Clusters WG report

J. Nevalainen, K. Kettula, E. Miller et al.

IACHEC meeting, Napa, 2012

Action items from Frascati 2011

1) Chandra/XMM soft band problems

2) Chandra/XMM flux problems

3) Deeper observations of the hottest clusters for better statistics of the FeXXV/XXVI line ratio measurement

4) MOS gain and redistribution calibration using cluster FeXXV K alpha line

5) Extend the XMM/Chandra comparison to contain all useful HIFLUGCS clusters and pointings available in 2011

6) Suzaku extension

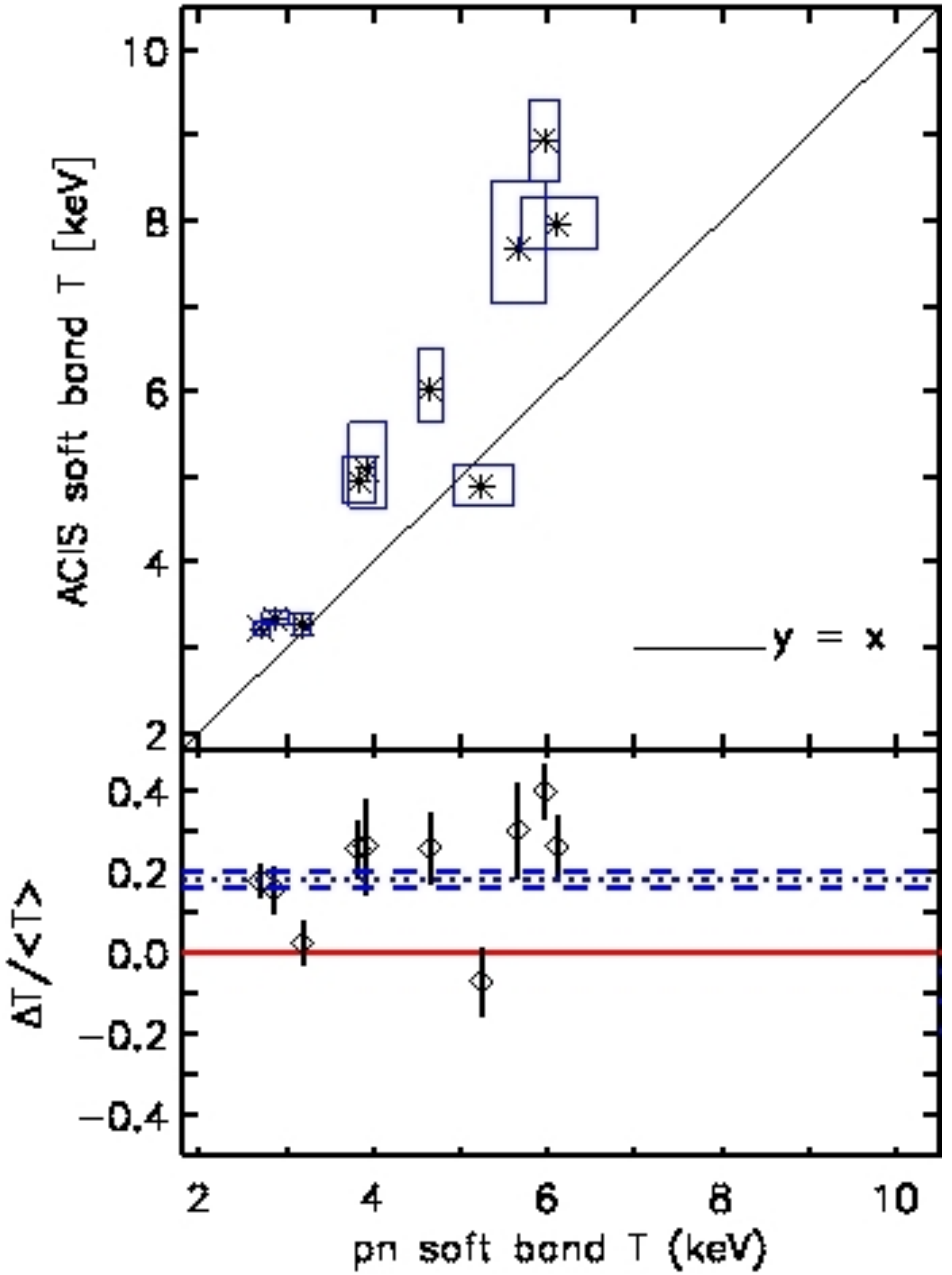
7) Swift extension

8) Data to IACHEC WIKI page

1) Chandra/XMM soft band temperature problems

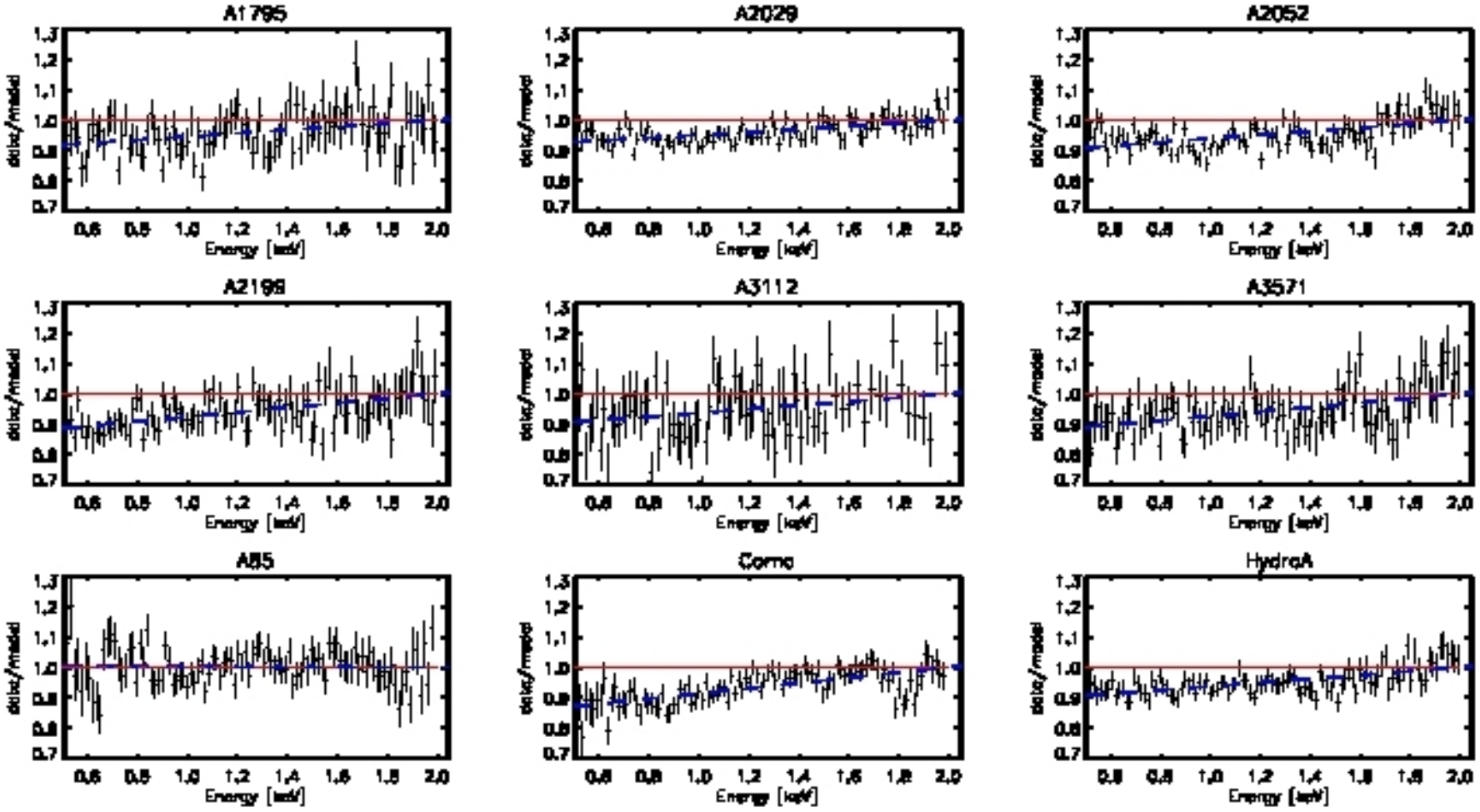
ACIS v.s. pn

- ACIS yields ~20% (9σ) higher soft band temperatures than pn
- Most of the photons are in the soft band ➔ full band temperatures biased by 10%



ACIS data / pn model

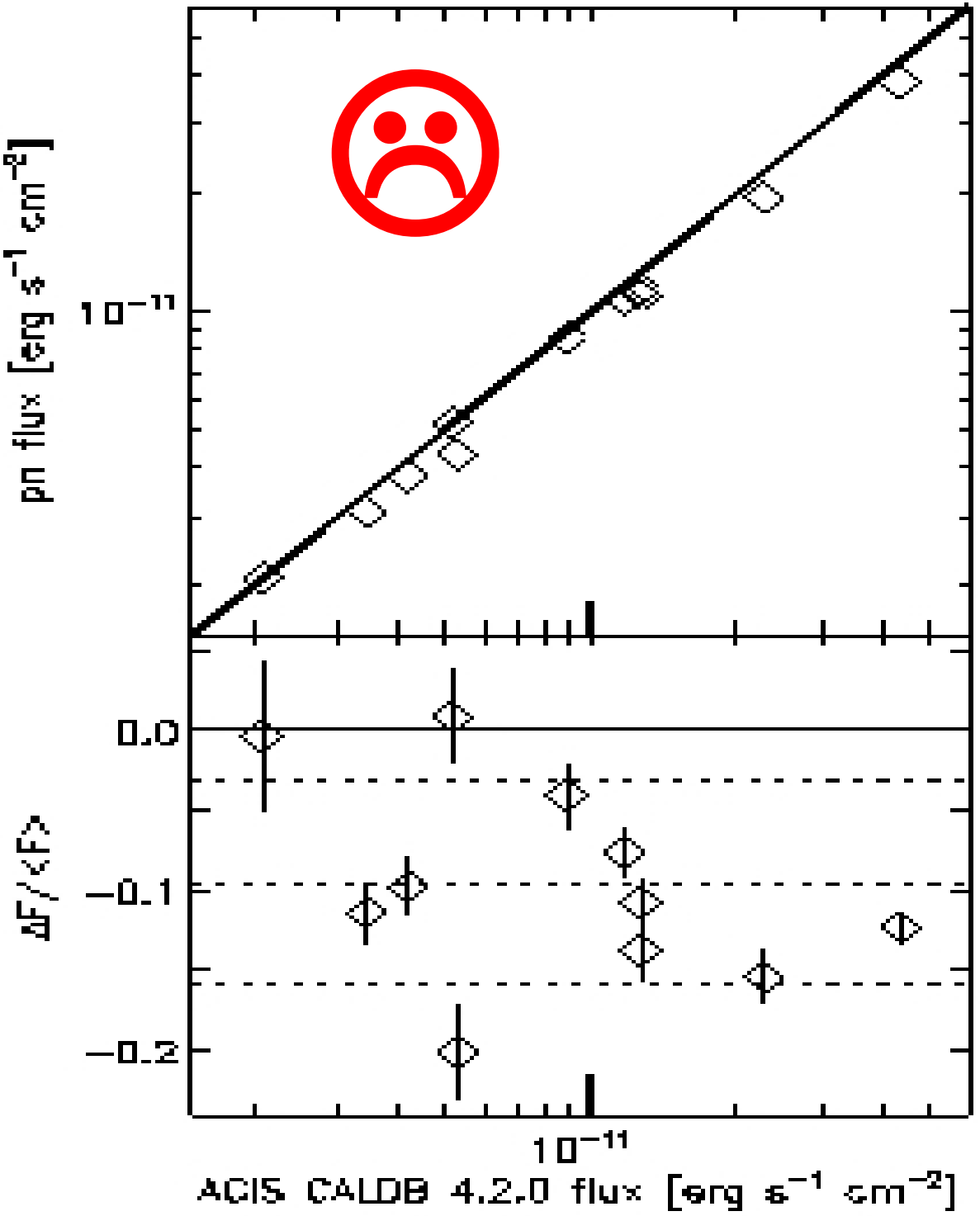
- ACIS data / pn model exhibit a linear trend with energy
- In pn effarea is correct, ACIS effarea too high by ~10% at 0.5 keV



- Confirm the systematic effects with different objects? SNR? NO PROGRESS
- See if Suzaku or Swift soft band temperatures agree with XMM-Newton or Chandra. SOME WORK DONE, PROGRESS?

2) Chandra/XMM flux problems

- ACIS flux exceeds that of pn by ~10% (ACIS/MOS ~5%)
  → relative effective area normalisation uncertain by this amount



- J. Nevalainen and L. David will examine in more detail some of the most problematic cases
- ROSAT PSPC? S. Snowden is working on a T-profile comparison btw. several instruments. Will provide ROSAT spectra for XMM/Chandra flux comparison.
- Chandra/XMM point source cross correlation ...L. David

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NO PROGRESS

3) Deeper observations of the hottest clusters for better statistics for the FeXXV/XXVI line ratio

FeXXV/XXVI line ratio

- Motivation: line ratio measurement adds an nearly continuum-independent temperature estimate, not affected much by the shape of the effective area
- Need to use all useful XMM data and make a physics paper on bremsstrahlung/ionisation temperature comparison, then evaluate if more time needed NO PROGRESS
- Need more photons to do this with Chandra. Calibration time is too limited. Need a physics proposal, but the physics can be done with XMM

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NO PROGRESS

4) MOS gain and redistribution calibration using cluster FeXXV K alpha line

- To do cluster physics with Fe XXV line need to know the gain, energy resolution and redistribution very accurately
- J. Nevalainen, M.Stuhlinger and S. Sembay will further investigate
- **Some progress**, too preliminary yet

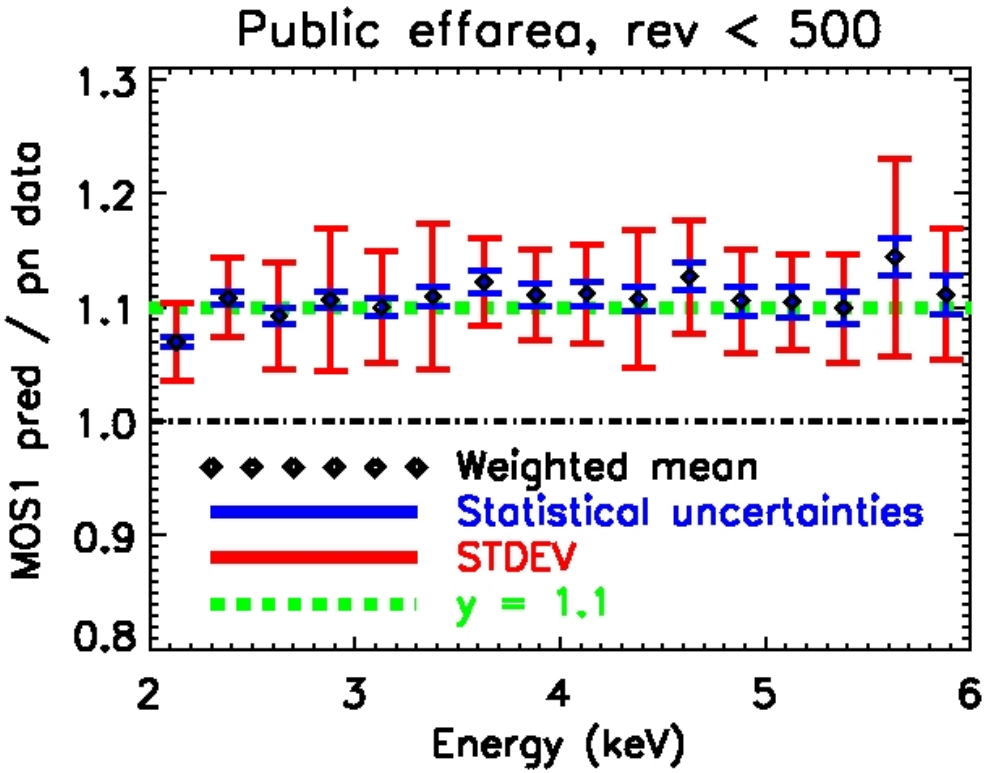
5) Extend the XMM/Chandra comparison to contain all useful HIFLUGCS clusters and pointings available in 2011

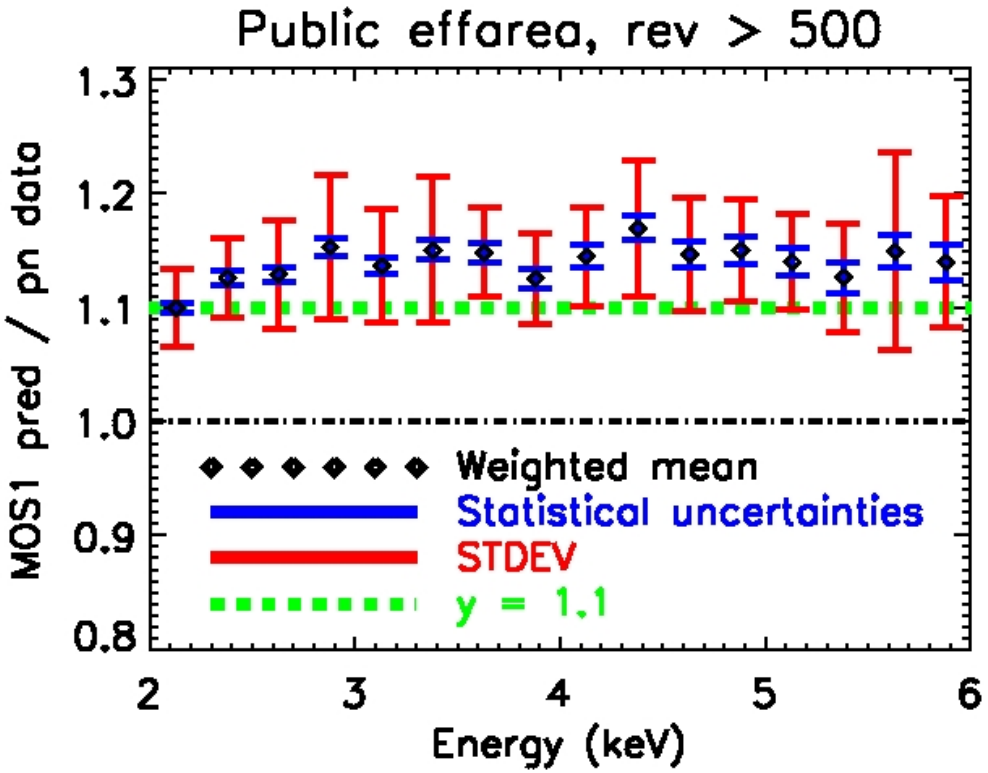
HIFLUGCS extension

- More data points, better statistics, results more reliable, can make distributions of parameters of interest
- Do smaller bands instead of soft and hard band to characterise better the energy dependence, do lower than 0.5 keV, up to 10 keV
- Different patterns
- MOS1 and MOS2 separately
- Could study cross-calibration accuracy as a function of time

Pre/post cooling

- New cluster sample: the available post rev 500 pointings for the same clusters as in the sample used in Nevalainen et al. (2010).
- Clusters yield 5% higher fluxes at rev > 500 than in rev < 500
- No change in temperatures





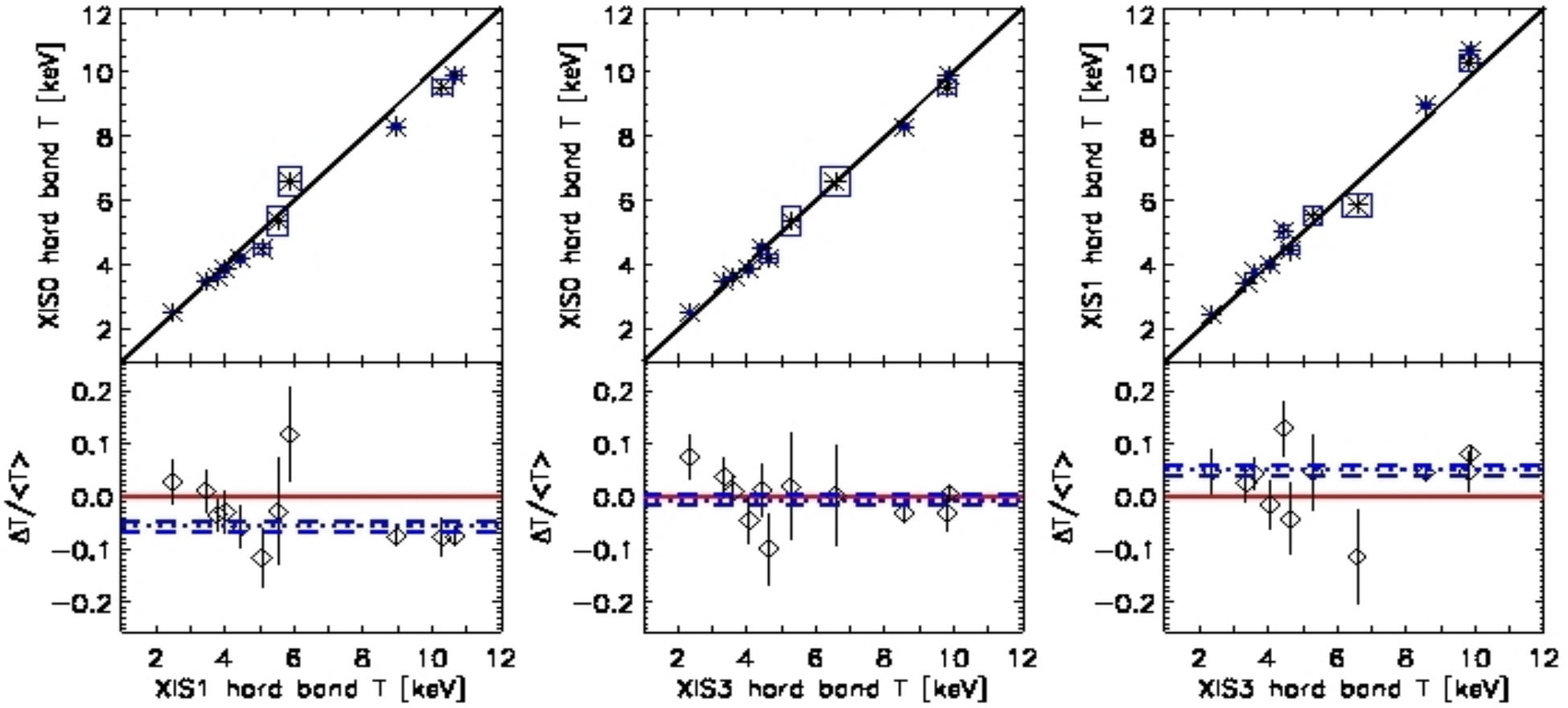
6) Suzaku extension

(K. Kettula et al., in prep.)

- Spectroscopic analysis of clusters using two stages of calibration: CALDB 20080709 and CALDB 20110608
- Sample contains 11 ~ relaxed clusters observed with both Suzaku and XMM: A1060, A1795, A262, A3112, A496, AWM7, Centaurus, Coma, Ophiuchus, Triangulum
- Fit with 1-T MEKAL model in 0.5-2.0 and 2.0-7.0 keV bands
- Extraction regions 3-6 arcmin in order to
  - Minimise PSF scatter to and from the extraction region (area wider than PSF). **The accuracy is being tested**
  - Minimise PSF scatter from the cool core. **The accuracy is being tested**
  - Not too large region to minimize background effects (bkg a few % of cluster emission)

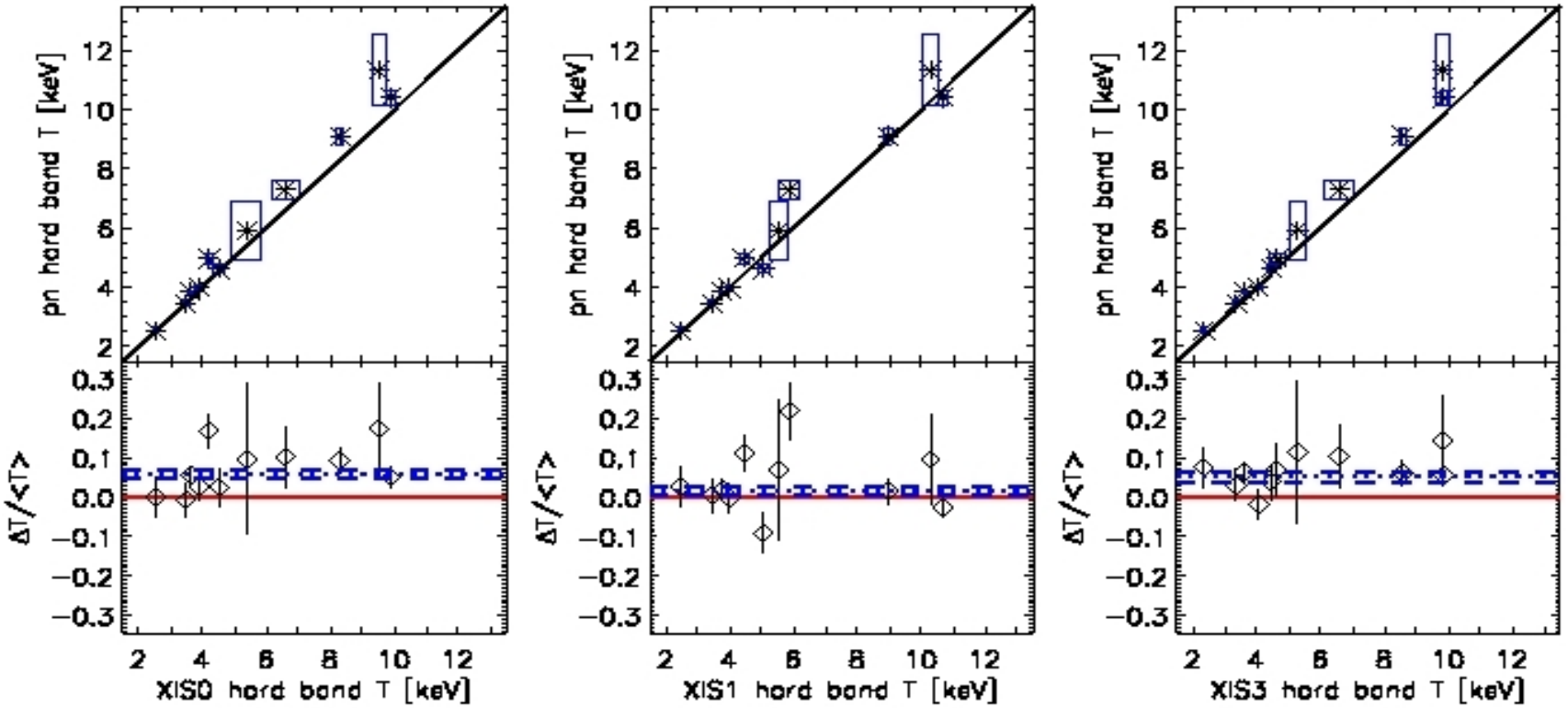
XIS hard band

- XIS0/XIS3 temperatures differ only by 1% (0.6σ)
- XIS1 temperatures 5% (5-6σ) higher. **Is this seen in other sources?**



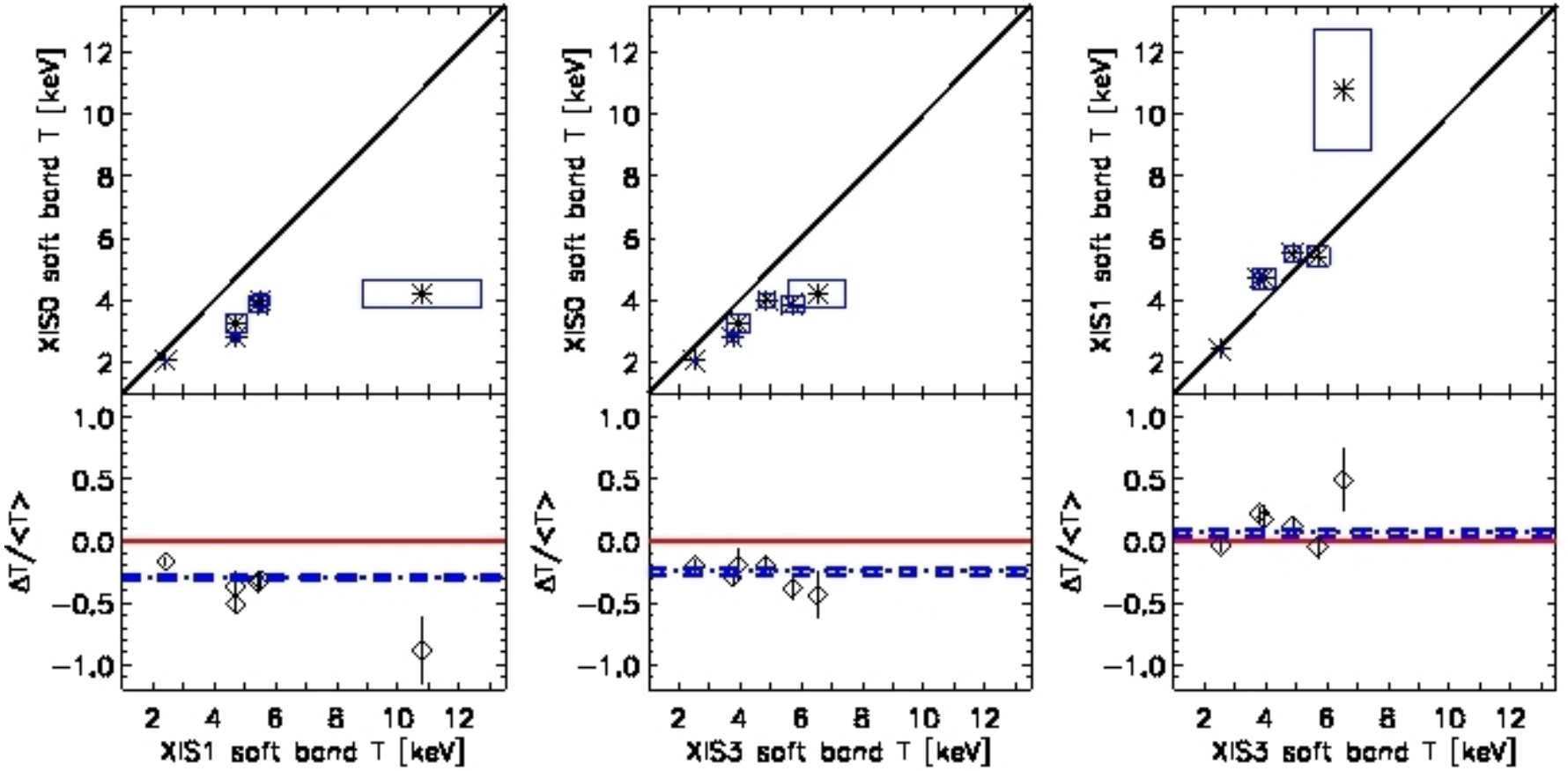
XIS/pn hard band

- XIS1/pn differ only by 2% (1σ). pn should be OK (Nevalainen et al., 2010) ➔ XIS1 should be OK
- XIS0 and XIS3 5% lower than pn. Suggested that XIS0 and XIS3 have a bit too hard effective area shape in 2-7 keV band. **Is this seen in other sources?**



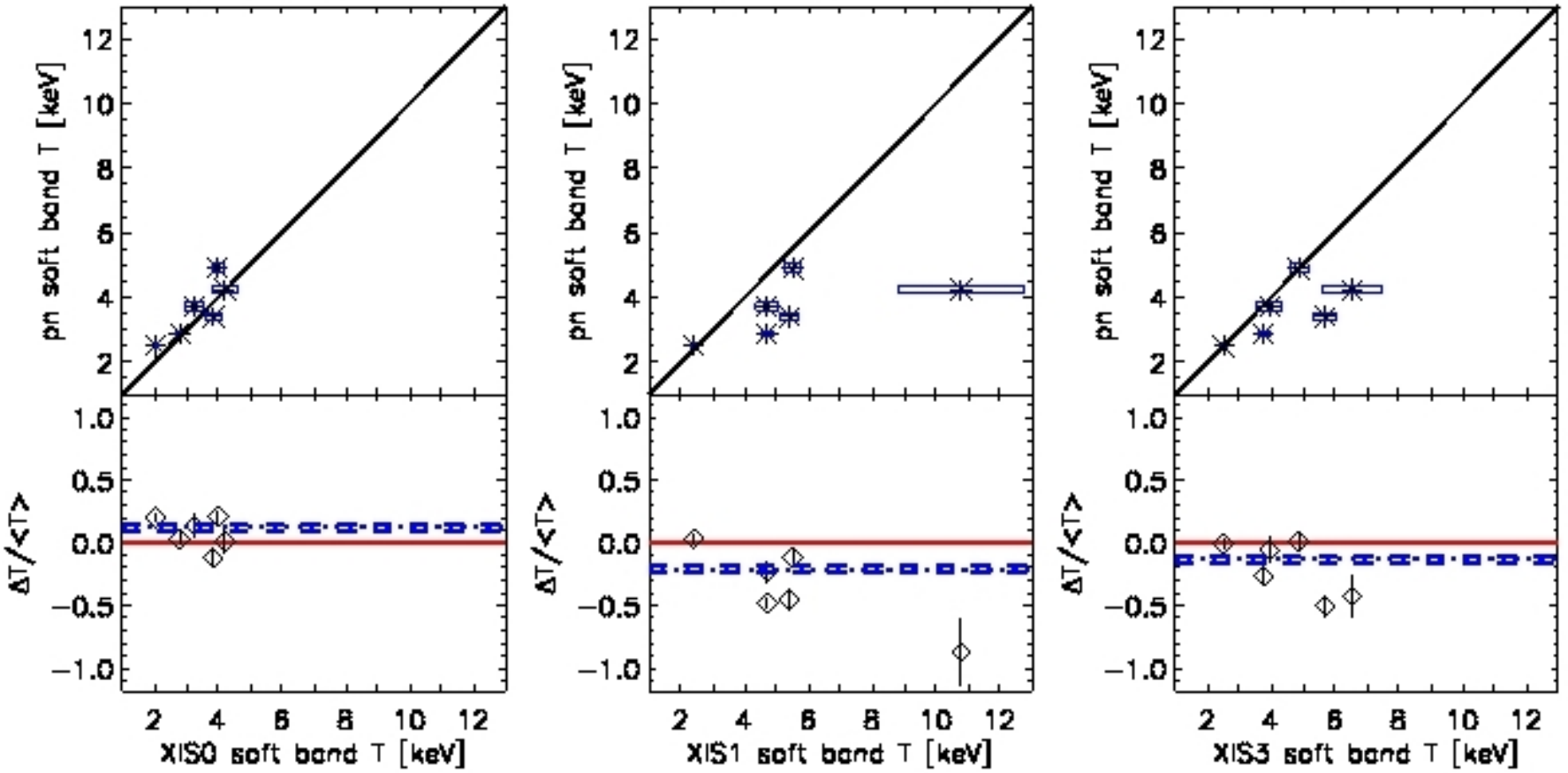
XIS soft band

- XIS1/XIS3 kT differ a bit (7%) but not very significantly (2.5σ)
- XIS0 yields 30% and 20% lower (10σ) temperatures. **Is this seen in other sources?**



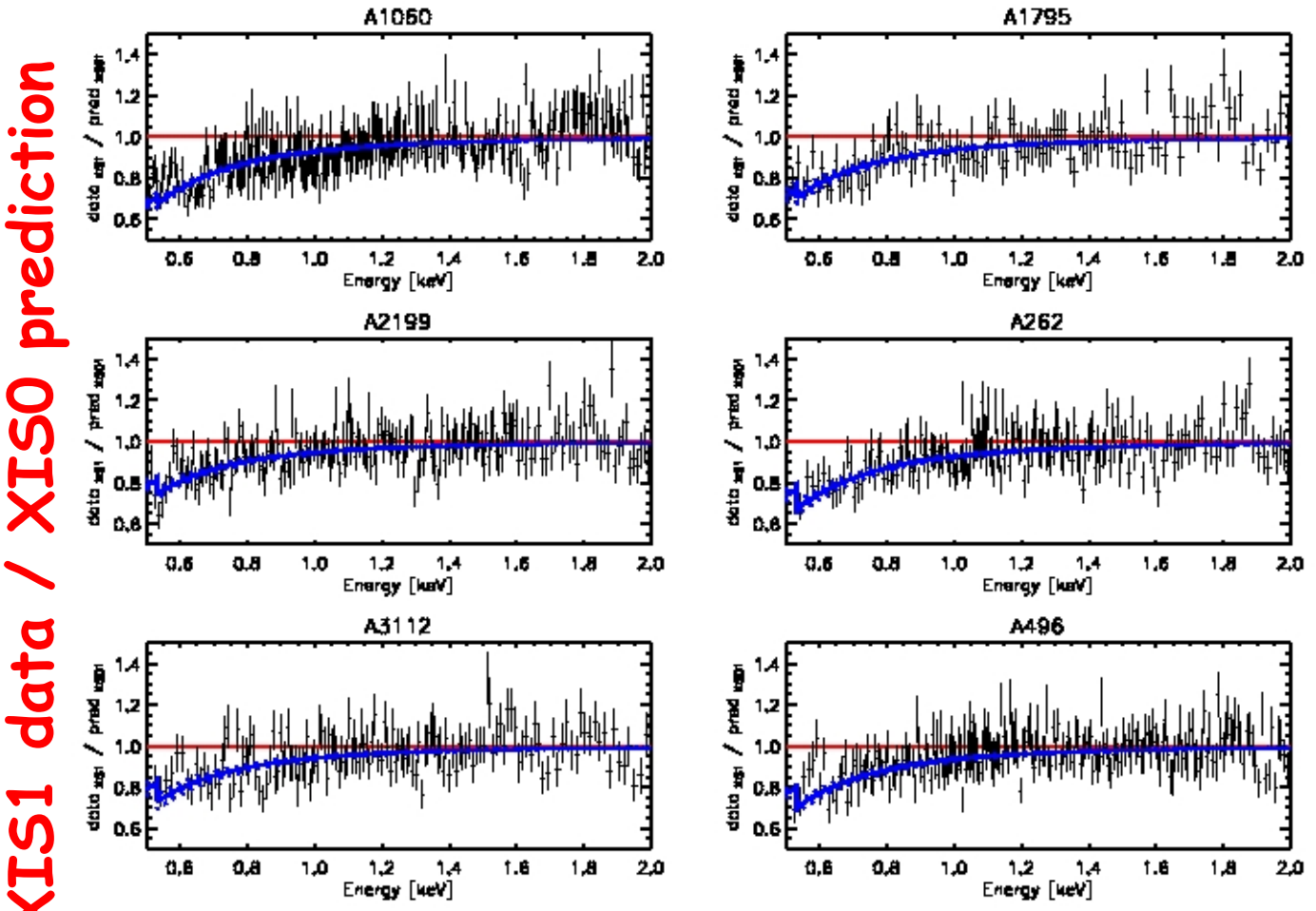
XIS/pn soft band

- None of the XIS instruments agree with pn
- The only agreement is btw. ACIS and XIS3



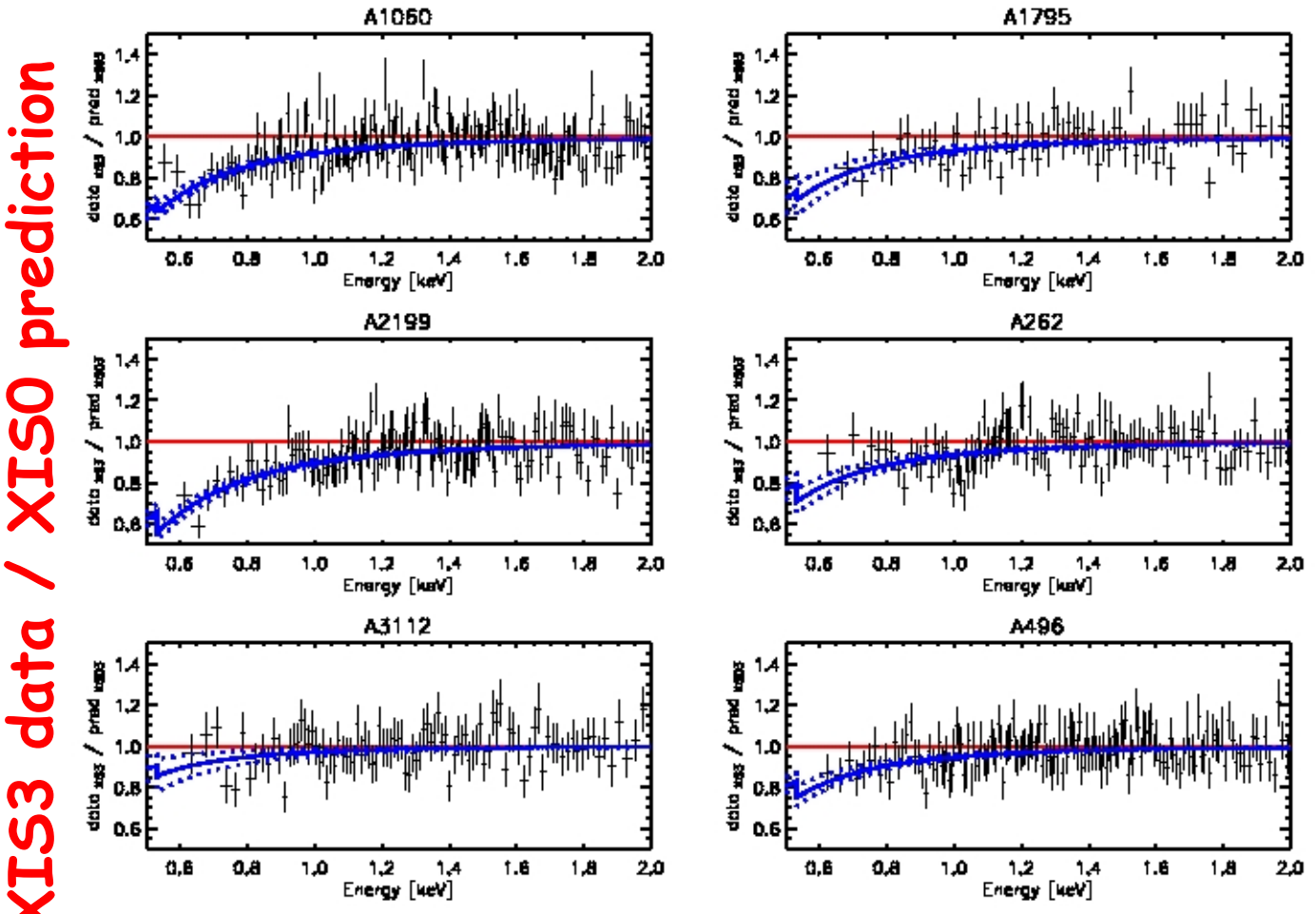
XIS1/XIS0 residuals

- XIS1 data divided by the best-fit XIS0 model folded through XIS1 response (crosses)
- Prediction too high at 0.5 keV: If XIS0 is correctly calibrated, XIS1 effarea is over-estimated by 20-40% at 0.5 keV



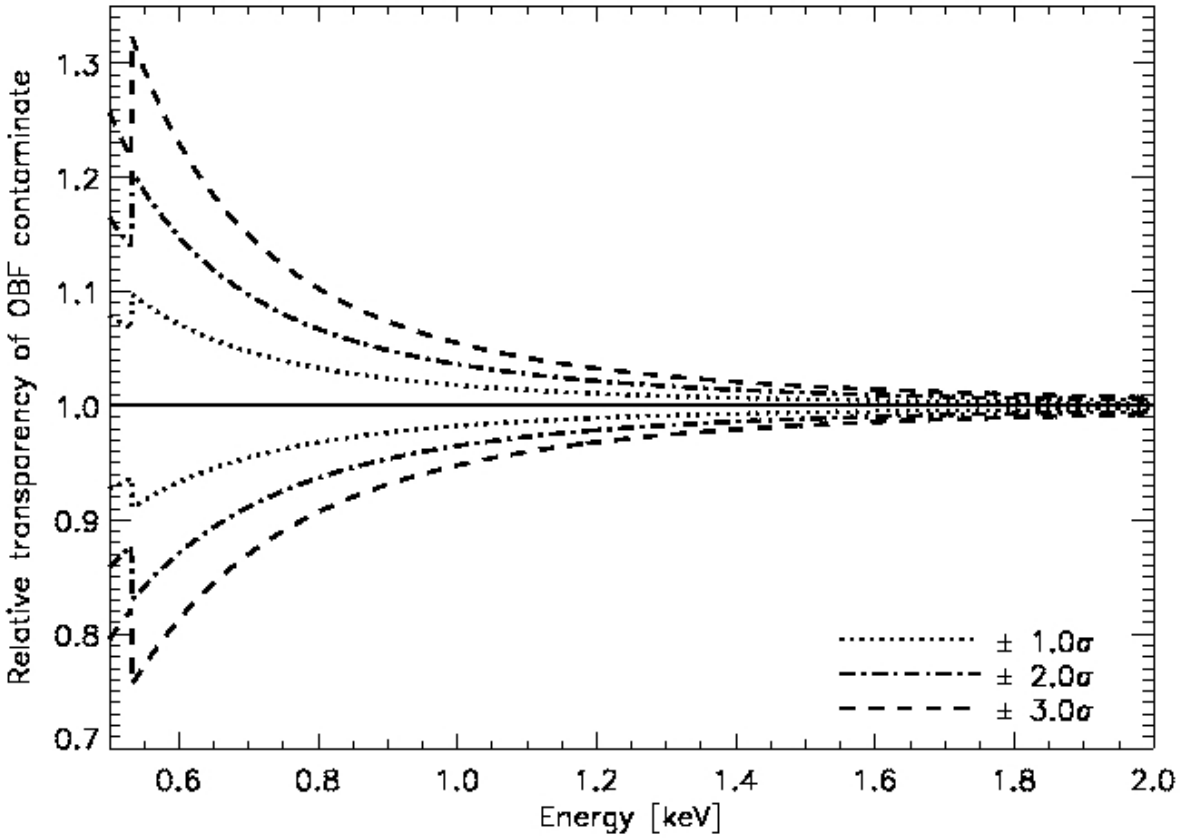
XIS3/XIS0 residuals

- XIS3 data divided by the best-fit XIS0 model folded through XIS3 response (crosses)
- Prediction too high at 0.5 keV: If XIS0 is correctly calibrated, XIS3 effarea is over-estimated by 10-40% at 0.5 keV



Is the contaminate to blame?

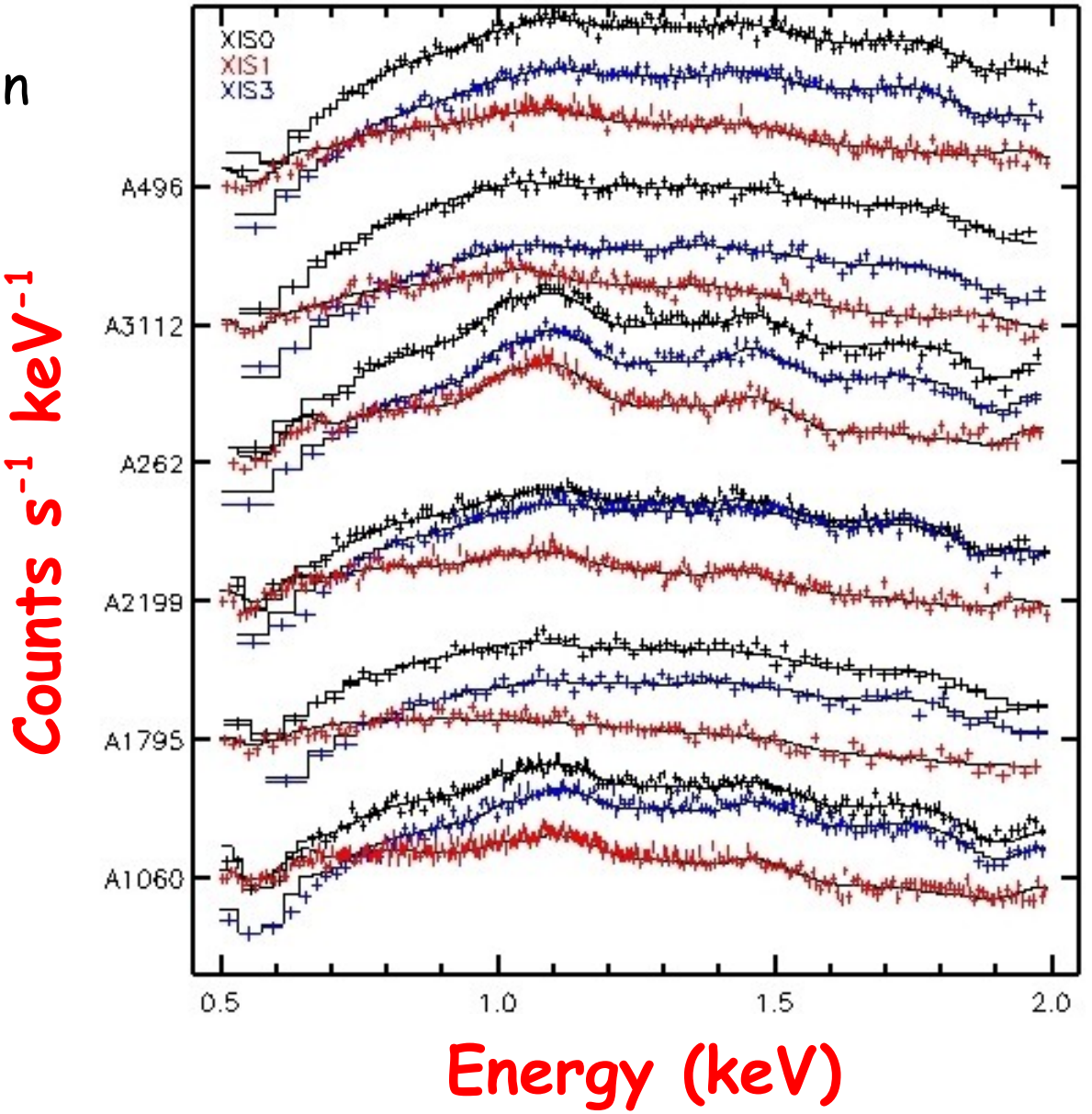
- We used a local XSPEC model hcorat to investigate the contaminate absorption effect
- We used 0.8 x 10^{18} cm^{-2} as reference O column density for 2007 epoch



- Varying N_O , the effctive area changes increasingly towards lower energies due to O edge
- Varying O column by 3σ (the reported O measurement stat. + sys uncertainty is ±5x10^{16} cm^{-2}) yields 20% effect as required by the clusters by minimum.

We can measure the total O column with clusters

- (assuming that the emission model is correct)



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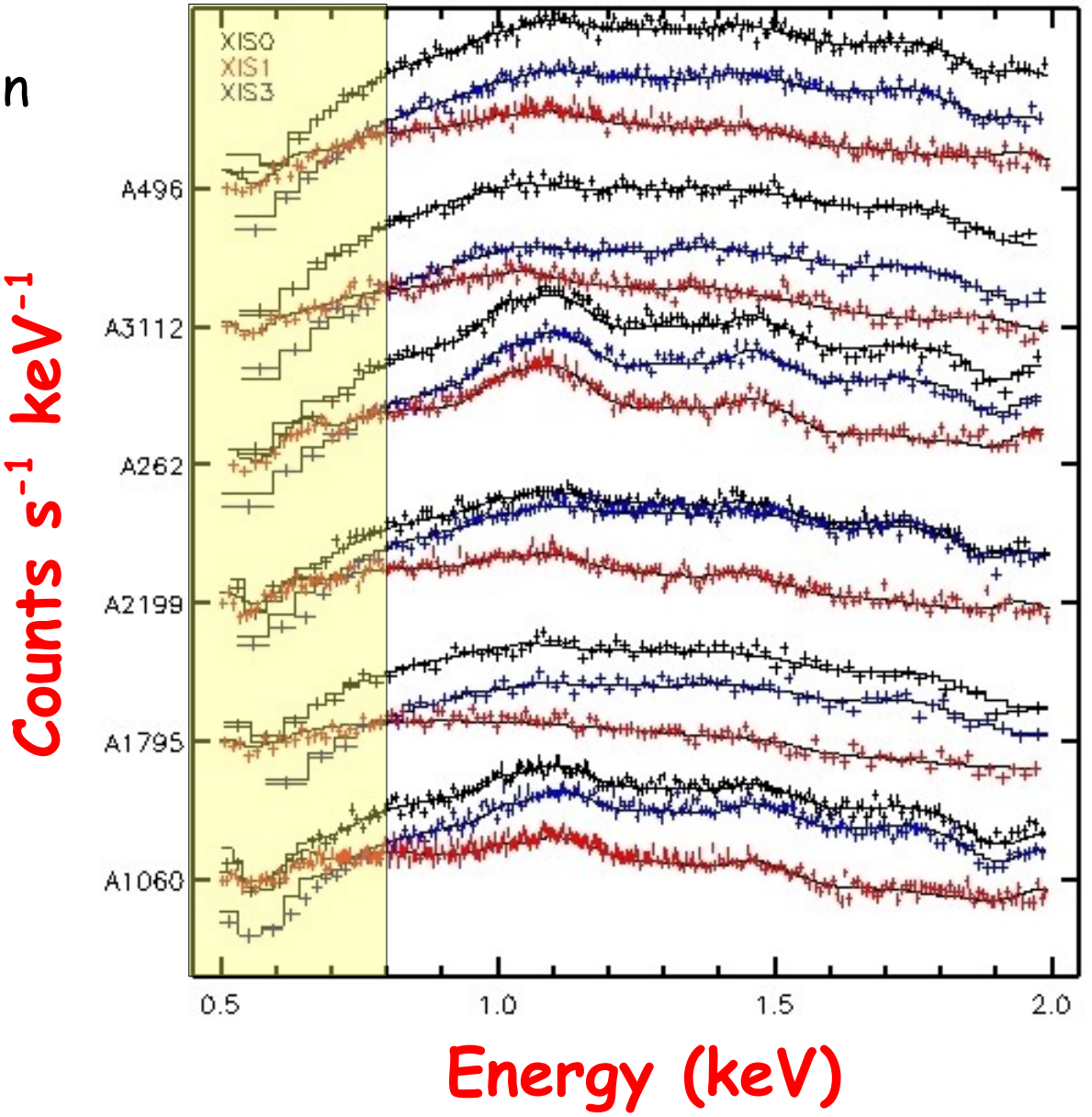
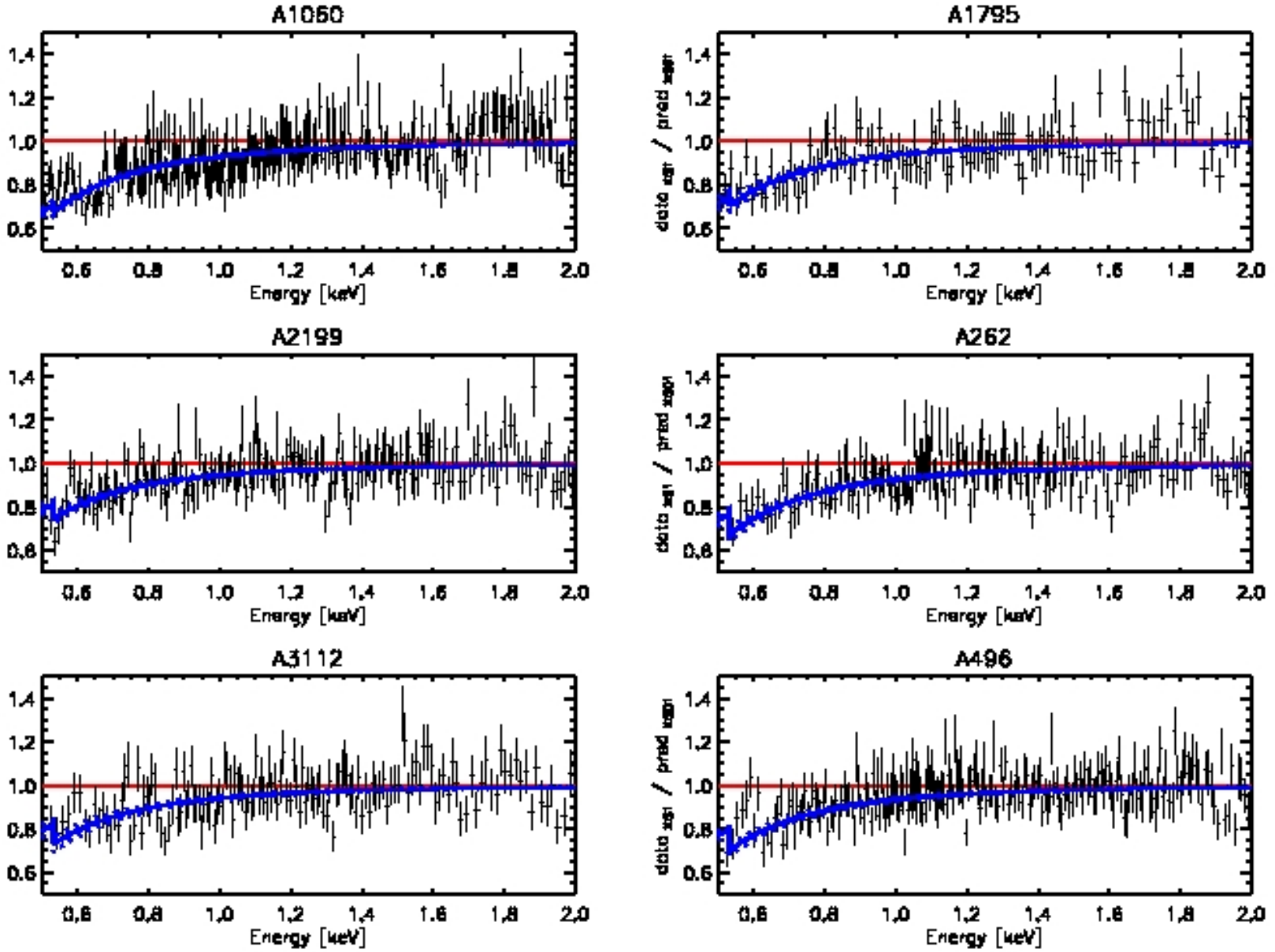


Fitting the arf

- Let's assume for a moment that XIS0 effarea is correctly calibrated, so that the best-fit model given by XIS0 is correct
- We fit the XIS1,3 cluster spectra with a model where the best-fit XIS0 MEKAL model is frozen and multiplied by a local XSPEC contaminate model **hcorat**
- H/C fixed to CALBD value
- O/C fixed to time dependent CALDB value
- We allow only the O column density to vary, in order to find the best effective area when keeping the emission model fixed
- The best-fit yields the required change in O column density ΔN_O to yield a match with XIS0 MEKAL model and XIS1,3 data

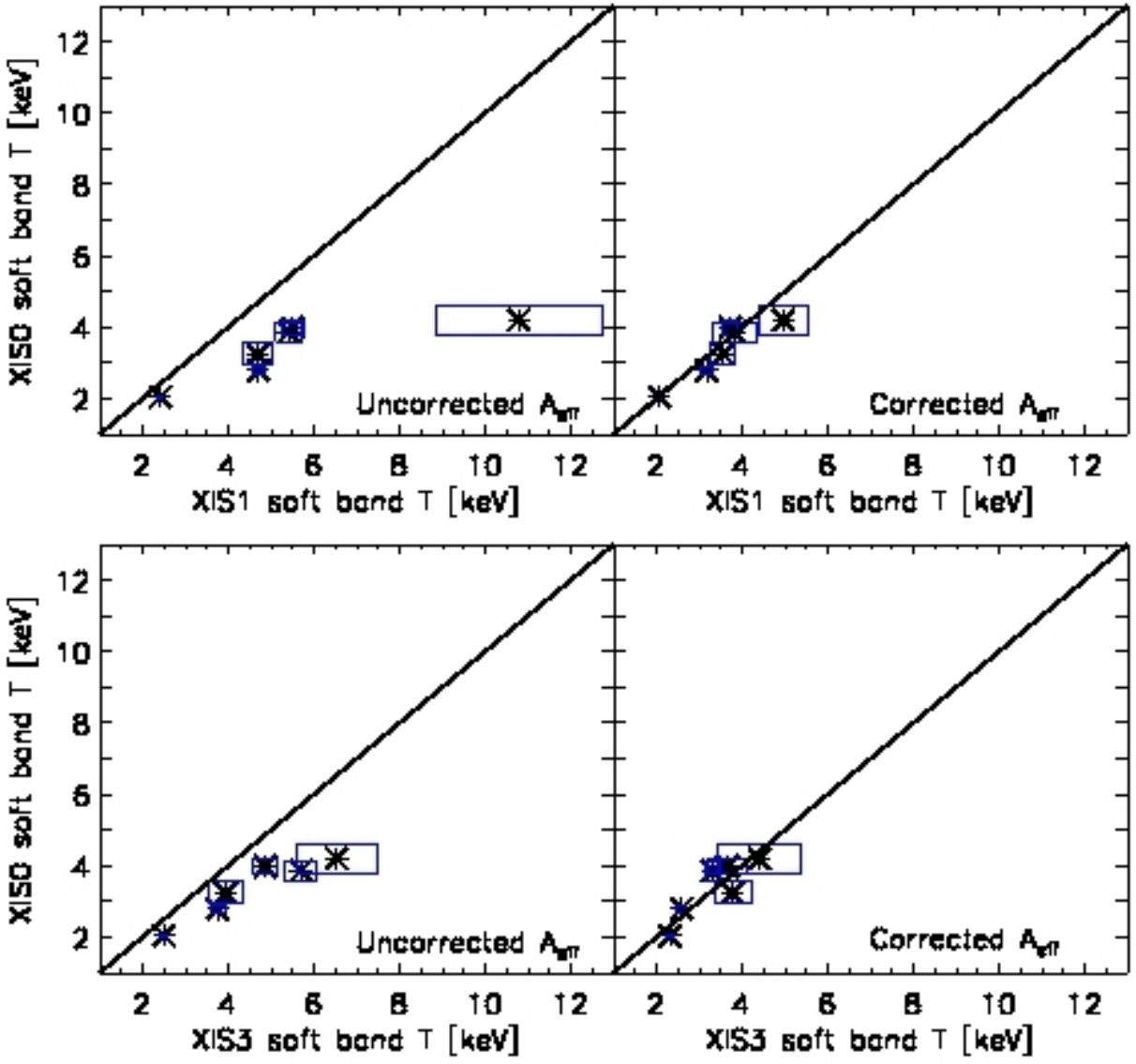
- The fits are statistically acceptable (chisq ~ 1) ➔ the energy dependence of the contaminate can qualitatively explain the XIS soft band temperature discrepancies

MODIFIED / ORIGINAL XIS1 ARF



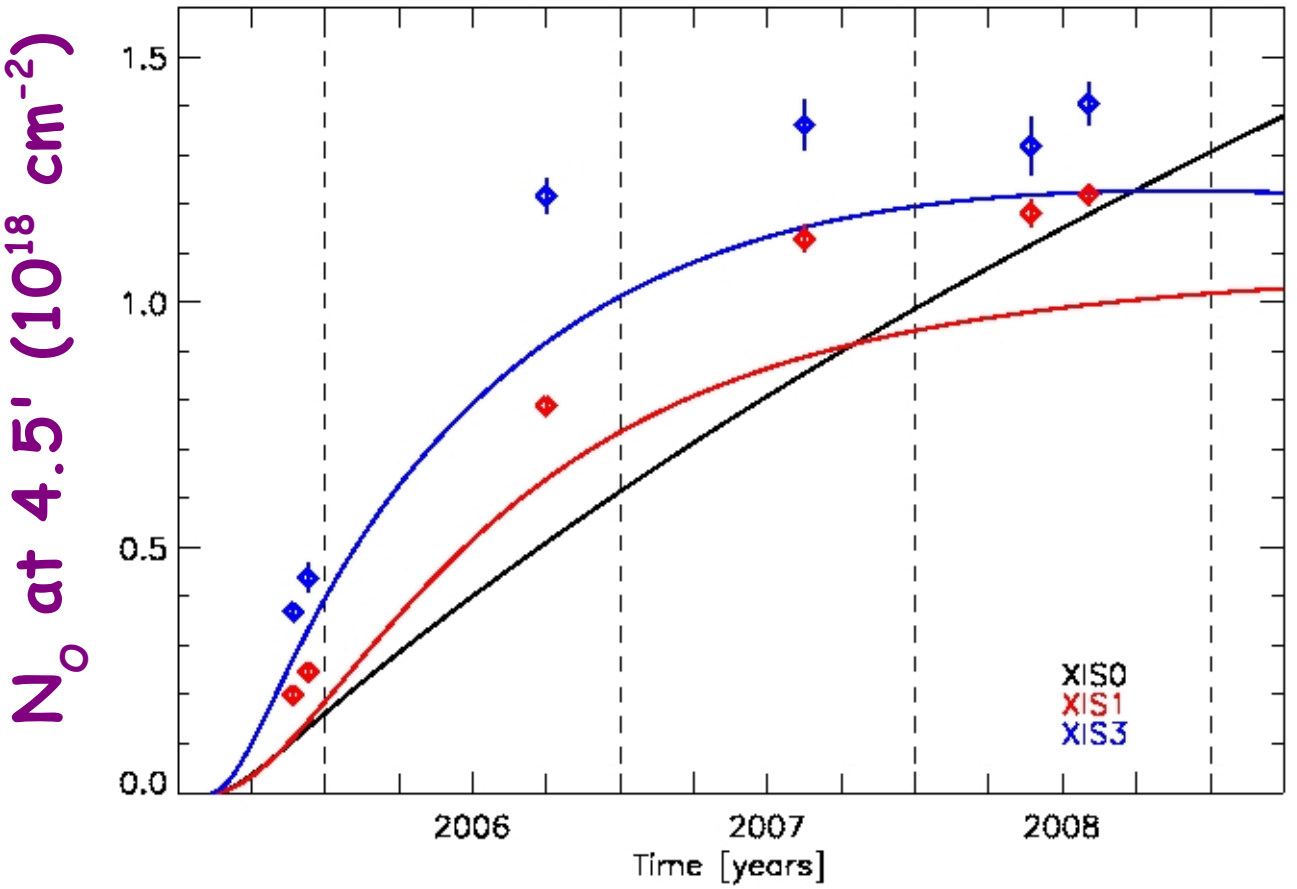
Fitting XIS1 and XIS3 spectra using modified response

- We then fitted 0.5-2.0 keV band XIS1 and XIS3 data with MEKAL model, all parameters free, using the response modified by additional N_O
- The temperatures agree by definition



- The resulting ΔN_O values 1-3 x 10^{17} cm^{-2} are quite high... **IS THIS ACCPTABLE?**

- The curves show the implemented O column density in CALDB 20110608 at 4.5 arcmin distance from the center of the FOV **(IT WOULD BE VERY USEFUL TO HAVE THE ACTUAL O COLUMN VALUE AS A KEYWORD IN THE HEADER**

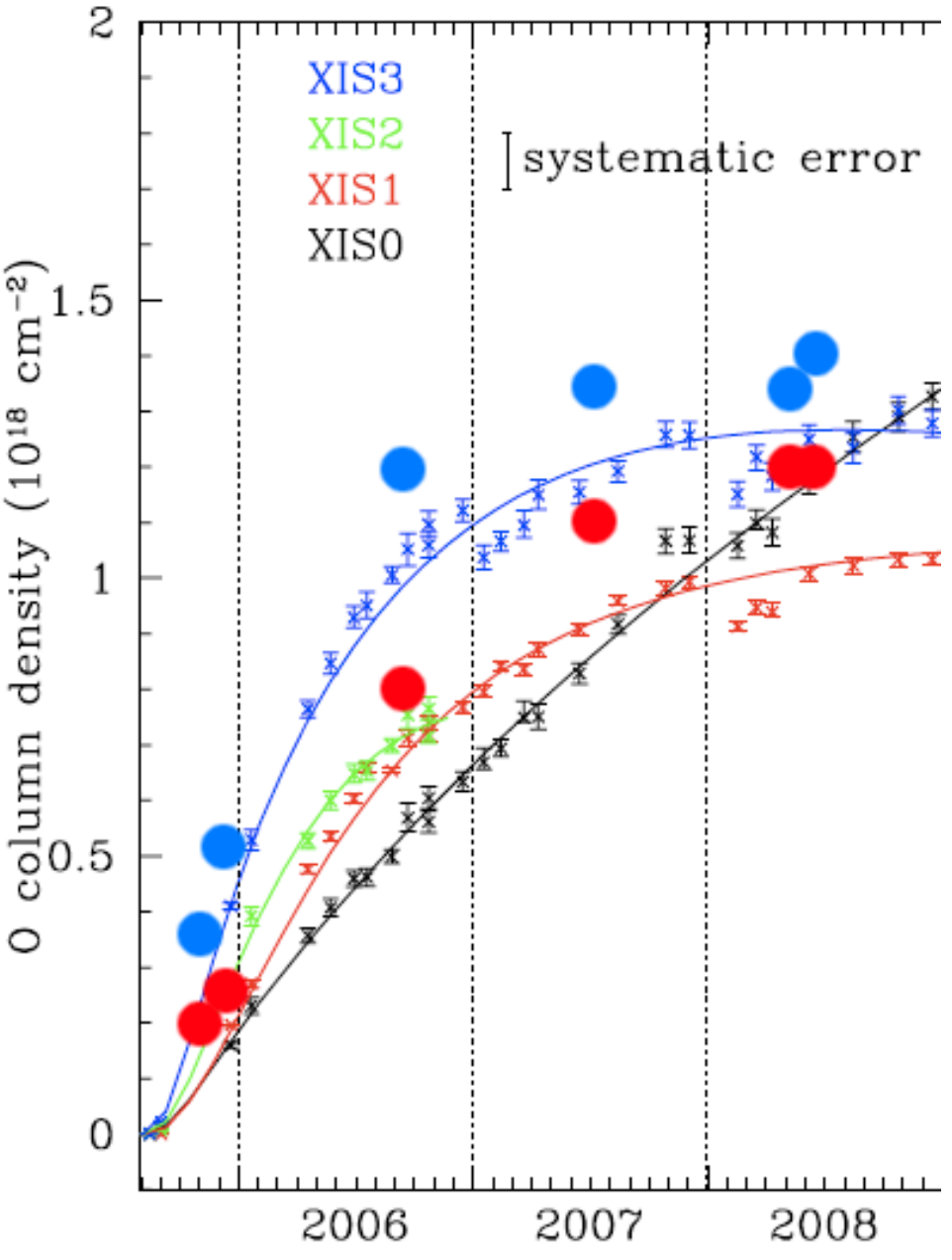


- The data points show the required O columns, if XIS0 is correct

- **These contradict the direct O measurements of 1E010?**

2011-08-22

- **On-axis** O measurements of 1E0102-72.3 (curves) + **off-axis** cluster measurements (dots)



CONCLUSIONS?

- WHICH CALIBRATION COMPONENTS COULD BRING XIS0 INTO CONSISTENCE WITH XIS1/XIS3 IN THE SOFT BAND, BUT NOT AFFECT THE HARD BAND, WHILE BEING CONSISTENT WITH THE 1E OBSERVATIONS?
- PERHAPS THE CONTAMINATION DOES NOT EXPLAIN THE CLUSTER DATA

7) Swift extension

Swift

- Swift/XRT can be used for the cluster comparison
- A.Breadmore will contact Moretti **PROGRESS!**
- Moretti busy due to family reasons, feasible in near future
- Comparison of temperatures and fluxes btw. EPIC and Swift/XRT

8) Data to IACHEC Wiki page

- **PROGRESS!**
- Link to data in clusters WG page
- One tar file per cluster, containing spectrum, bkg, rmf, arf, XSPEC session file and README file for pn, MOS1+2 and ACIS
- Should we have MOS1 and MOS2 separately?
- Regions are those used for XMM/Chandra comparison, i.e. excluding the cool core and extending to ~3 arcmin
- For flux comparisons, divide the values by the fraction of the full extraction annulus covered by a given instrument