4) Gravitational lensing v.s. X-ray masses

Clusters of galaxies WG report

J. Nevalainen, on behalf of the Clusters WG

9th IACHEC meeting 2014, Airlie, Warrenton

1) Samples

- HIFLUGCS (Schellenberger et al., submitted, arXiv:1404.130)
- Multi-mission study (J. Nevalainen)

2) New missions

- ASTROSAT
- ASTRO-H

3) NuSTAR

- A1795 feasibility (N.J. Westergaard)
- NuSTAR Coma analysis experience (F. Gastaldello)

4) Grav lensing

- Weak-lensing v.s. XMM-Newton X-ray masses (A. von Linden)
- Weak-lensing v.s. Chandra X-ray masses (H. Israel)

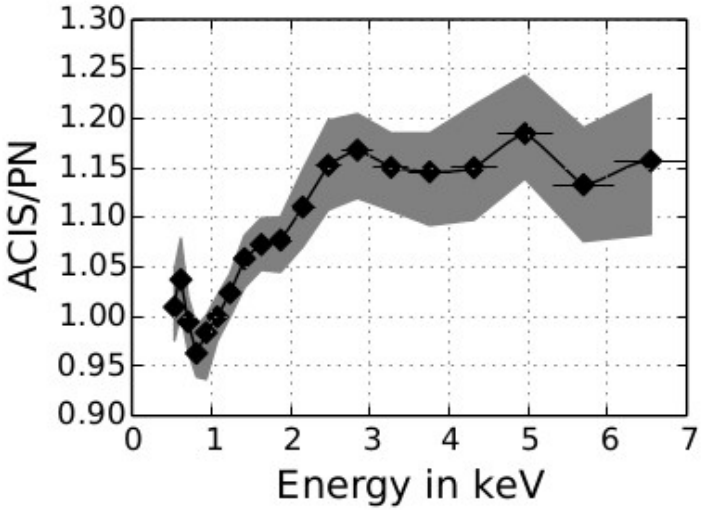
1) Samples

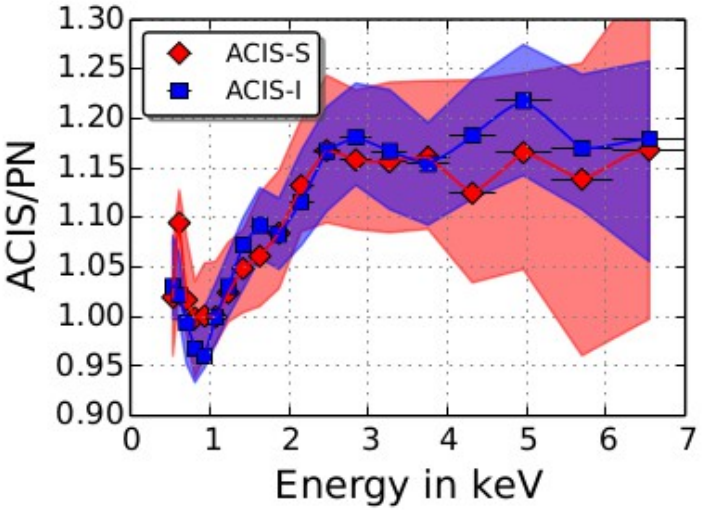
HIFLUGCS

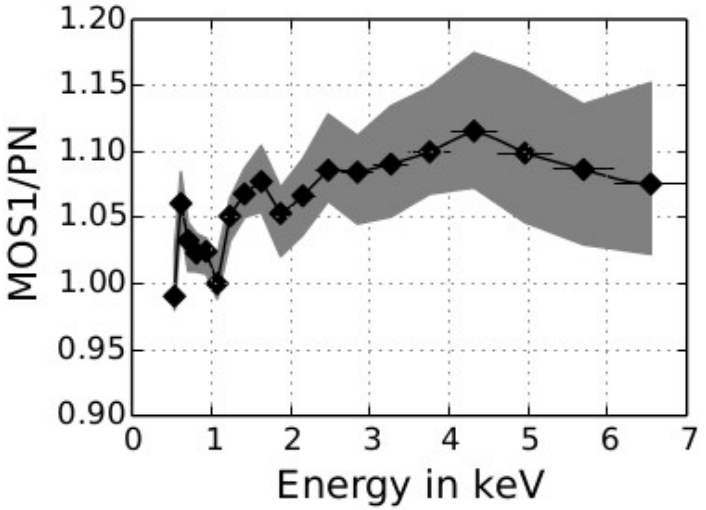
G. Schellenberger, T. Reiprich, L. Lovisari,
J. Nevalainen, L. David

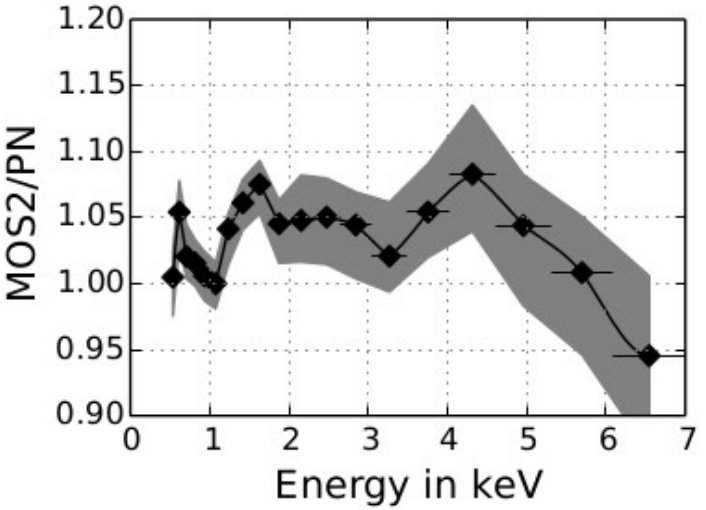
HIFLUGCS

$$R_{i\,\mathrm{over}\,pn} = \frac{data_i}{model_{pn} \otimes resp_i} \times \frac{model_{pn} \otimes resp_{pn}}{data_{pn}}$$







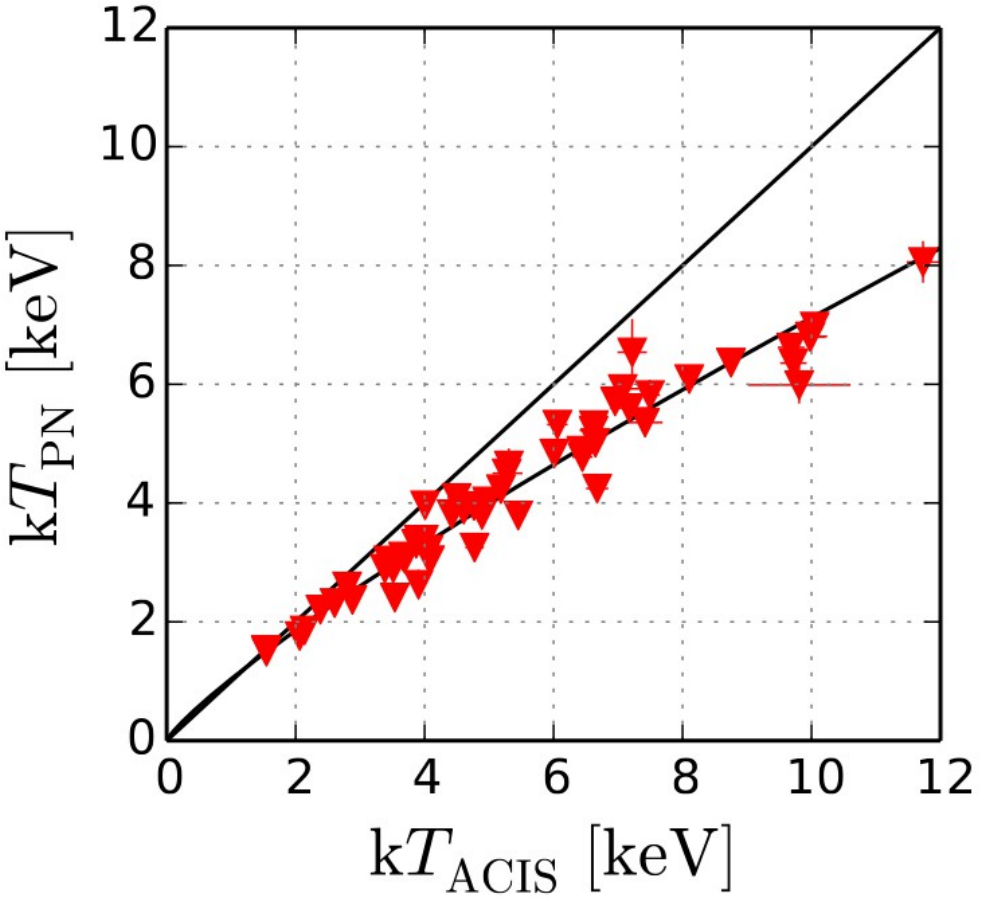


Spline parameters for stack residuals ratio = effective area cross-cal uncertainty

Energy	ACIS/PN		MOS1/PN		MOS2/PN	
[keV]	y	y''	y	y''	y	y''
0.54	1.01	-14.69	0.99	-9.32	1.00	-11.37
0.62	1.04	-0.81	1.06	-1.23	1.05	-1.08
0.71	0.99	0.02	1.03	0.16	1.02	0.32
0.81	0.96	0.49	1.02	0.20	1.02	-0.02
0.94	0.98	-0.06	1.02	-0.34	1.01	-0.06
1.08	1.00	0.02	1.00	0.56	1.00	0.35
1.24	1.02	0.07	1.05	-0.23	1.04	-0.16
1.42	1.06	-0.10	1.07	0.01	1.06	0.02
1.63	1.07	-0.08	1.08	-0.18	1.08	-0.23
1.88	1.08	0.09	1.05	0.14	1.05	0.13
2.15	1.11	0.03	1.07	0.03	1.05	-0.00
2.48	1.15	-0.06	1.09	-0.07	1.05	-0.00
2.84	1.17	-0.09	1.08	0.02	1.04	-0.07
3.27	1.15	0.03	1.09	-0.00	1.02	0.12
3.76	1.15	-0.01	1.10	0.03	1.05	0.02
4.32	1.15	0.09	1.12	-0.06	1.08	-0.12
4.96	1.18	-0.17	1.10	0.01	1.04	0.05
5.70	1.13	0.15	1.09	-0.01	1.01	-0.12
6.55	1.16	-0.17	1.08	0.05	0.95	0.32

HIFLUGCS

$$\log\frac{\{kT_{pn}\}}{\{1\,keV\}} = 0.836 \times \log\frac{\{kT_{ACIS}\}}{\{1\,keV\}} + 0.016$$

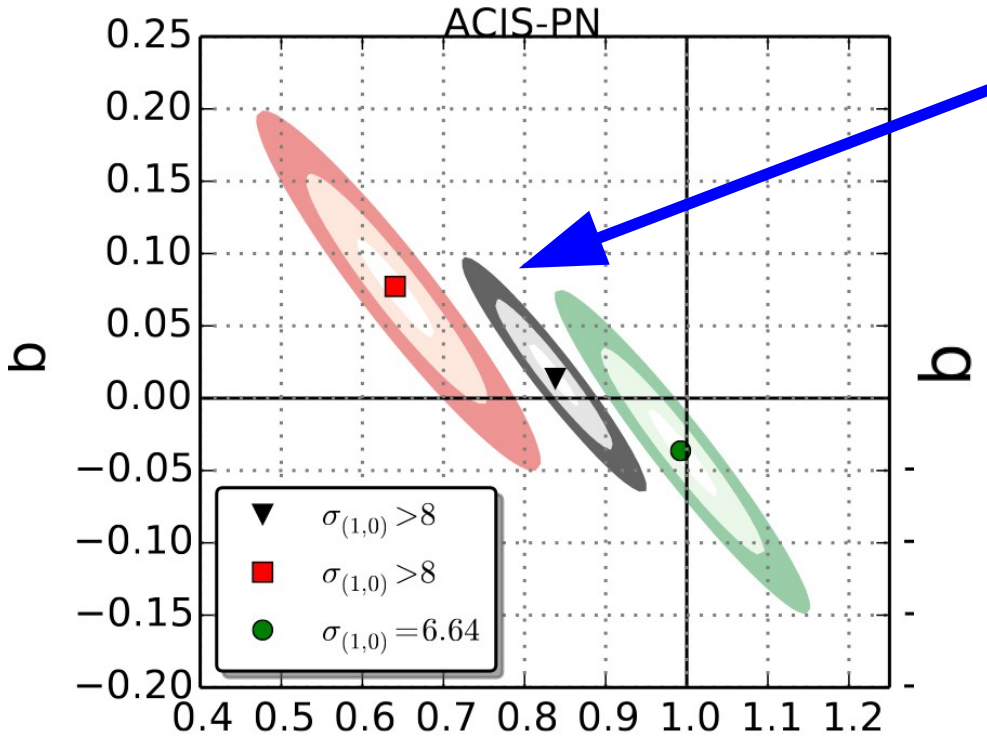


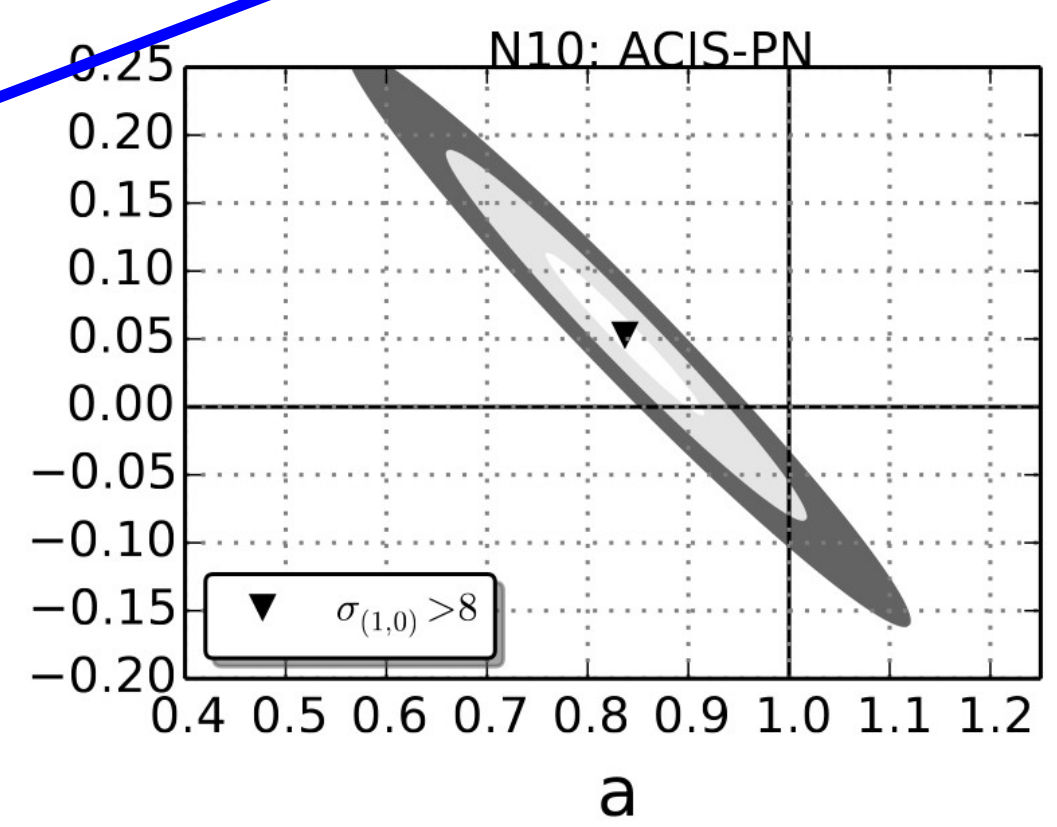
Scaling between ACIS and pn 0.7-7.0 keV band temperatures

Schellenberger et al, 2014 v.s. Nevalainen et al., 2010

$$\log\frac{\{kT_{pn}\}}{\{1\,keV\}} = a \times \log\frac{\{kT_{ACIS}\}}{\{1\,keV\}} + b$$

Consistent





Multi-Mission Study

J. Nevalainen, A. Beardmore, L. David, F. Gastaldello, E. Miller, S. Snowden

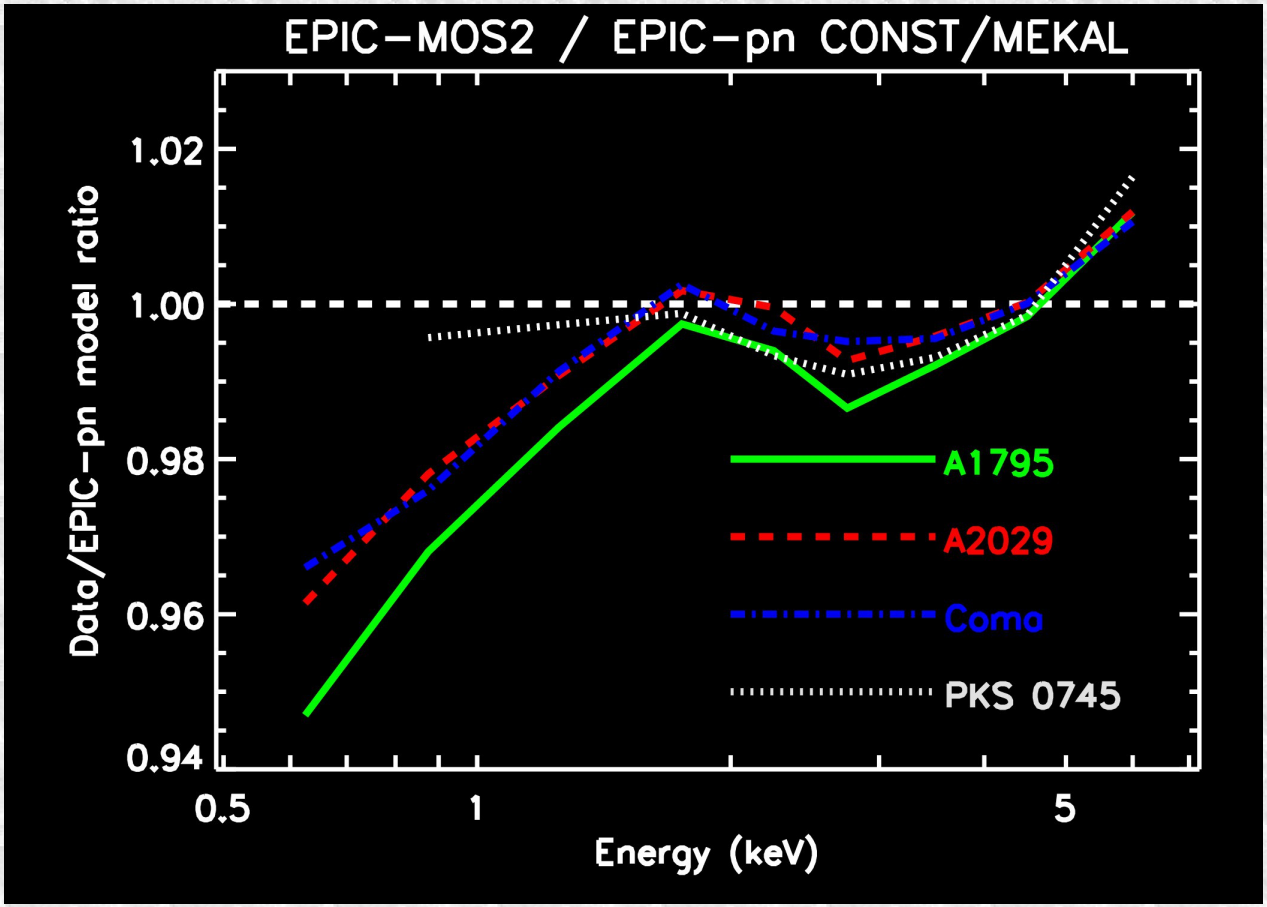
- Comparison of cluster measurements with XMM-Newton/EPIC, Chandra/ACIS, Swift/XRT, Suzaku/XIS, ROSAT/PSPC and NuSTAR: 6 missions, 10 instruments
- Residual ratios to evaluate the effective area cross-calibration:
  - We use EPIC-pn as a reference. (Try also ACIS, **TBD**)
  - For instrument **i** we calculate the median and the mean absolute deviation of the ratio

$$R_{i\,\mathrm{over}\,pn} = \frac{data_i}{model_{pn} \otimes resp_i} \times \frac{model_{pn} \otimes resp_{pn}}{data_{pn}}$$

- The latter term corrects for deviations btw. pn model and pn data which cannot be produced by the model (no point in comparing other data with a model which does not fit pn data)

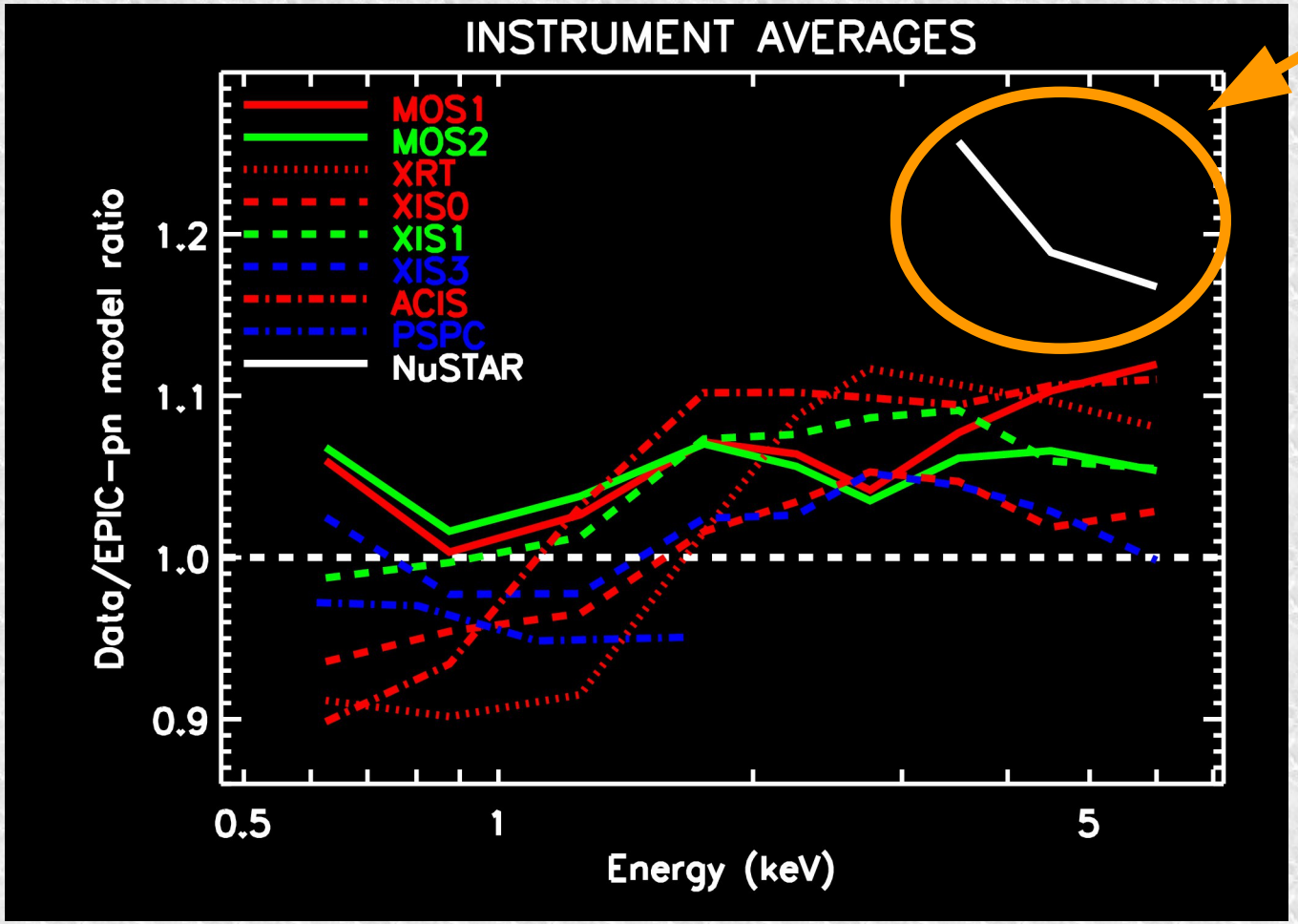
Model accuracy does not matter much

- For the relative effective area comparison the accuracy of the reference model does not matter much
- Proof: MOS2/pn residuals ratios for the sample using phabs x mekal or a constant model for fitting pn spectra: above 1 keV differeces at the level of statistical error of 2%. A bit bigger at lower energies, why?



Summary of residuals ratios

- The average instr/pn residual ratio of each pair



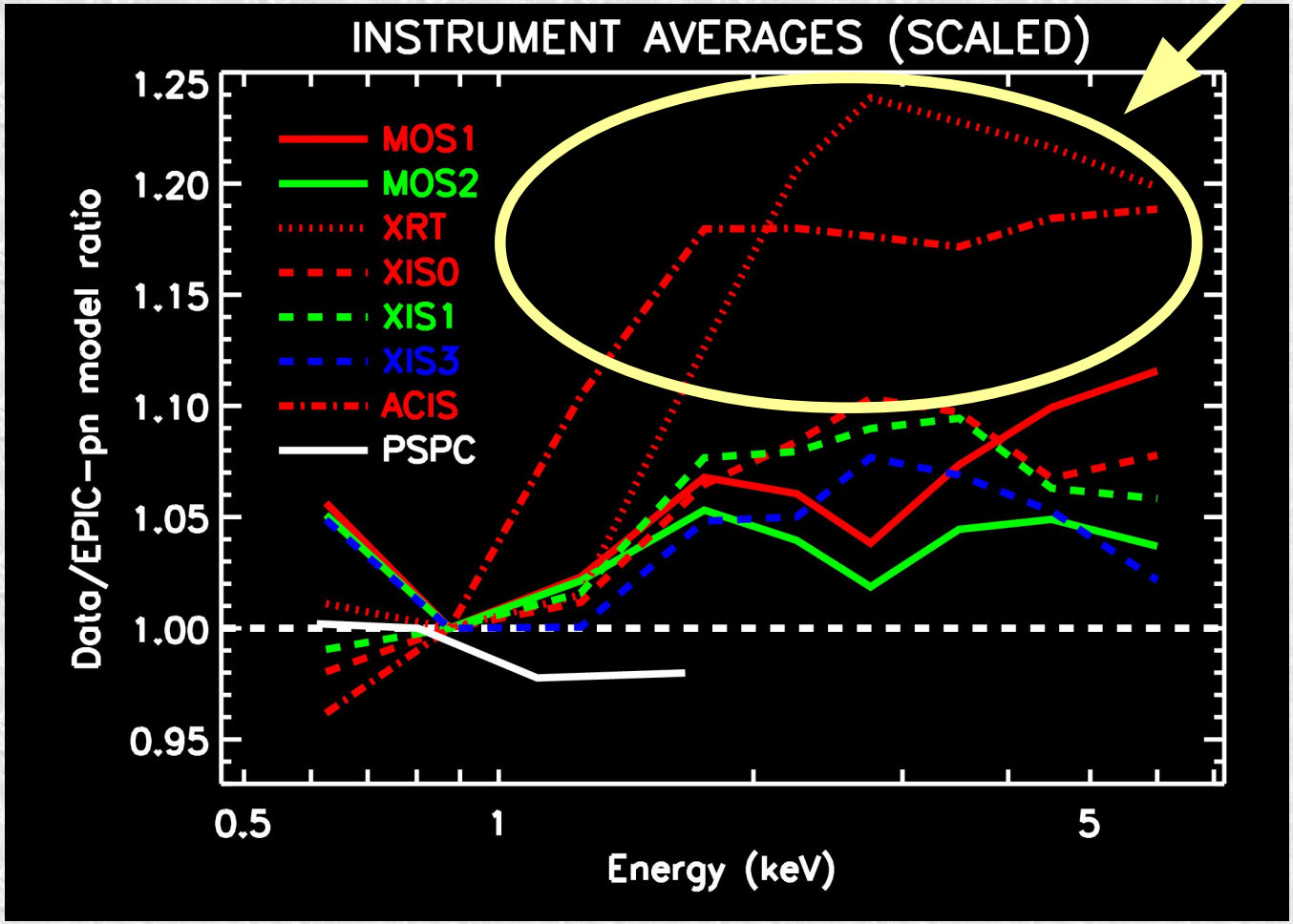
NuSTAR

All instruments show higher flux than pn at > 2 keV, but with a varying degree

Most instruments show lower flux than pn at < 2 keV, but with a varying degree

Summary of scaled residuals ratios

- The average instr/pn residual ratio of each pair, scaled to unity at 0.75-1.0 keV



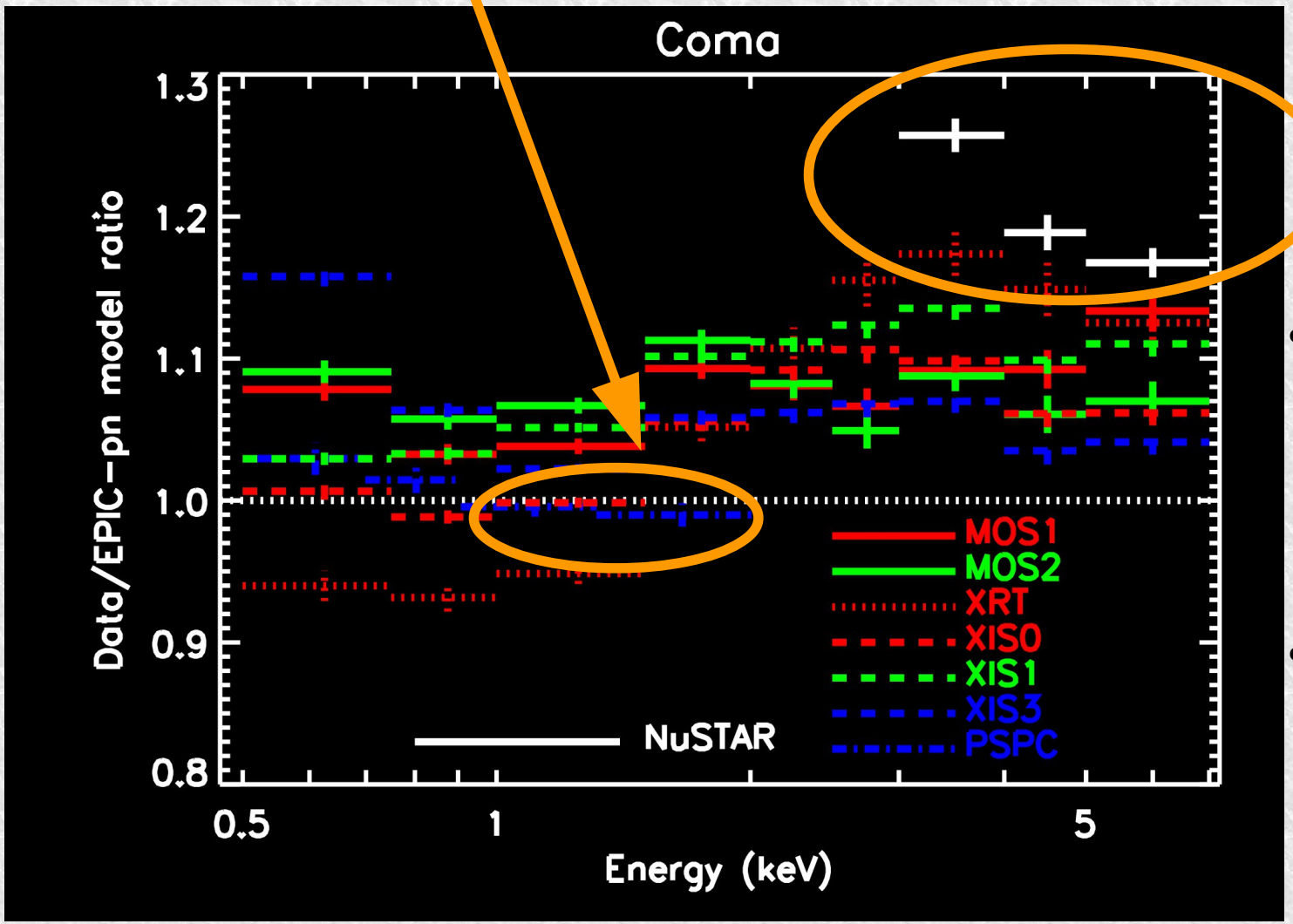
Swift/XRT and Chandra/ACIS show a larger magnitude for the 1-2 keV gradient and 2-7 keV flux difference.

Changing pn effective area with the average residuals ratio would not make ACIS and Swift into agreement with the others

PSPC agrees with pn in 1-2 keV band

Coma

NuSTAR



- NuSTAR 3-7 keV band flux 15-25% higher than that of pn
- Indication of energy dependence

2) New missions

ASTROSAT

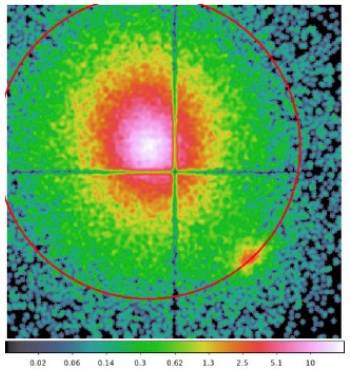
ASTROSAT

- Several clusters considered for the ASTROSAT SXT calibration plan
- PKS0745
- A1060
- A1795
- A262
- A3112
- A496
- AWM7
- Perseus

ASTRO-H

3) NuSTAR

A1795 ray-tracing simulations for NuSTAR (N.J. Westergaard)



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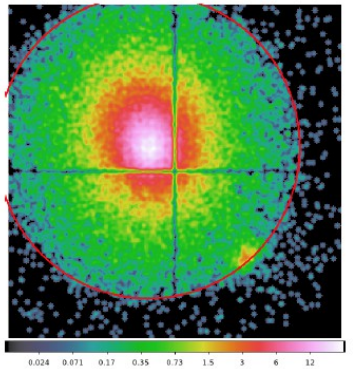
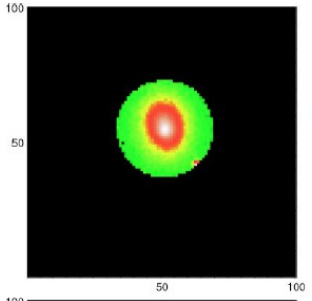
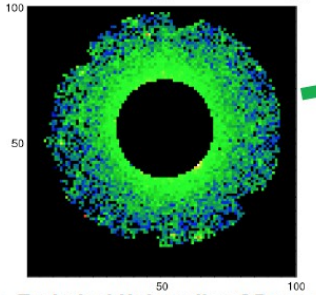
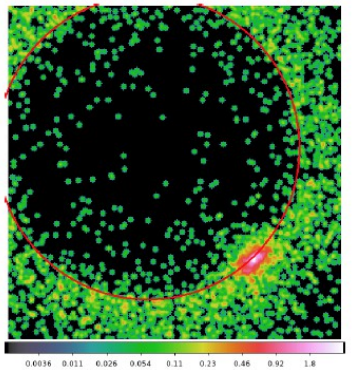
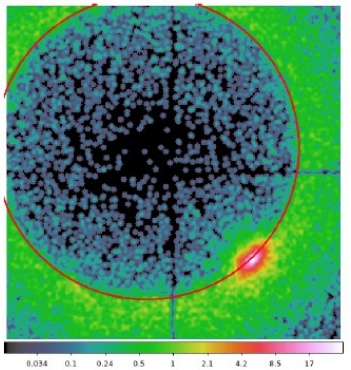






10 x as many photons



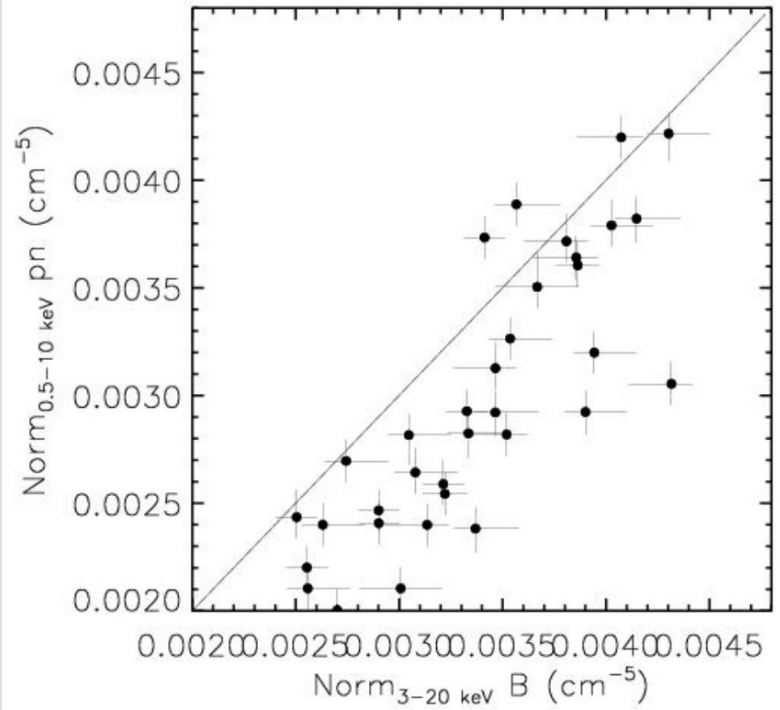


Ghost rays 1% effect of the intrinsic cluster emission within central r=6 arcmin region

Arf for extended sources problematic

NuSTAR Coma analysis (F. Gastaldello)

COMPARISON norm B 3-20 pn 0.5-10 keV



With nustardas 1.2.0 and caldb 20130509

Mean of the ratio B/pn 1.147 with stdev 0.158

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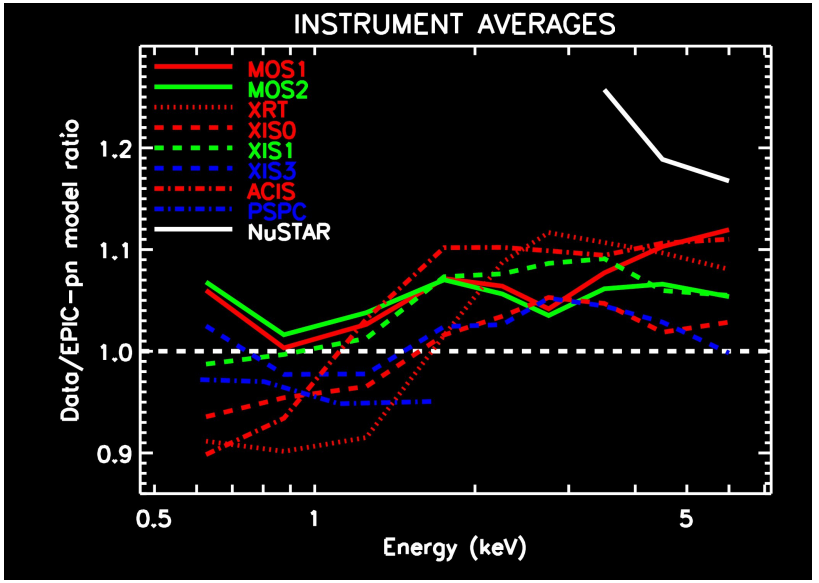
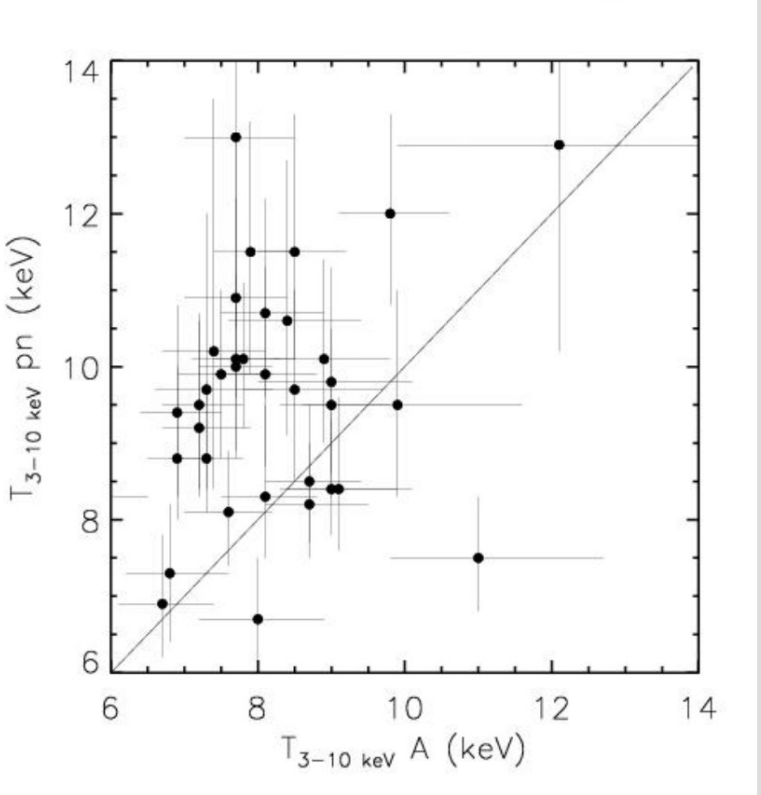
Indication of 15% higher NuSTAR fluxes compared to pn



NuSTAR Coma analysis (F. Gastaldello)

COMPARISON T A-pn 3-10 keV



Mean of the ratio pn/A 1.185 with stdev 0.204

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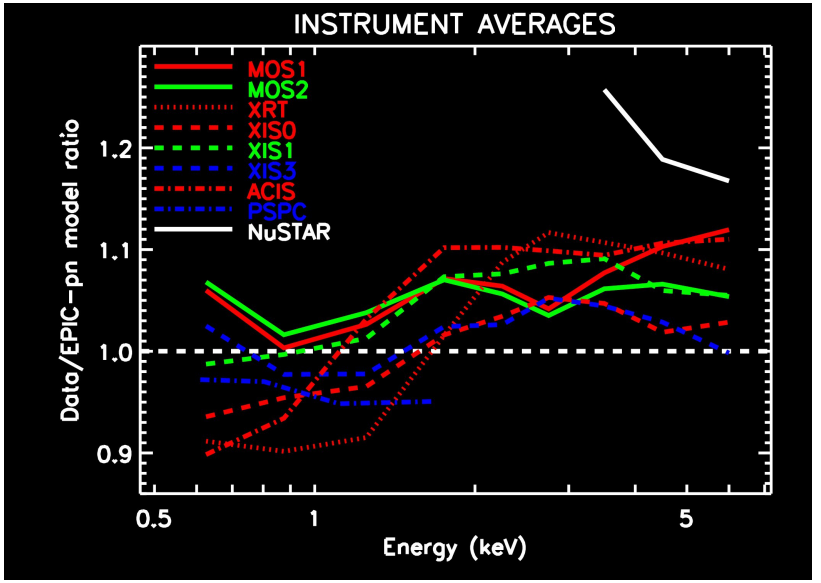
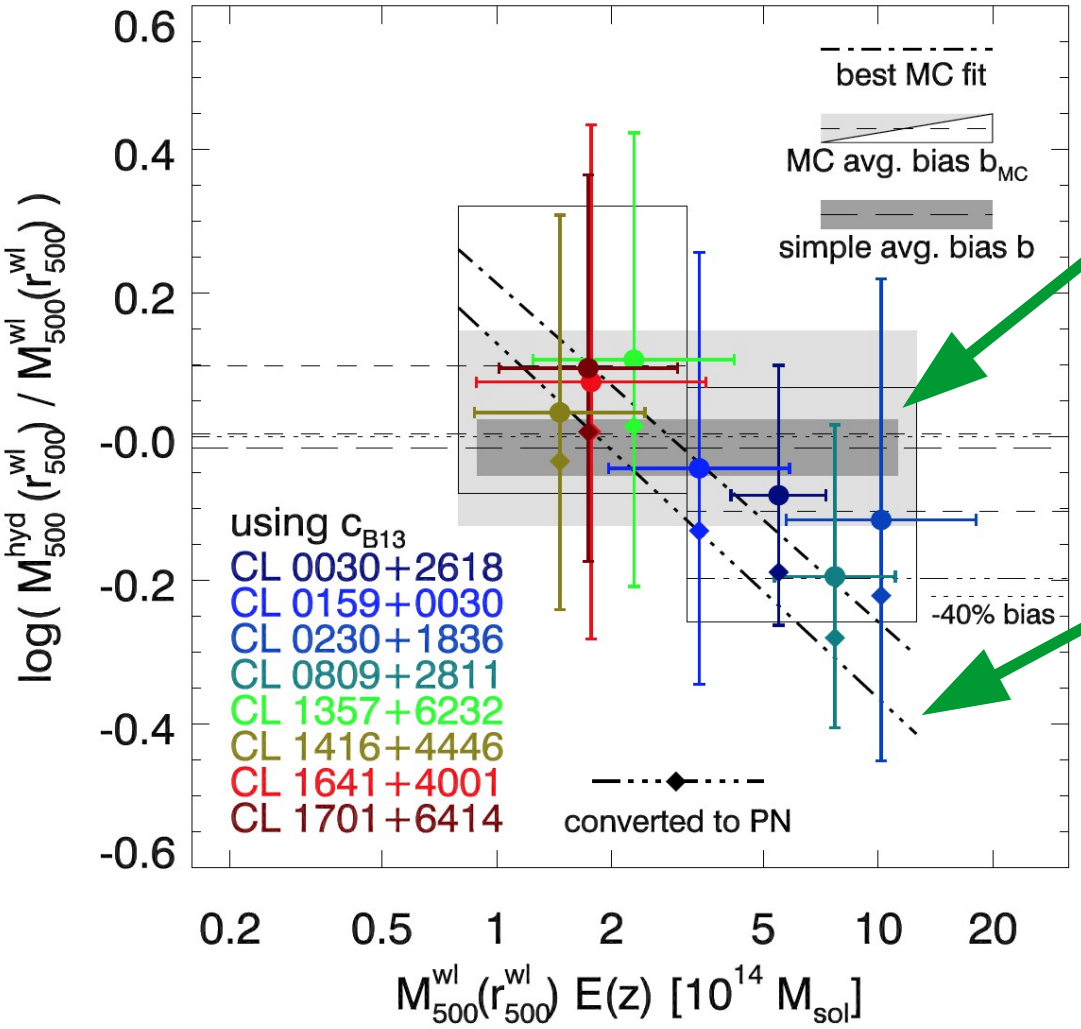
Indication of 20% lower NuSTAR temperatures compared to pn in the overlapping 3-10 keV band



H. Israel, et al., "The 400d Galaxy Cluster Survey weak lensing programme: III: Evidence for consistent WL and X-ray (Chandra) masses at z~0.5", arXiv:1402.3267



Chandra X-ray masses consistent with GL

Scaling Chandra temperatures to XMM with Gerrit's HIFLUGCS relation: XMM X-ray masses 20% lower.

XMM consistent with cluster simulations: non-thermal pressure causes hydrostatic bias

ASTRO-H might help by measuring turbulent motions via broadening of Fe XXV line

Hottest clusters not seen with pn

- Press-Schechter – kind mass function for cluster mass (= temperature) distribution per volume yields prediction of X clusters / Mpc3 hotter than 10 keV
- If pn sees 0 clusters, argument for pn eff area adjustment