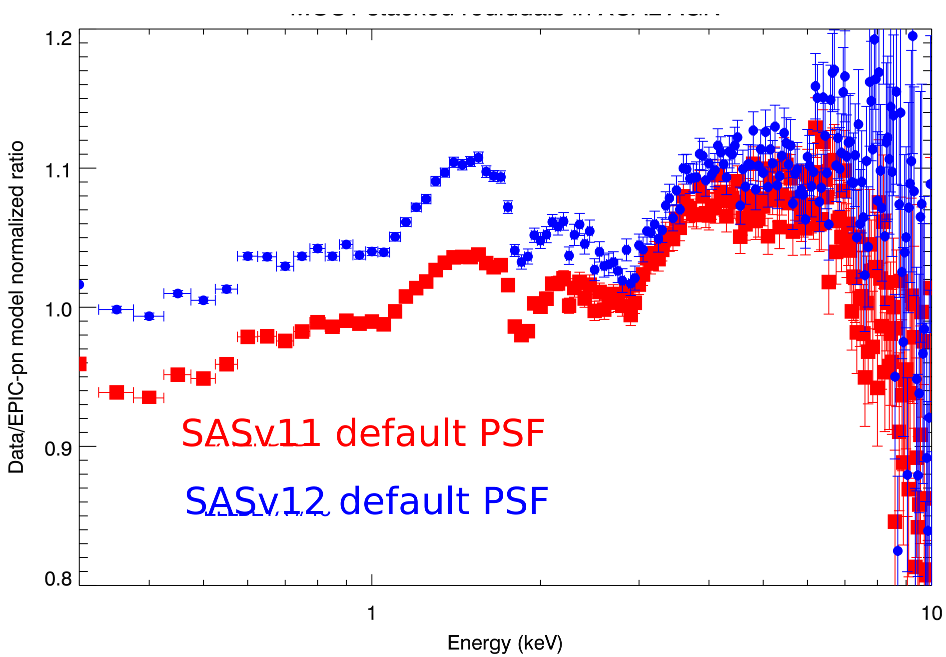
(Courtesy of C.de Vries)

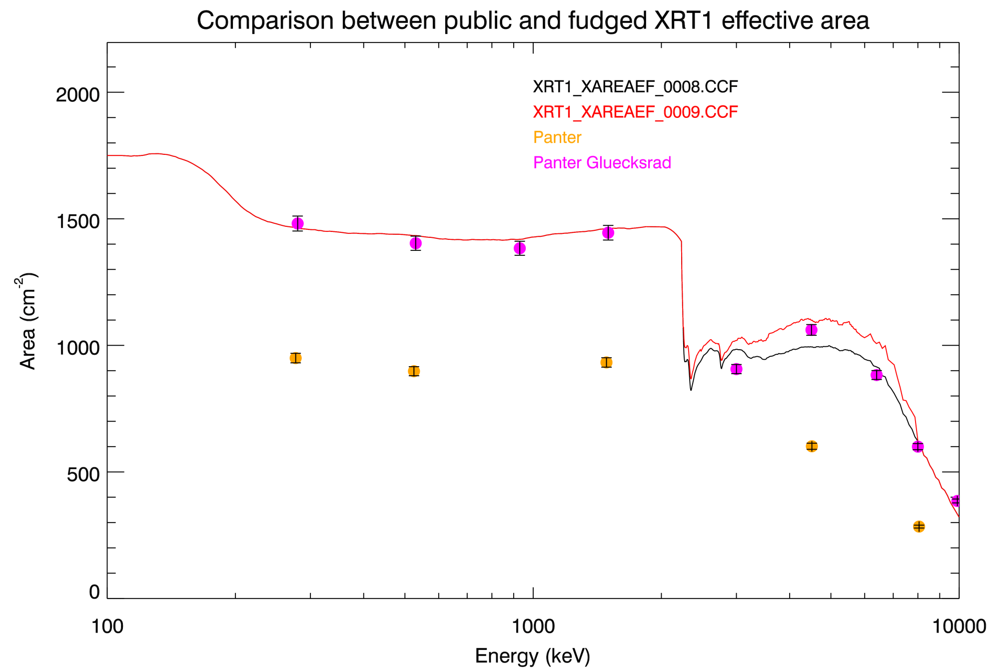


# EPIC cross-calibration vs. E

Stacked EPIC-MOS residuals against the best-fit EPIC-pn model for 25 obervations of bright non-thermal XCAL sources (mainly radio-loud AGN)

MOS1



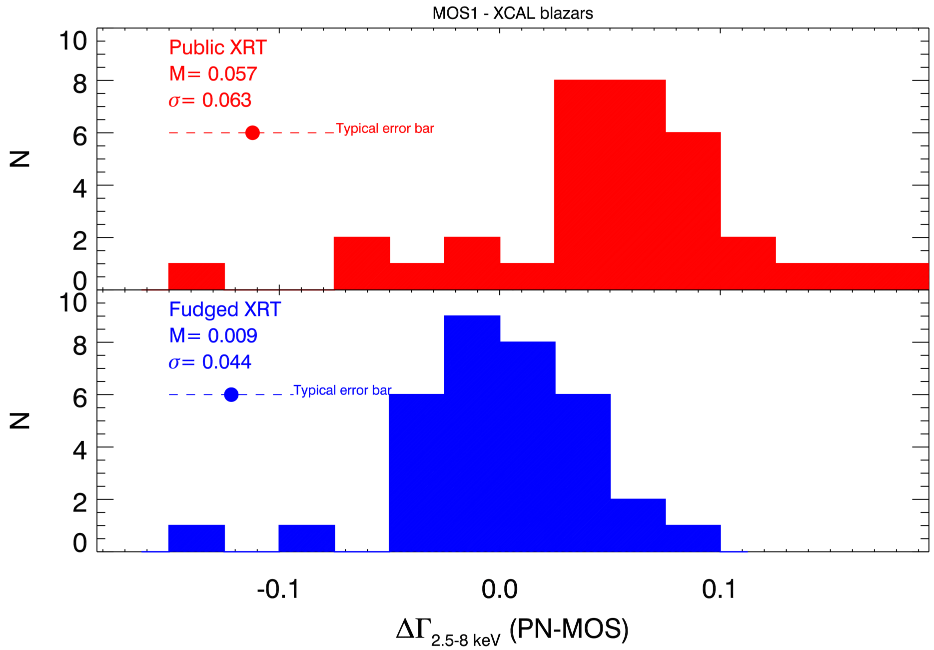



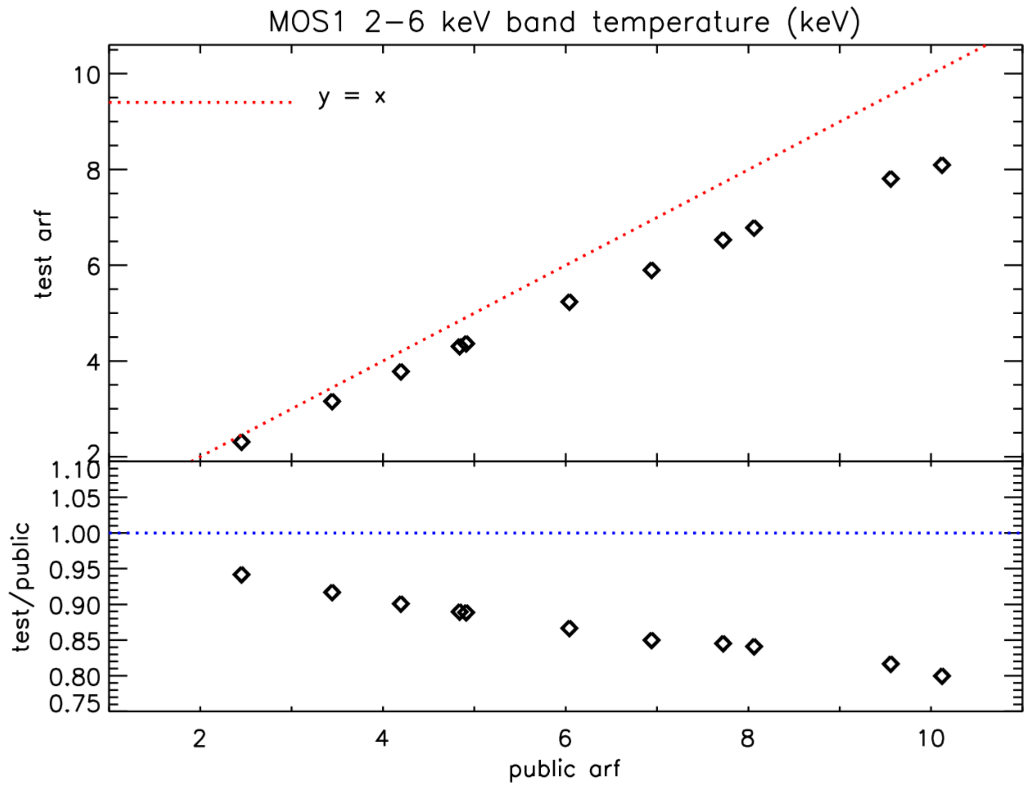

Ground-calibration data require a MOS1 larger effective area at ≃4.5 keV

# Empirical correction to the optics effective area

(Cortesy M.Stuhlinger, J.Nevalainen)

An effective area correction, based on the cross-calibration results, behaves well on AGN (*left*), badly on clusters (*right*)



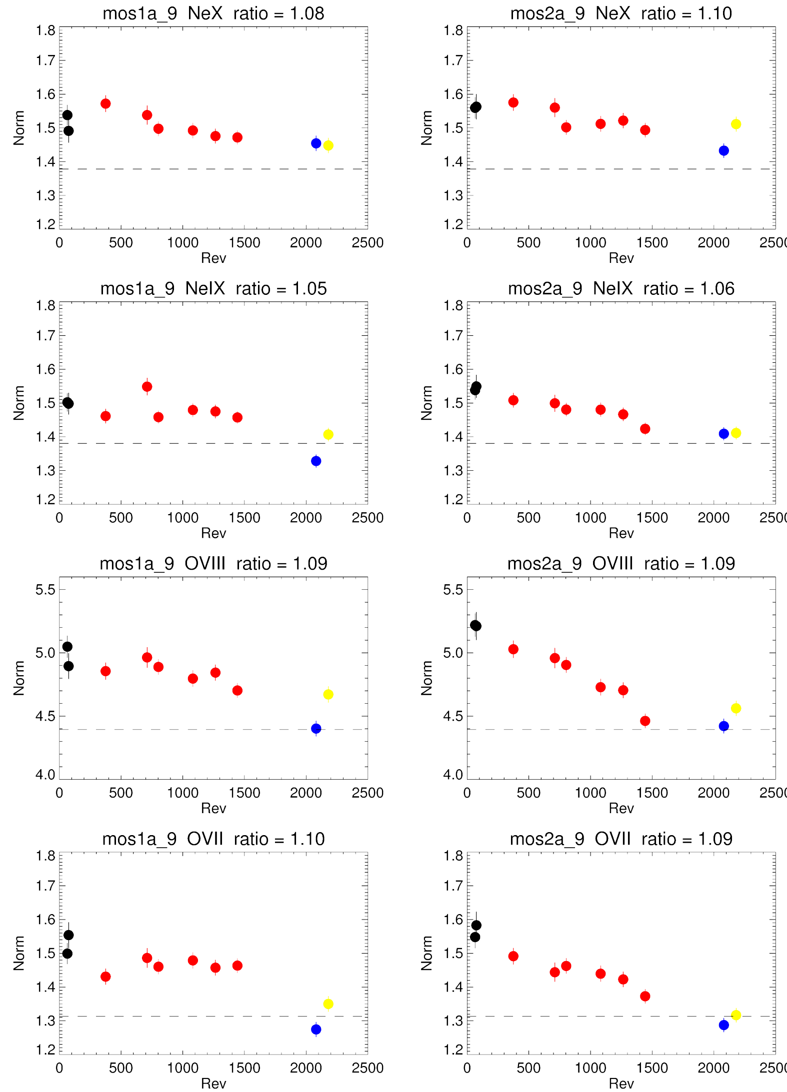

Post-correction 2.5-8 keV slopes in radio-loud AGN agree within **±0.01.**

Time-dependence? 6 keV measurement?

# Time-evolution of the MOS effective area

(Courtesy S.Sembay)

- 1E0102-72 line normalization decreasing with time in the MOS
    - stronger in the MOS2 then in MOS1
- Seen in other sources (*e.g*. ςPuppis)
- Interpretation still unclear:
    - Uncertainties in the energy scale do not dominate
    - Complex interplay between redistribution and effective area



# Future outlook

- Energy scale in EPIC-pn Timing Mode (X-Ray Loading, Rate-Dependent CTI)
- Gain/CTI in EPIC-MOS (novel software being developed at LUX)
- Soft X-ray redistribution/effictive area in the EPIC-MOS
- Timing accuracy of the EPIC-pn
- CTI and wavelength scale in RGS
- Empirical parametrisation of the EPIC-pn redistribution
- EPIC Pile-up correction

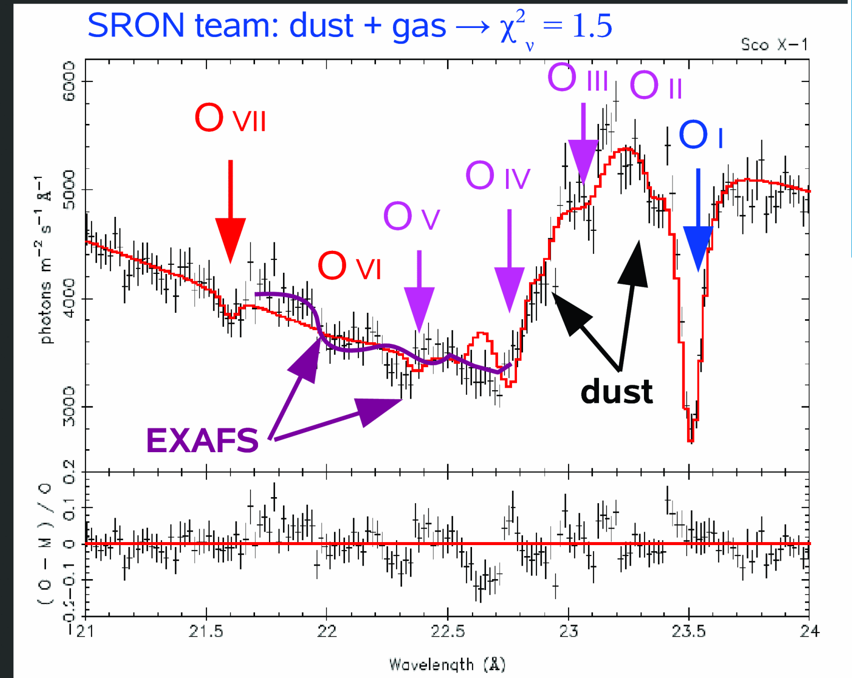
Separating instrumental and ISM features near O I K edge at 23 Å (de Vries et al. 2003).

Evidence for silicates dust grains (Costantini et al. 2005-2012, Pinto et al. 2010). Evidence for EXAFS in Sco X-1 (de Vries and Costantini 2009).

RGS Calibration through Crab (Kaastra et al. 2009).

Complete physical ISM model and abundances mapping (Pinto et al. 2010-2012a,b).

>2σ detection of $H_2O$ ice and silicates




## Objections:

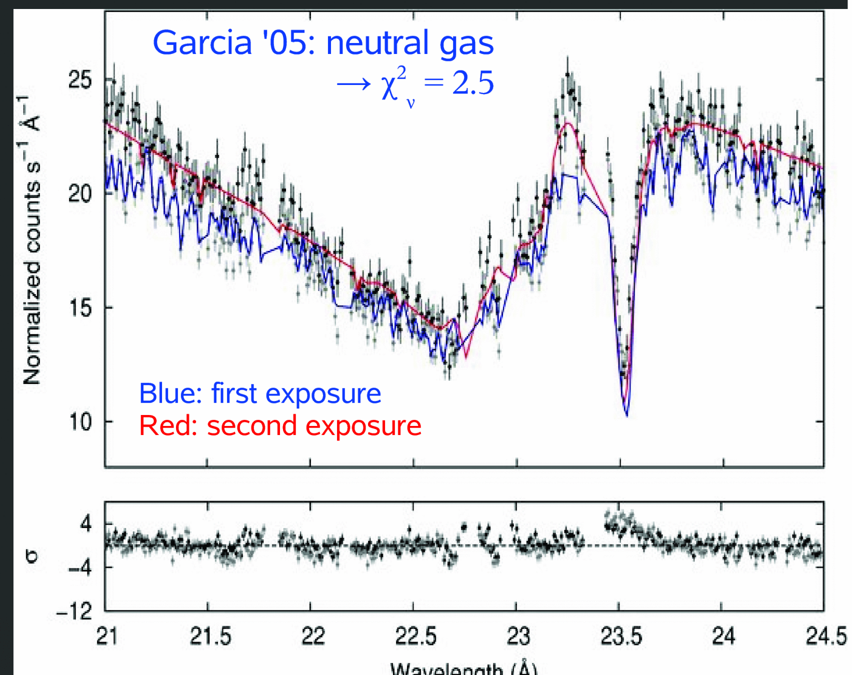
Garcia et al. 2011: Atomic data used for Sco X-1 at SRON not consistent with Stolte '97.

Photo-ionized OI with $\xi = 10^{-4}$ erg cm s$^{-1}$

Conclusion: No evidence of non-atomic oxygen

But their models have average ±2σ (local ±4σ) deviations and $\chi^2_\nu > 2.4$.

Velocity dispersion, ionizing SED, source Luminosity not shown. Only part of dataset used.



# Additional material

# Nature of the LSF change

(Pollock, 2011, XMM-CCF-REL-275)