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

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Basic Scheme: For a given epoch and spatial region...

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

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

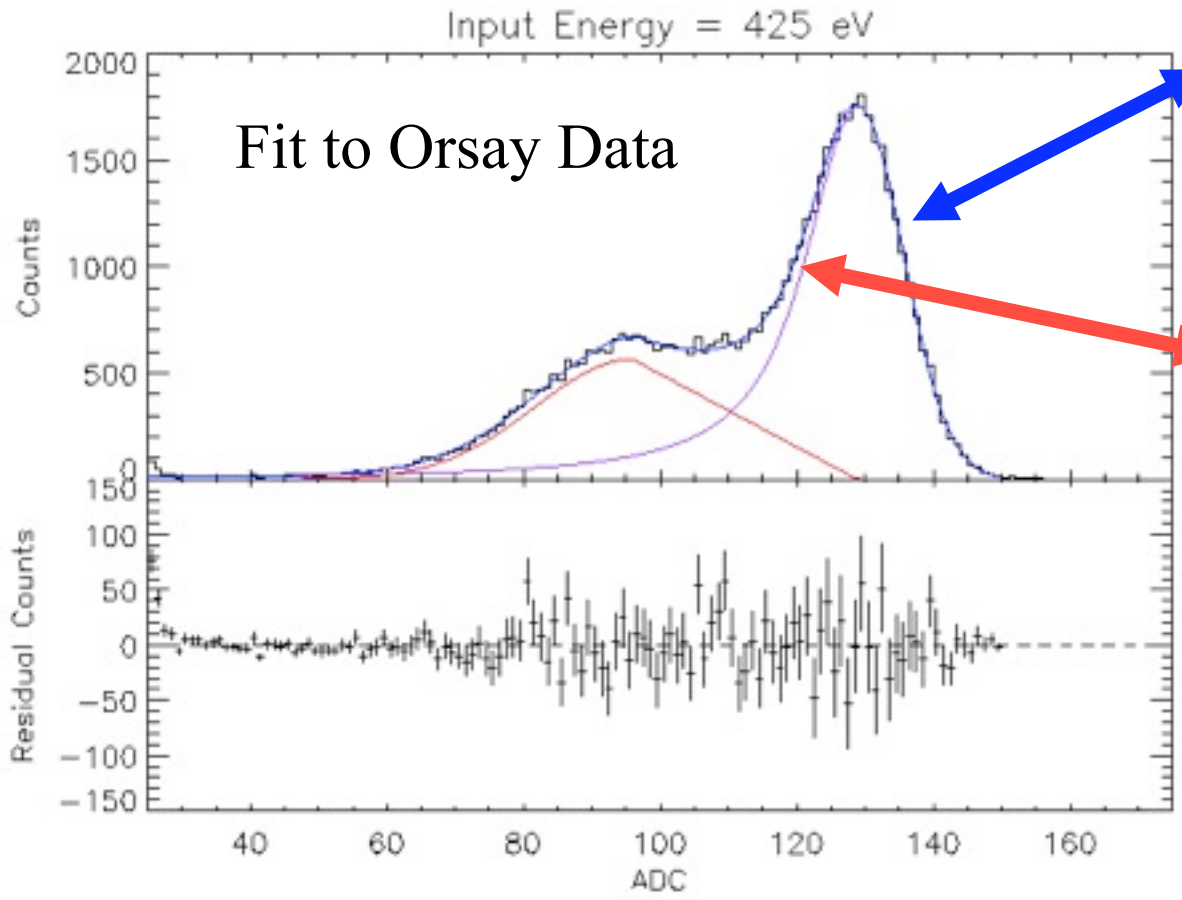
...

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

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

$$\Sigma ((O_i - D_i)/\delta O_i)^2 + \Sigma ((O_i - D_i)/\delta O_i)^2 + \ldots + \Sigma ((O_i - D_i)/\delta O_i)^2$$

Previous Phenomenological Model: The VRMF Model

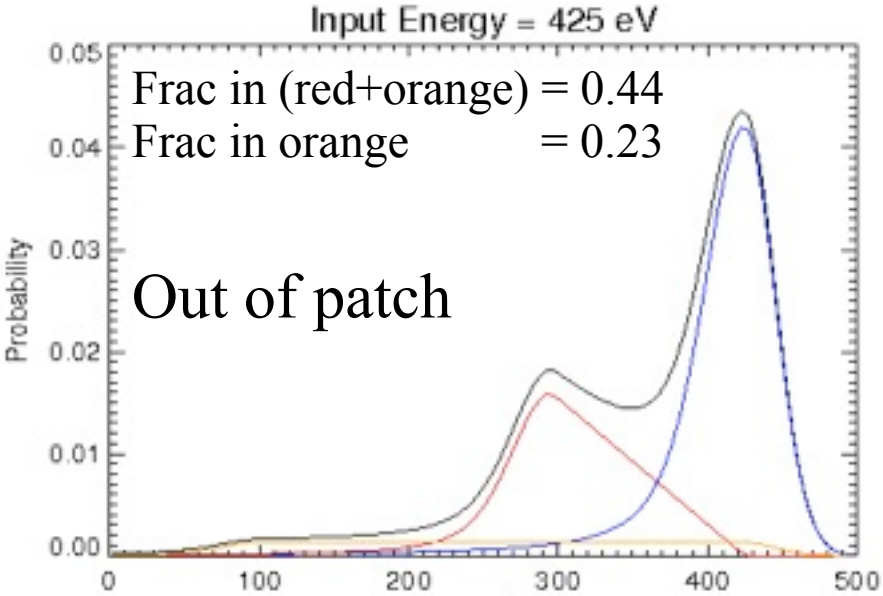


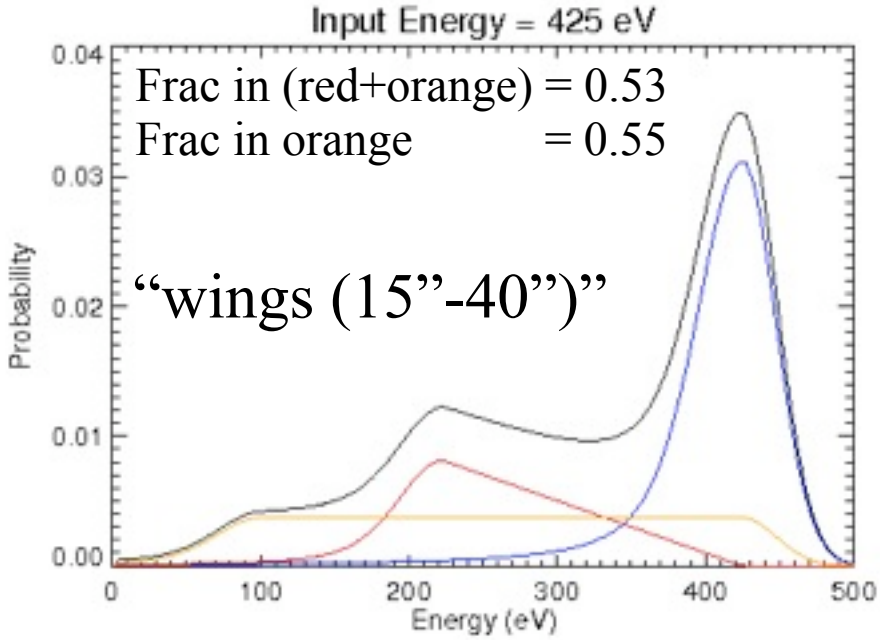
Blue Wing:
Gaussian

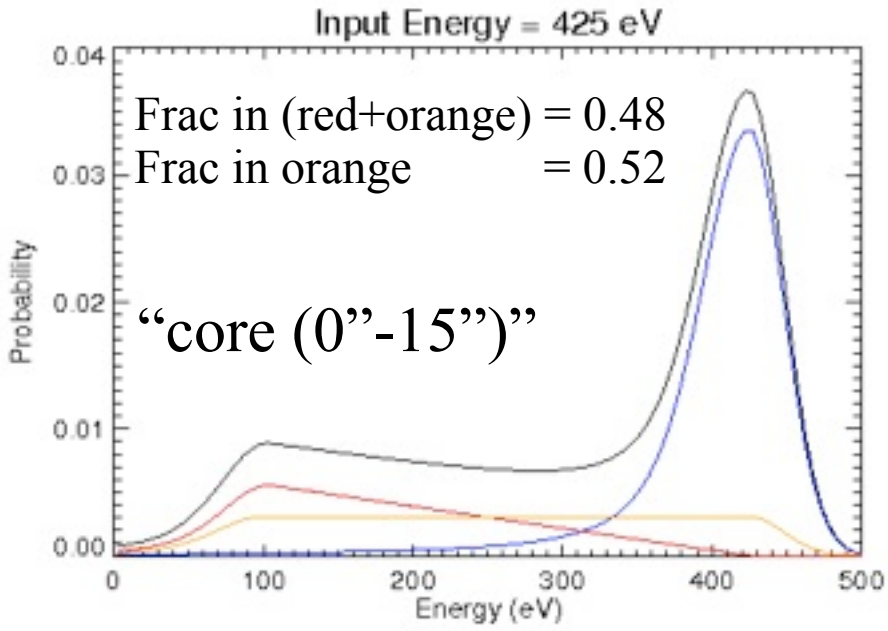
Red Wing:
Voigt Function

= Gaussian convolved
with a Lorentian.

Dampening factor
= 0 (Gaussian)
> 0 (Lorentz-like)







New model adds a flat "shelf"

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

Parameters which define redistribution matrix, R

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

Dampen $= \alpha_2 \exp(-(e0-\beta_2) / \gamma_2)$ for $\beta_2 > e0$

$= \alpha_2$ $\beta_2 <= e0$

i.e. tends to zero for large e0 (more Gaussian)

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

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

$$F_{Loss\_peak} = \alpha_4 \exp(-(e0-\beta_4)/\gamma_4) \quad \text{for } \beta_4 > e0$$
$$= \alpha_4 \quad \beta_4 <= e0$$

$$E_{Eloss}/e0 = \alpha_5 \text{ for } e0 < 300 \text{ eV}$$
$$= \alpha_6 \text{ for } e0 > 400 \text{ eV}$$

Total parameters = 13

Not counting parameters giving intensity of silicon fluorescence and escape peaks (fixed to previous calibration)

Time to derive one solution for a given set of input spectra ~ 3 to 6 hours.

“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

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“Standard Candle” Spectral Models

1) The white dwarf CAL83

See next slides

2) The isolated neutron star RXJ 1856

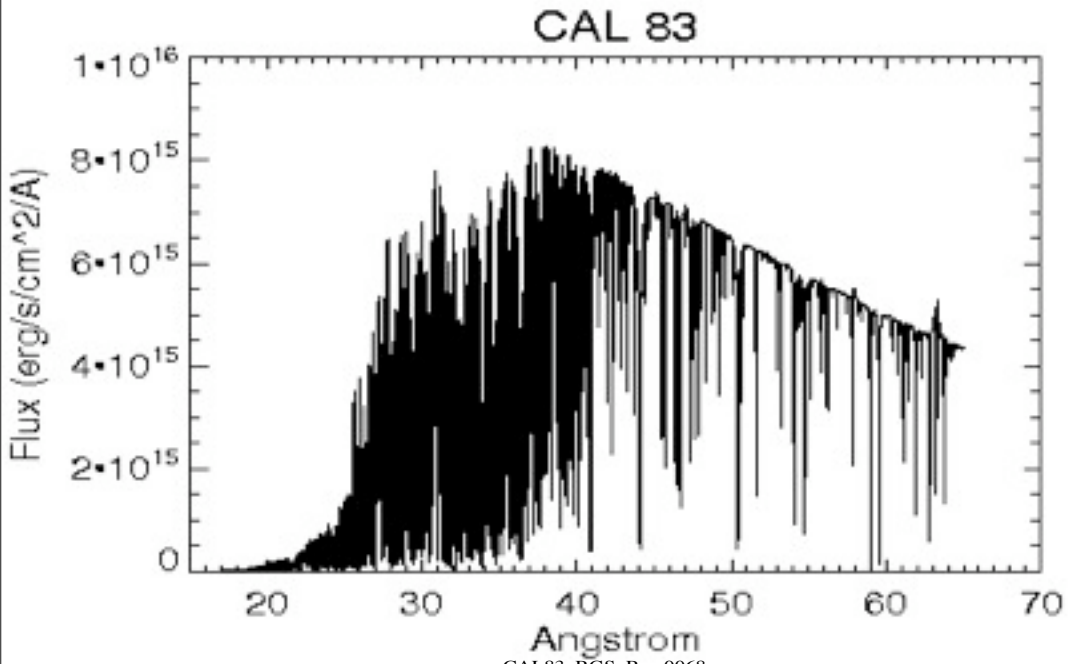
phabs * (bb + bb) (V. Burwtiz pn model)

3) The O star Zeta Puppis

Frank’s RGS model

4) The SNR 1ES0102

The IACHEC WG model (Plucinsky et al.)

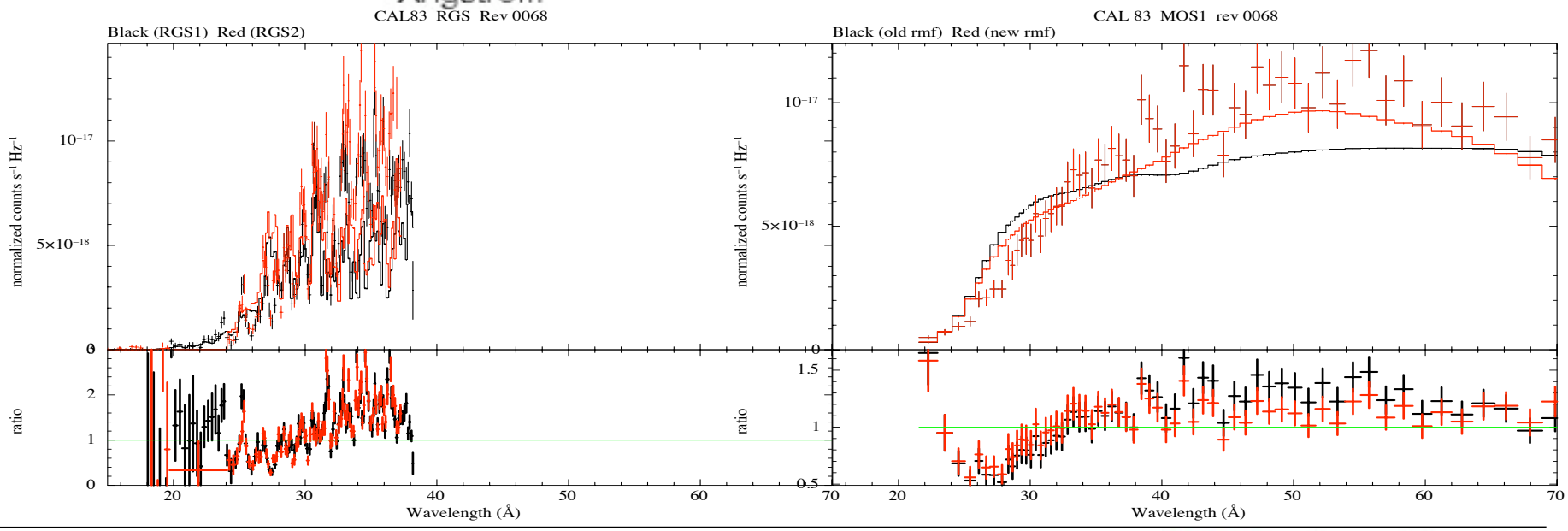


Lantz, T, et al. (2005) ApJ, 619, 517

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*)



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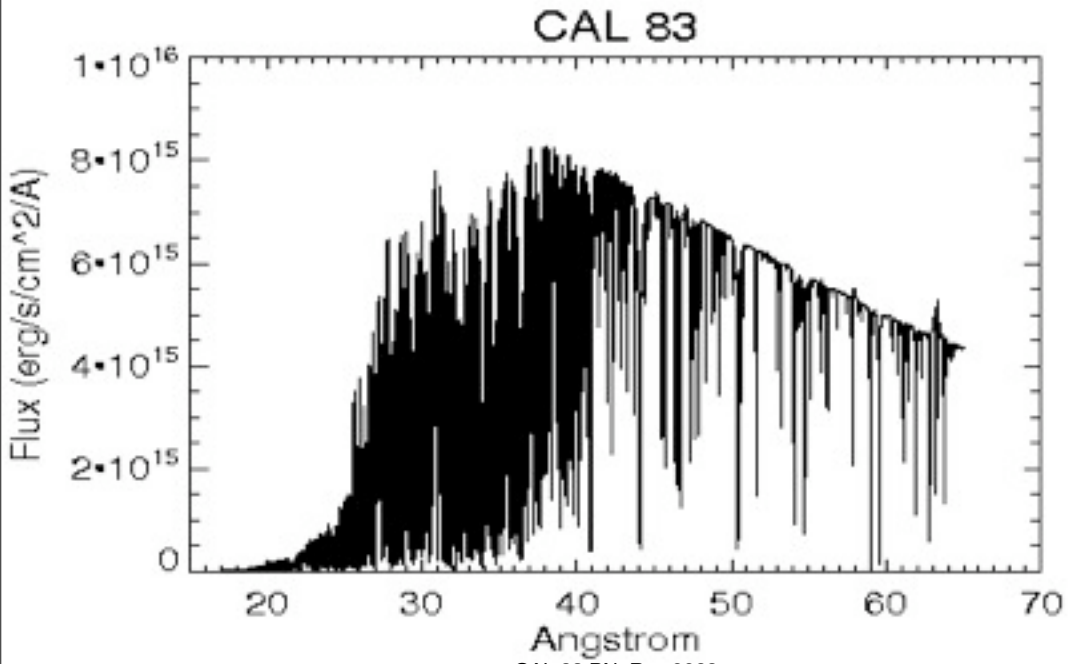

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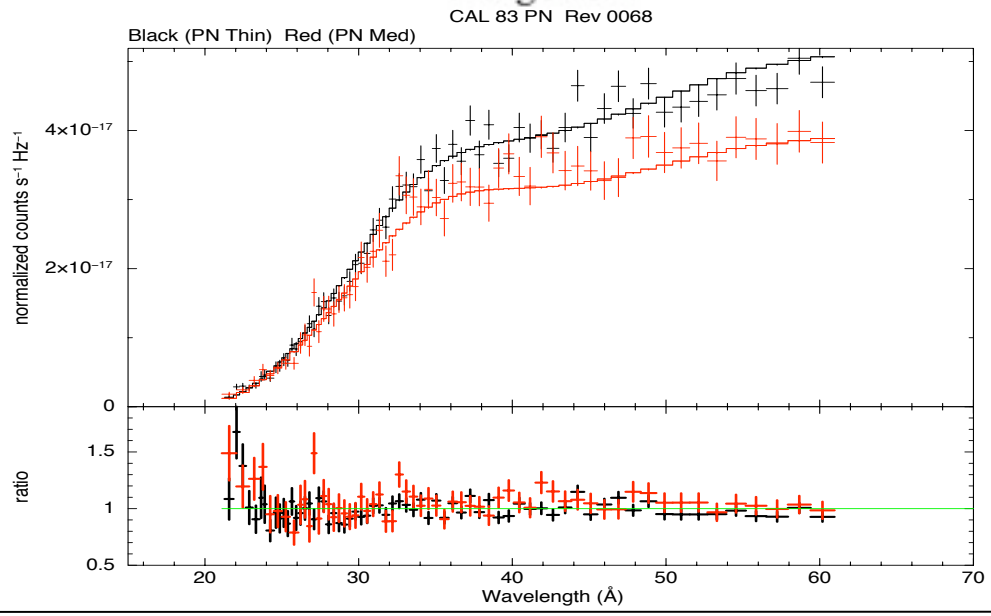

Use instead best fit *descriptive* model to PN = phabs * bb (abund *wilm*)

$n_H = 1.11 \times 10^{21}$ cm^{-2}

kT = 0.034 keV

Epoch 1: Revolution 0065 - 0156

“Pre-Patch”

Standards:

1E0102 (Rev 65)
Cal 83 (Rev 68)
Puppis (Rev 156)

Test Sources:

MS0737 (BL Lac) (Rev 63)
3C 273 (Blazar) (Rev 94)

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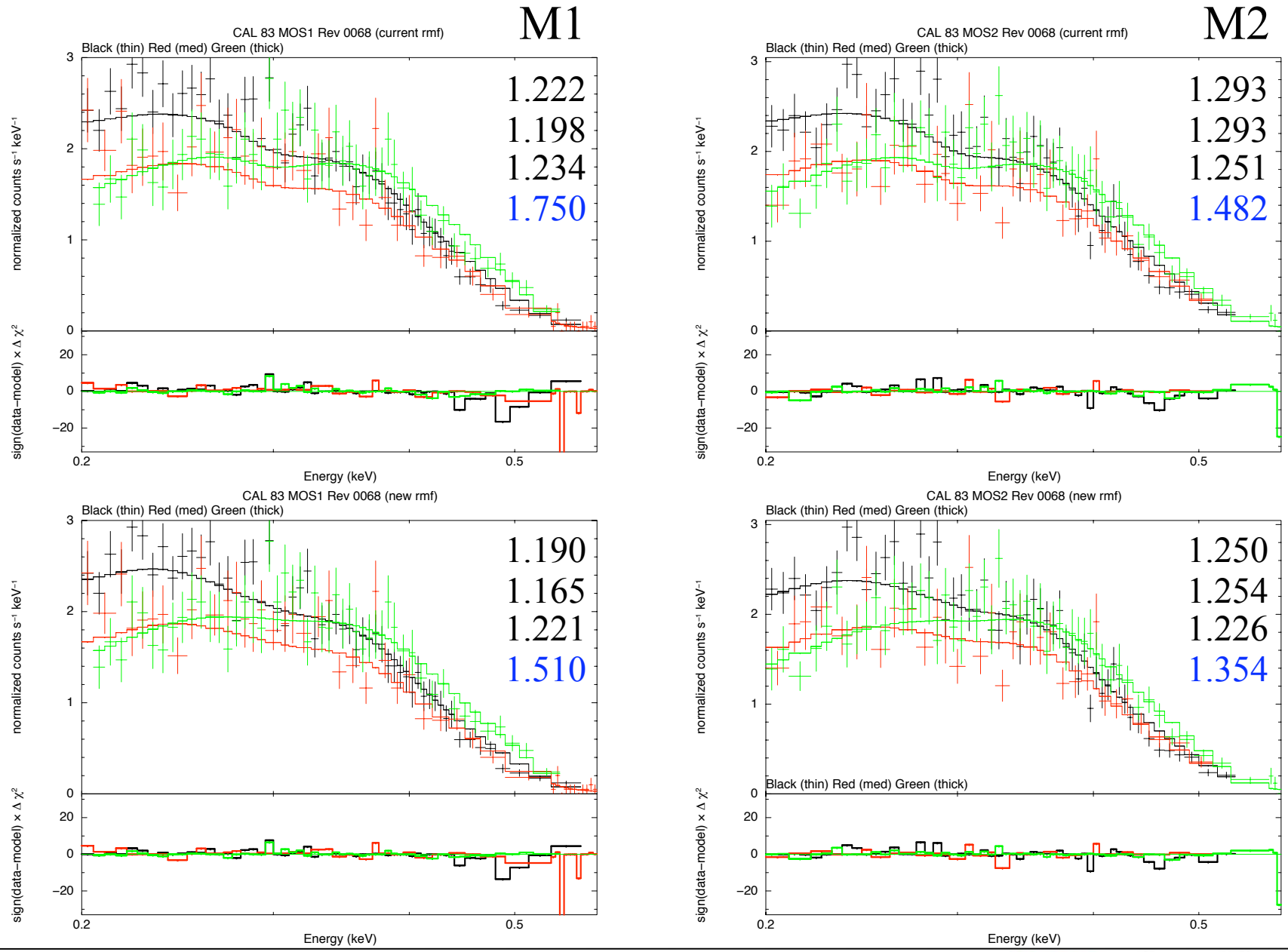

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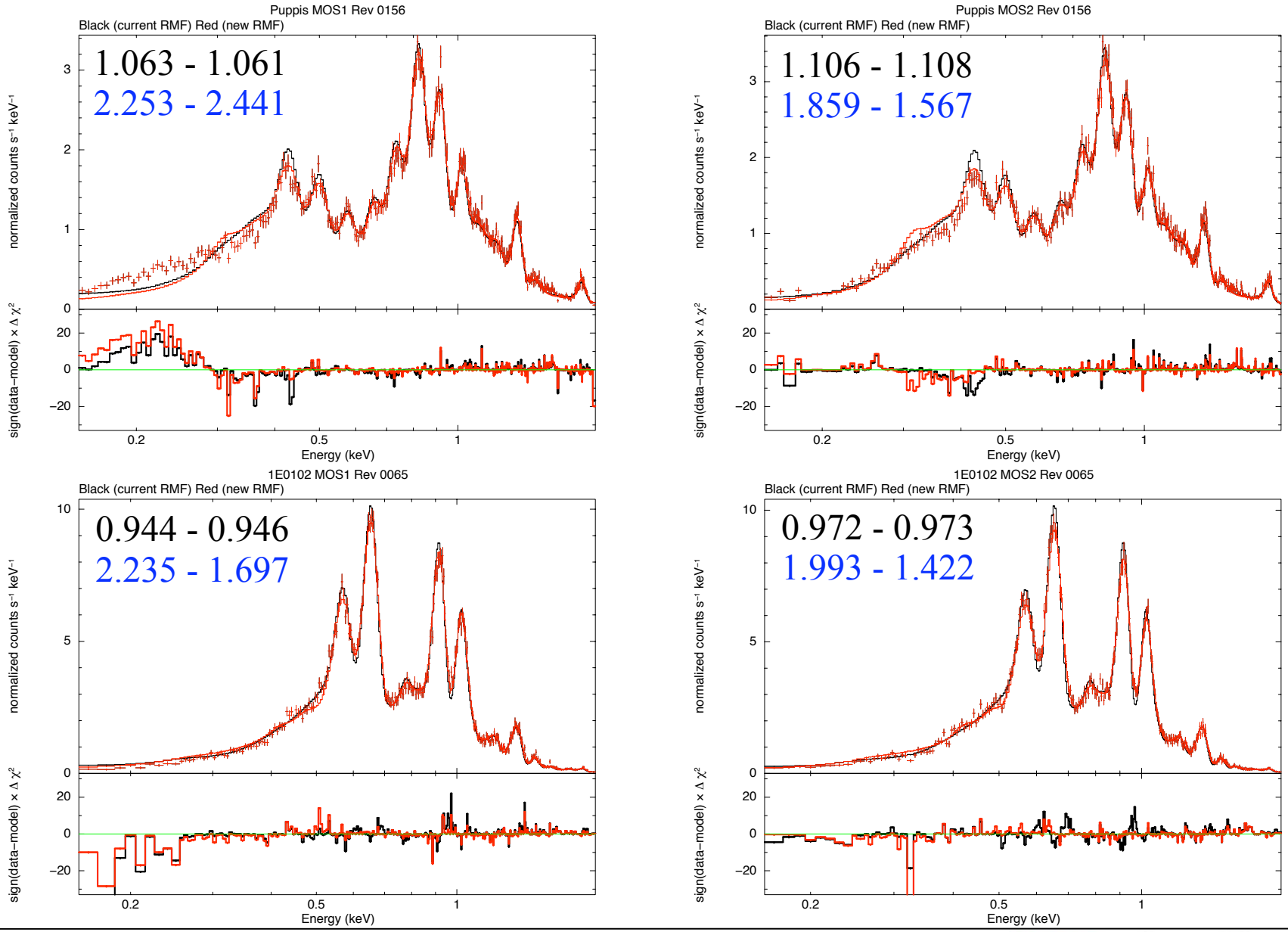

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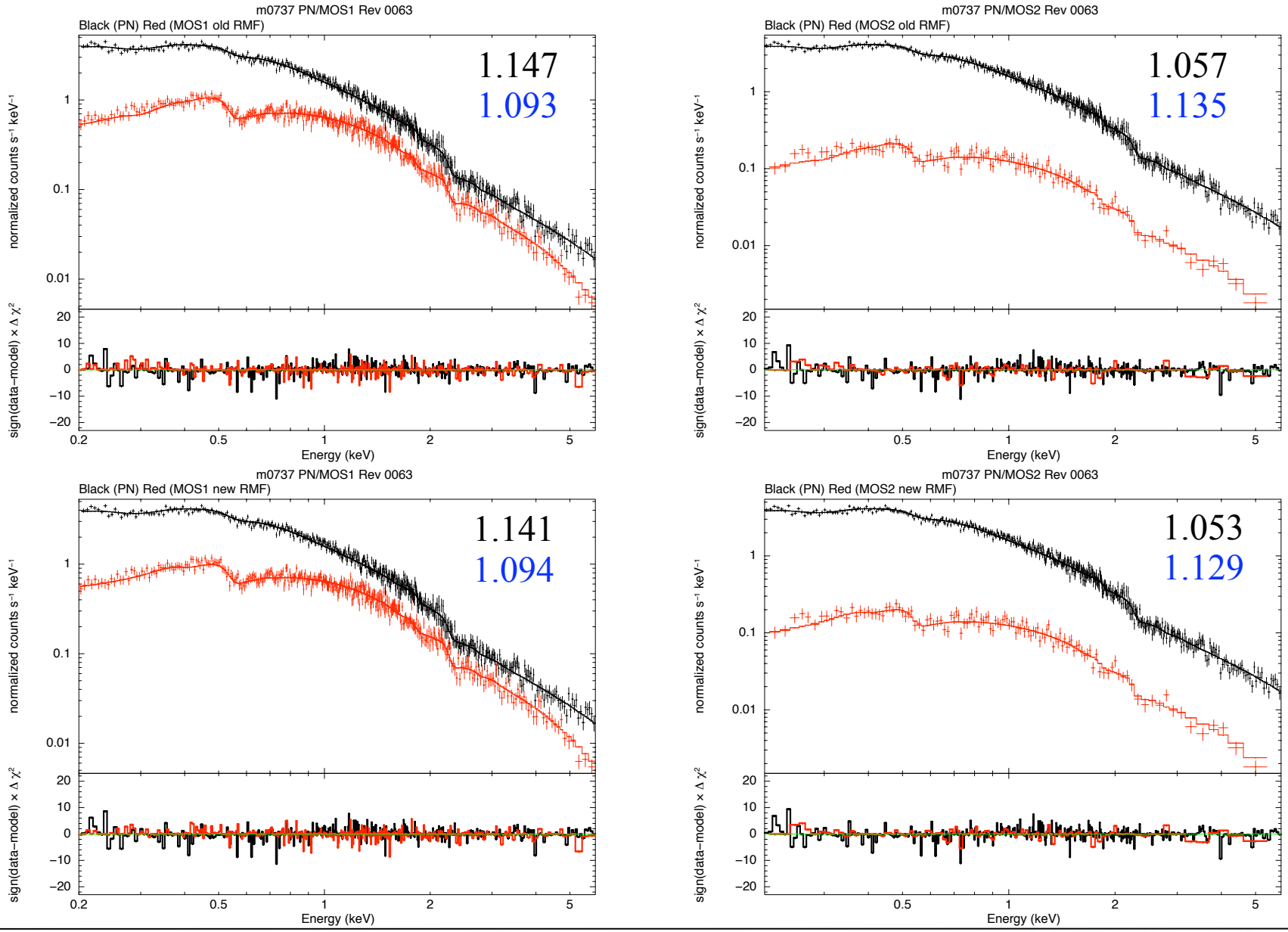

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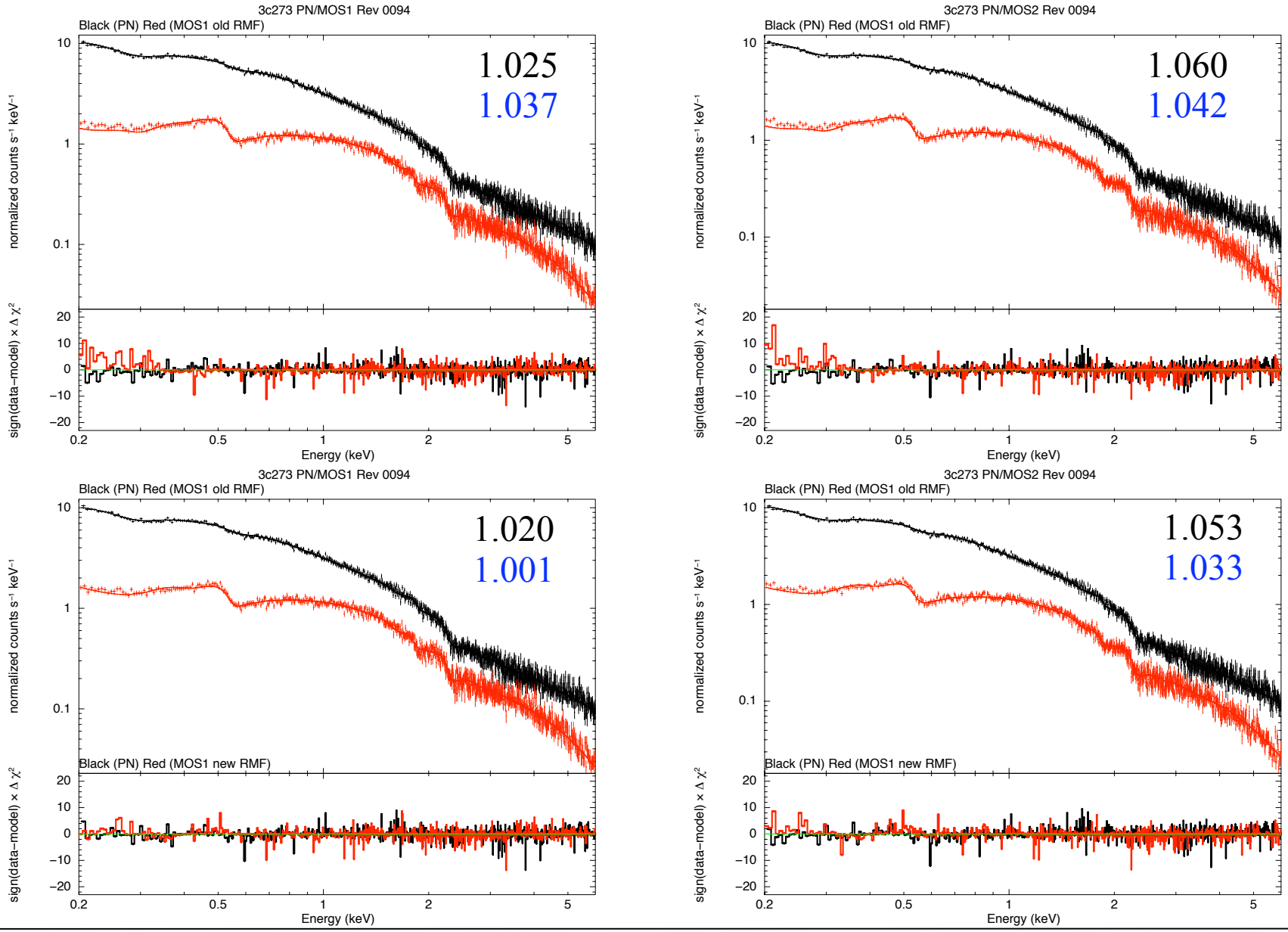

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Epoch 2: Revolution 0795-0900

On-axis, “patch affected”

Standards:

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

Test Sources:

H1426 (BL Lac) (Rev 939)

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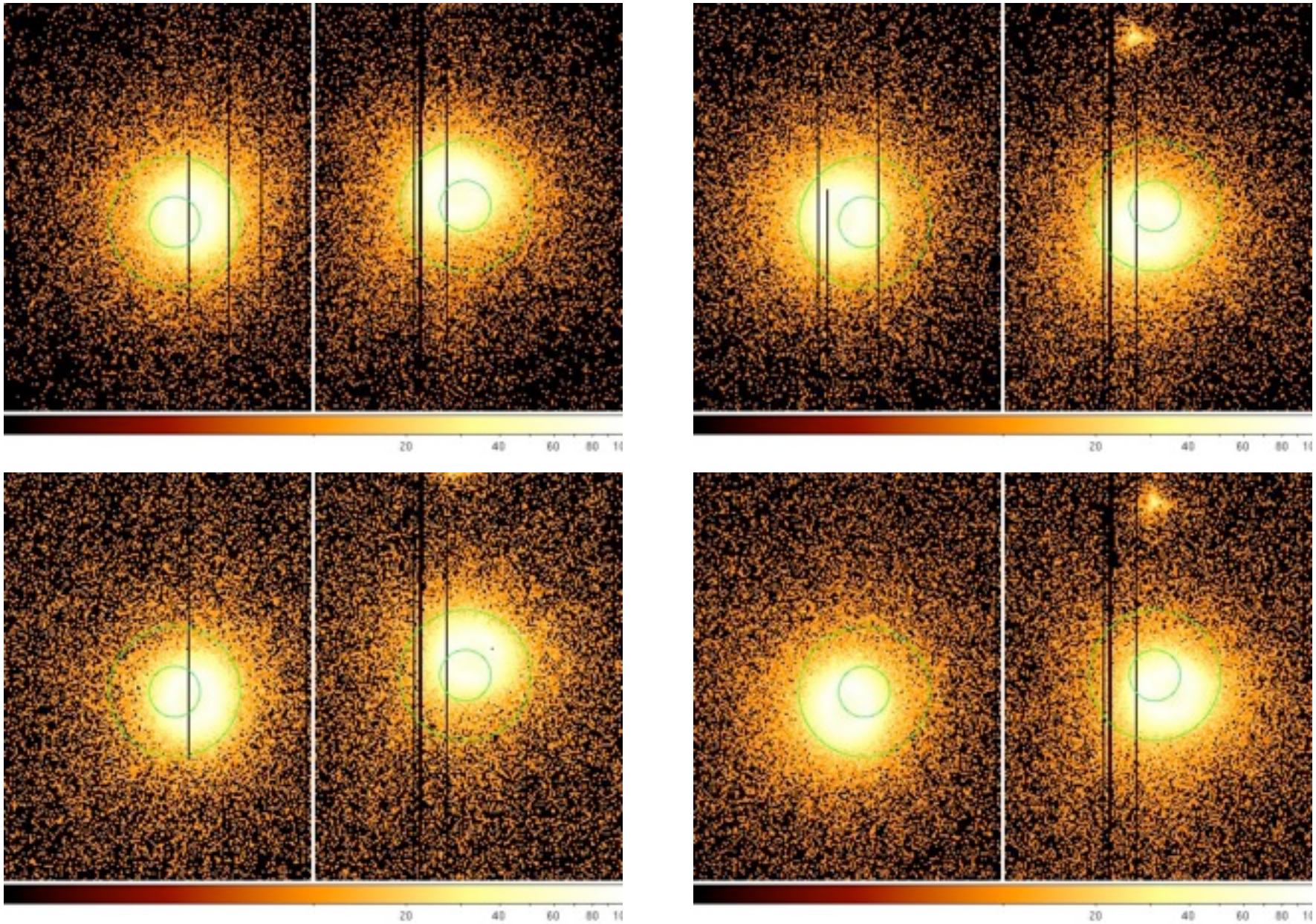
20
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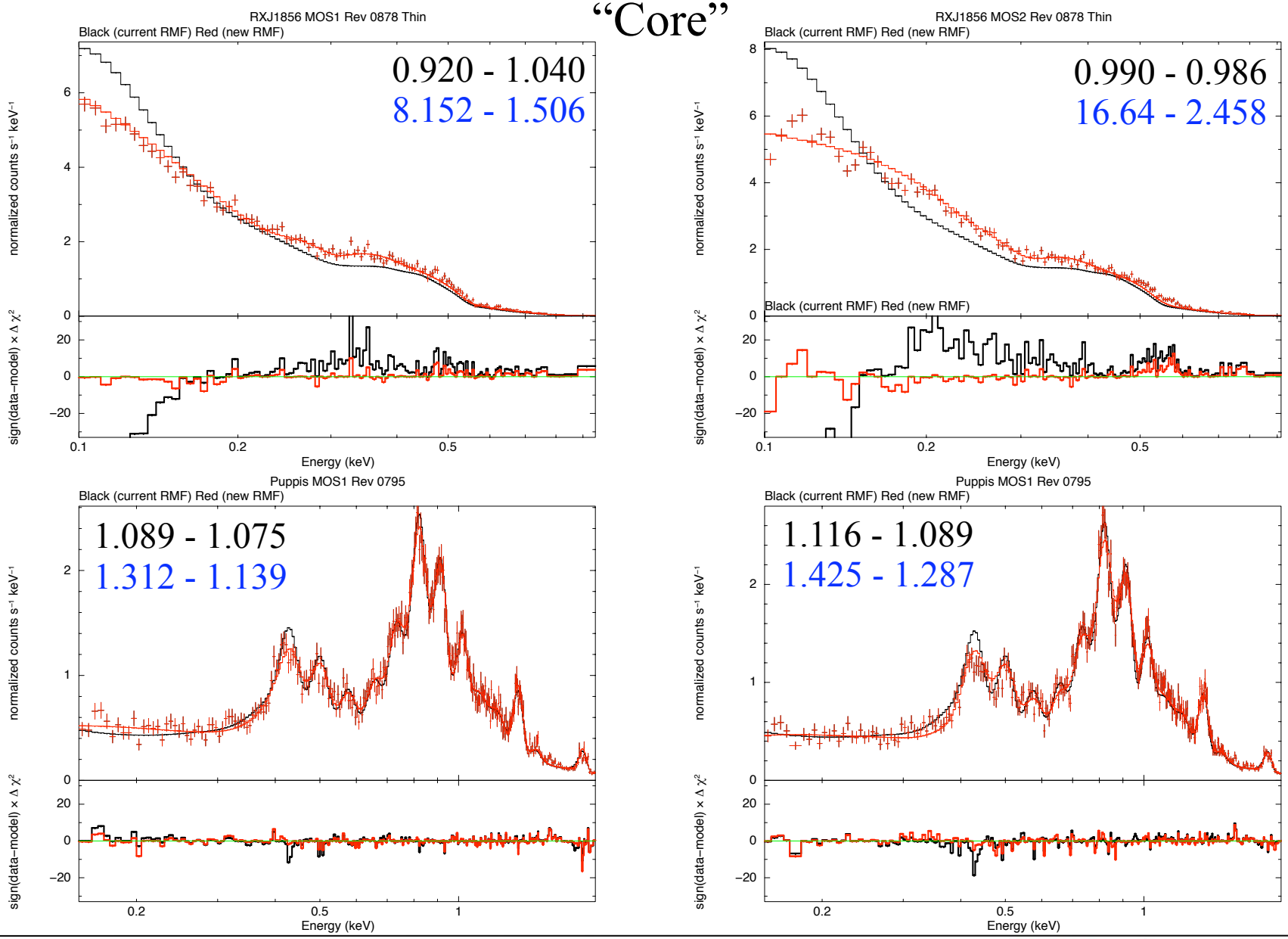
80

“Core”



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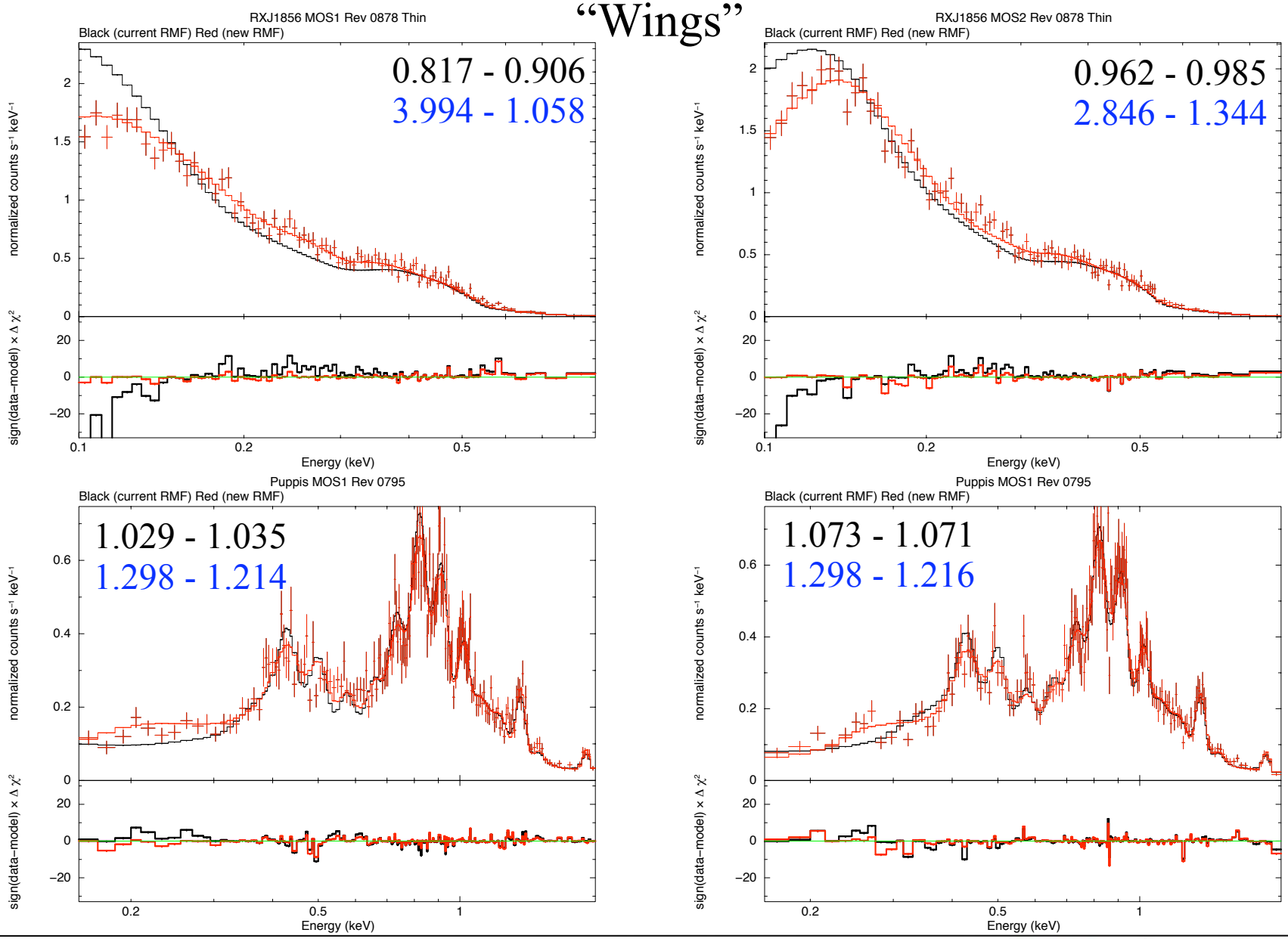
“Wings”



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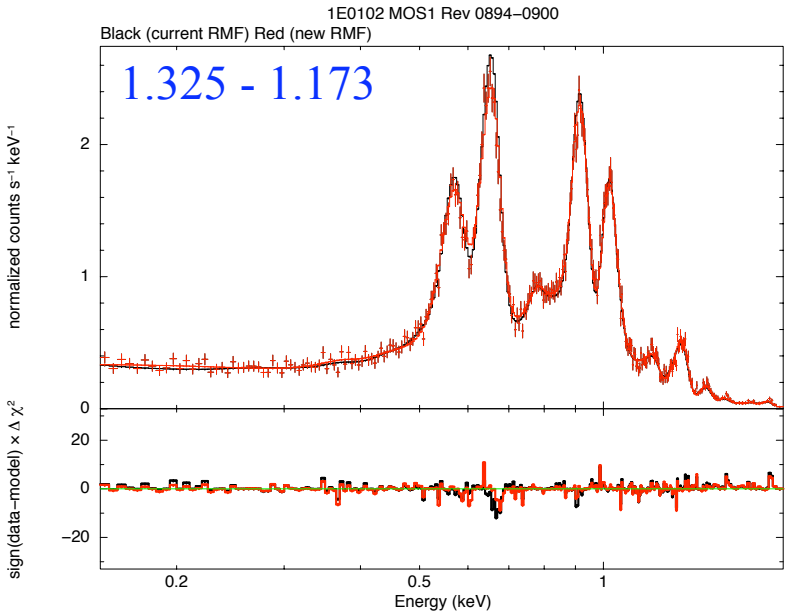
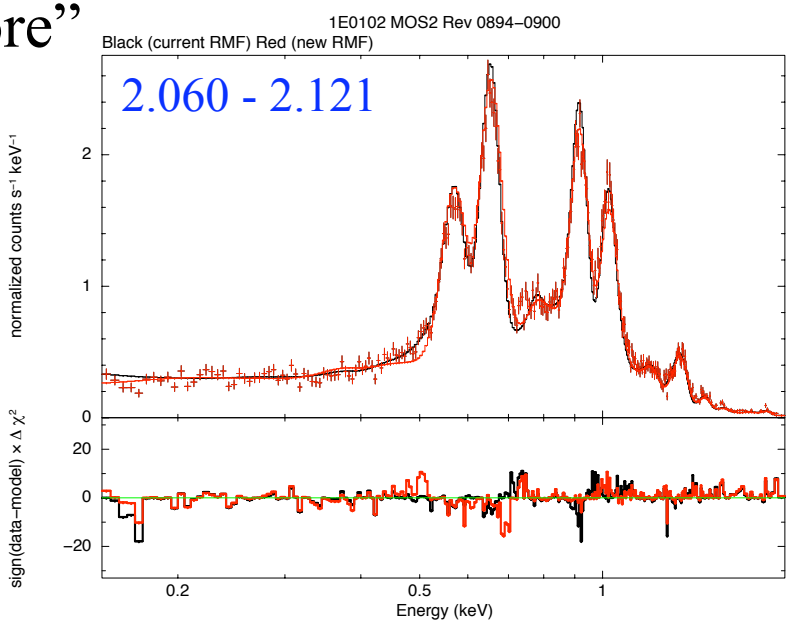
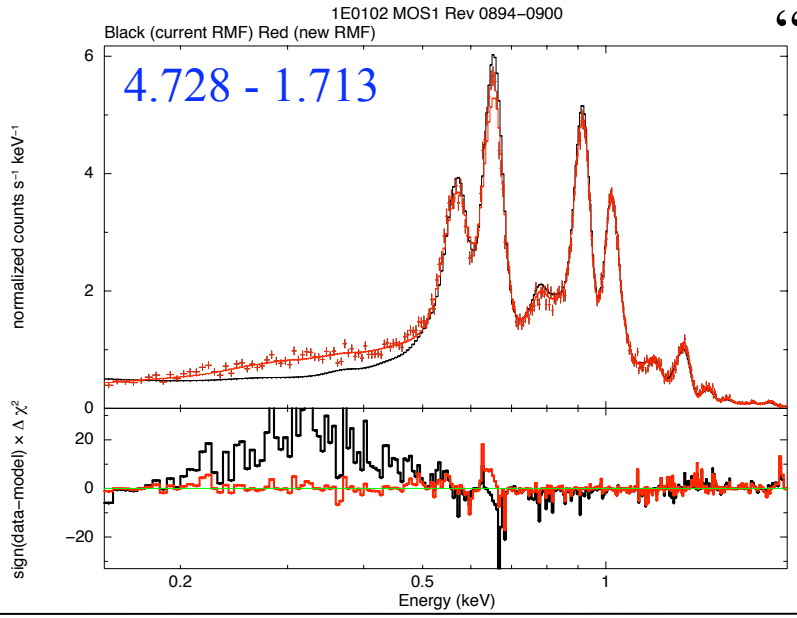
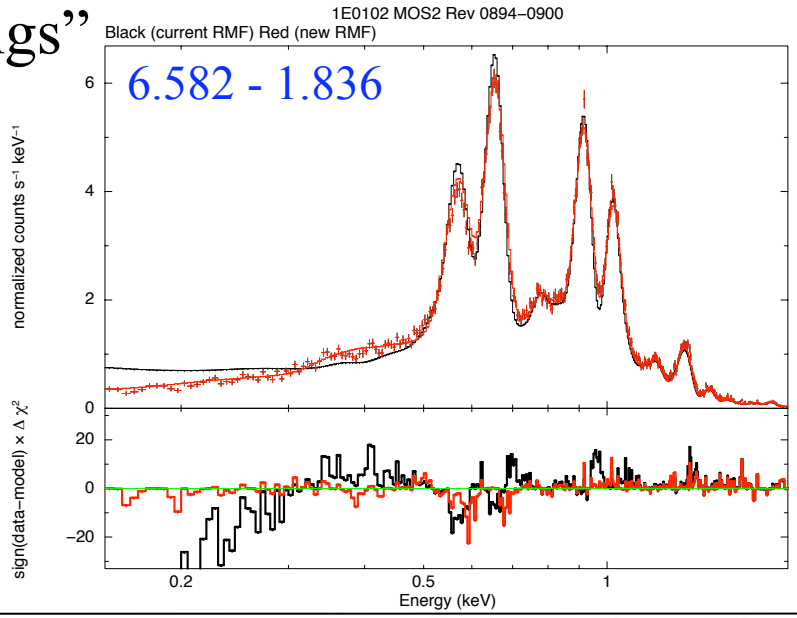
“Core”

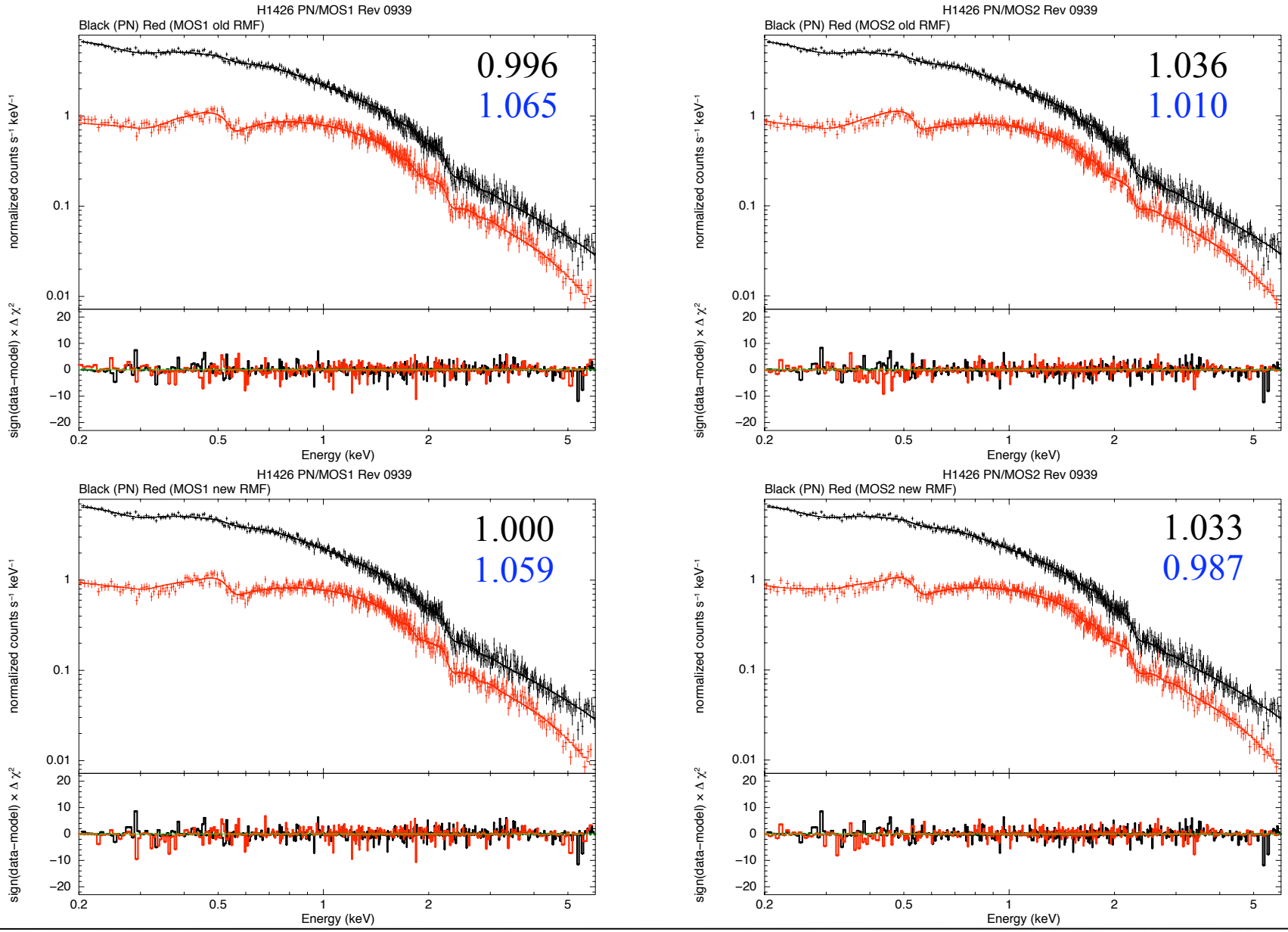

1E0102 MOS1 Rev 0894–0900
Black (current RMF) Red (new RMF)
1.325 - 1.173
normalized counts s⁻¹ keV⁻¹
sign(data−model) × Δ χ²
Energy (keV)


1E0102 MOS2 Rev 0894–0900
Black (current RMF) Red (new RMF)
2.060 - 2.121
normalized counts s⁻¹ keV⁻¹
sign(data−model) × Δ χ²
Energy (keV)

“Wings”


1E0102 MOS1 Rev 0894–0900
Black (current RMF) Red (new RMF)
4.728 - 1.713
normalized counts s⁻¹ keV⁻¹
sign(data−model) × Δ χ²
Energy (keV)


1E0102 MOS2 Rev 0894–0900
Black (current RMF) Red (new RMF)
6.582 - 1.836
normalized counts s⁻¹ keV⁻¹
sign(data−model) × Δ χ²
Energy (keV)



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Epoch 3: Revolution 1265-1335

Off axis (Still on CCD1)

Standards:

1E0102 (Rev 1265)
RXJ1856 (Rev 1335)

Test Sources:

REJ 2248 (AGN) (Rev 1361)

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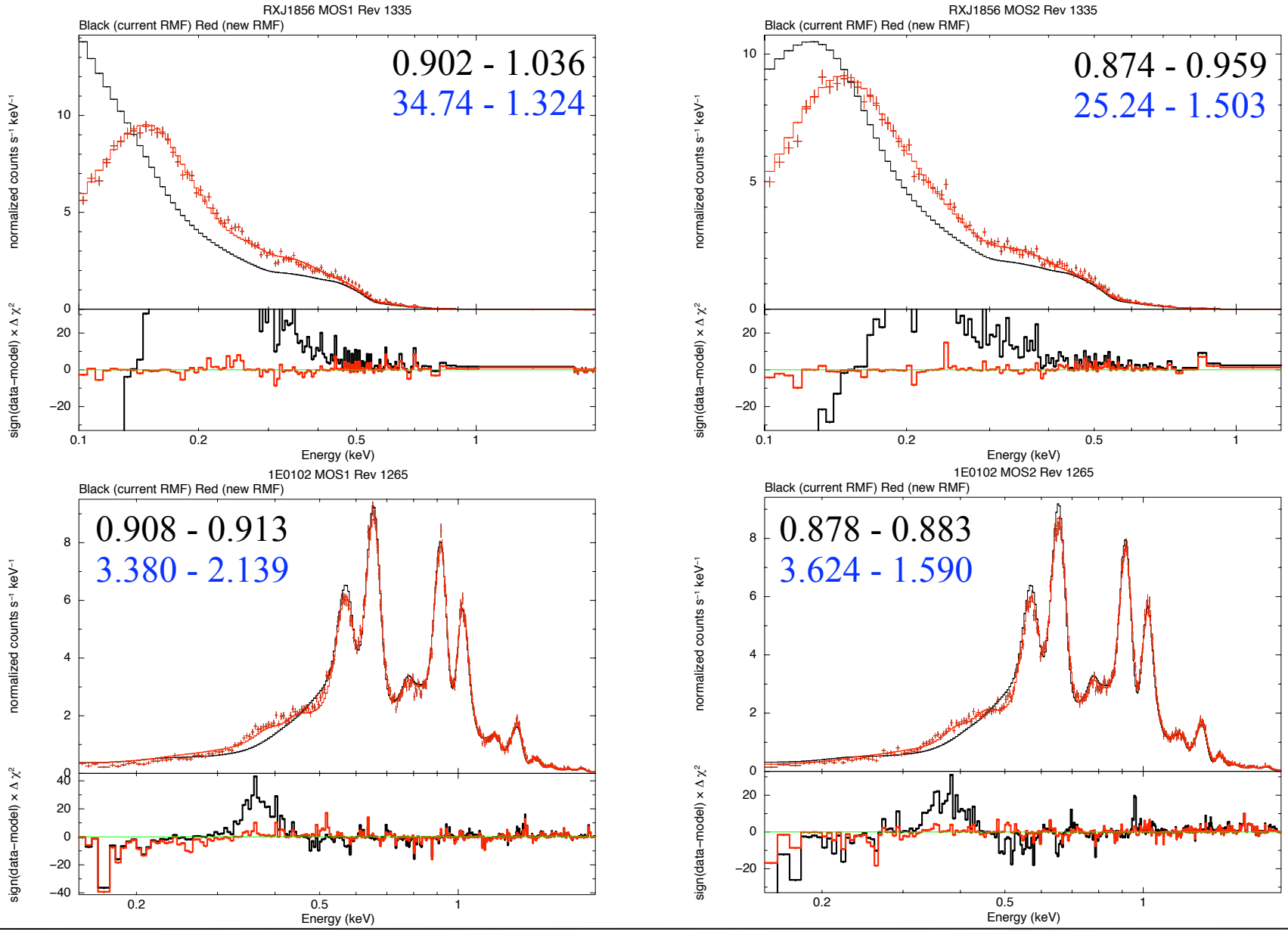

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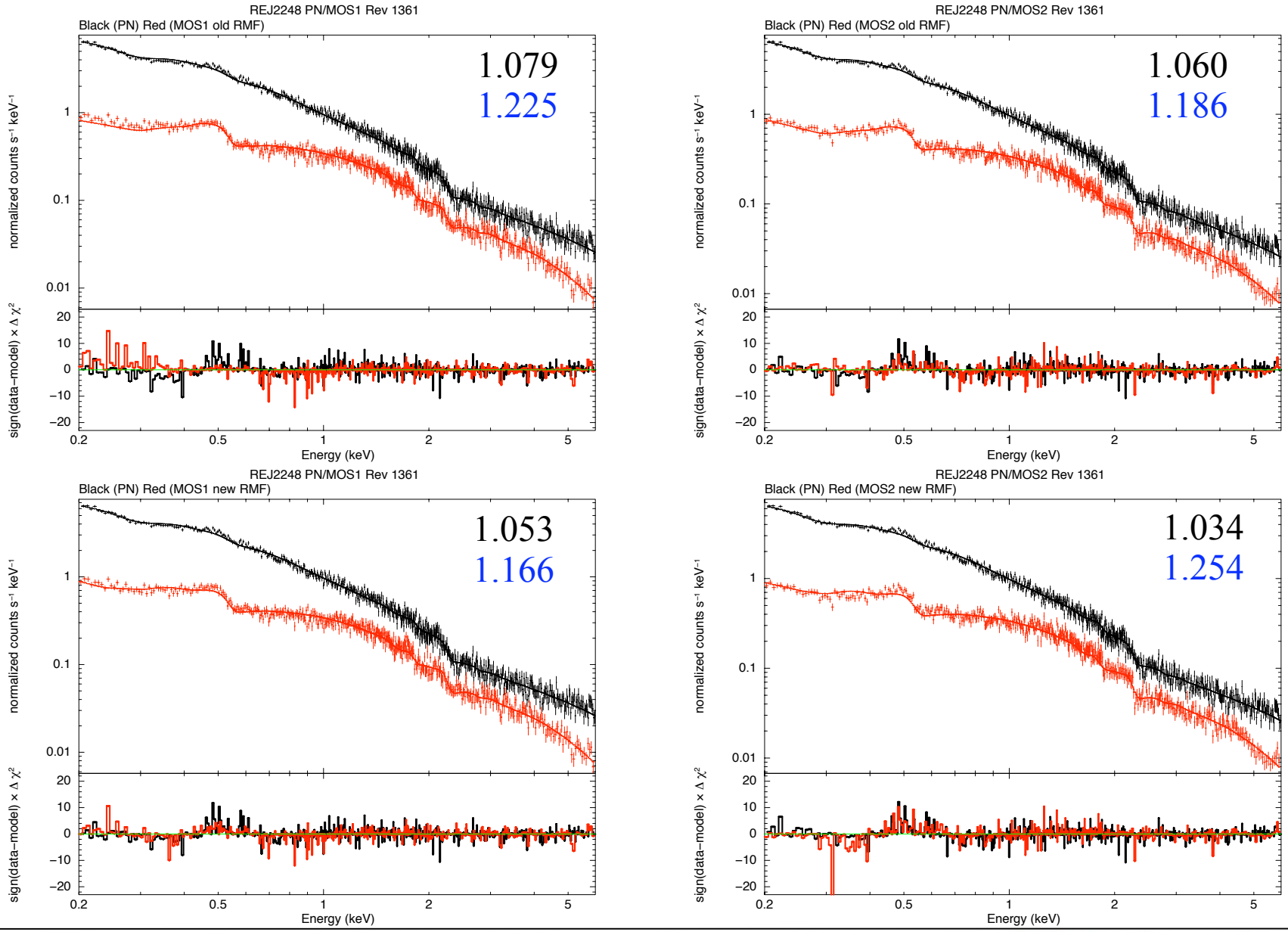

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Epoch 4: Revolution 1616-1636

On-axis, “patch affected”

Standards:

RXJ1856 (Rev 1616)
1E0102 (Rev 1636)

Test Sources:

3C 273 (BL Lac) (Rev 1649)

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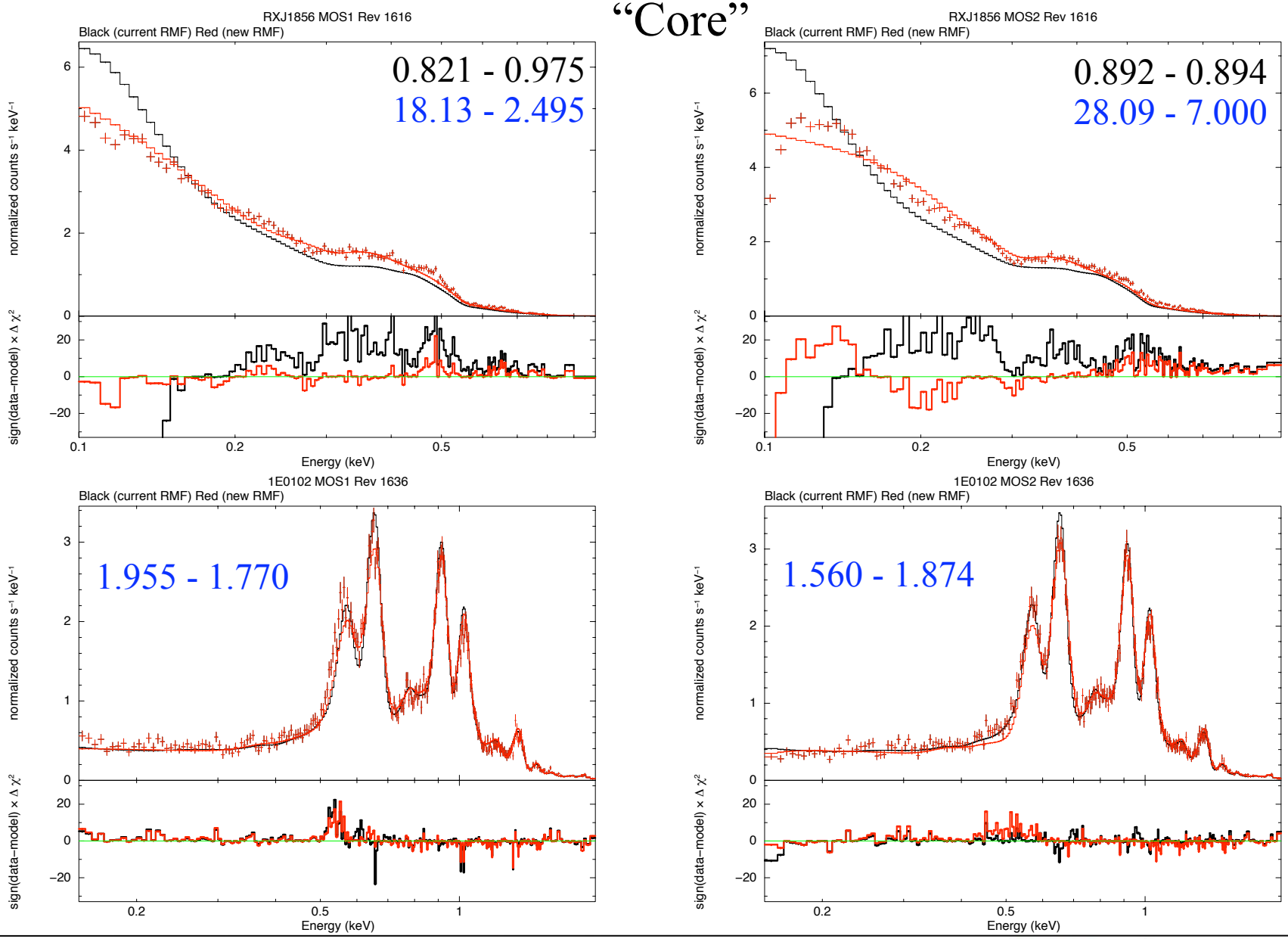
“Core”



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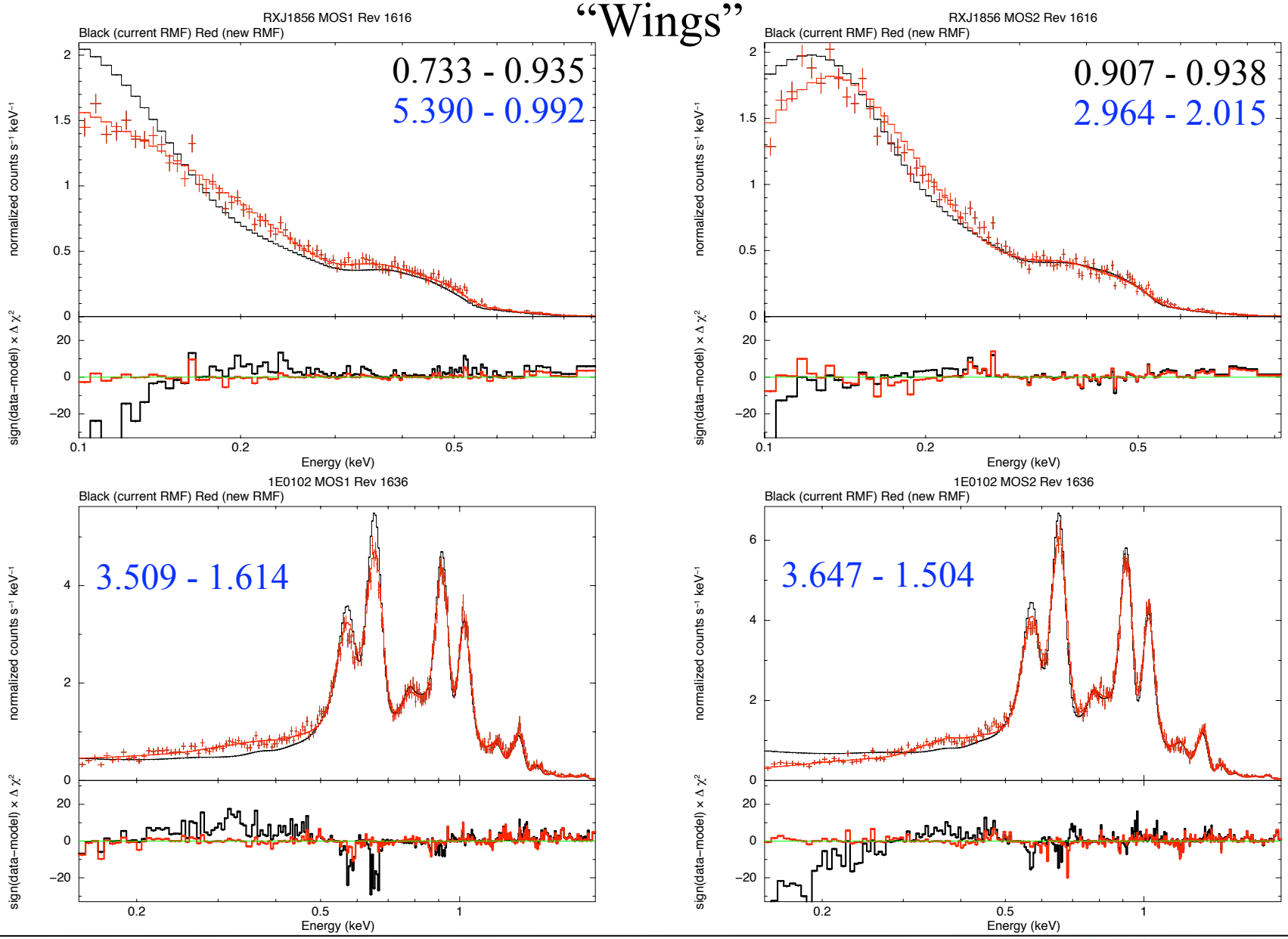

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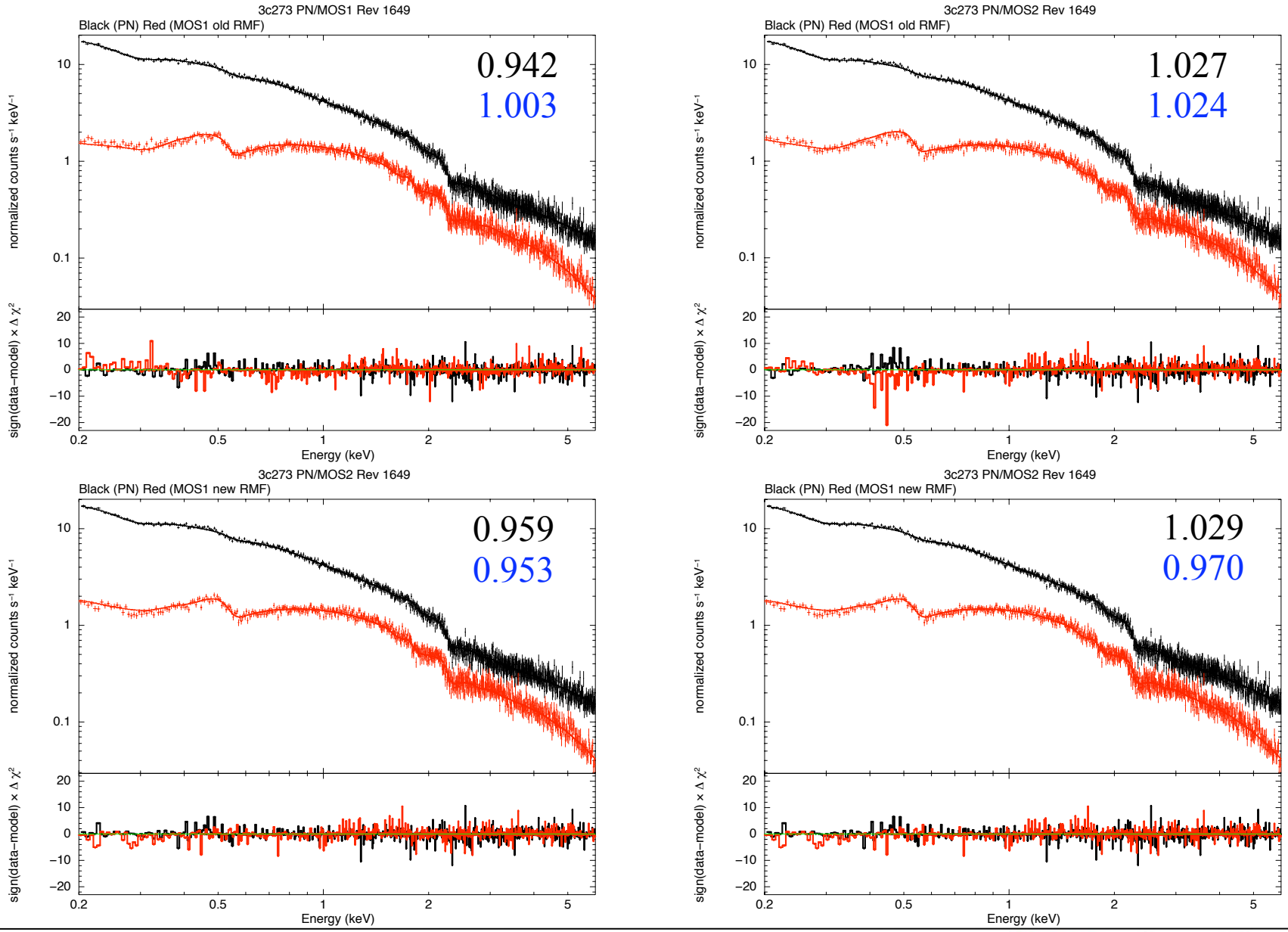

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Conclusions:

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.

End

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