Cross calibration of XMM-Newton EPIC and Suzaku XIS instruments with clusters of galaxies

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Method

- Intracluster medium (ICM) emits thermal bremsstrahlung with line emission due to collisional excitation
- Fit with single temperature MEKAL model for bremsstrahlung (Mewe, R., Kaastra, J., & Liedahl, D. 1995, Legacy, 6, 16)

  → temperature from shape of X-ray spectrum
- Compare temperatures obtained with different instruments from same annular sky region

  → cross-calibration of the energy dependence of the effective area

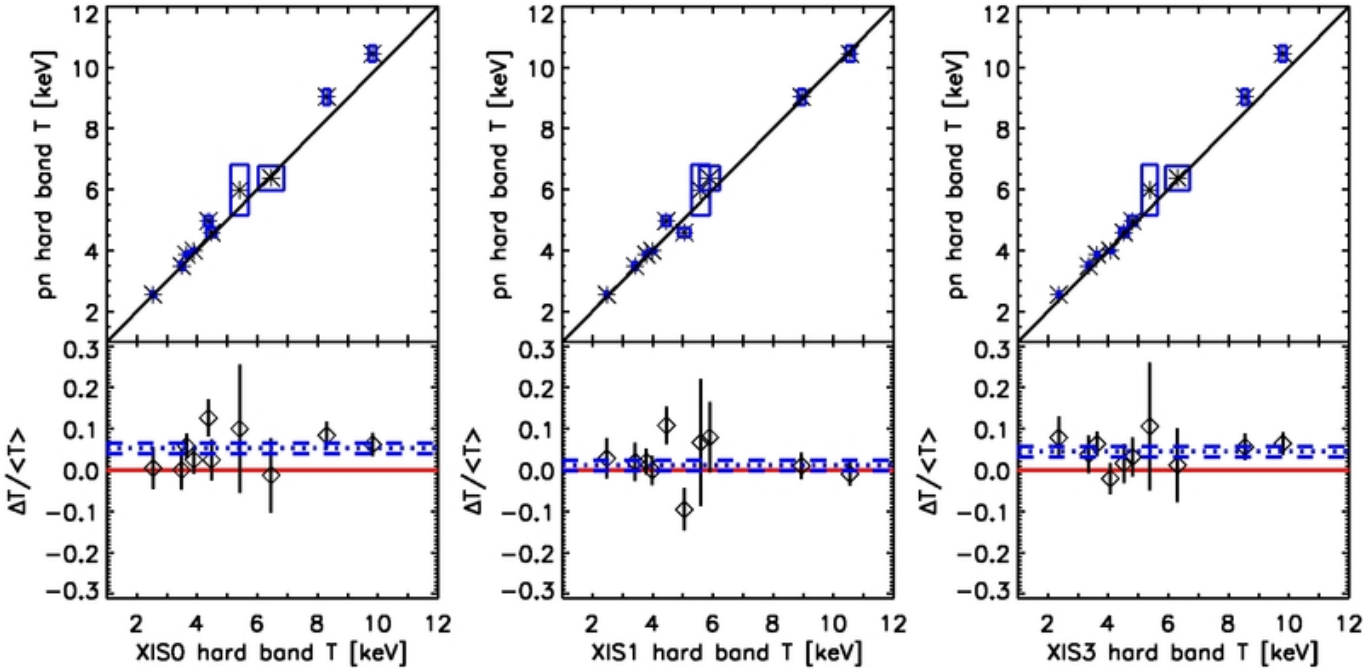
XMM – Chandra study

- Nevalainen et al, A&A 523, A22 (2010)
- XMM-Newton EPIC and Chandra ACIS data of 11 nearby and bright clusters
- Hard band (2.0 – 7.0 keV)
  - No significant systematic differences in temperature → hard band effective area energy dependence accurately calibrated
- Soft band (0.5 – 2.0 keV)
  - ACIS ~ 18 % (8.6σ) hotter than EPIC → 10 – 15 % uncertainty in wide band cluster temperature measurements

Suzaku – XMM sample

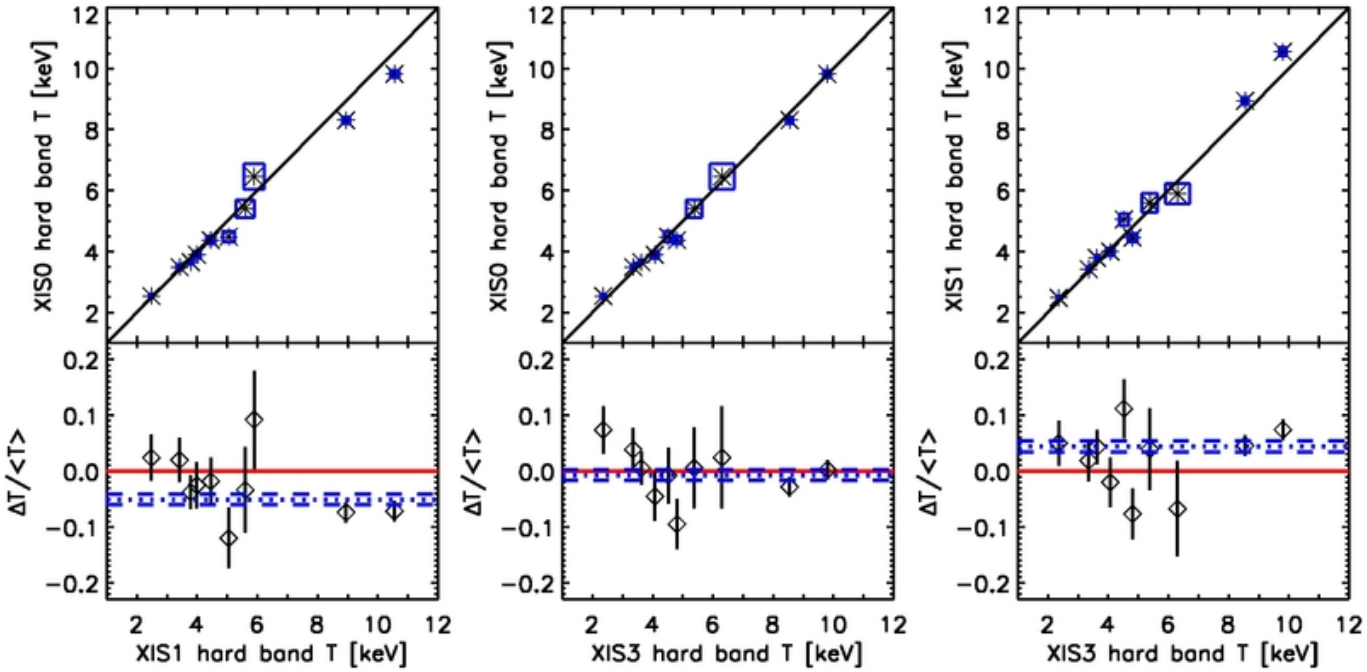
- Close and bright clusters with public data available
  - Soft band (0.5 – 2.0 keV): A1060, A1795, A2199, A262, A3112, A496
  - Hard band (2.0 – 7.0 keV): Soft band sample + AWM7, Centaurus, Coma, Ophiuchus
- Clusters with Galactic absorption column density > 6 x 10^{20} cm^{-2} accepted to hard band sample, because galactic absorption is insignificant in the hard band
- 3' – 6' annulus within FOV

Suzaku – XMM hard band



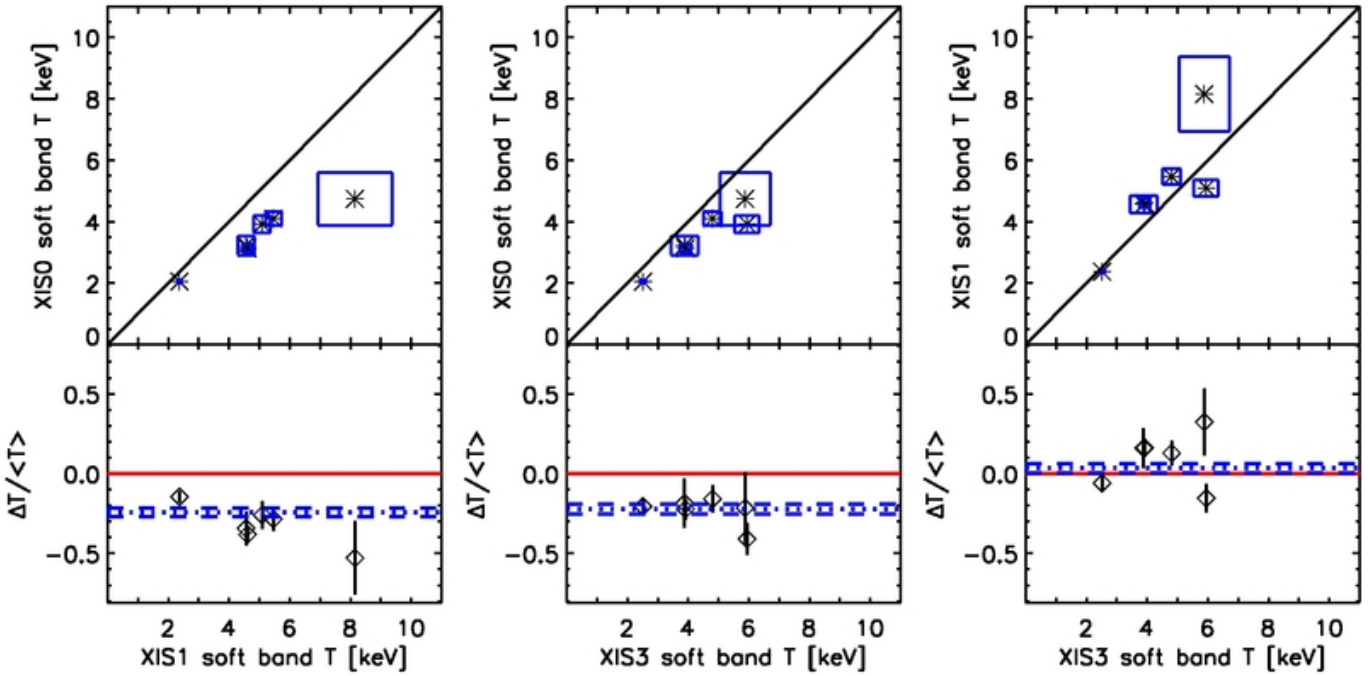
- XMM-Newton EPICs consistent → compare XIS only to pn
- PSF-scattering of cool gas from cluster core?
- XIS1 consistent with pn, XIS0 and XIS3 ~ 5 % cooler

Suzaku hard band



- XIS1 ~ 5 % hotter than XIS0 and XIS3
- Difference mainly due to Coma and Ophiuchus

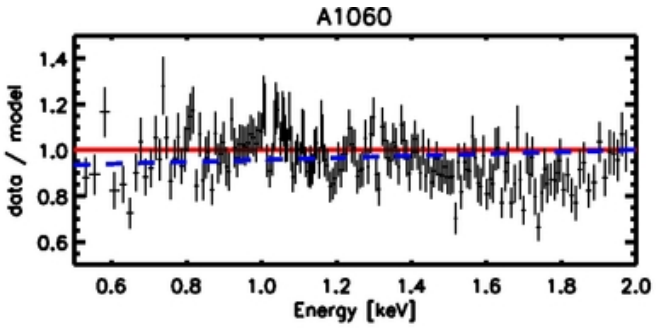
Suzaku soft band

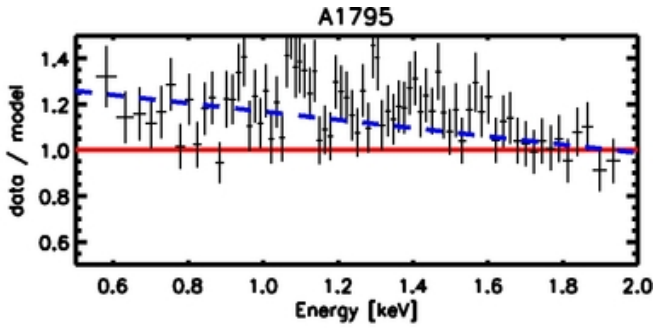


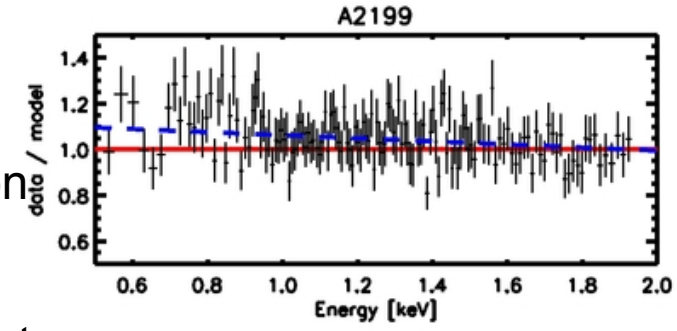
- XIS0 ~ 23 % (7.1 – 9.6σ) cooler than XIS1 and XIS3
- XIS1 and XIS3 agree

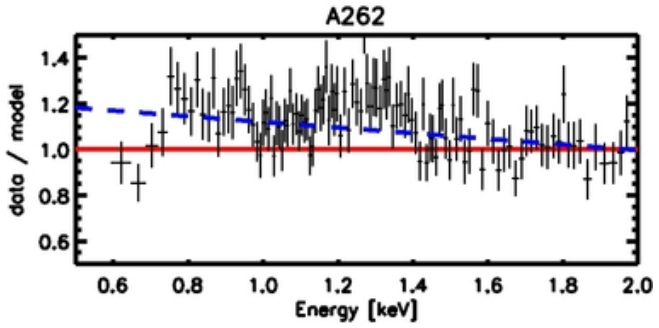
Suzaku soft band

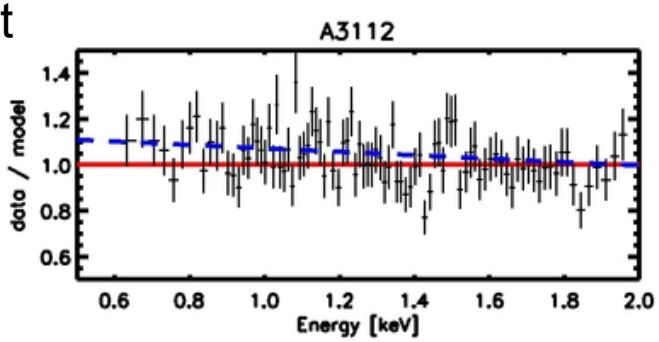
- ASSUMING that XIS1 and XIS3 responses are correct
- “Correct “XIS1 model folded through XIS0 responses
- If model prediction differs from XIS0 data, then XIS0 response incorrect
- Ratio ~ 1.1 at 0.5 keV
- XIS0 response underestimated (or vice versa)

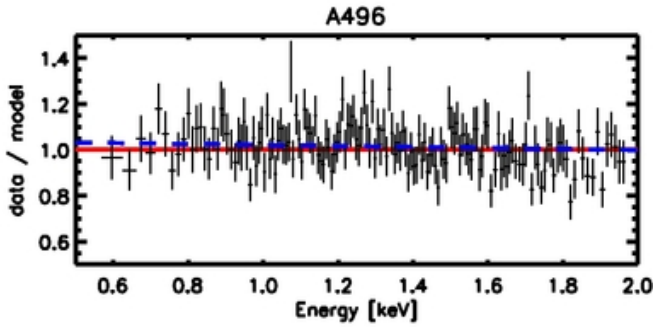




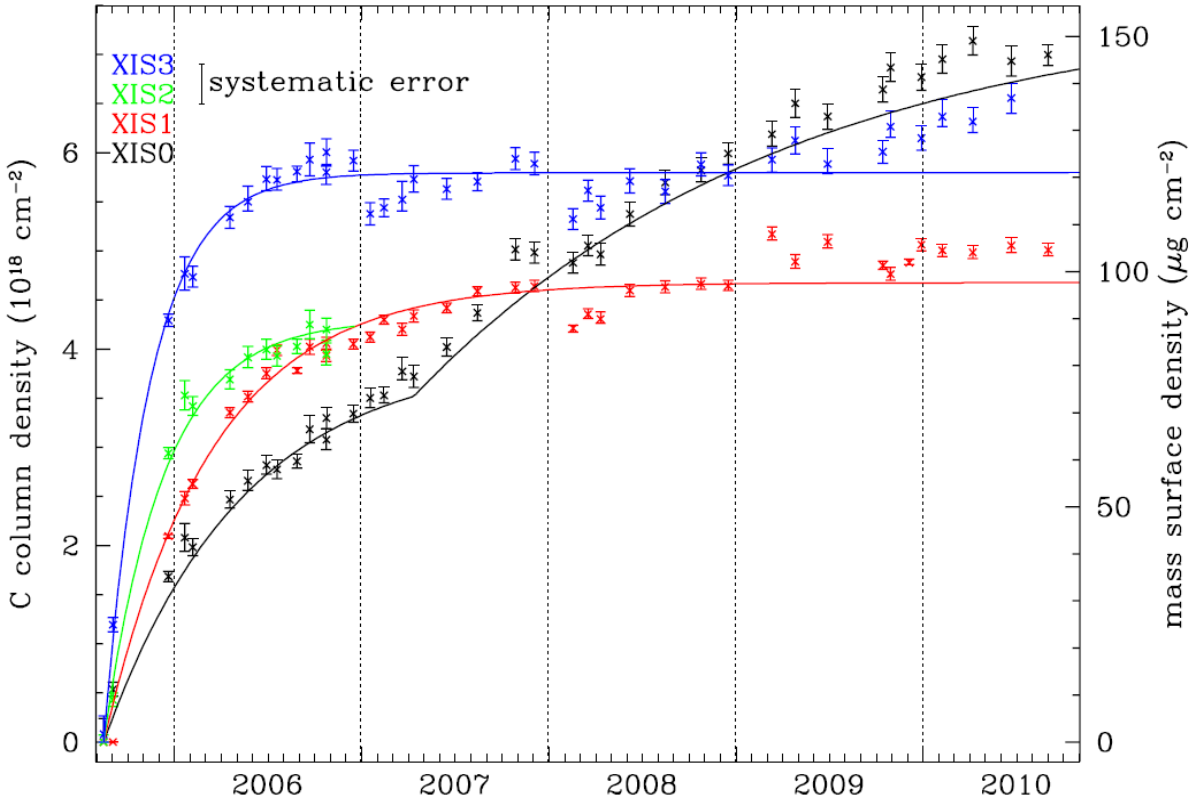






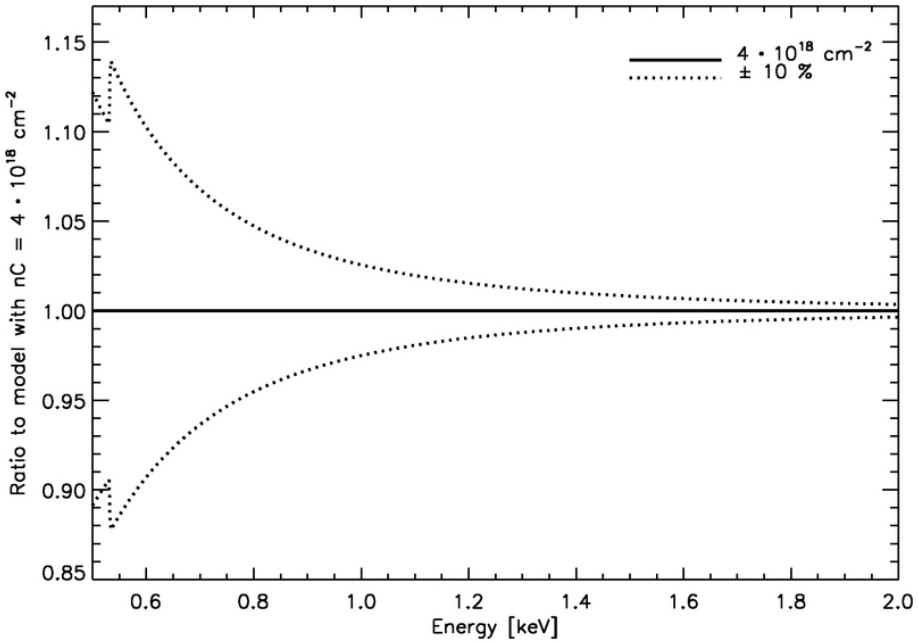


Suzaku OBF contamination



- OBF contamination possible explanation
- http://space.mit.edu/XIS/monitor/contam/e0102_20101006_rate.pdf

Suzaku OBF contamination



- DEPH ($C_{24}H_{38}O_4$) absorption model in XSPEC

  → Form of Carbon absorption qualitative explanation

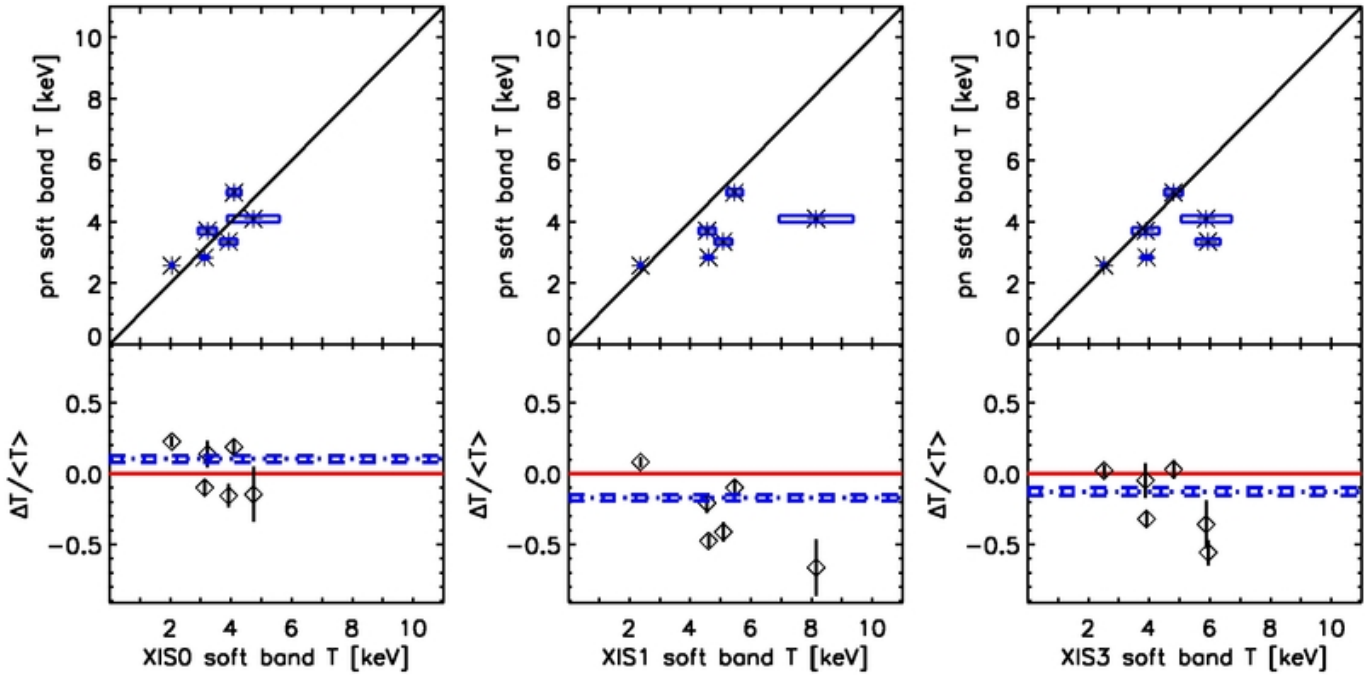
- 10 % change in absorption column density

  → 11 – 12 % change in absorption model at 0.5 keV

Suzaku OBF contamination

- If XIS1 model is correct, XIS0 absorption is overestimated (or vice versa)
- Qualitatively carbon absorption CAN explain residuals in XIS1 – XIS0 discrepancy
- Is 10 % uncertainty in OBF modeling realistic?

Suzaku – XMM soft band



- XIS0 ~10 % (4.4σ) cooler than pn → overestimated absorption?
- XIS1 and XIS3 13 – 17 % (4.6 – 7.8σ) hotter than pn → underestimated absorption?
- XIS1 and XIS3 consistent with Chandra ACIS?

Summary

- Hard band
  - Minor inconsistencies
  - XIS PSF scatter simulations
- Soft band
  - Major inconsistencies
  - Problem in modeling of OBF contamination CAN explain Suzaku XIS differences
  - → XIS0 absorption overestimated or XIS1 (and XIS3) absorption underestimated
- Work in progress...