Cross-calibration status in the 0.5-7 keV

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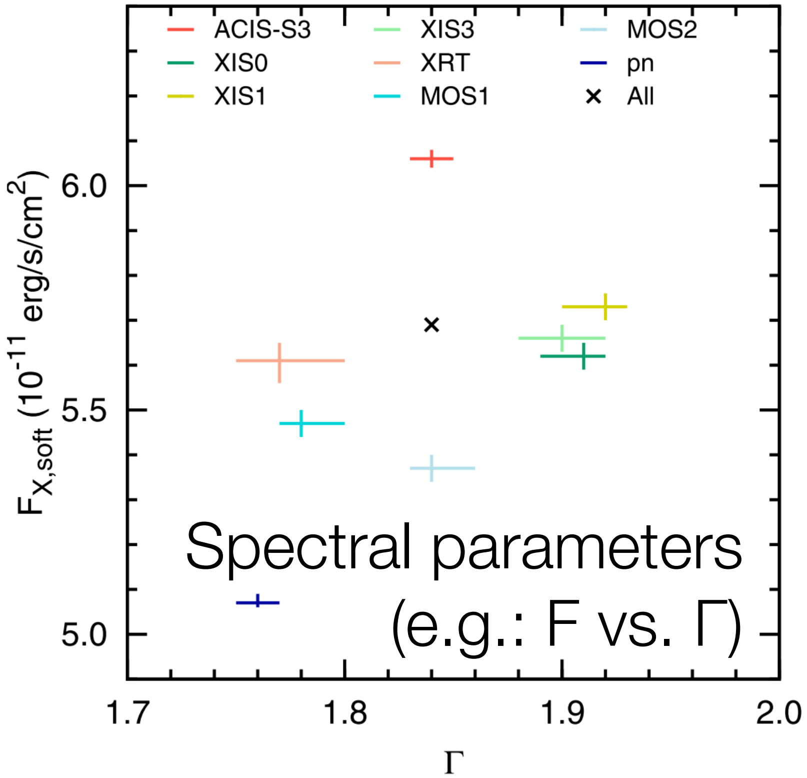
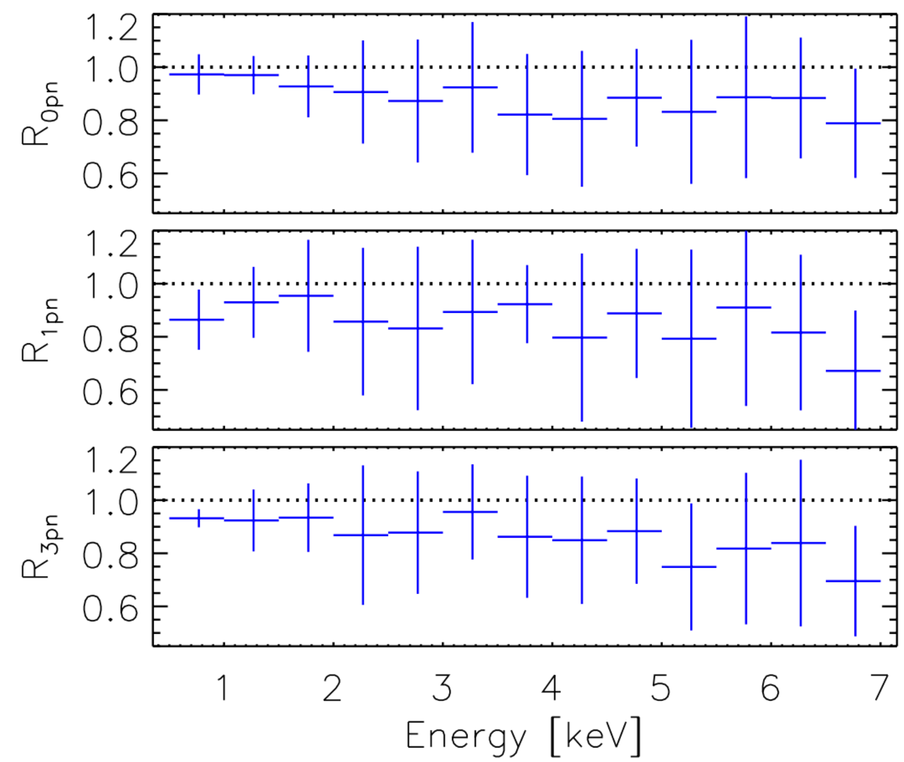
IACHEC papers

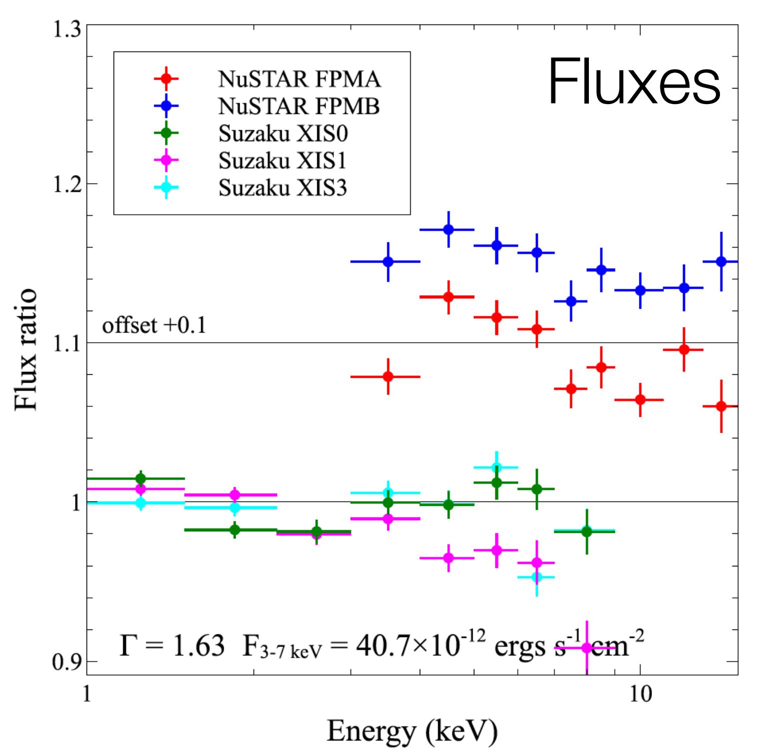
- Galaxy Clusters [Nevalainen et al. 2010, Kettula et al. 2013; Schellenberger et al. 2015]
- G21.5-0.9 [Tsujimoto et al. 2011]
- PKS2155-304/3C273 [Ishida et al. 2011; Madsen et al. 2017]
- 2XMM sources [Read et al. 2014]
- 1E0102-72 [Plucinsky et al. 2017]

Results

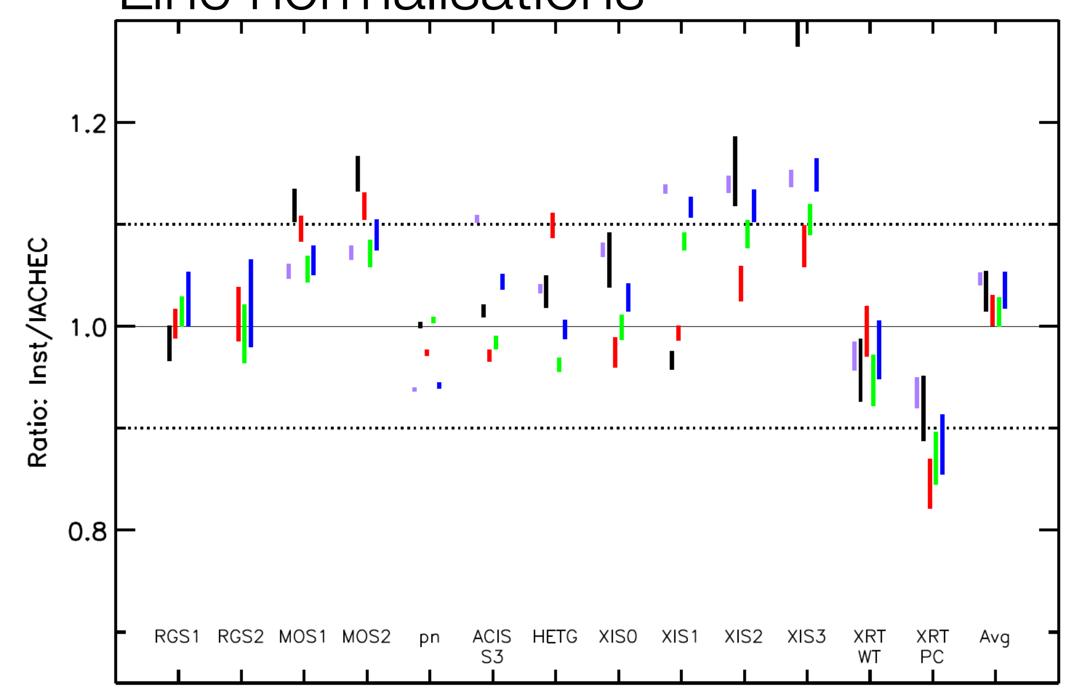


"Stacked residuals"





Line normalisations



Residuals ≠ effective area cross-calibration

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- Effective area cross-calibration (on-axis + vignetting)

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- Energy redistribution

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- Data analysis (e.g. background subtraction)

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- Effective area cross-calibration (on-axis + vignetting)
- Energy redistribution
- Pile-up
- Encircled Energy Fraction correction
- Data analysis (e.g. background subtraction)
- History (software/calibration changes from 2010 to 2017)

Goals

1. Verify the current global status of the effective area cross-calibration in the ~0.5-~7 keV energy band. At which level do IACHEC paper results "tell the same story"?

2. disentangling on-axis effective area discrepancies from other effects (→ pure area input to the "concordance project")

Methodology

1. Ask the IACHEC Working Groups to reduce spectra with the same version of software and calibrations

2. Choose a method (Stacked Residuals Spectra, SRS)

3. Choose a reference instrument (EPIC-pn)

4. Compare the energy-dependent $SRS_{EPIC\text{-}pn}$ produced by each project

Preliminary results are shown here.
G21.5-0.9 spectra (and few others) still missing

Stacked Residual Spectra (SRS) method

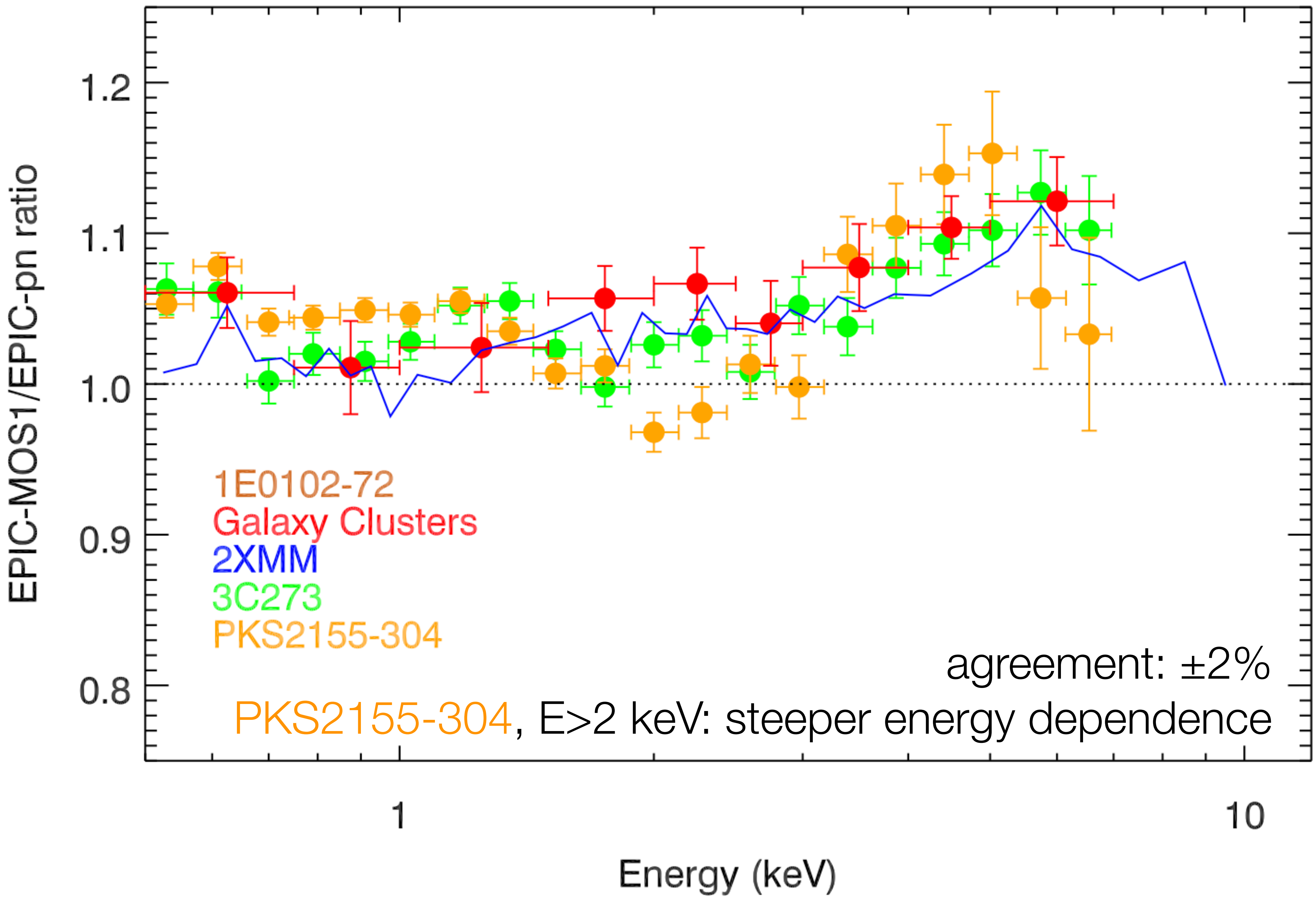
Longinotti et al., 2008, RMxAC, 32, 62; Read et al., 2014, A&A, 564, 75

[For a given source and astrophysical model …]

- Choose a reference instrument
- Create the spectrum of the residuals against the best-fit model for the reference instrument
- Create the spectrum of the residuals of each of the other instruments against the reference spectrum best-fit
- Divide the residual spectrum of each instrument by the residual spectrum of the reference spectrum

[Works well *as long as there aren't strong gradient in the effective area*]

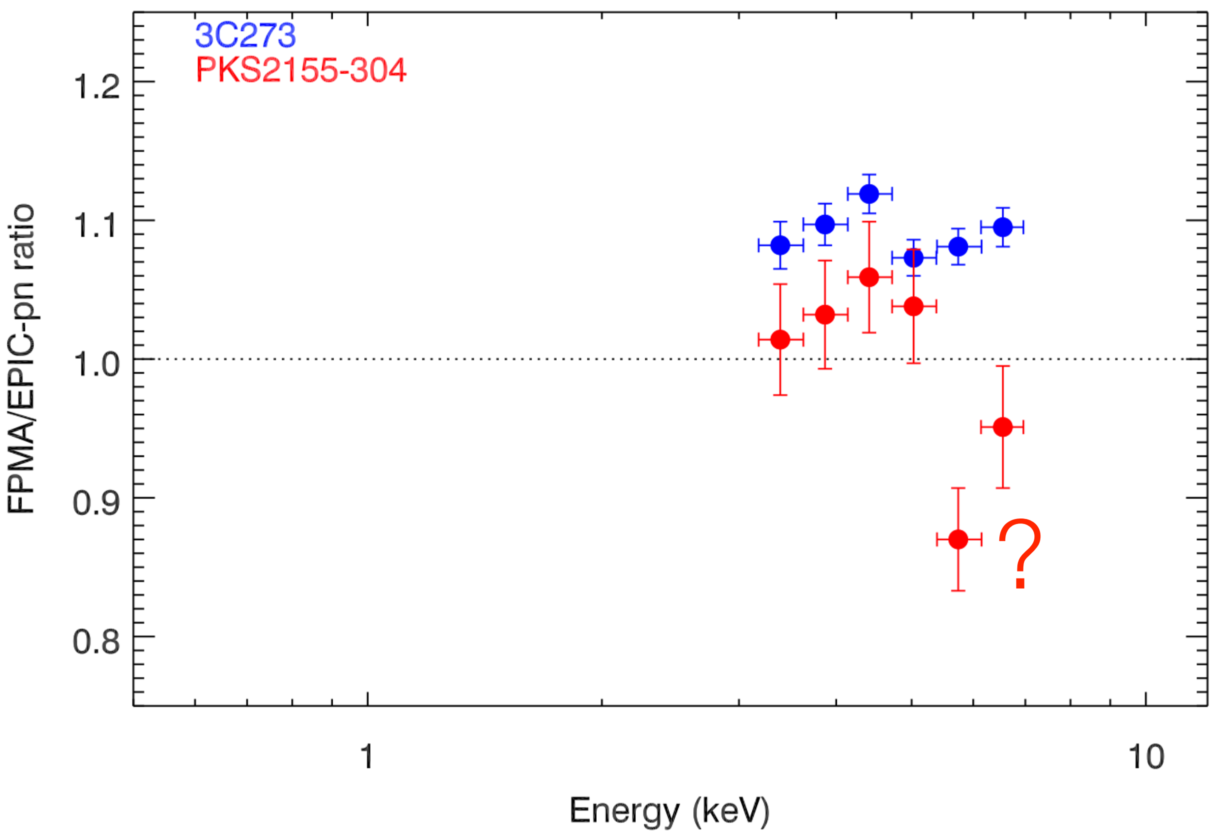
EPIC-pn vs. EPIC-MOS1



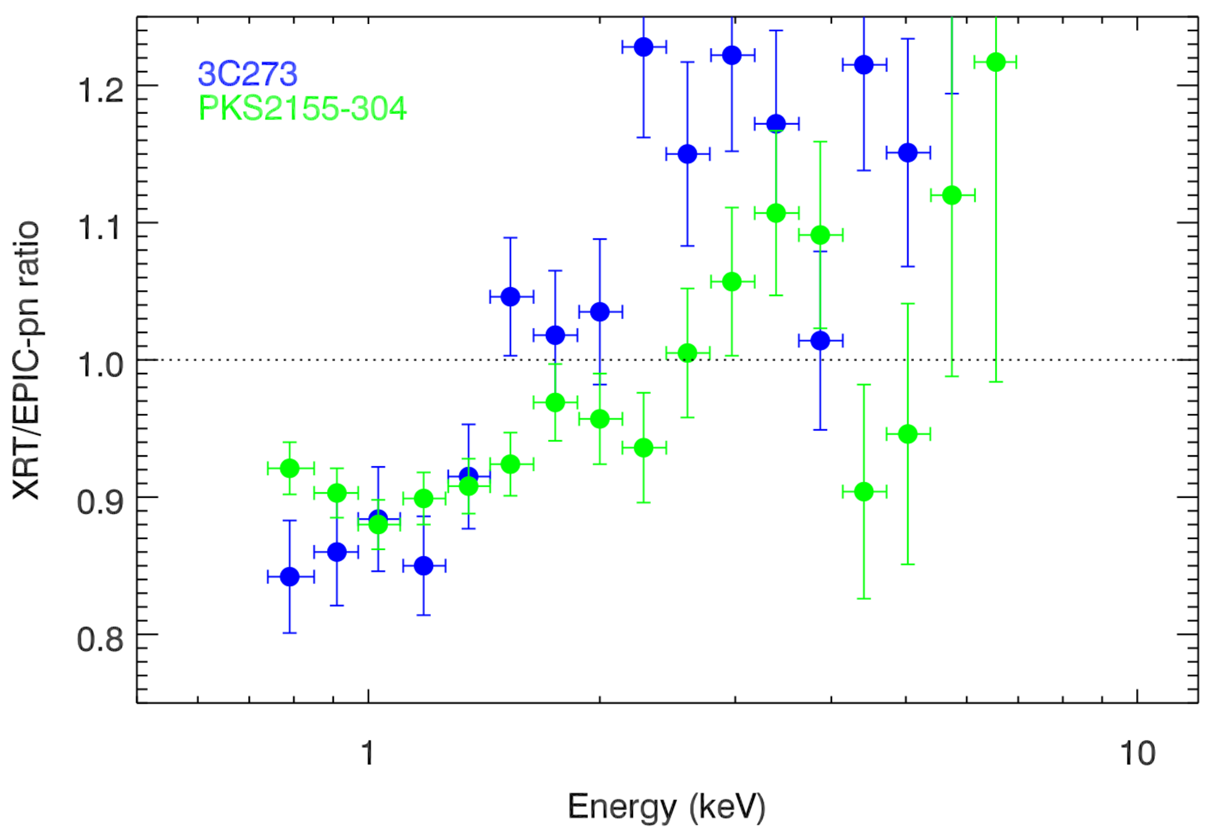
3C273/PKS2155-304: NuSTAR and XRT

3C273/PKS2155-304 NuSTAR and XRT SRS differ also by ~5%, but *in the opposite direction* to EPIC-MOS*

*[so, it is not EPIC-pn's fault]

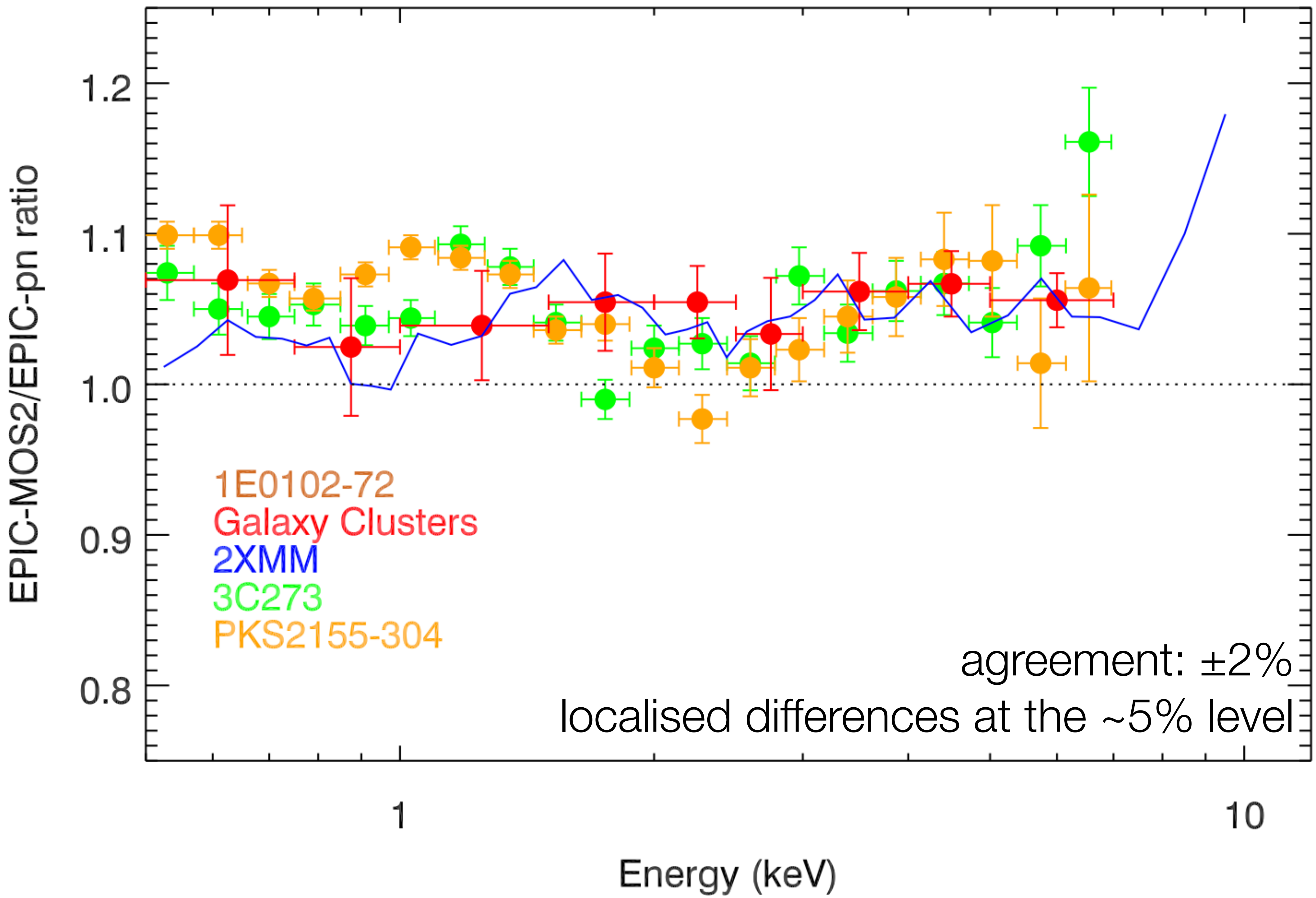


FPMA

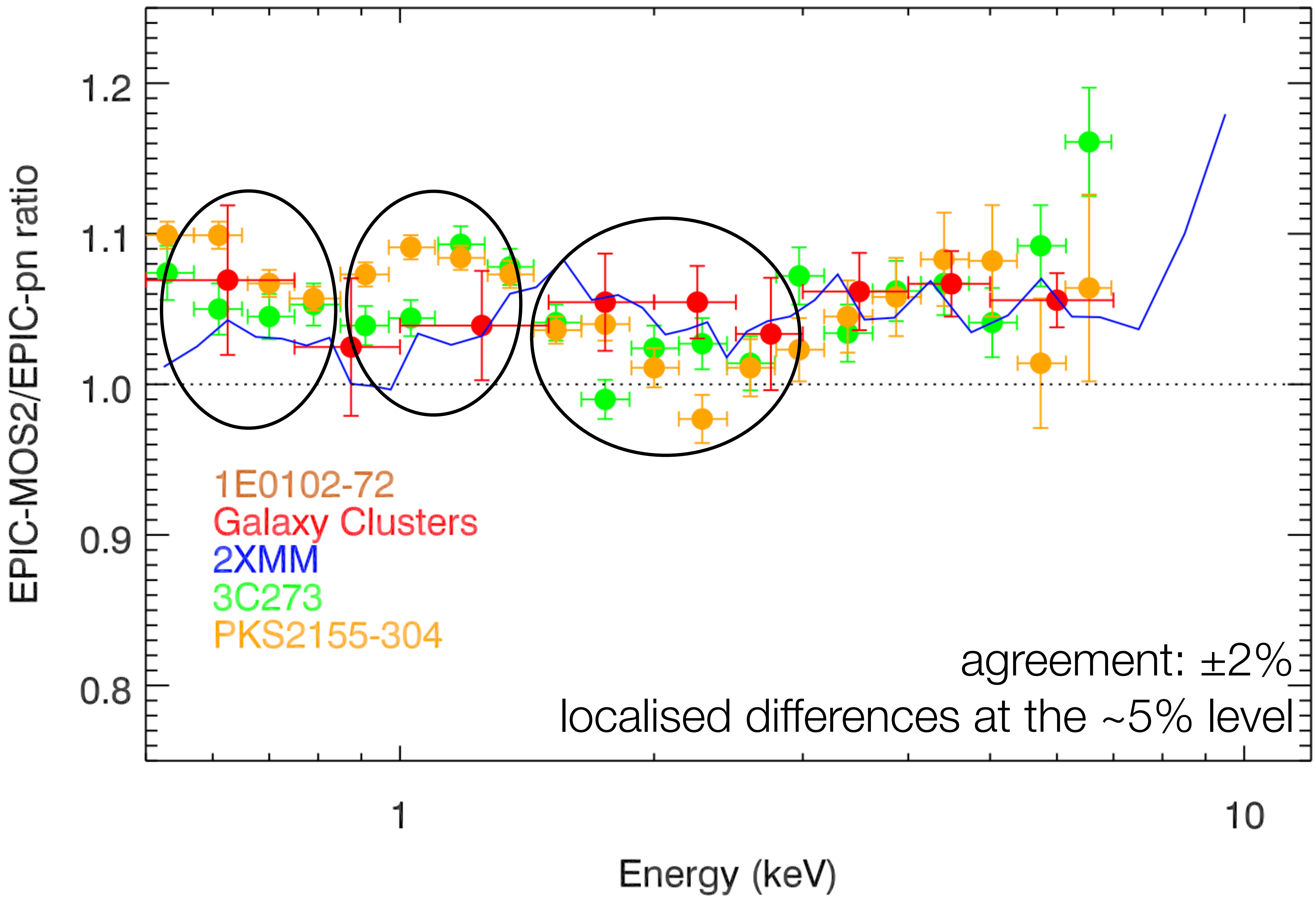


XRT

EPIC-pn vs. EPIC-MOS2

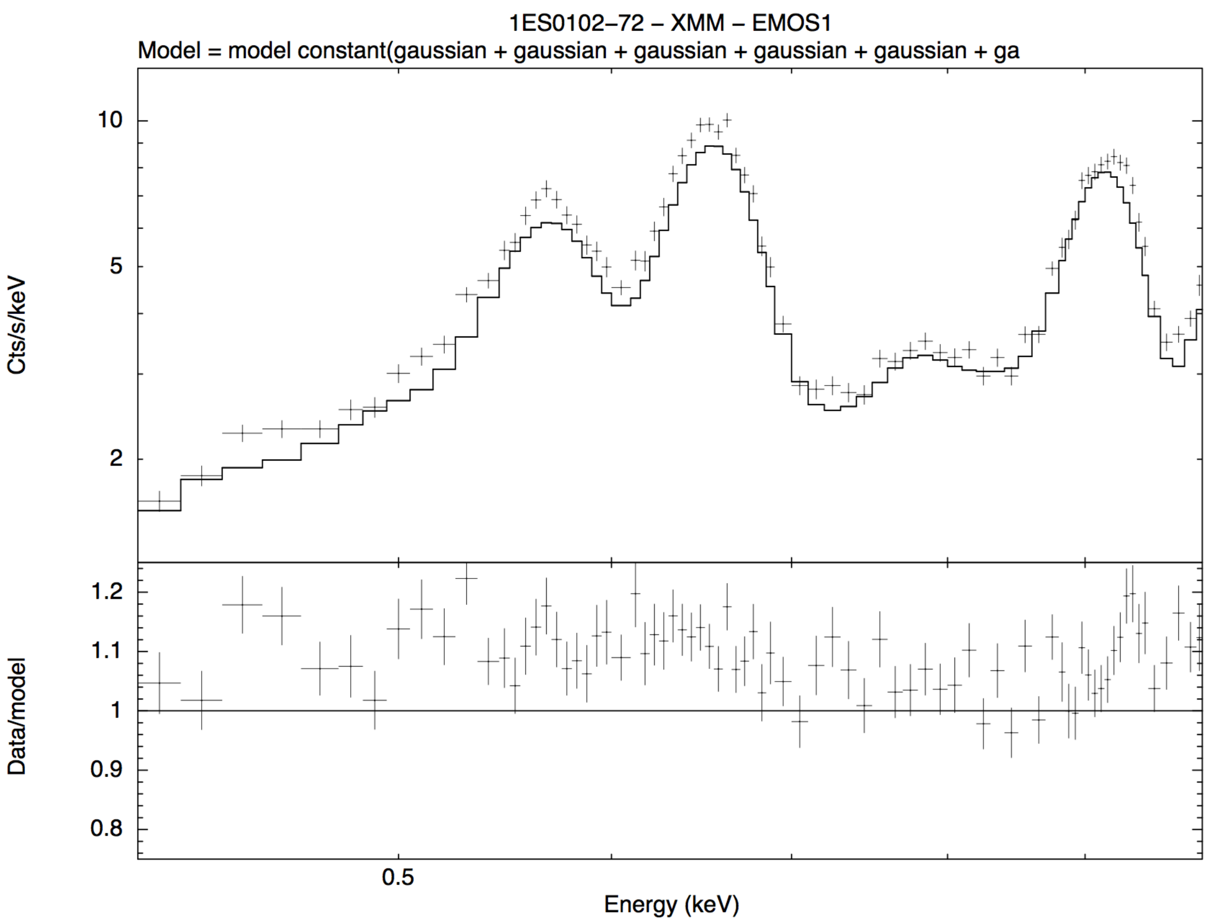


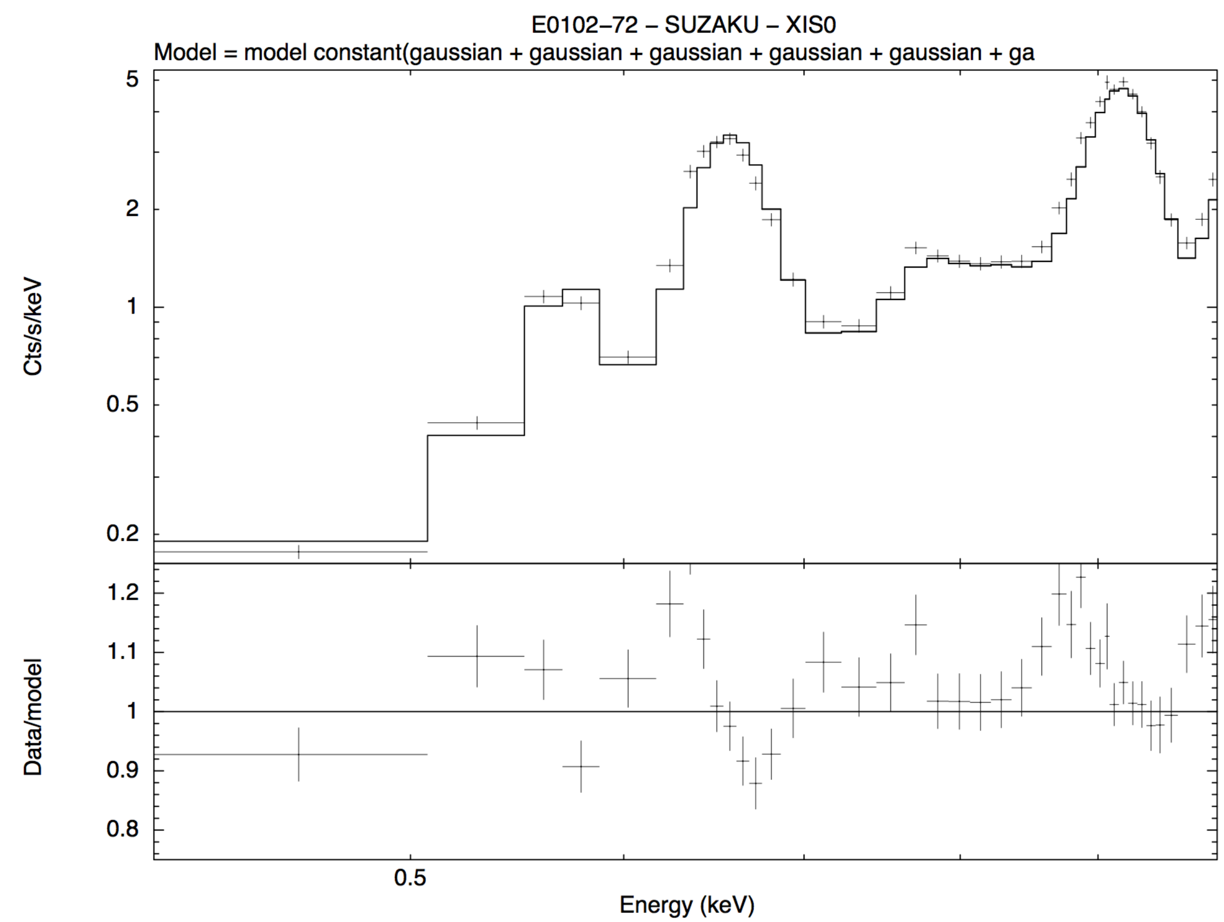
EPIC-pn vs. EPIC-MOS2



SRS of CCD-resolution spectra of line-rich sources

SRS are affected by uncertainties in the gain/resolution in line-rich spectra





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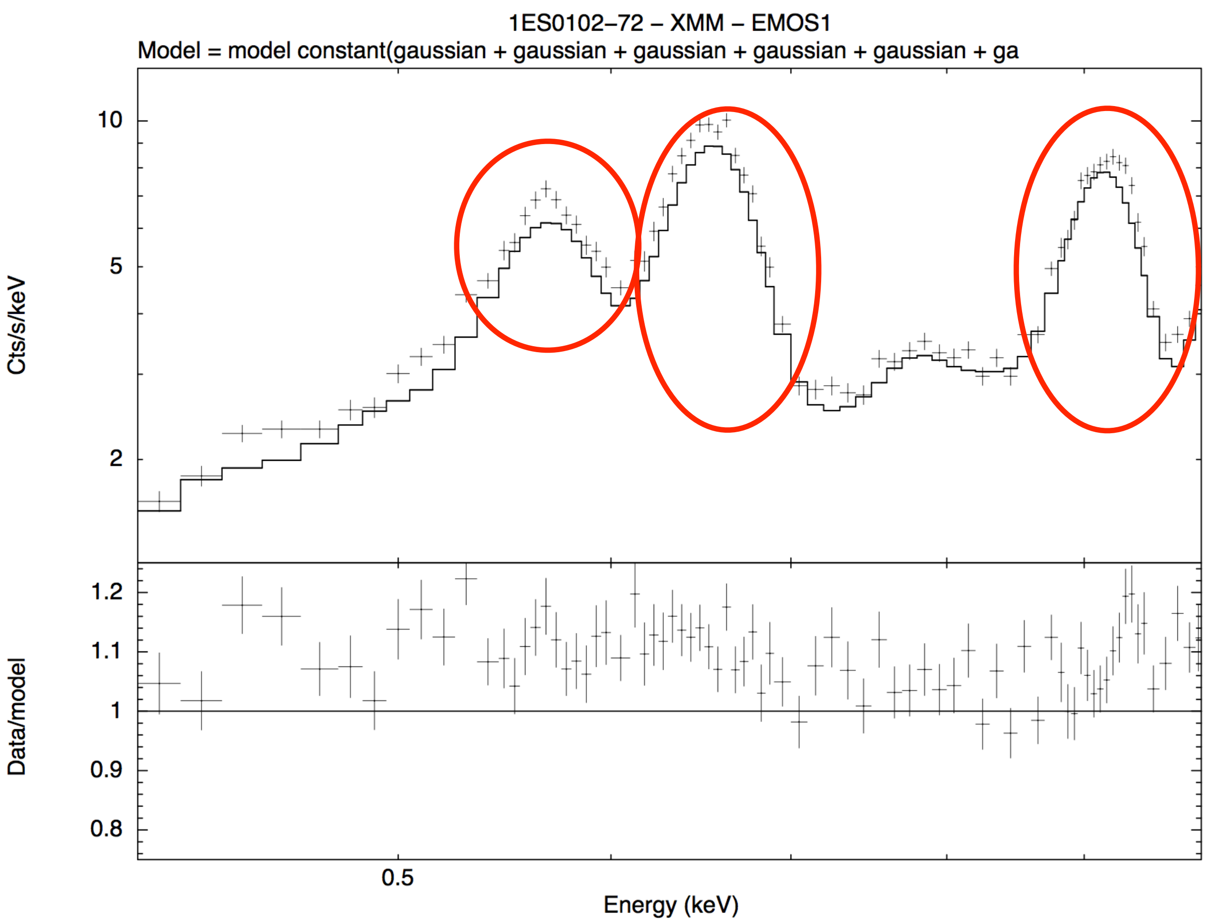
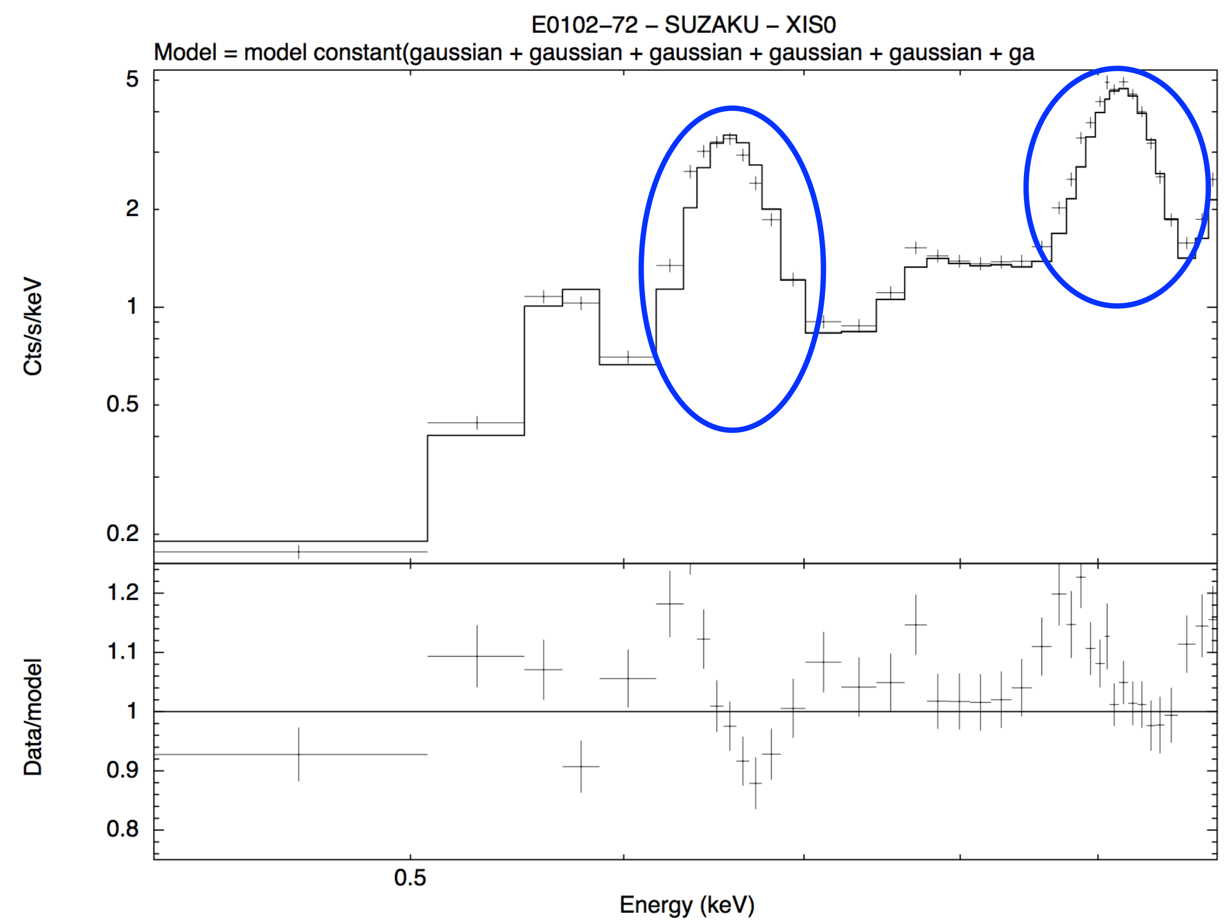
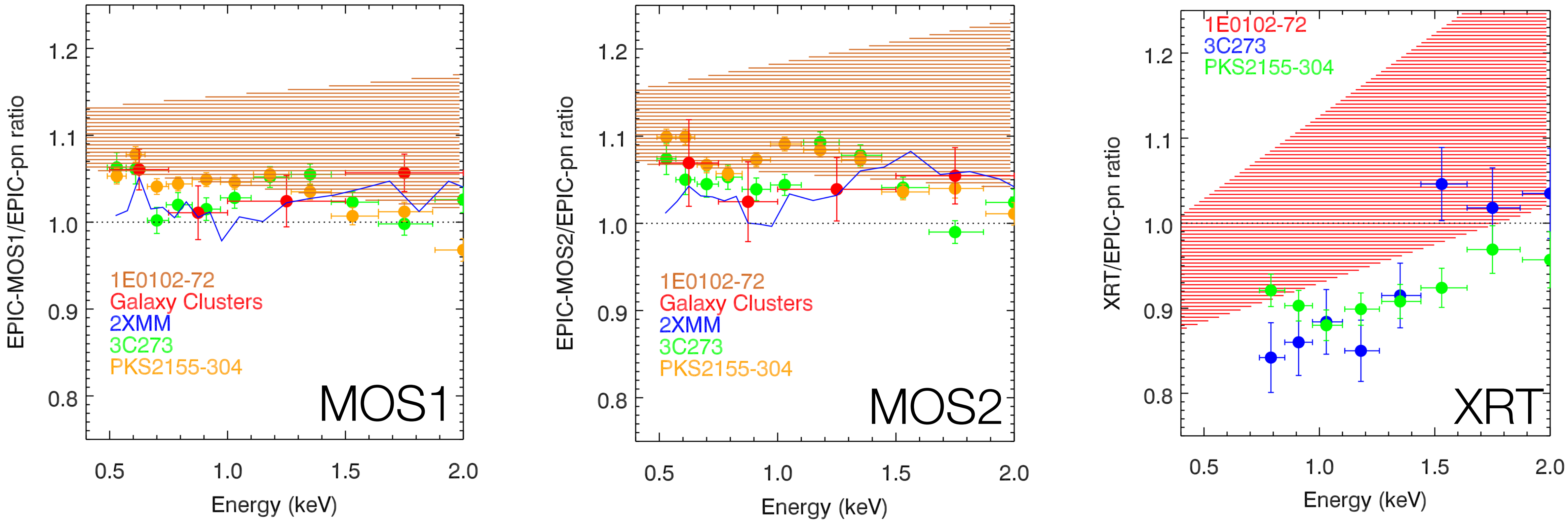




In the following plots, the envelope 1E0102-72 SRS *linear best-fit* is shown

SRS: 1E0102-72 vs. smooth continuum sources

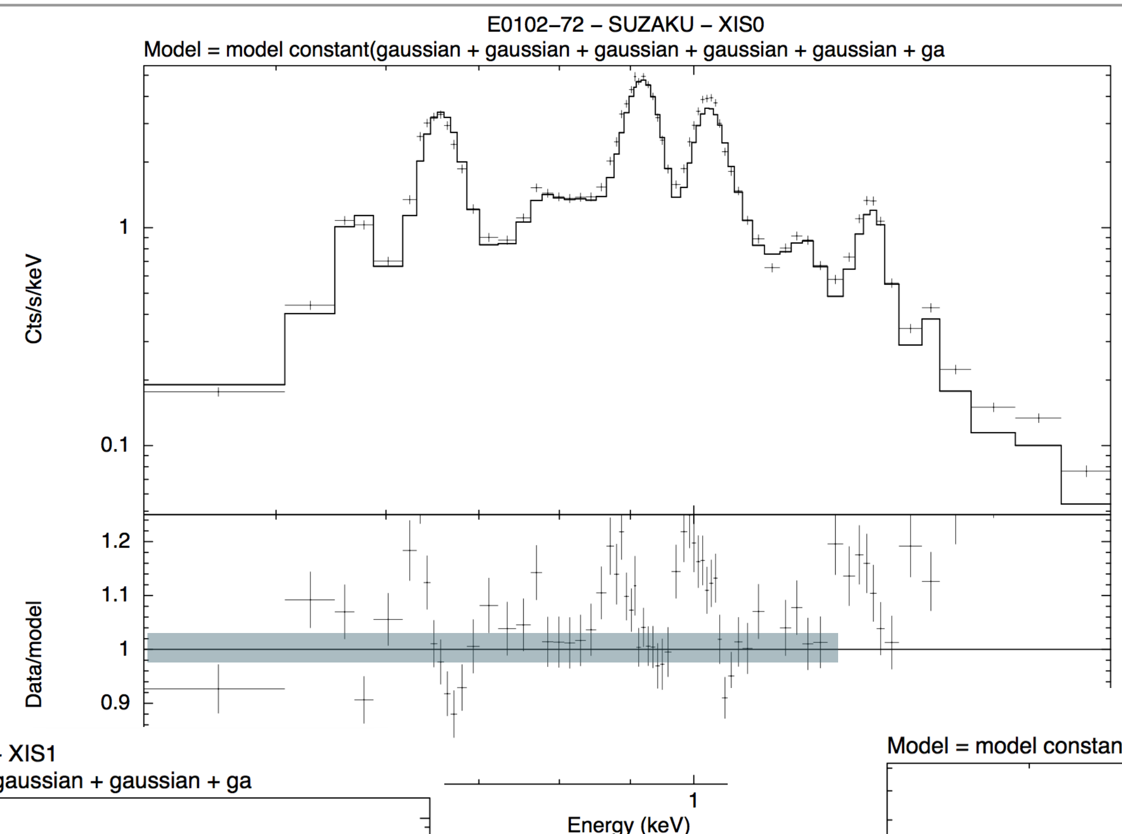
Comparison of 1E0102-72 SRS (shadows) with continuum sources

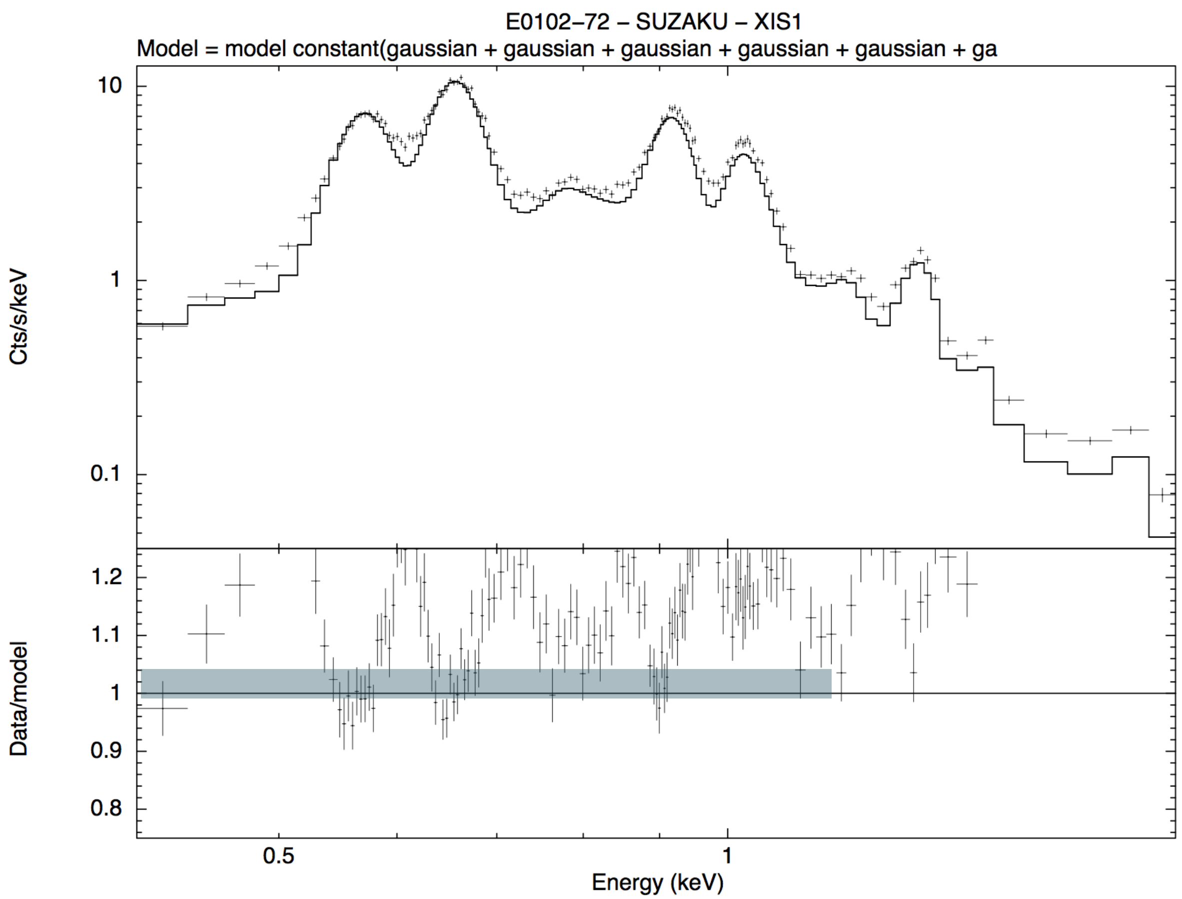


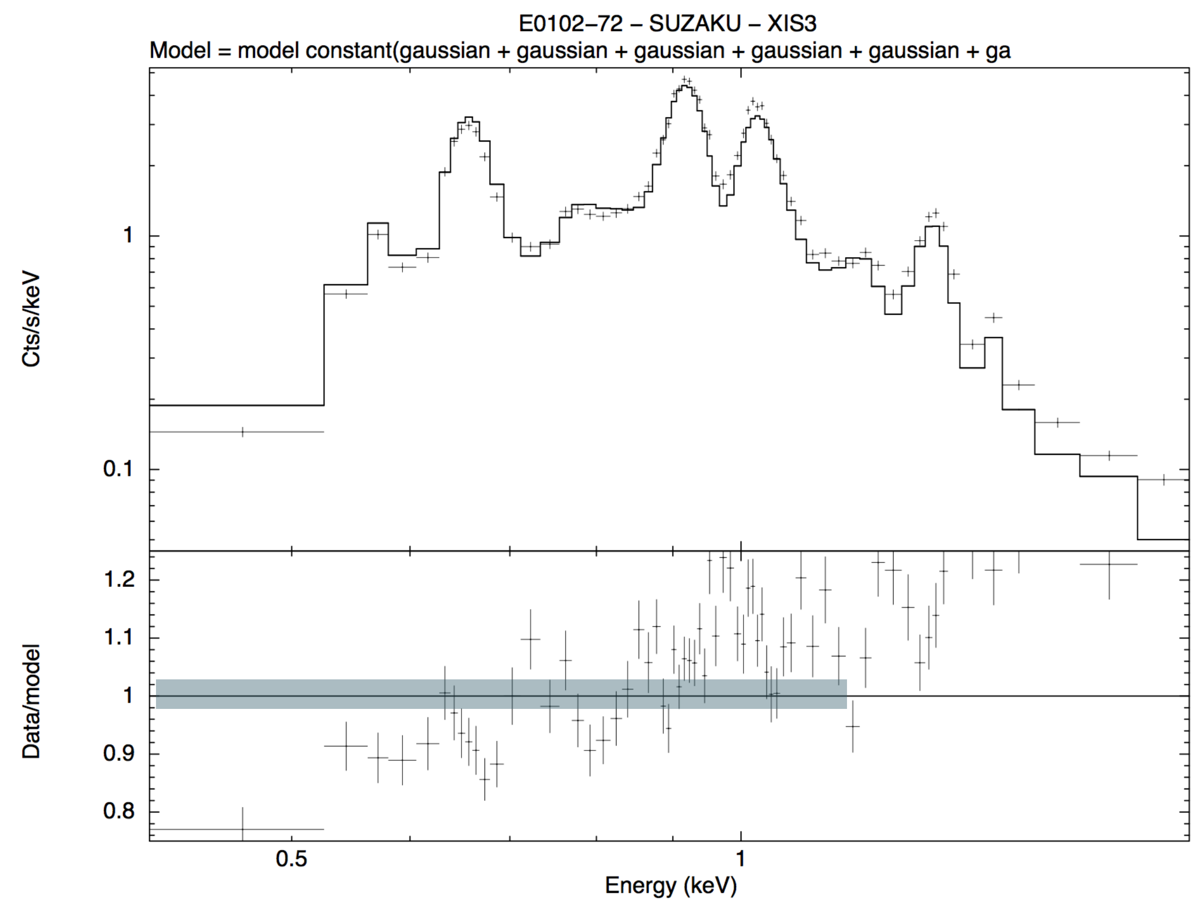
Same energy dependence, 1E0102-72 SRS 5-10% higher

1E0102-72 vs. 3C273 SRS for XIS

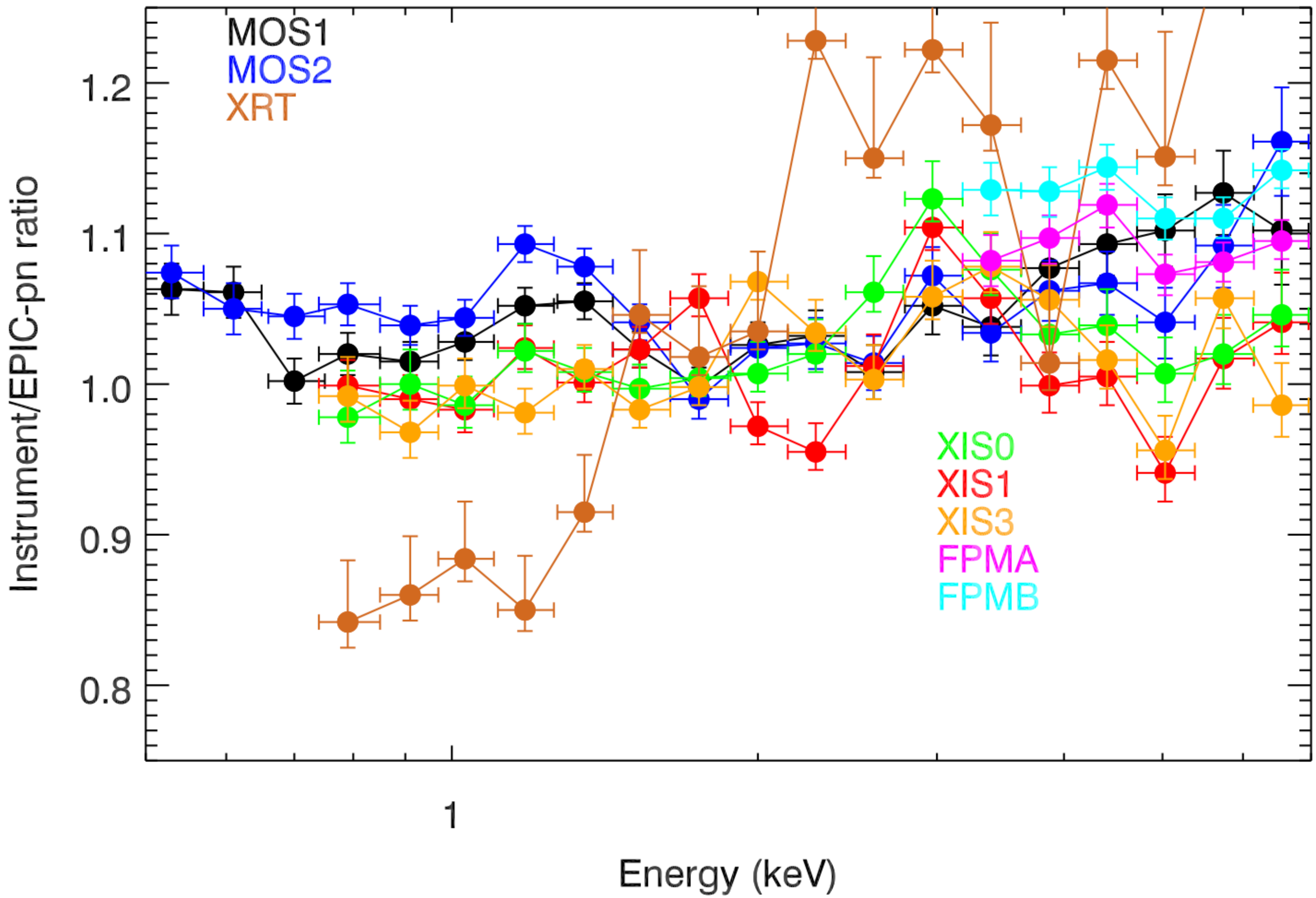
3c273 XIS/EPIC-pn
[reduction 2016]



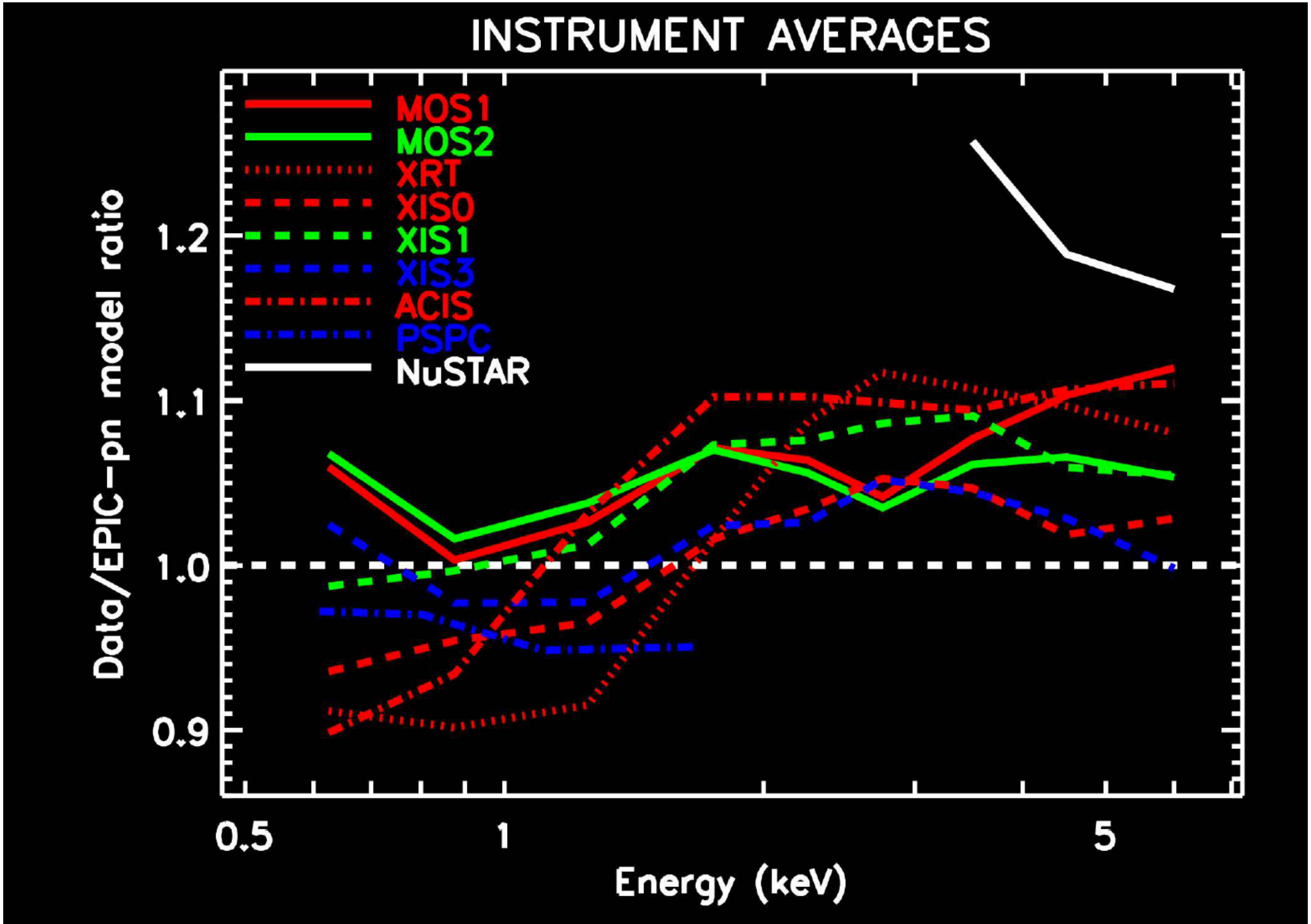




Multi-instrument 3C273 SRS



Multi-Mission Project (Galaxy clusters, J.Nevalainen)



Summary SRS (continuum vs. Jukka's MMS)

E<2 keV

- MOS1: flat, ~1.0-1.06 (1.0-1.05)
- MOS2: flat, ~1.03-1.1 (1.0-1.05)
- XIS: flat, ~1.00 (0.95-1.05)
- XRT: steep, 0.85 → 1.1 (0.9 →1.1)

1E0102-72: 5-10% higher than continuum sources

E>2 keV

- ACIS: flat (1.1)
- MOS1, moderately steep, 1.05-1.1 (1.05-1.1)
- MOS2: flat, ~1.05 (1.05)
- NuSTAR: 1.05-1.1 (?)
- XIS: flat: ~1.05 (1.02-1.07)
- XRT: wavy, 1.1-1.2 (1.1)

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1. The IACHEC papers yield 0.5-7 keV ±5% self-consistent cross-calibration results

2. Which sources to use for the concordance project? galaxy clusters (O.K.); 3C273 (O.K.); G21.5-0.9? 3XMM vs. CSC (2XMM, O.K.)? Archival data of scientific coordinated observations?