Using Standard Candle X-ray spectra to calibrate the strongly variable MOS response

"Calibration or just a *mathematical* exercise?"

Ties together three themes....

1) Computationally quick phenomenological RMF model

2) Derivation of RMF model parameters via optimisation algorithm

3) Use of "standard candle" spectra to constrain RMF solution

XMM
EPIC
MOS

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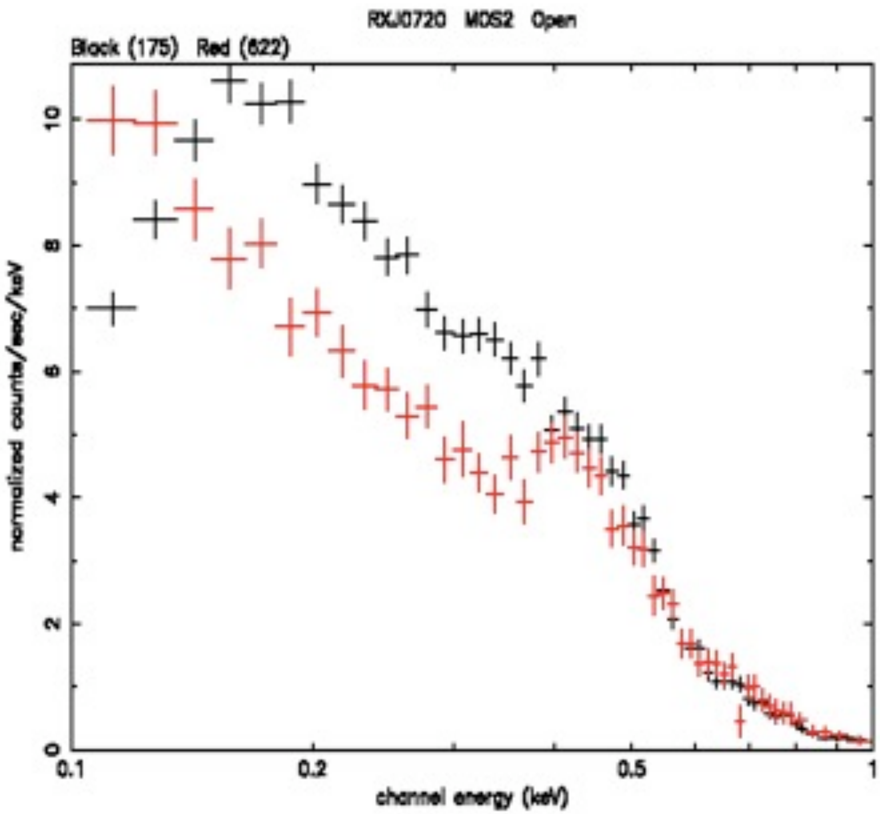
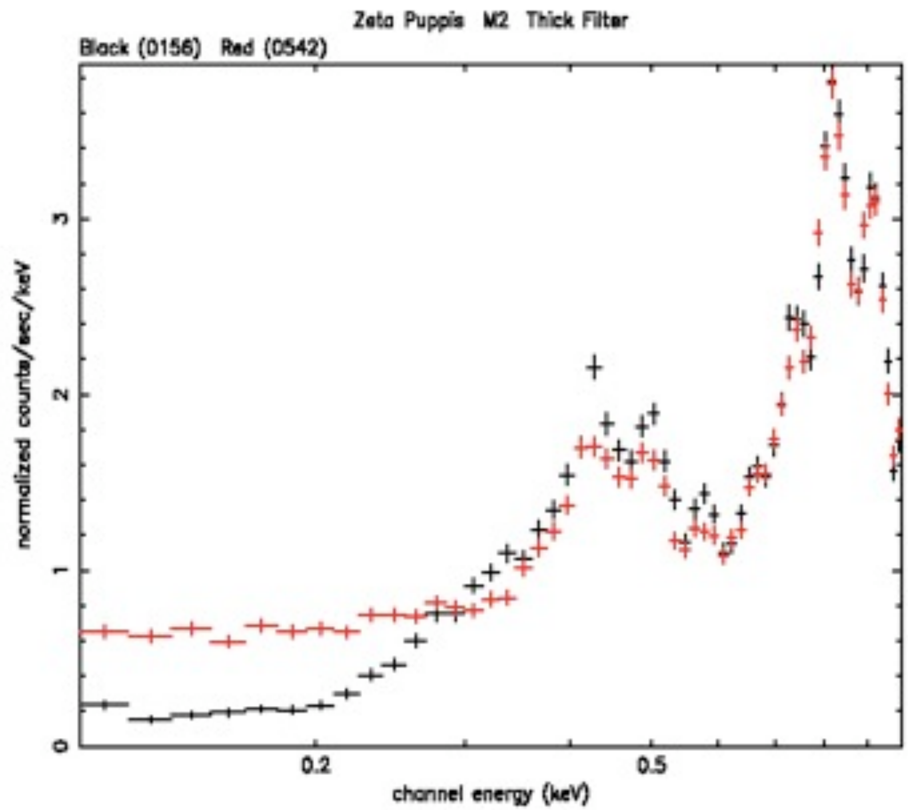
Changes in the MOS redistribution: increased redistribution from higher to lower energies.

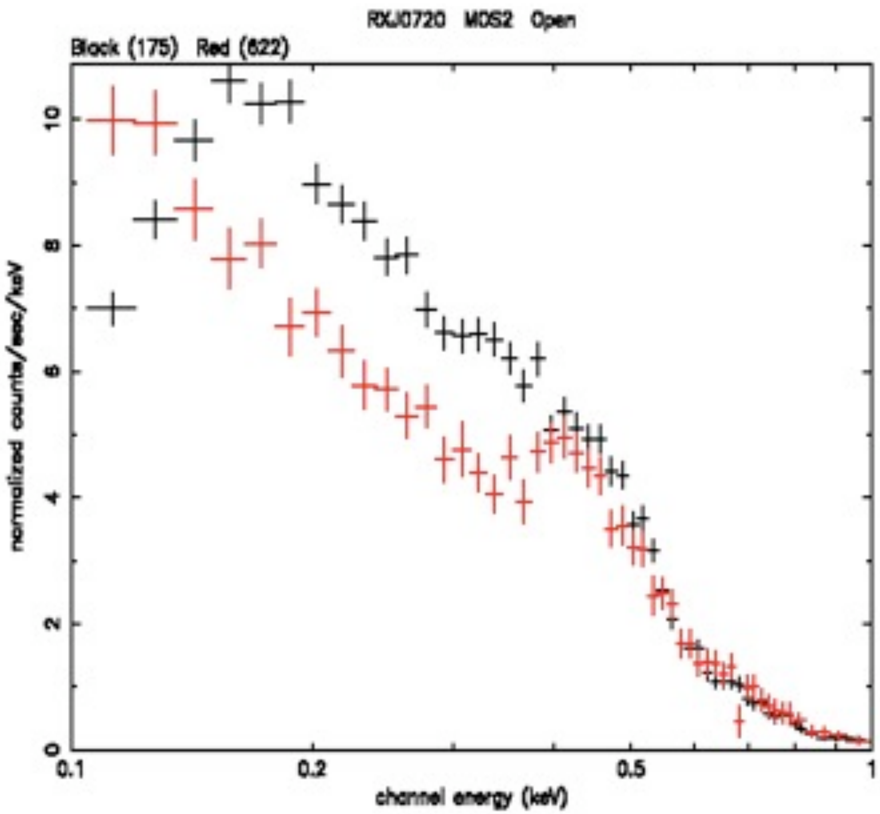


The INS RX J0720-3125

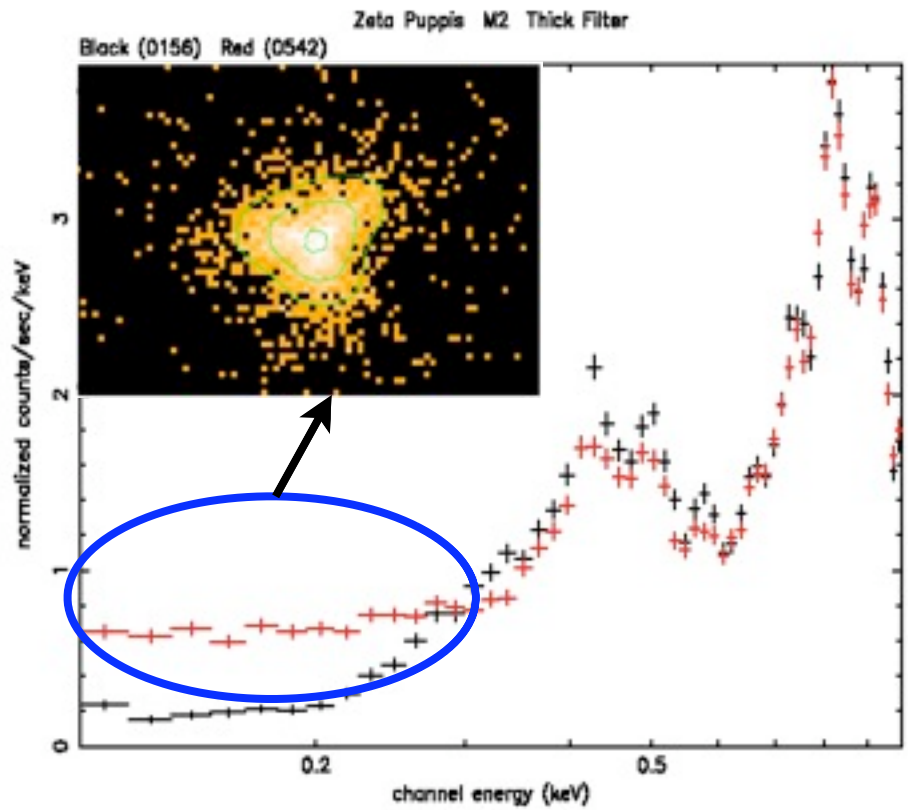


The O star Zeta Puppis

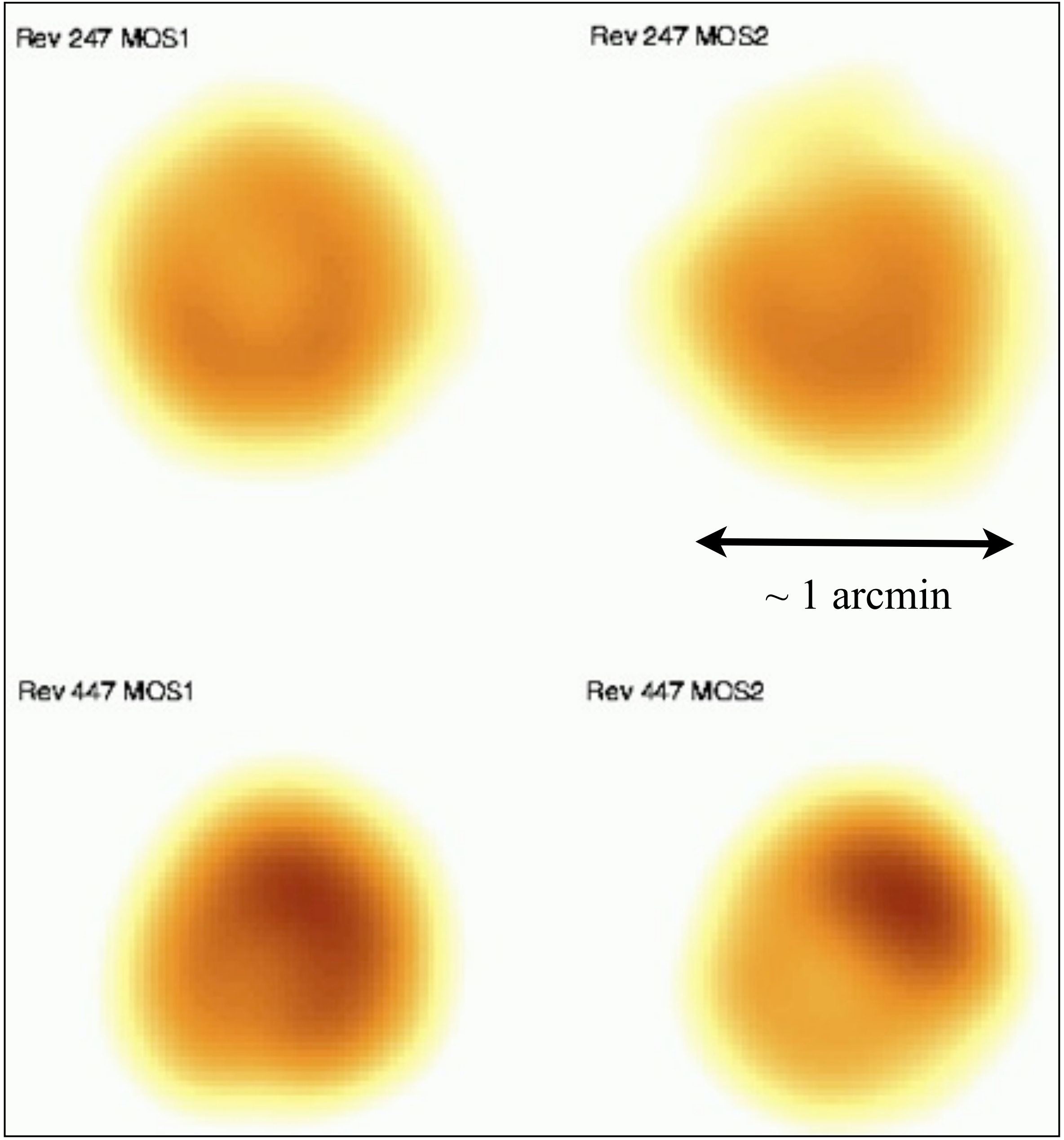
Changes in the MOS redistribution: increased redistribution from higher to lower energies.



The INS RX J0720-3125



The O star Zeta Puppis

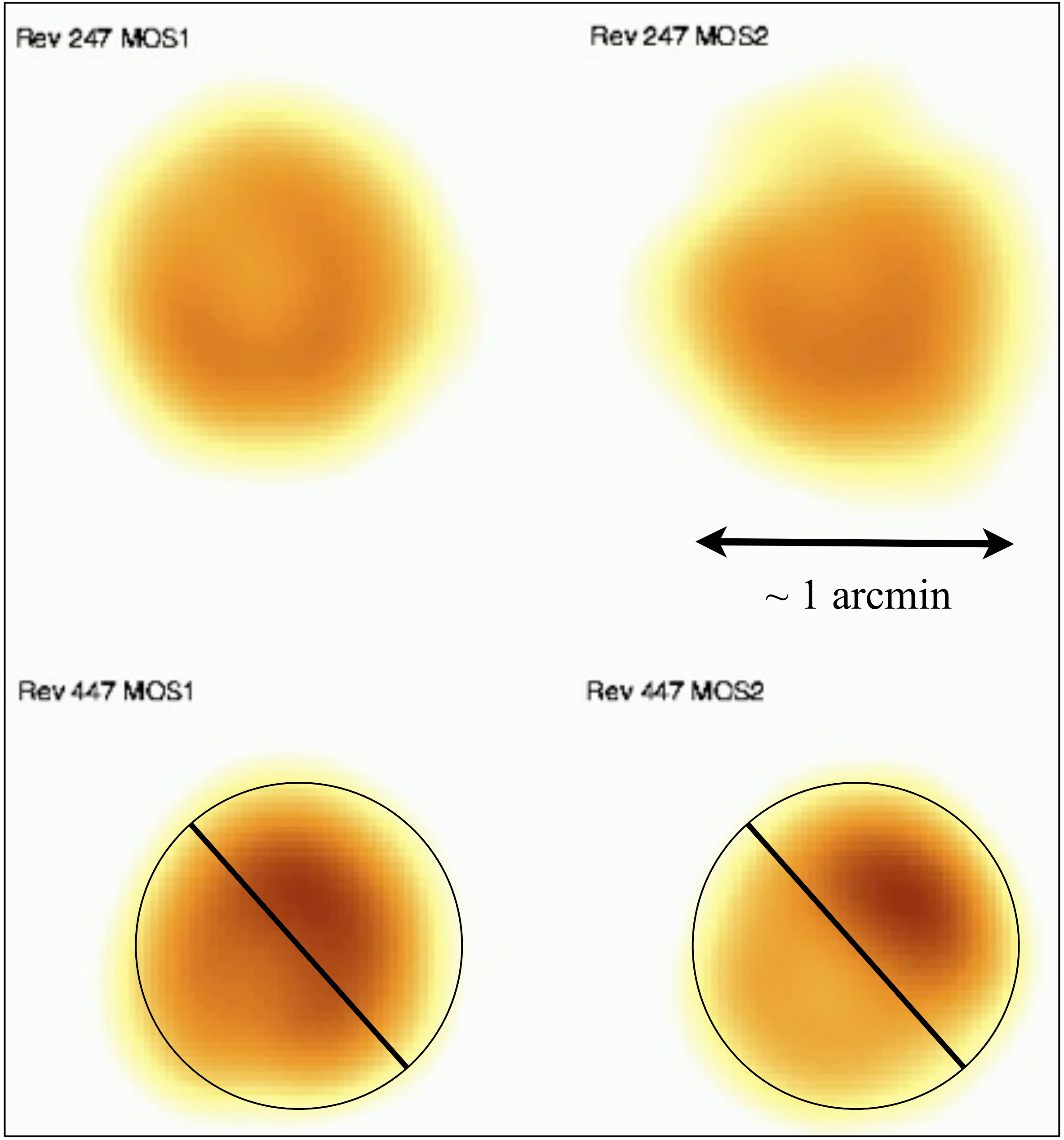


~ 1 arcminute off-axis

1ES0102

0.1-0.35 keV images

~ On-axis



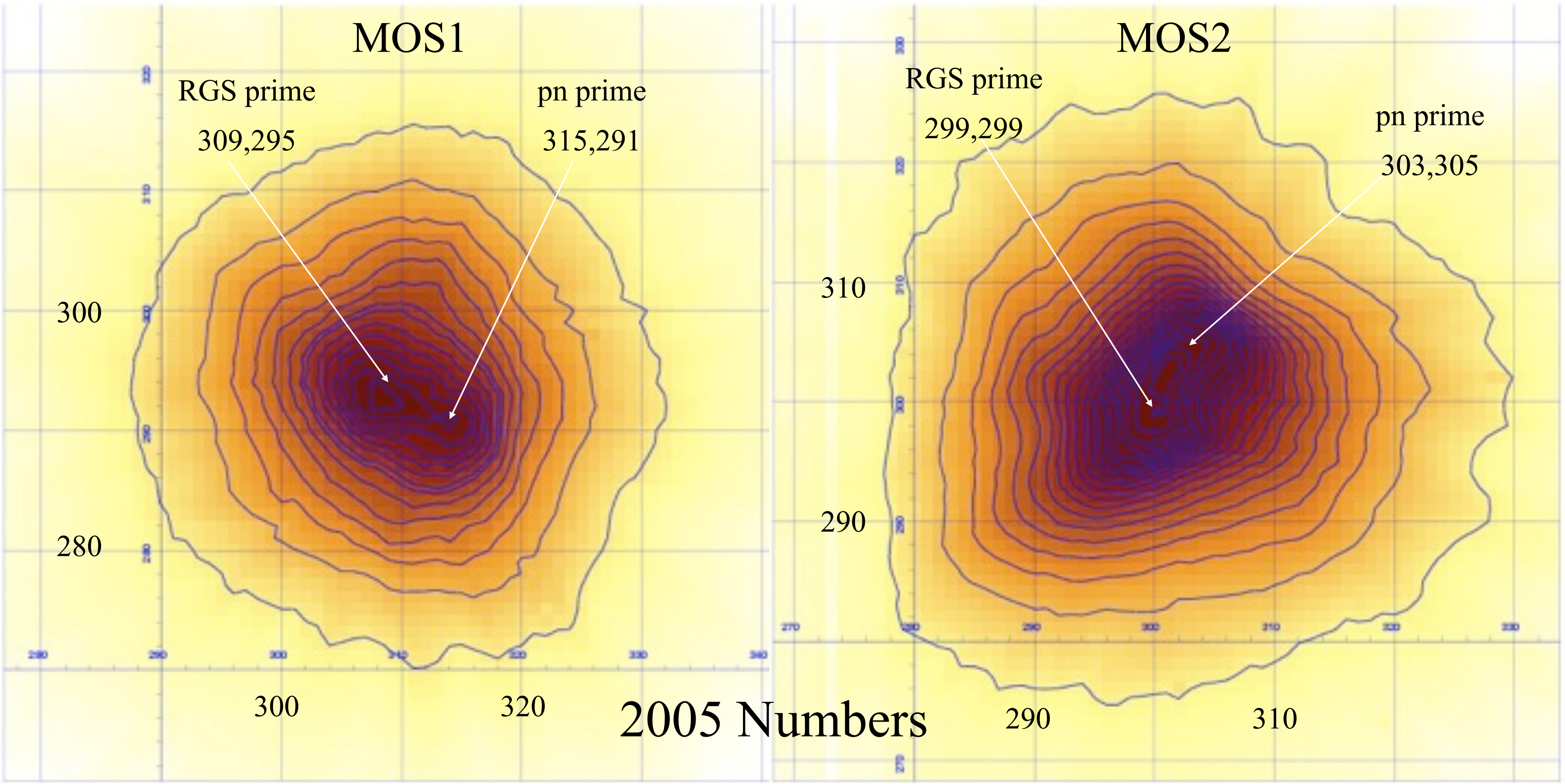
~ 1 arcminute off-axis

1ES0102

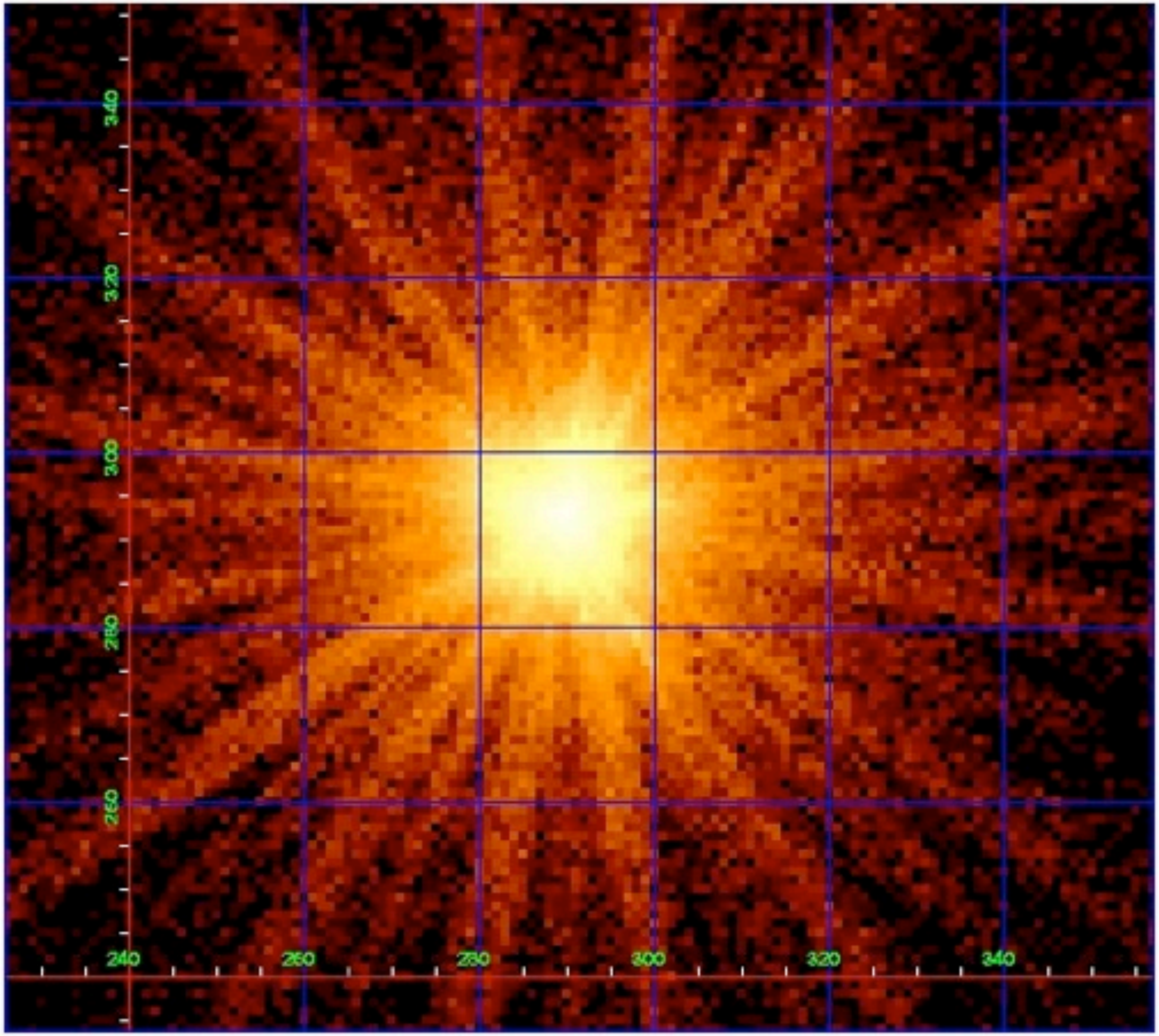
0.1-0.35 keV images

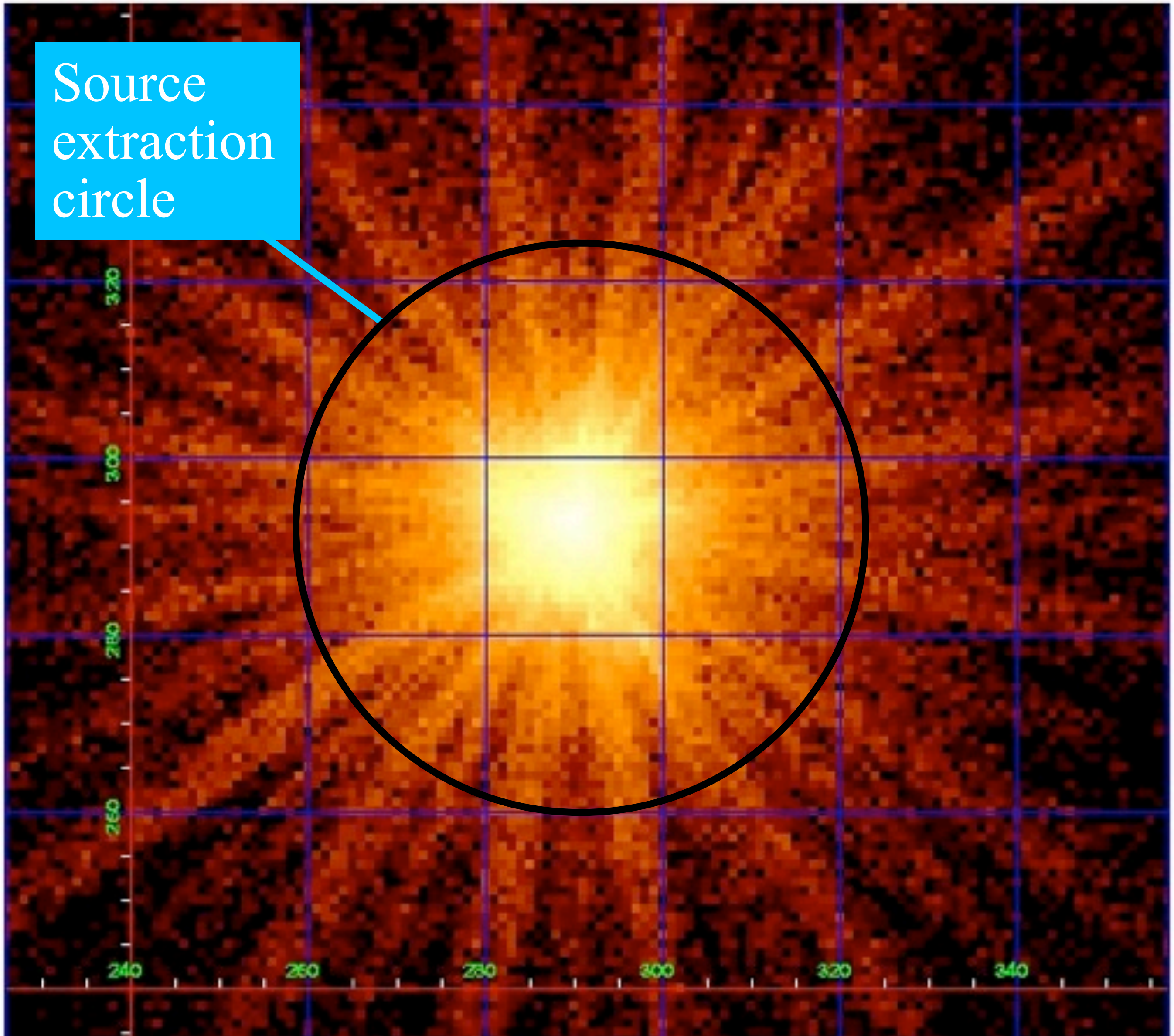
~ On-axis

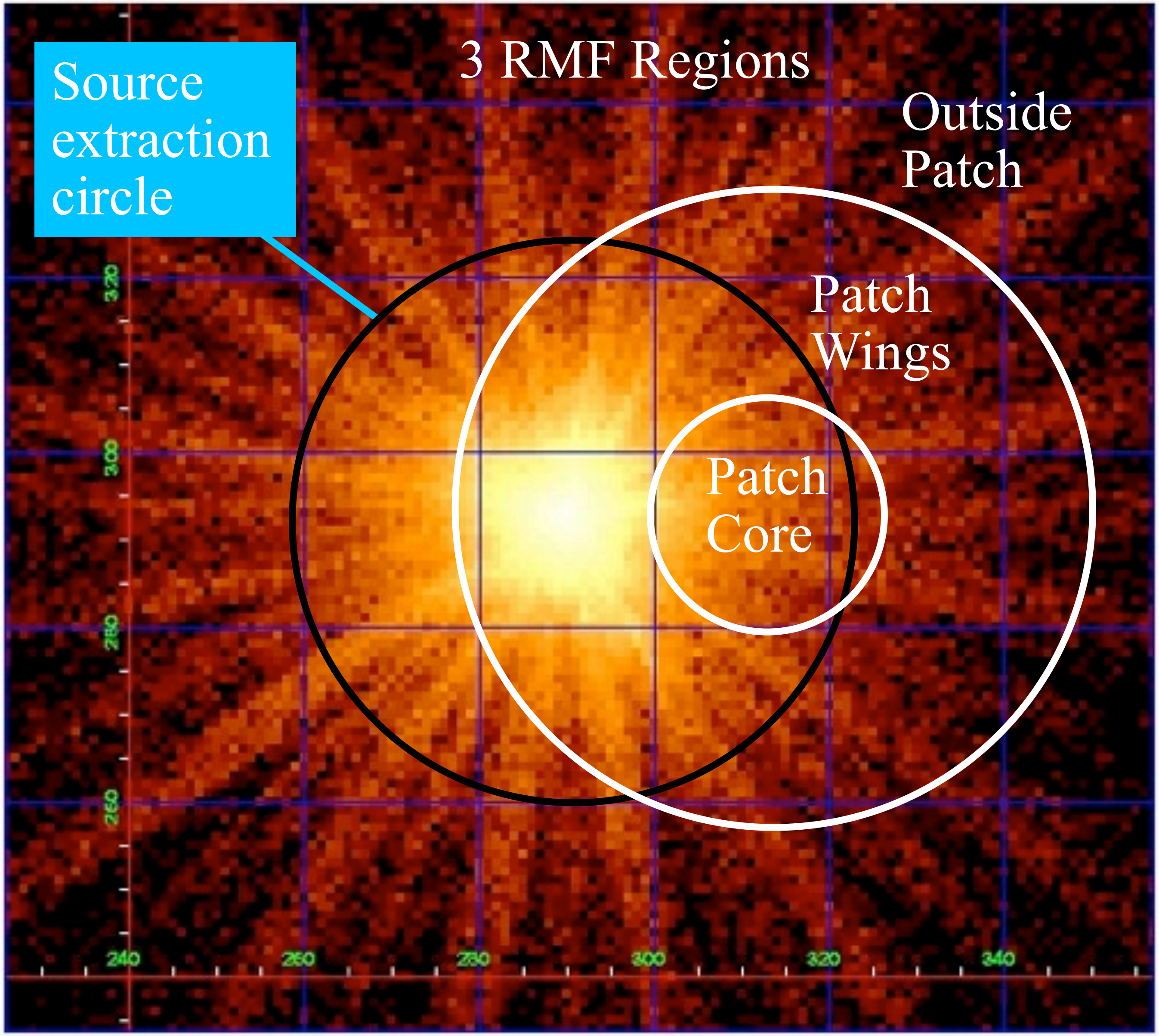
Patch position and dimensions seem to "correlate" with accumulated number of detected source photons.



Andy Read (amr30@star.le.ac.uk)

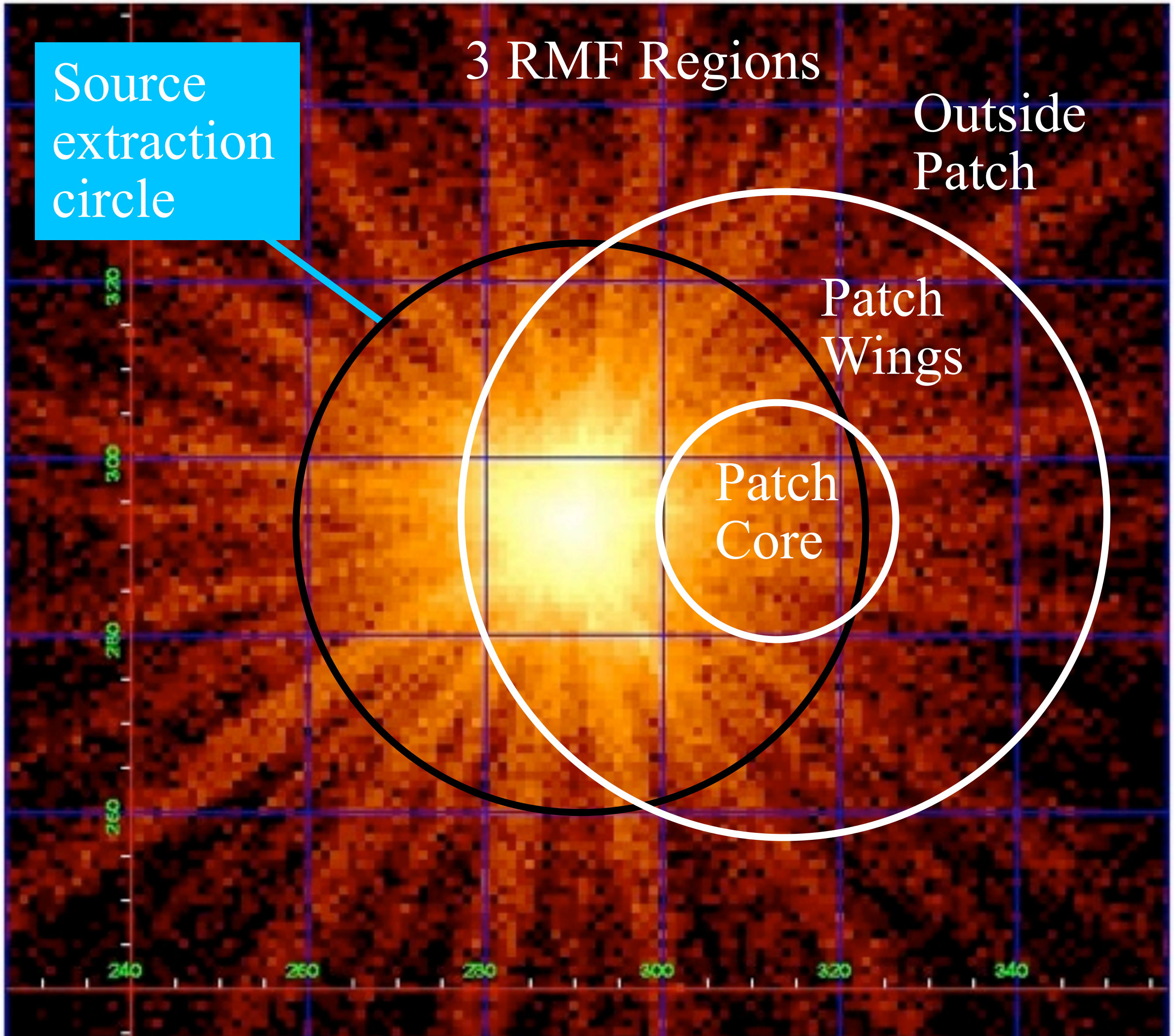

340
320
300
280
260
240
260
280
300
320
340


Source extraction circle
320
300
280
260
240
260
280
300
320
340



MOS Response:

3 RMF regions
0"-15", 15"-40",>40"



MOS Response:

3 RMF regions
0”-15”, 15”-40”,>40”

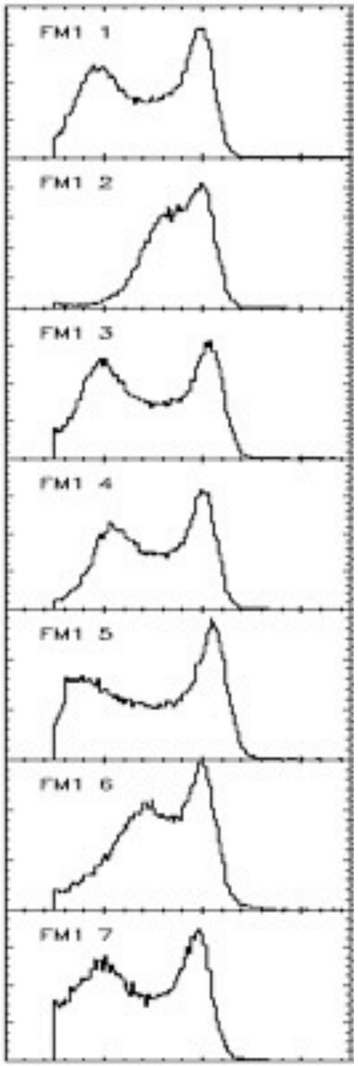
2 Instruments

9 Epochs

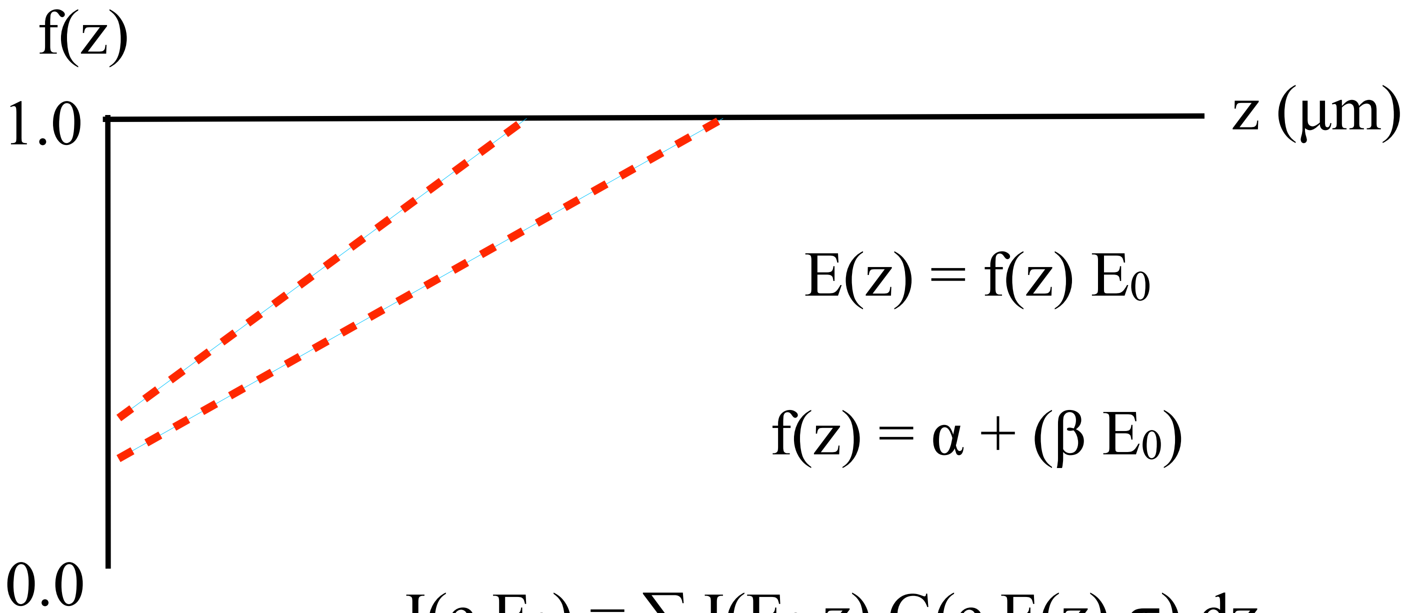
= 54 parameter files!

PSF (rmfgen default) or flat weighting to create average RMF (automatically generated in SAS)

FM1



Current Empirical Surface Loss Model

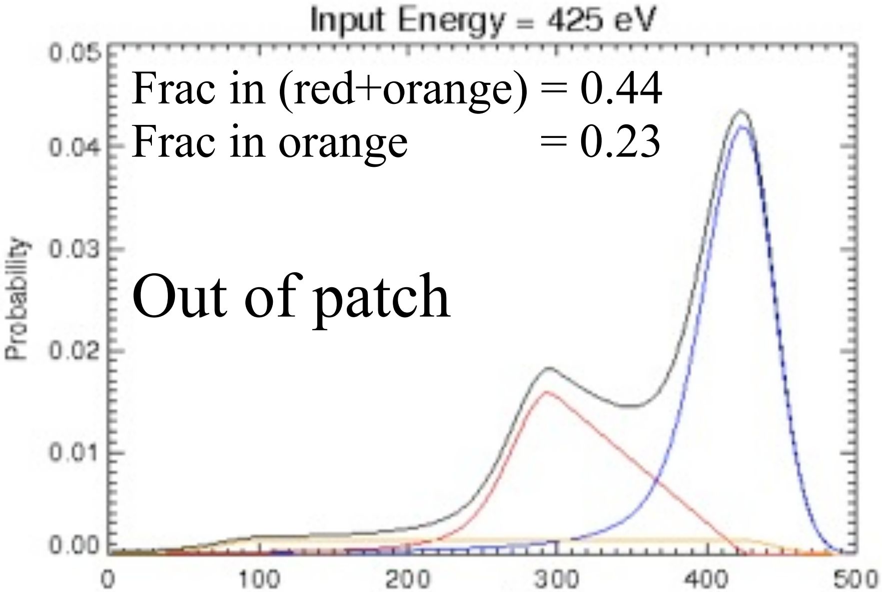


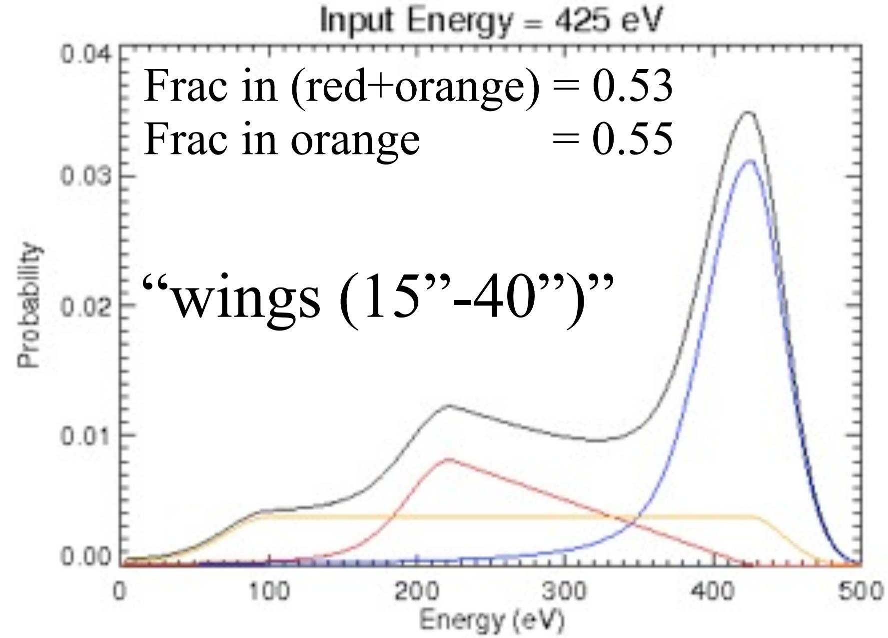
$$E(z) = f(z)\,E_0$$

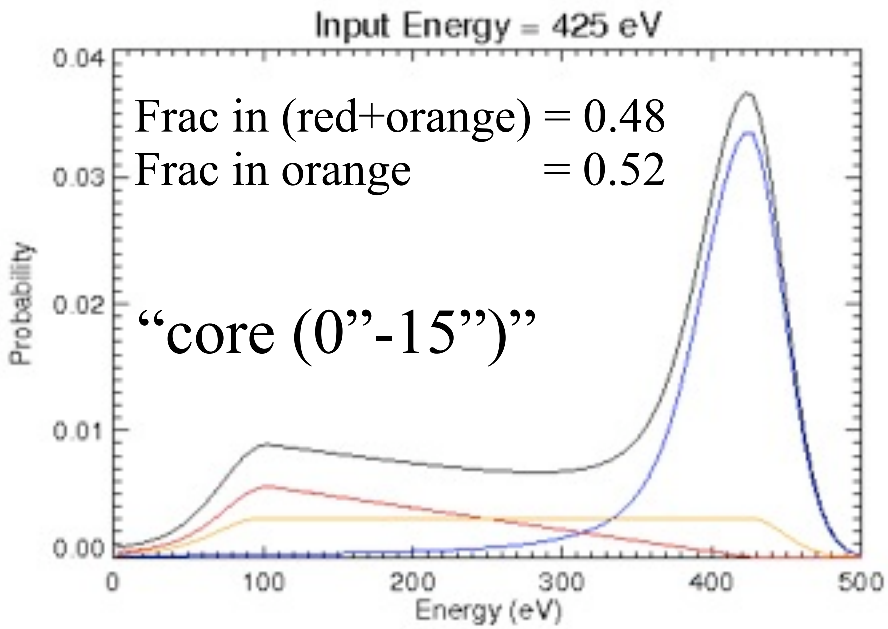
$$f(z) = \alpha + (\beta\,E_0)$$

$$I(e,E_0) = \sum I(E_0,z)\,G(e,E(z),\sigma)\,dz$$

$$\alpha = \alpha(E_0),\ \beta = \beta(E_0)$$







New model avoids the time consuming integration and describes the rmf by various mathematical shapes.

Evaluation time for 2400 x 2400 array (5eV binning) ~ 3.5 seconds in IDL

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Parameters which define redistribution matrix, R, have simple functions with energy.

$$\text{Resolution} = \alpha_1 + \beta_1 \times \text{sqrt}(e0)$$

$$F_{Loss} = \alpha_2 \exp(-(e0-\beta_2) / \gamma_2) \quad \text{for } \beta_2 > e0$$
$$= \alpha_2 \quad \beta_2 <= e0$$

$$F_{Loss} = F_{Loss\_peak} + F_{Loss\_shelf}$$

$$F_{Loss\_peak} = \alpha_3 \exp(-(e0-\beta_3) / \gamma_3) \quad \text{for } \beta_3 > e0$$
$$= \alpha_3 \quad \beta_3 <= e0$$

Basic Scheme: For a given epoch and spatial region, take set of standard spectra, $S^1, S^2, \dots, S^n$

$$D_i^1 = N^1 \Sigma R_{ij} A_j^1 S_j^1$$

$$D_i^2 = N^2 \Sigma R_{ij} A_j^2 S_j^2$$

...

$$D_i^n = N^n \Sigma R_{ij} A_j^n S_j^n$$

Adjust parameters (using tnmin algorithm) which define rmf, R, and global normalisations, N, to minimise

$$\Sigma ((O_i^1 - D_i^1)/\delta O_i^1)^2 + \Sigma ((O_i^2 - D_i^2)/\delta O_i^2)^2 + \dots + \Sigma ((O_i^n - D_i^n)/\delta O_i^n)^2$$

"Standard Candle" Spectral Models

1) The white dwarf CAL83

2) The isolated neutron star RXJ 1856

3) The O star Zeta Puppis

4) The SNR 1ES0102

"Standard Candle" Spectral Models

1) The white dwarf CAL83

See next slides

2) The isolated neutron star RXJ 1856

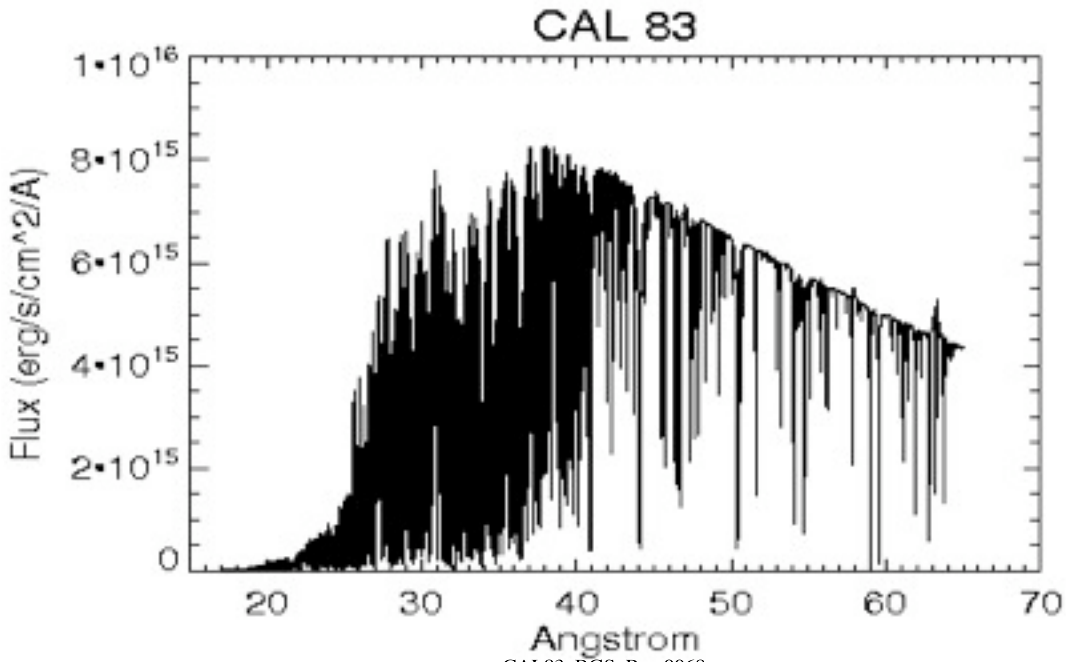
phabs * (bb + bb) (V. Burwtiz pn model)

3) The O star Zeta Puppis

Frank Haberl's RGS model

4) The SNR 1ES0102

The IACHEC WG model (Plucinsky et al.)

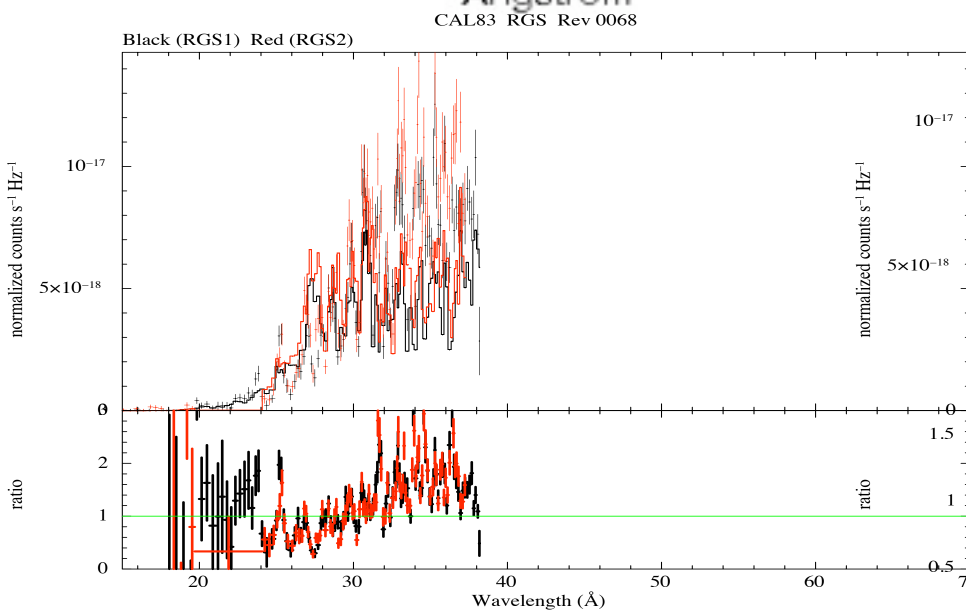


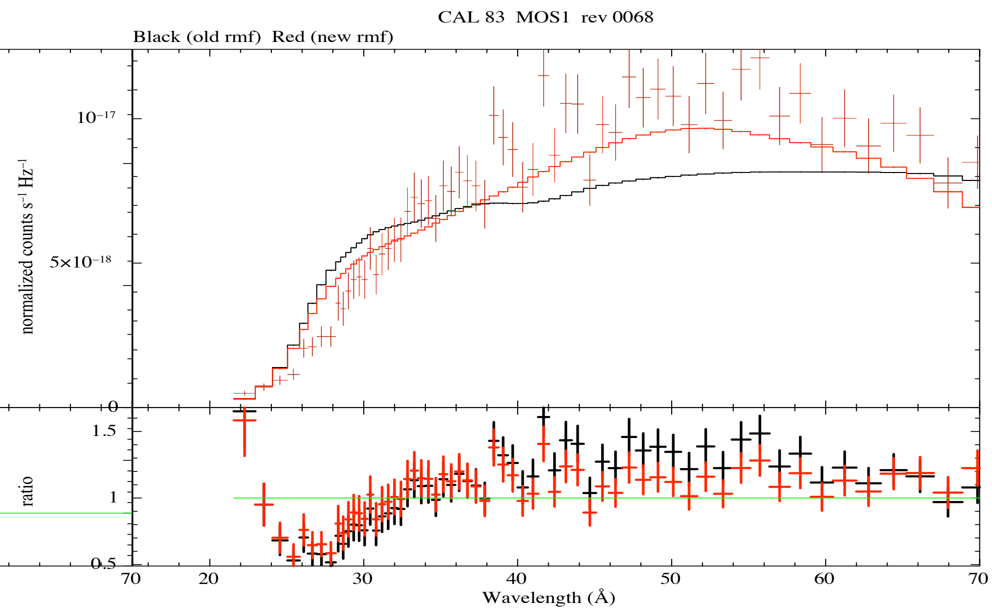
Lantz, T, et al. (2005) ApJ, 619, 517

Non-LTE Model atmosphere derived from LETG and RGS (Rev 0068)

Model file converted to atable model

$n_H = 6.5 \times 10^{20}\ cm^{-2}$ (abund *wilm*)





Example Epoch: Revolution 0795-0900

On-axis, “patch affected”

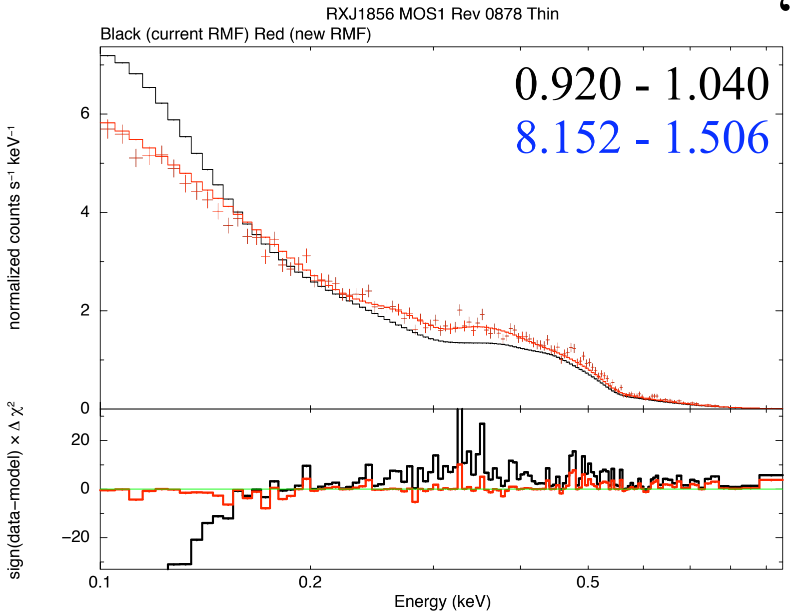
Standards:

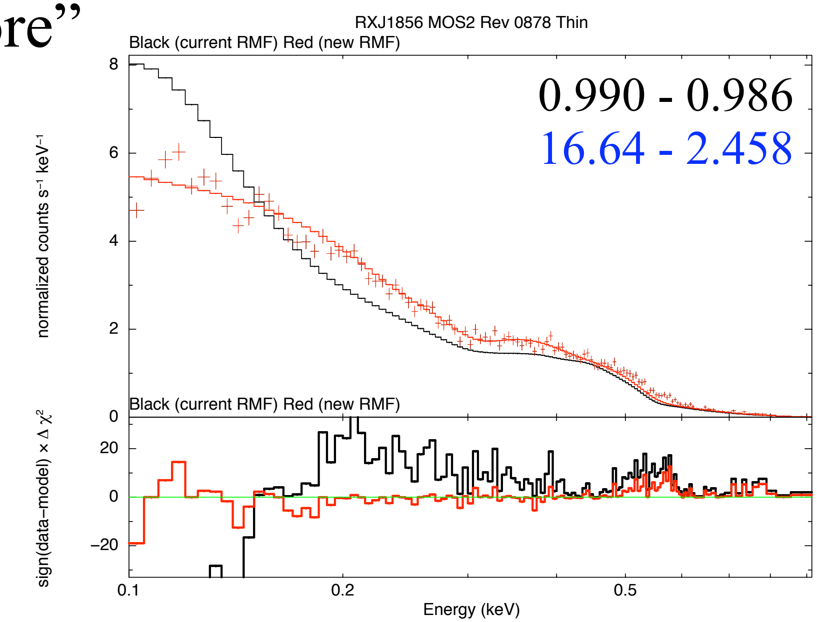
RXJ1856 (Rev 878)
Puppis (Rev 795)
1E0102 (Rev 894-900)

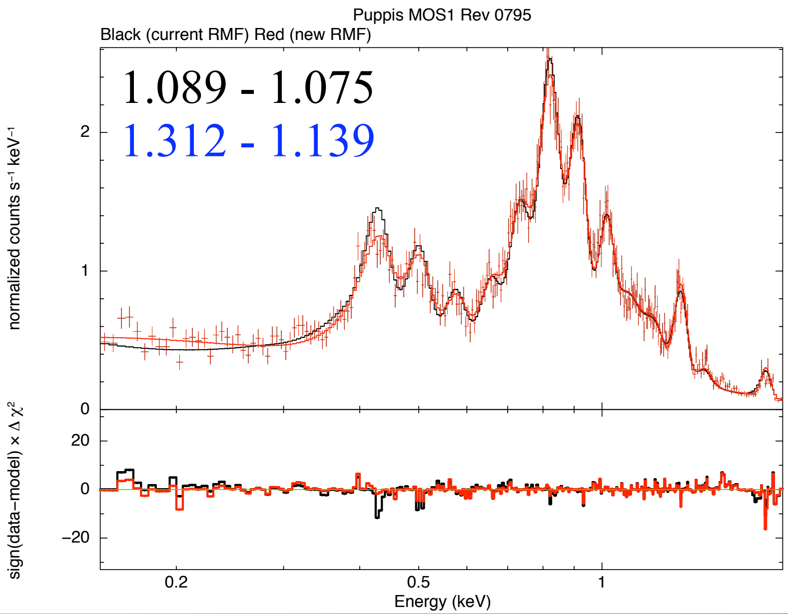
Test Sources:

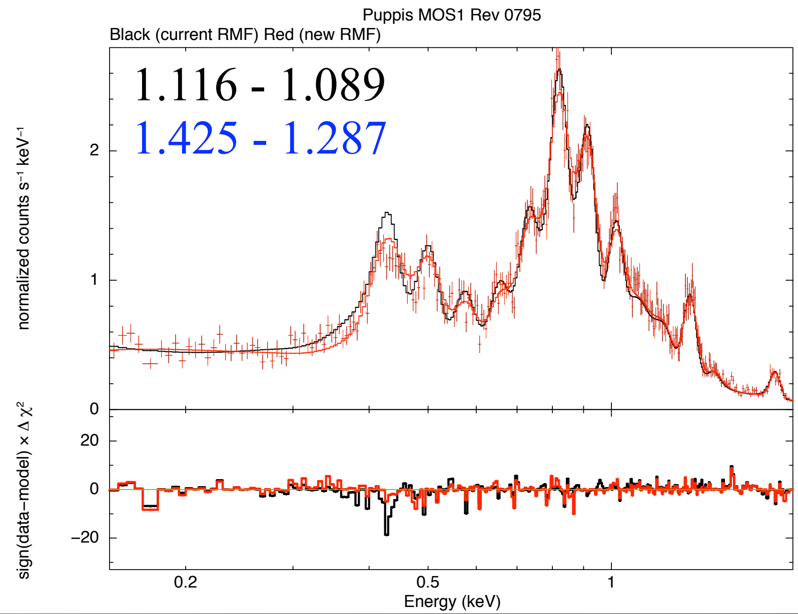
H1426 (BL Lac) (Rev 939)

"Core"









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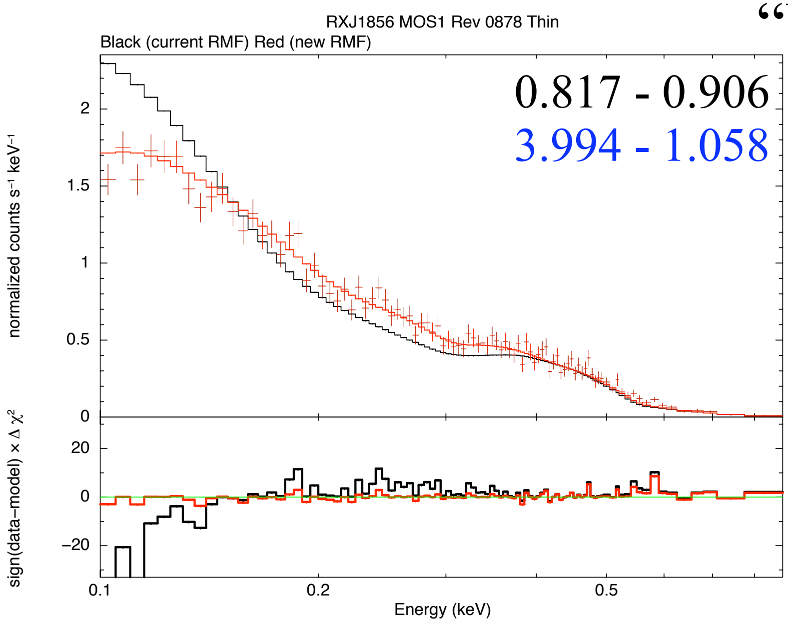
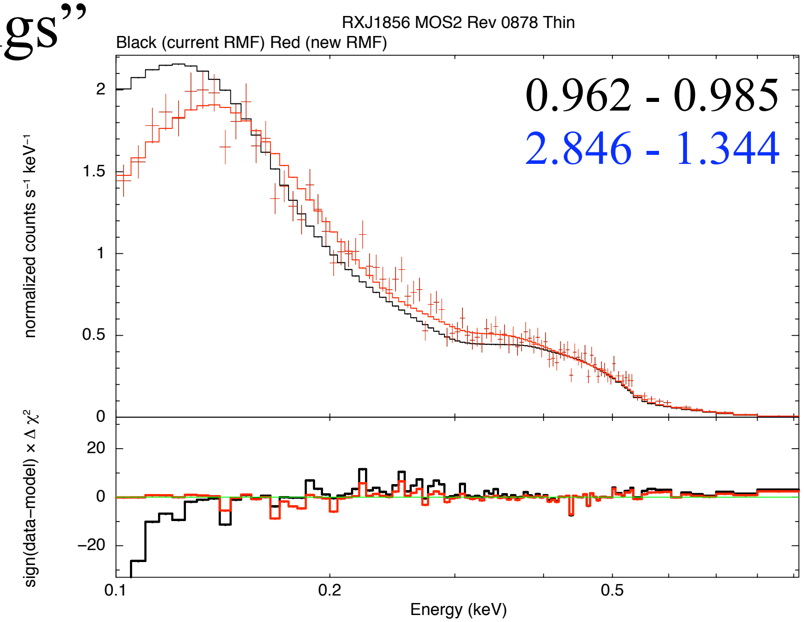
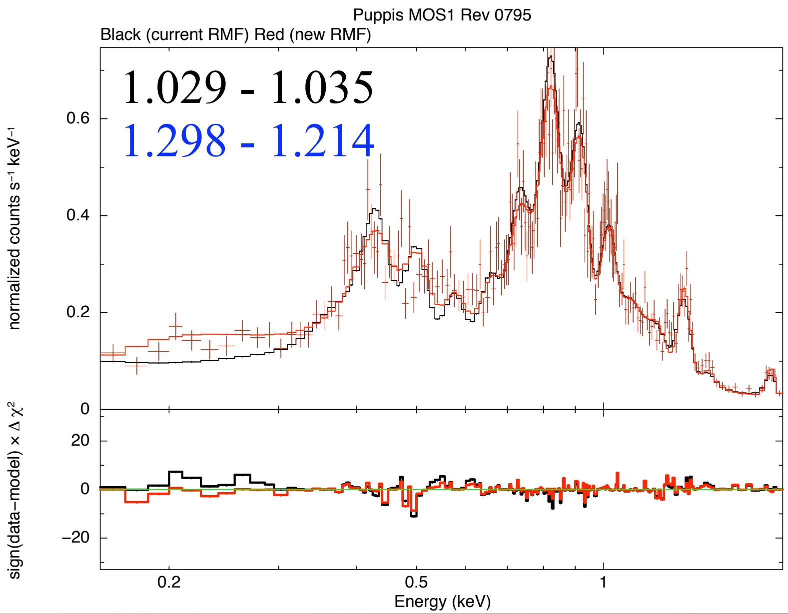
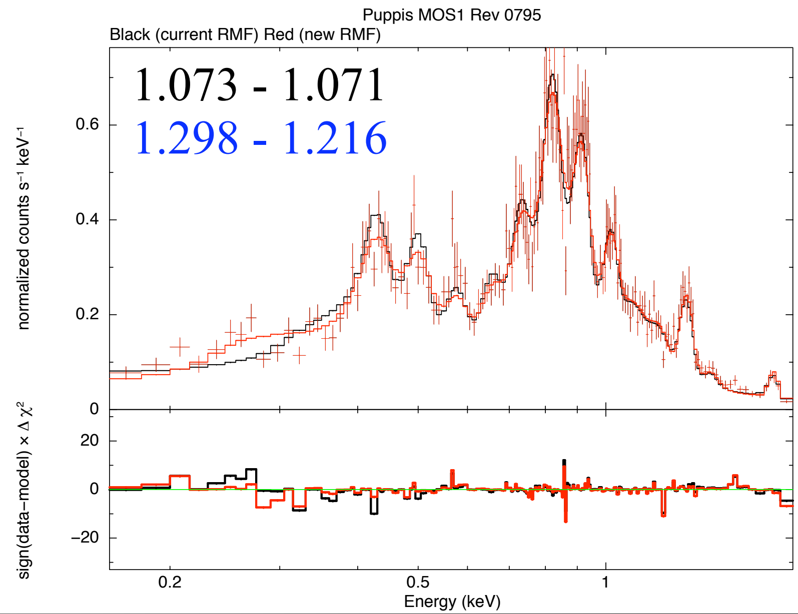
“Wings”

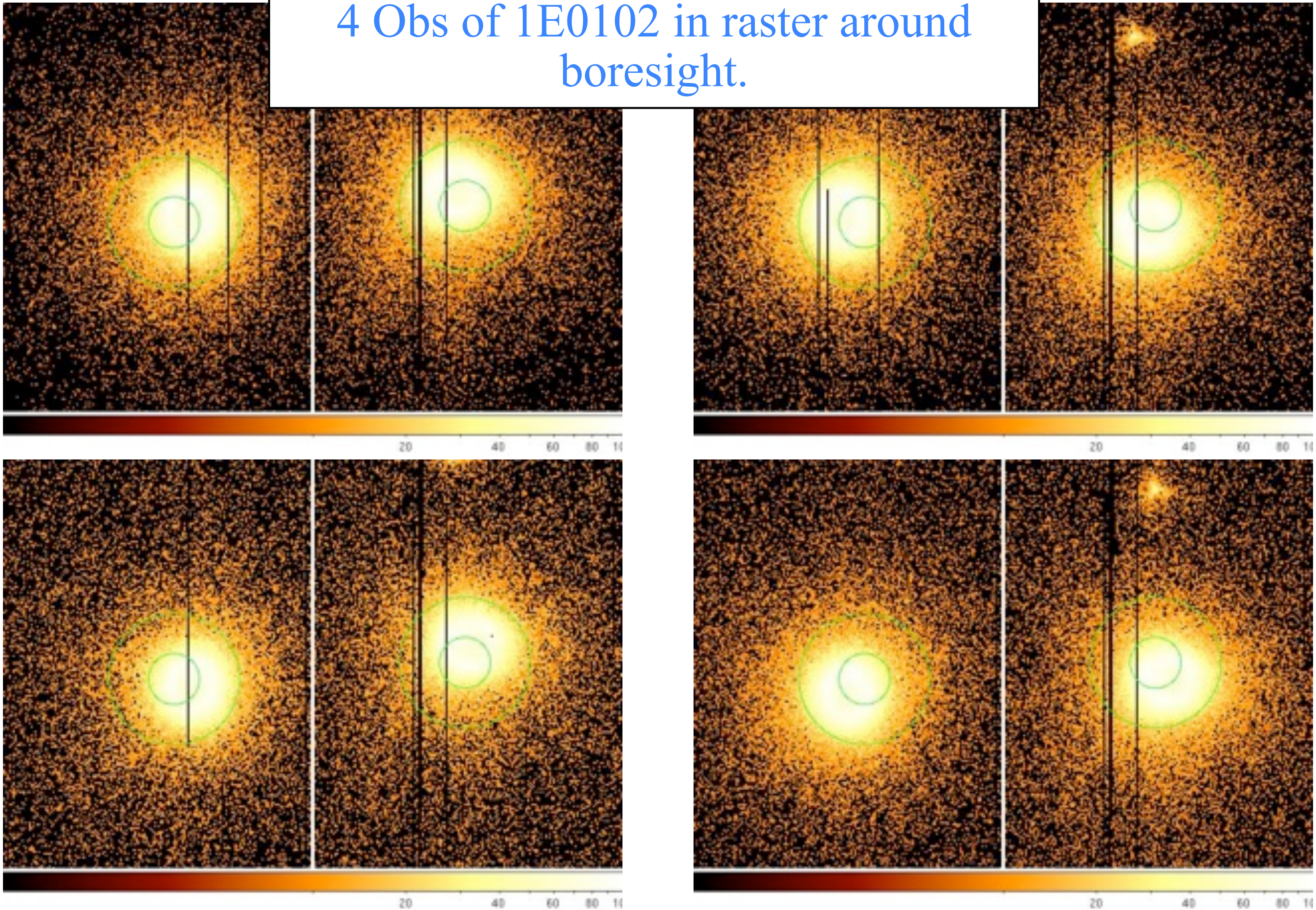

RXJ1856 MOS1 Rev 0878 Thin
Black (current RMF) Red (new RMF)
0.817 - 0.906
3.994 - 1.058
normalized counts s⁻¹ keV⁻¹
sign(data−model) × Δ χ²
Energy (keV)


RXJ1856 MOS2 Rev 0878 Thin
Black (current RMF) Red (new RMF)
0.962 - 0.985
2.846 - 1.344
normalized counts s⁻¹ keV⁻¹
sign(data−model) × Δ χ²
Energy (keV)

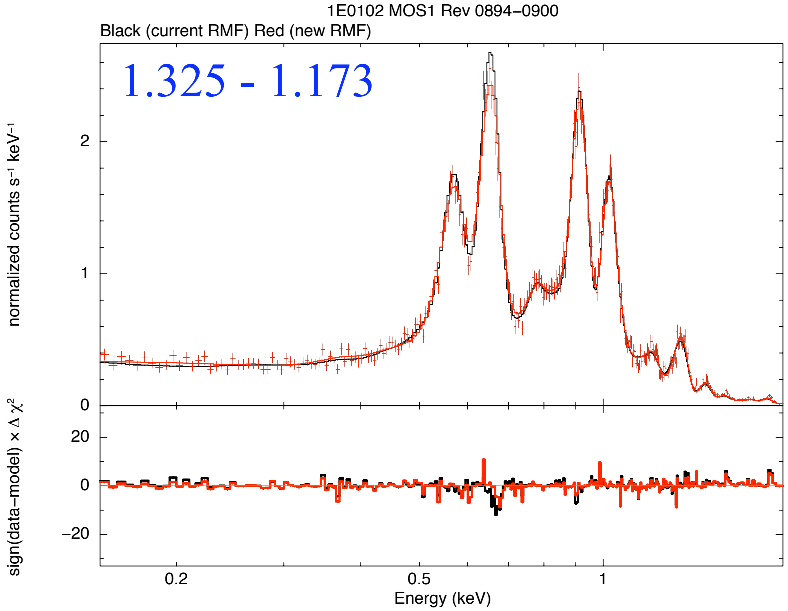

Puppis MOS1 Rev 0795
Black (current RMF) Red (new RMF)
1.029 - 1.035
1.298 - 1.214
normalized counts s⁻¹ keV⁻¹
sign(data−model) × Δ χ²
Energy (keV)

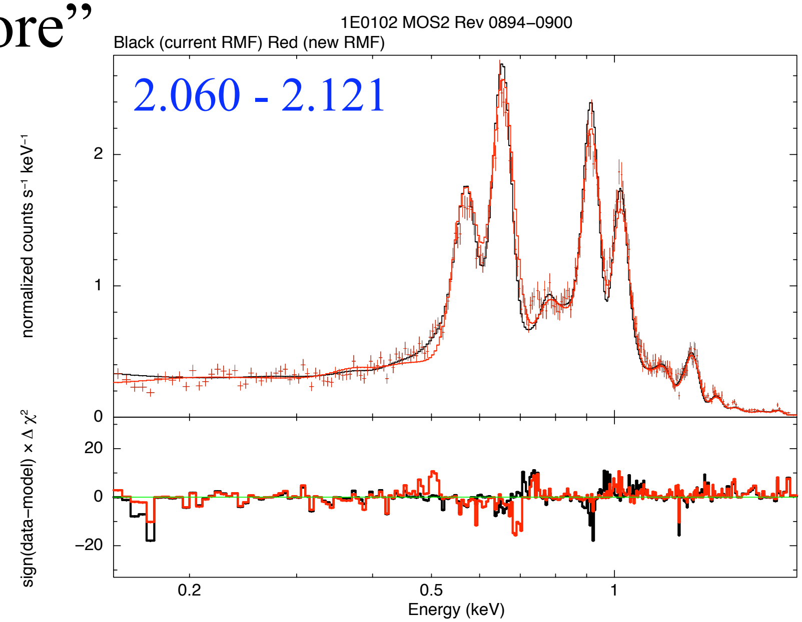

Puppis MOS1 Rev 0795
Black (current RMF) Red (new RMF)
1.073 - 1.071
1.298 - 1.216
normalized counts s⁻¹ keV⁻¹
sign(data−model) × Δ χ²
Energy (keV)

4 Obs of 1E0102 in raster around boresight.

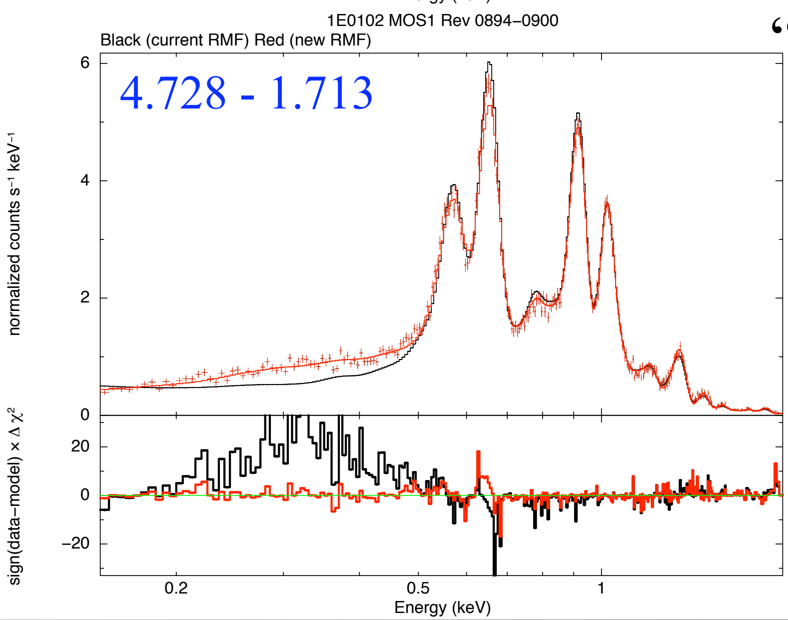


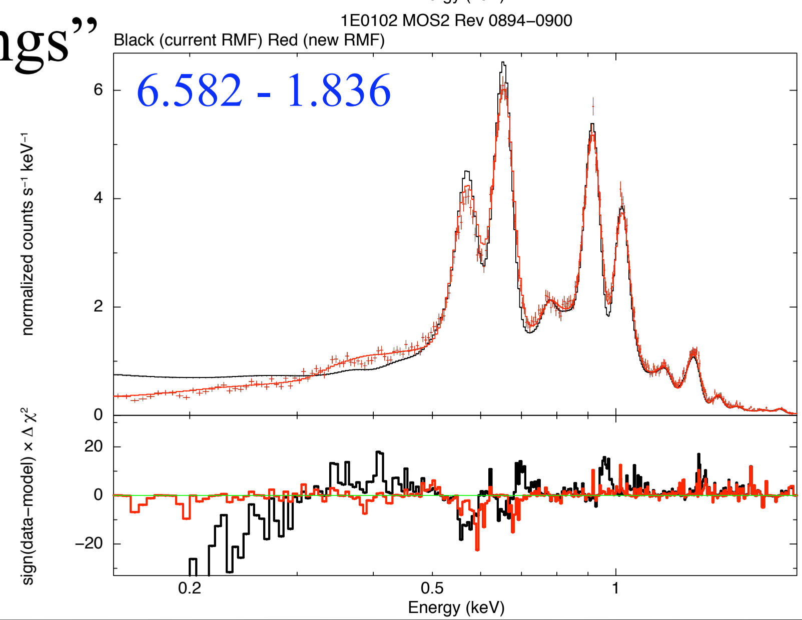
“Core”





“Wings”





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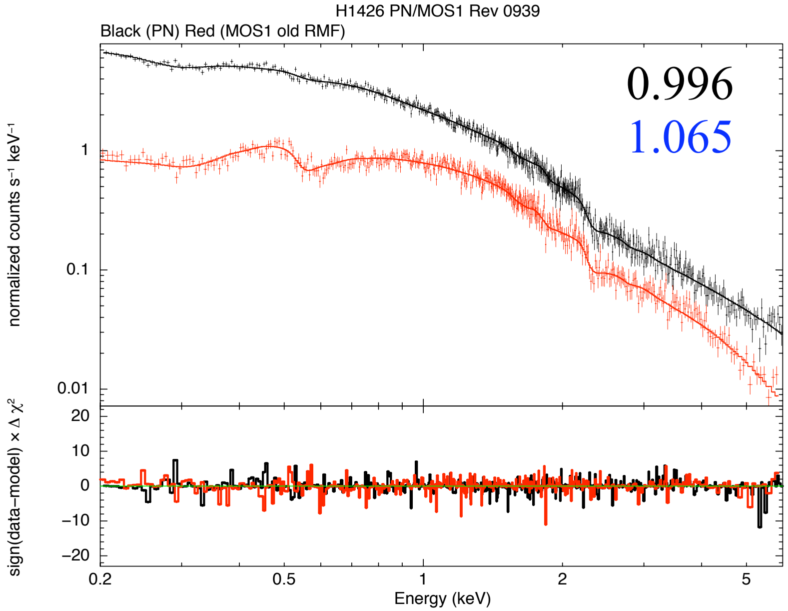
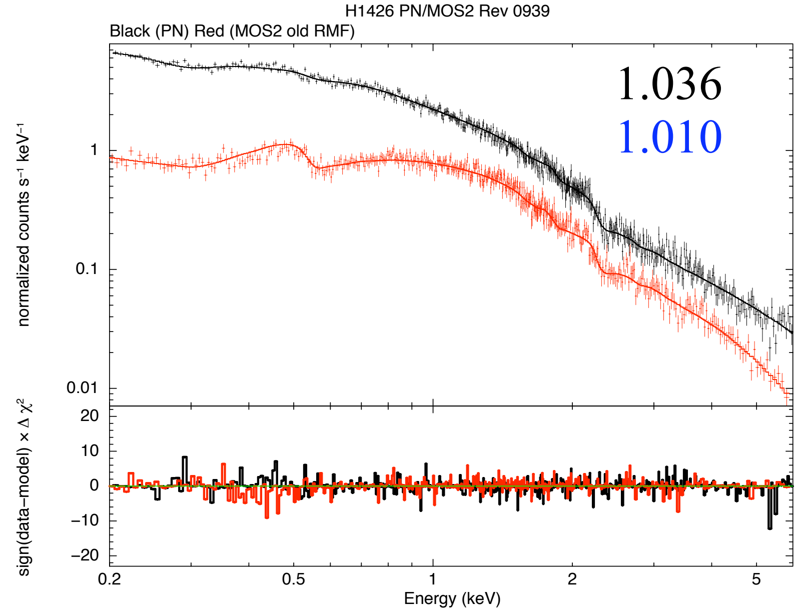
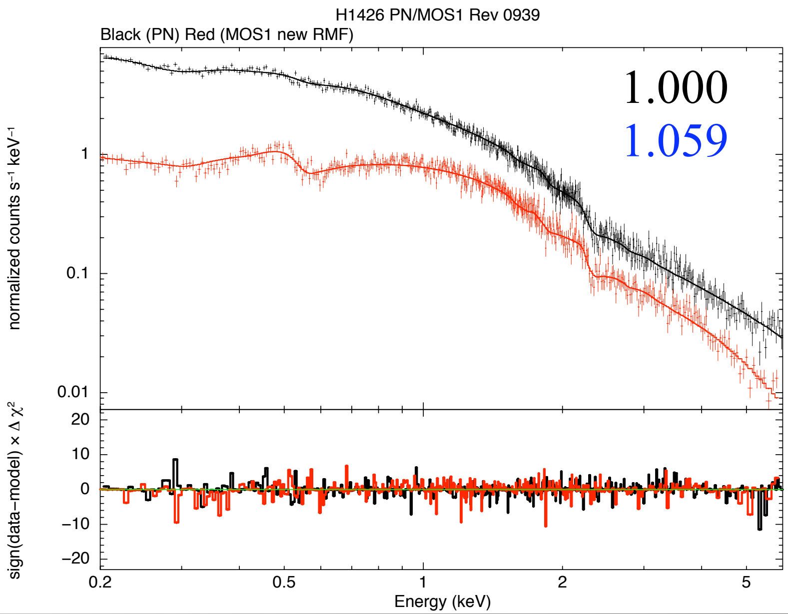
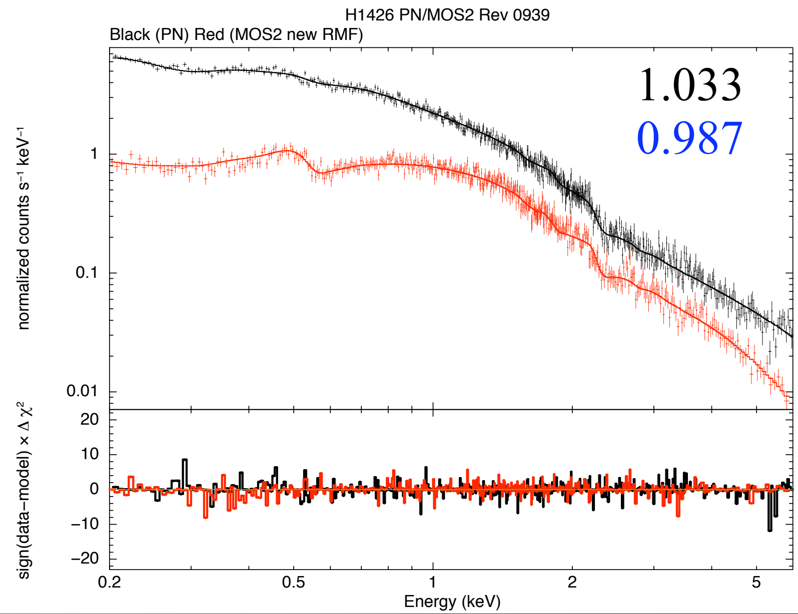

H1426 PN/MOS1 Rev 0939
Black (PN) Red (MOS1 old RMF)
0.996
1.065
normalized counts s⁻¹ keV⁻¹
sign(data−model) × Δ χ²
Energy (keV)


H1426 PN/MOS2 Rev 0939
Black (PN) Red (MOS2 old RMF)
1.036
1.010
normalized counts s⁻¹ keV⁻¹
sign(data−model) × Δ χ²
Energy (keV)


H1426 PN/MOS1 Rev 0939
Black (PN) Red (MOS1 new RMF)
1.000
1.059
normalized counts s⁻¹ keV⁻¹
sign(data−model) × Δ χ²
Energy (keV)


H1426 PN/MOS2 Rev 0939
Black (PN) Red (MOS2 new RMF)
1.033
0.987
normalized counts s⁻¹ keV⁻¹
sign(data−model) × Δ χ²
Energy (keV)

Conclusions:

1) The MOS has a strongly variable on-axis response and needs to calibrated against "something" given that we have no physical model of the response which explains the changes we see.

2) The best we can do is probably pick models of astrophysical sources for which there is some consensus within the community of what these models should be....i.e. so-called "standard candles"

3) We have a mathematical model of the response which looks to give a good fit to a chosen subset of these "standard candles"

4) If we adopt this route we need to make the ALL the "standard candle" models publically available to the community (i.e. XSPEC xcm files) with documentation as to how these models were derived.