Clusters of galaxies WG report

J. Nevalainen, on behalf of the Clusters WG

10th IACHEC meeting, 2015, Fragrant Hill, Beijing

Clusters of Galaxies WG program

April 20, first meeting room

- **13:30 - 14:50 HIFLUCS**

  1) G. Schellenberger: *"Chandra/XMM-Newton cross calibration using HIFLUGCS: Updates and future plans"*

  2) J. Nevalainen: *"Modarf"*

  3) J. Nevalainen: *"HIFLUGS data to WIKI"*

- **14:50-15:20 coffee break**
- **15:20-17:30 Other projects**

  4) J. Nevalainen, on behalf of H. Israel: *"X-ray cluster masses and hydrostatic bias"*

  5) J. Nevalainen: *"Cluster masses"*

  6) J. Nevalainen: *"Multi Mission Study"*

  7) J. Nevalainen: "NuSTAR"

  8) J. Nevalainen: *"Coordination of Astro-SAT, AstroH and eRosita cross-calibration with IACHEC clusters"*

Clusters of Galaxies WG program

April 22 VIP room A

- **13:30 - 15:30**

9) G. Schellenberger: *"More HIFLUCS stuff"*

10) Chen Y. et al: “XMM-Newton/Chandra cross calibration

1) XMM/Chandra cross cal by our Chinese collegues

XMM-Newton/Chandra Cross Calibration

Chen Y., Song L.M.
Jia S.M., Li C.K., Zhao H.H., Wang Y.H.

Cluster of Galaxies Group / IHEP

2015.4.22

Introduction

- **Main work:** Statistical studies on X-ray properties of clusters
- **A cluster sample (XMM-Newton/Chandra)—164 clusters**

  Chandra : 112 (subsample I)

  XMM-Newton : 124 (subsample II)

  Both: 72 (subsample III)
- **Studies on X-ray properties of subsamples:**

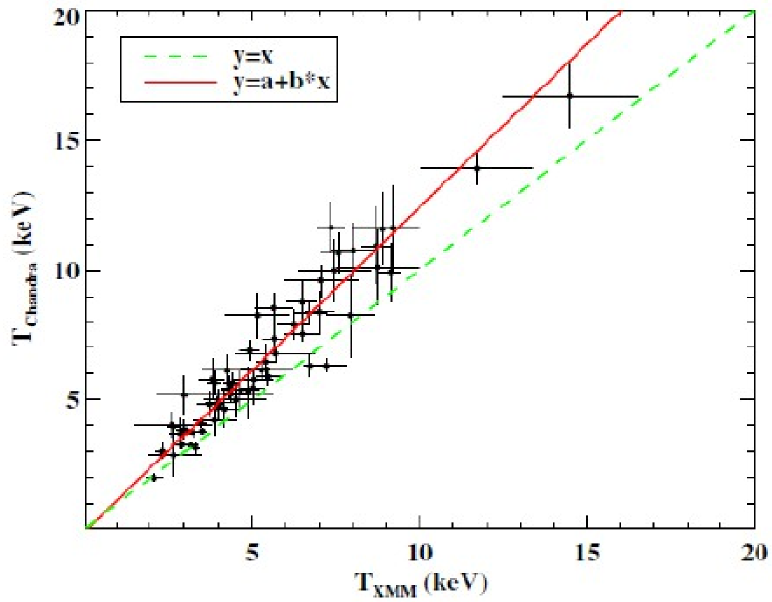
  T, M, L, S, L-M, L-T, M-T……

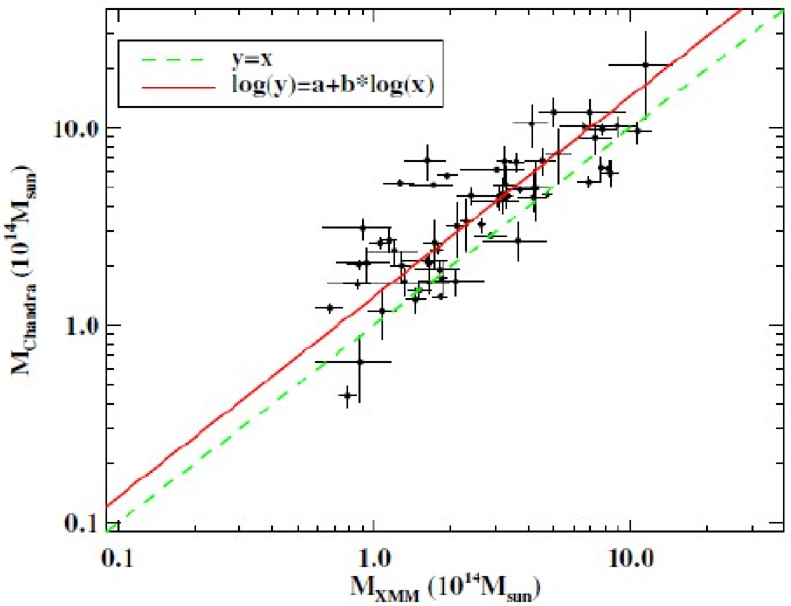
  BUT: the properties from XMM-Newton and Chandra are different
- **First, we have to find a way to combine the subsamples**

  Using subsample III (62)

  Relations of the properties between XMM-Newton and Chandra

Temperature & Mass





$$T_{\mathrm{Chandra}} = 1.25 \times T_{\mathrm{XMM}} - 0.13$$

$$\log_{10} M_{\mathrm{Chandra}} = 1.02 \times \log_{10} M_{\mathrm{XMM}} + 0.15$$

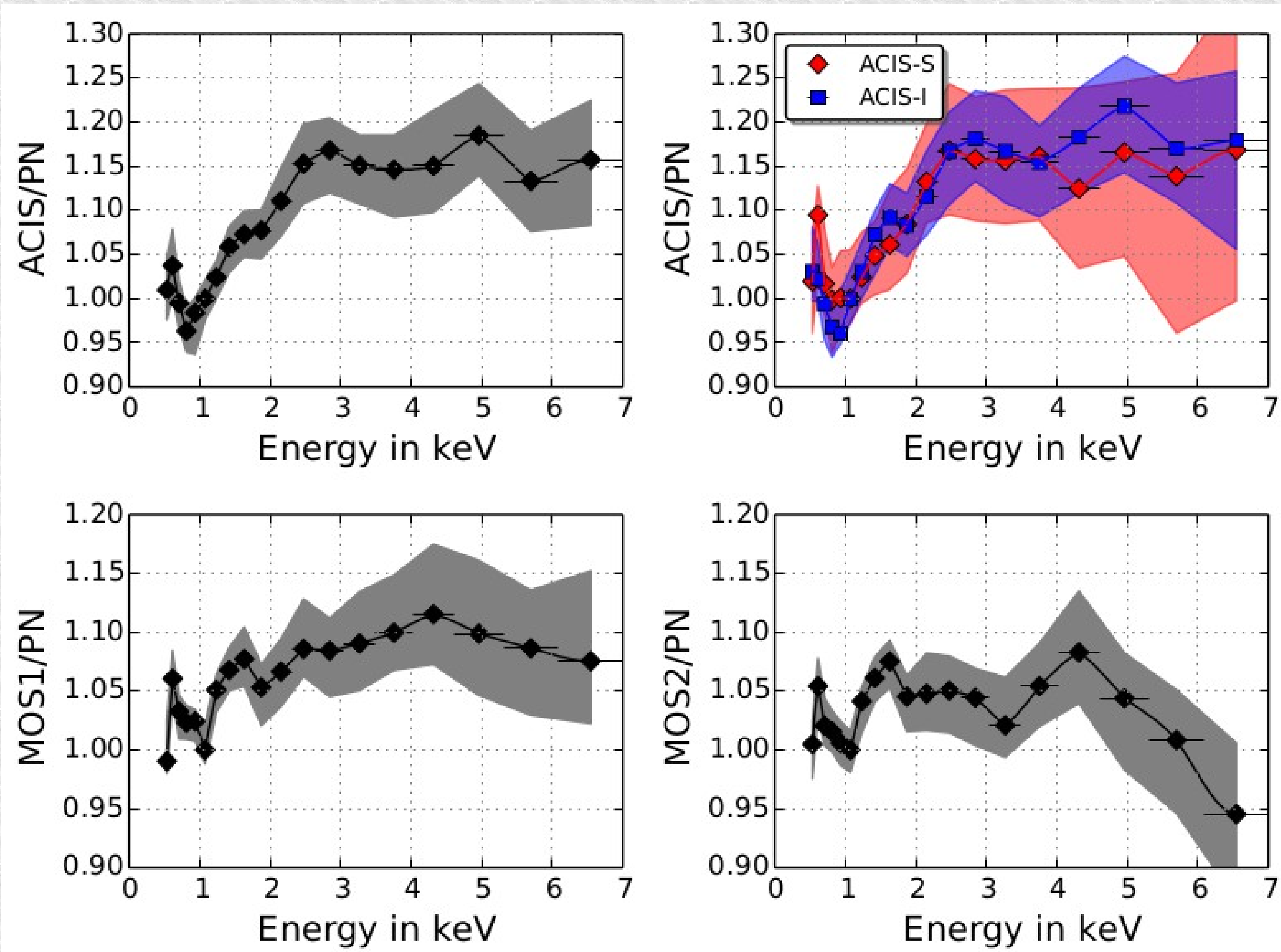
Zhao H.H. et al. 2015

2) modarf tool

HIFLUGCS

Schellenberger et al., 2015, A&A, 575, 30

$$R_{i\,7\,pn} = \frac{data_i}{model_{pn} \otimes resp_i} \times \frac{model_{pn} \otimes resp_{pn}}{data_{pn}}$$



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

Energy [keV]	ACIS/PN y	ACIS/PN y''	MOS1/PN y	MOS1/PN y''	MOS2/PN y	MOS2/PN 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

- MODARF - Python-Script for modification of XMM-Newton/EPIC and Chandra/ACIS effective areas according to the stack residual ratios in Schellenberger et al. 2015, A&A, 575, 30

- MODARF tool in the IACHEC WIKI page:
https://wikis.mit.edu/confluence/display/iachec/Data3

- Modifies the input arf, assuming the user-defined reference instrument arf is accurately calibrated

- Only the shape (i.e. energy dependence) of the effective area is correctly modified. The normalisation of the effective area is forced to remain unchanged at 1.1 keV during the arf modification. Thus, the tool is valid for studying the cross-calibration uncertainty effect on the temperatures, but not on fluxes.

- Scaling factors were computed with Chandra CALDB 4.5.5.1 and XMM-Newton calibration files from 14.12.2012 .

- Requirements: python(2.x), astropy (pyfits), numpy

- Usage: python modarf.py [input-arf] [outfile] [mode]

mode	input_instr	reference_instr
1	ACIS	PN
2	ACIS	MOS1
3	ACIS	MOS2
4	PN	ACIS
5	PN	MOS1
6	PN	MOS2
7	MOS1	ACIS
8	MOS1	PN
9	MOS1	MOS2
10	MOS2	ACIS
11	MOS2	PN
12	MOS2	MOS1

3) X-ray v.s. grav lens

RECONCILING *PLANCK* CLUSTER COUNTS AND COSMOLOGY?

Chandra/XMM instrumental calibration and hydrostatic mass bias

Holger Israel
Durham University

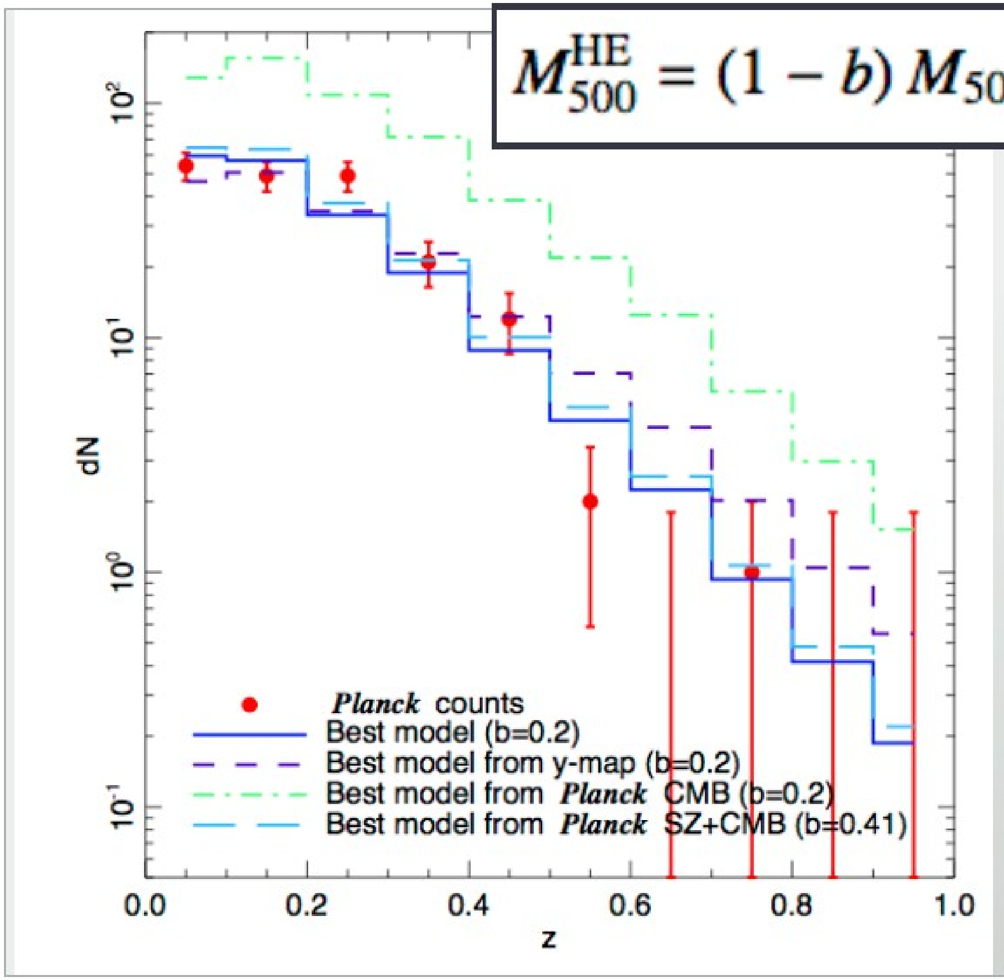
Birmingham Extragalactic Workshop

2015-02-17

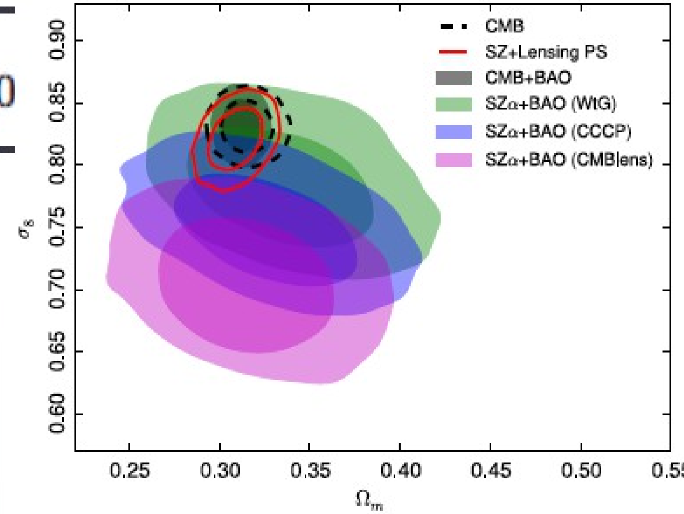
HI, G. Schellenberger, J. Nevalainen, R. Massey, T. Reiprich: MNRAS 448, 814 (2015); arXiv/1408.4578v2

The *Planck* cluster counts – CMB discrepancy

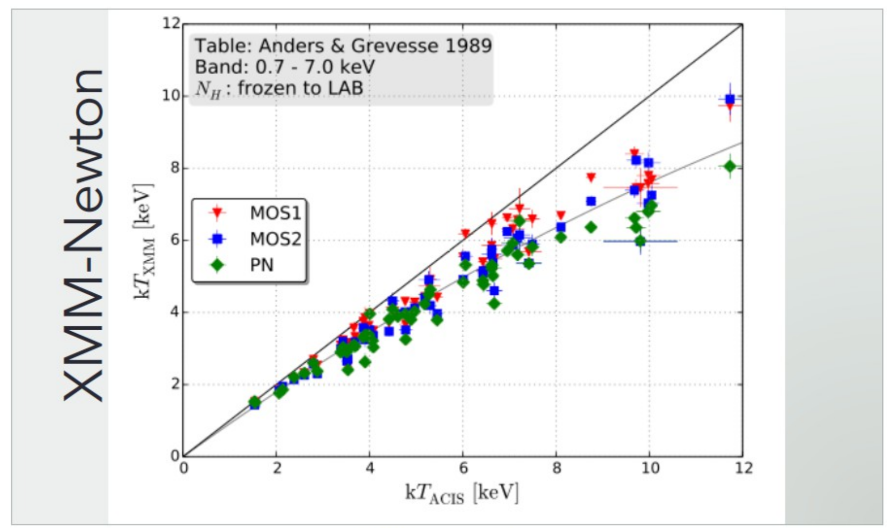
$$M_{500}^{\mathrm{HE}} = (1-b)\, M_{500}$$



Planck Collab. 13 XX, Planck Collab. 15 XXIV



Chandra and XMM temperatures disagree



XMM-Newton

Chandra

Schellenberger+14

Chandra masses

XMM masses

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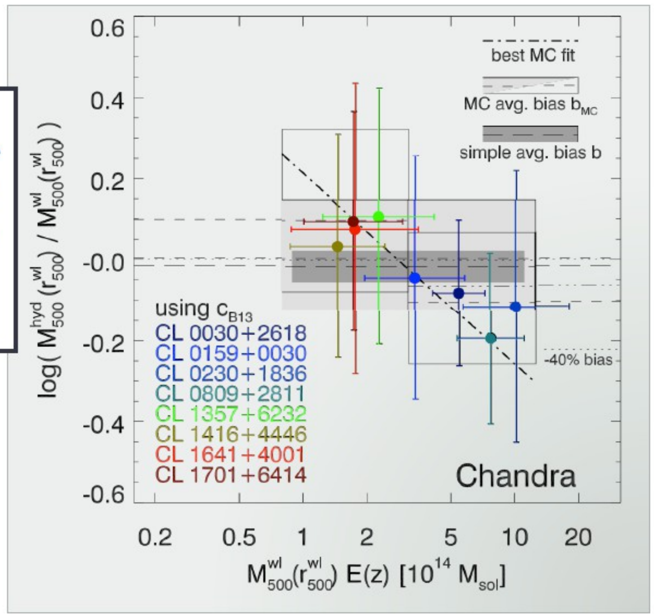
Hydrostatic mass bias in the *400d* clusters

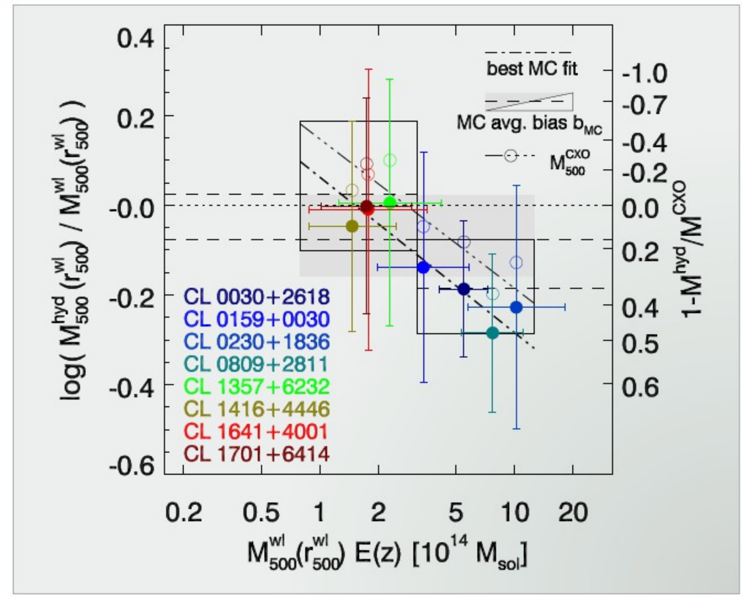
Direct calculation of hydrostatic mass profile Vikhlinin+09a *Chandra* T_X and density profiles, assuming Reiprich+13 temperature profile



HI+14a

11

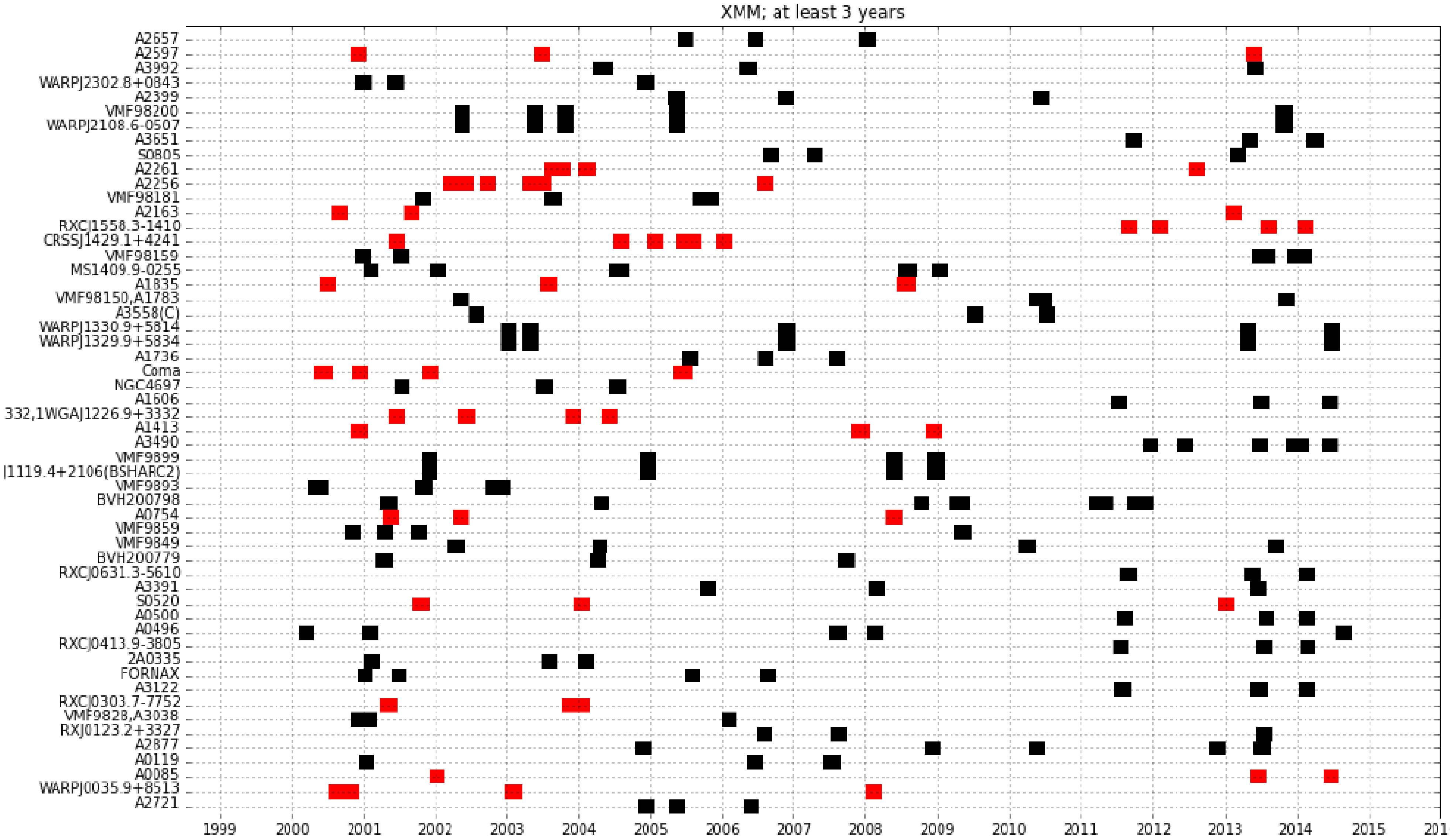
A larger hydro mass bias after conversion



HI+14b

- If XMM is accurately calibrated, there is 20% hydrostatic bias, as expected from simulations
- If Chandra is accurately calibrated, there is no hydro bias
- Who knows?

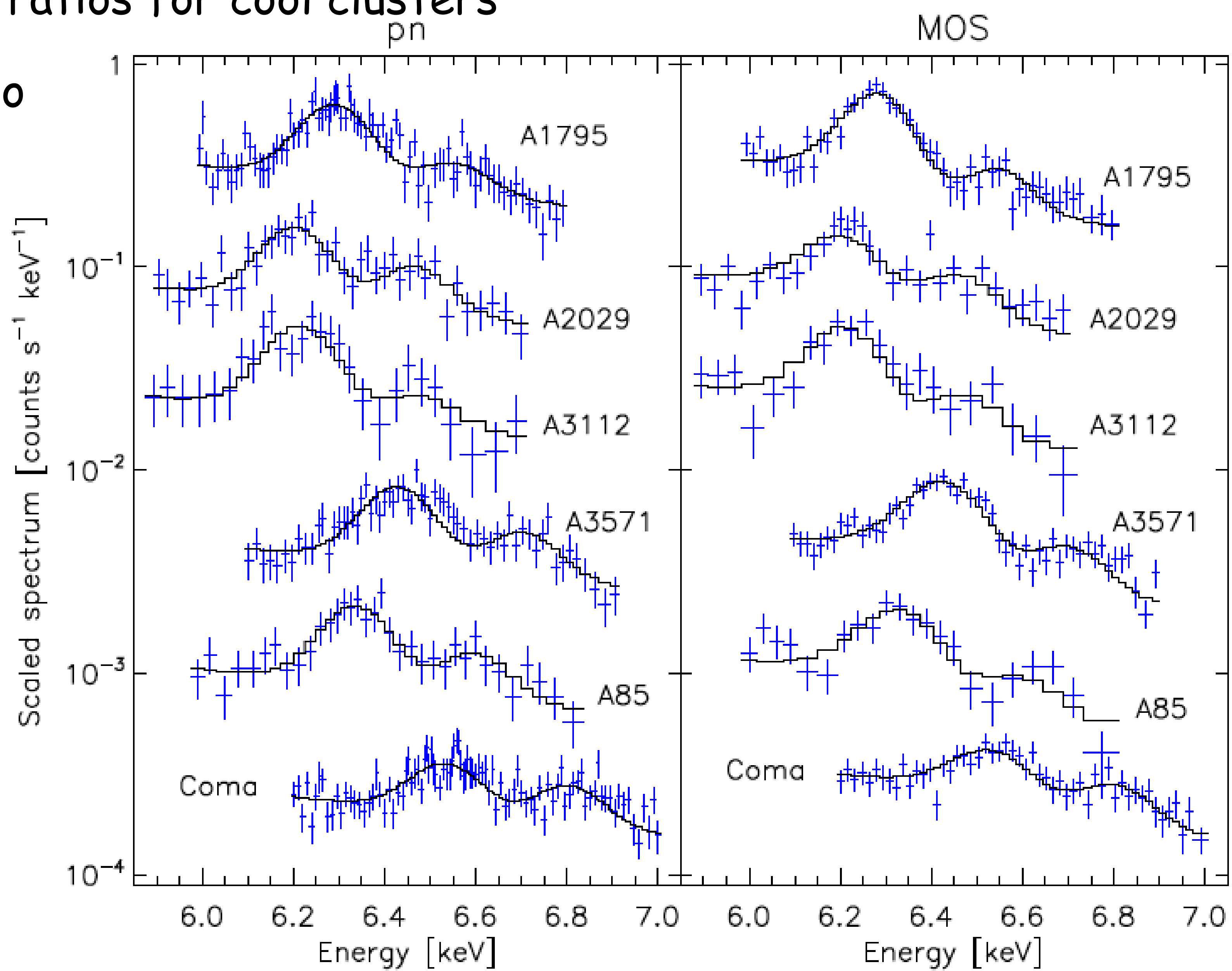
4) Plans for using HIFLUGCS sample for time variablity study and Fe XXV/XXVI calibration



- Multiple pointings of a given cluster
- Stability/time variability of effective area
- Is this interesting?

- Fe XXV/XXVI with bigger sample and more exposure time than in Nevalainen+2010
- Also S line ratios for cool clusters
- Chandra too

J. Nevalainen et al.: IACHEC cluster calibration



5) Multi-Mission Study

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

10th IACHEC meeting 2015, Fragrant Hill, Beijing

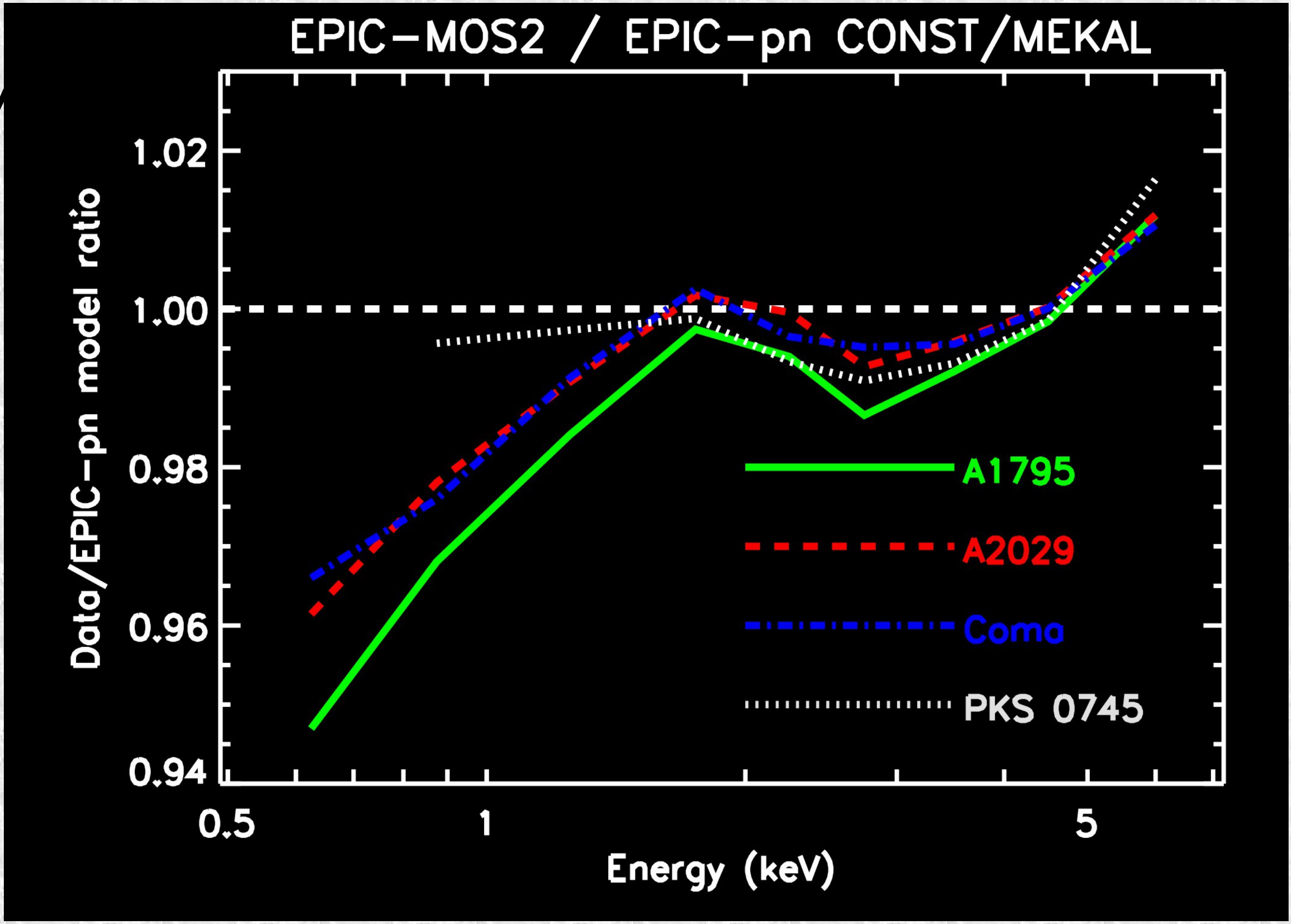
- Comparison of cluster measurements with XMM-Newton/EPIC, Chandra/ACIS, Swift/XRT, Suzaku/XIS, ROSAT/PSPC and NuSTAR: 6 missions, 12 instruments
- Residual ratios to evaluate the effective area cross-calibration:
  - We use EPIC-pn as a reference. (Try also ACIS, **TBD**)
  - For instrument **i** we calculate the median and the mean absolute deviation of the ratio

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

- 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 differences at the level of statistical error of 2%.



Cluster selection criteria

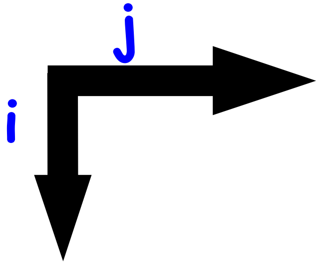
- Hot enough so that we
  - have enough counts at the highest energies
  - minimise the 1 keV line emission (we are studying the effective area, not PSF or energy scale calibr.)

  → kT > 6 keV

- Not too distant so that the cluster is not too faint i.e. z < X
- Observed with XMM-Newton, Chandra, Suzaku, Swift and ROSAT by > 10ks

  → **A1795, A2029, Coma, PKS 0745-19**

  (Maybe more, TBD)



Data base

	A1795	A2029	Coma	PKS 0745-19
XMM	☺	☺	☺	☺
Chandra	☺	☺	☺	☺
Suzaku	☺	☺	☺	☺
Swift	☺	☺	☺	☺
Rosat	☺	☺	☺	☺
NuSTAR	GO?	GO?	☹	GO?
eRosita	?	?	?	?
AstroSat	☺	?	?	☺
Astro-H	☹	☹	☹	☹

Astro-H

- Clusters do not contribute much in the HXD
- Clusters not good for internal AstroH calibration
- Blazars good for both internal and cross-mission calibration, and thus are preferred
- A1795 (off-set)
- A3571 mentioned in the calibration source list...
- Coma mentioned in the calibration source list...
- Have to do through science AO

Astrosat

- Currently **A1795, PKS 0745-19**, A496, Perseus in the calibration program
- JN discussed with K. Mukerjee about adding A2029 and Coma to Astrosat calibration program. He will talk with Astrosat team about this
- Might not work, because clusters do not contribute much on the hard band.
- If it does not work, JN will write a science proposal for these.

eRosita

- All sky observed, including MMS list, but only shortly ($\approx$ 1ks)
- Michael Freyberg from eRosita team tries to cover our clusters with pointed observations

NuSTAR AO1

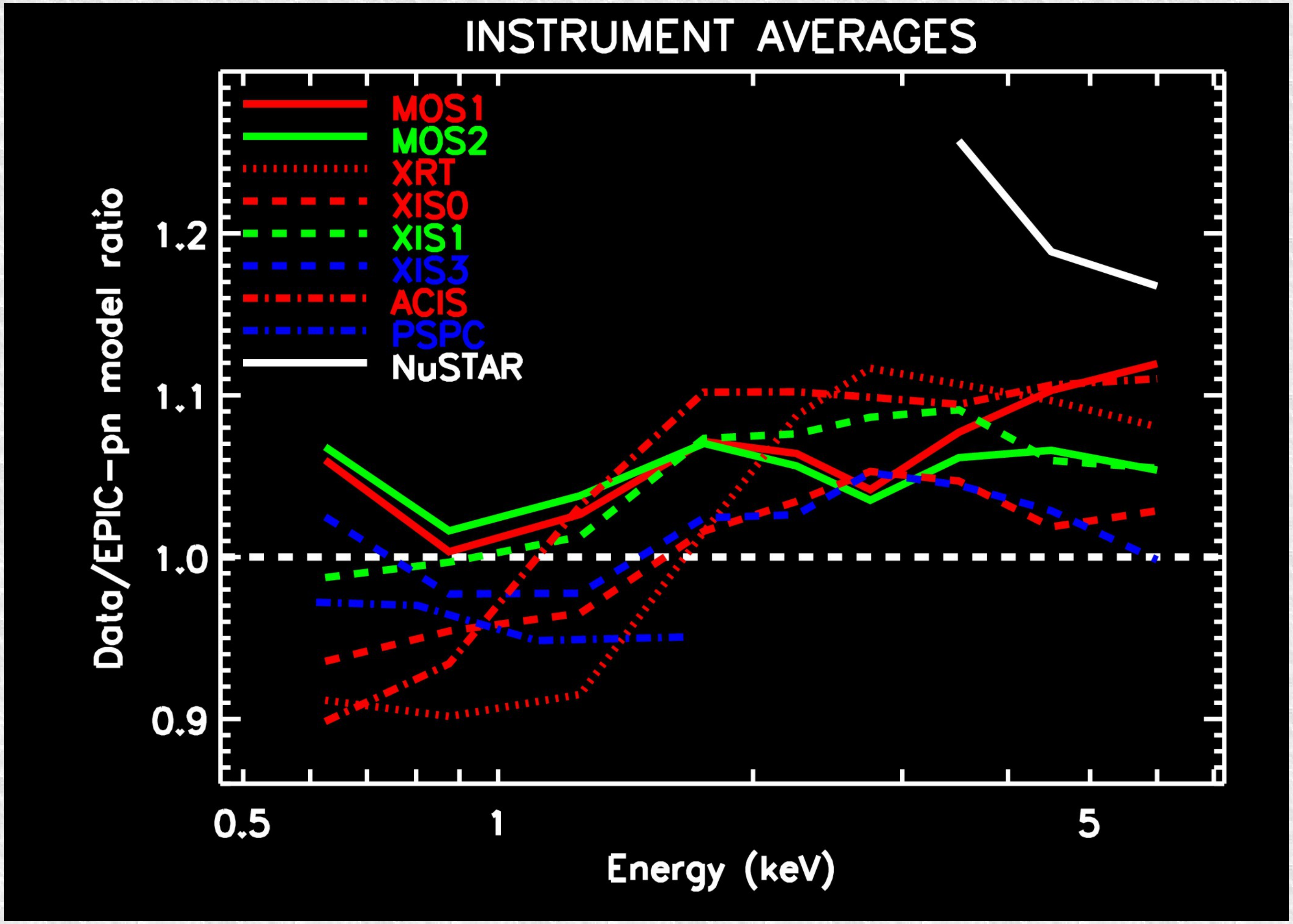
- Coma from our list already observed, but problematic due to large extent: bright out-of-fov regions produce stray light
- In 1st AO (2014) only one cluster accepted: A2163
- How many proposed?
- Let's propose A2029, A1795 and PKS 0745-19 for temperature constrain at high energies, can be used also for the cross-calibration. Collaboration with Karl Forster.

5.1 Preliminary results

(ACIS COMA TBD)

Residuals ratios

- The average instr/pn residual ratio of each pair

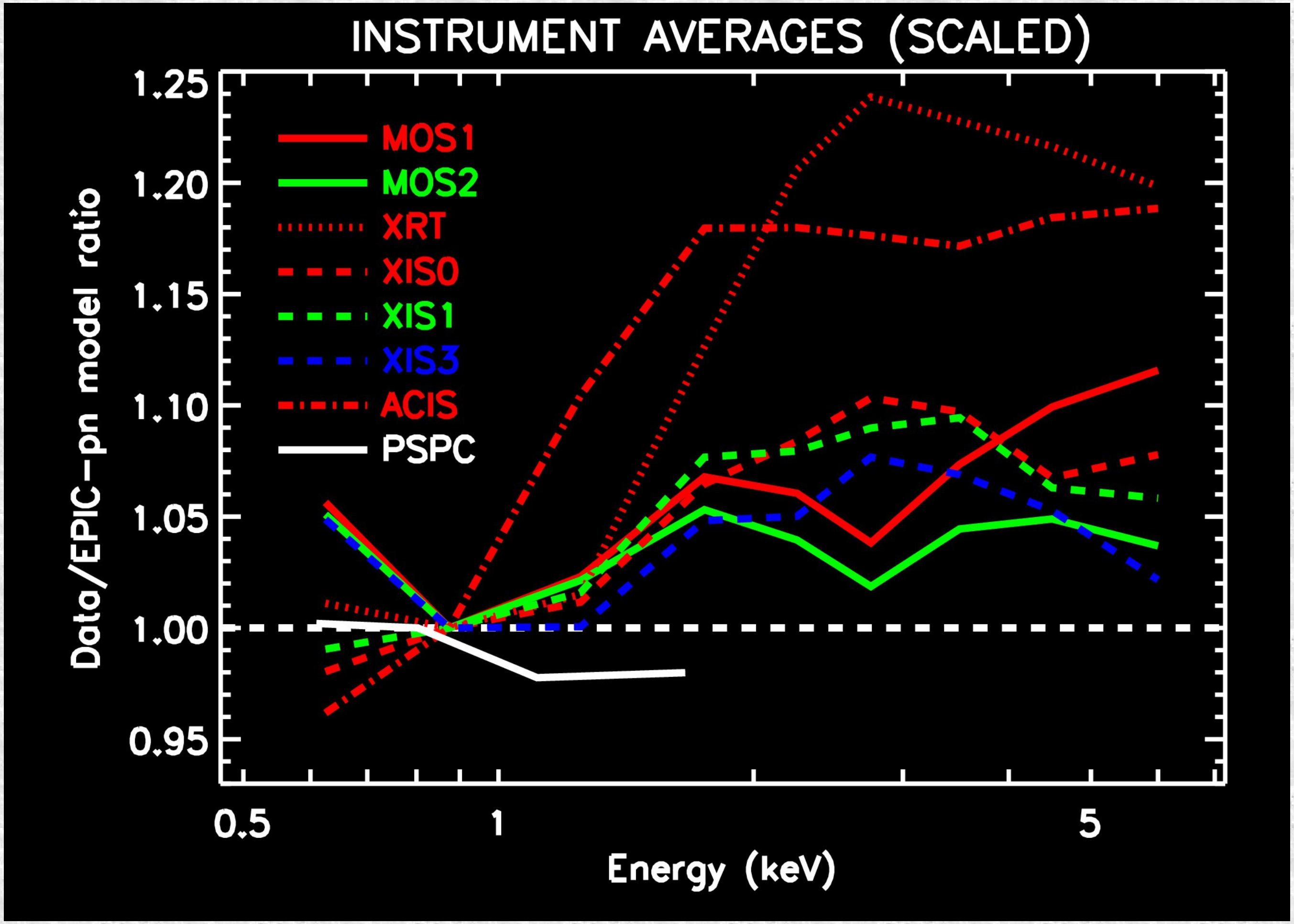


All instruments show higher flux than pn at > 2 keV, but with a varying degree

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

Scaled residuals ratios

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



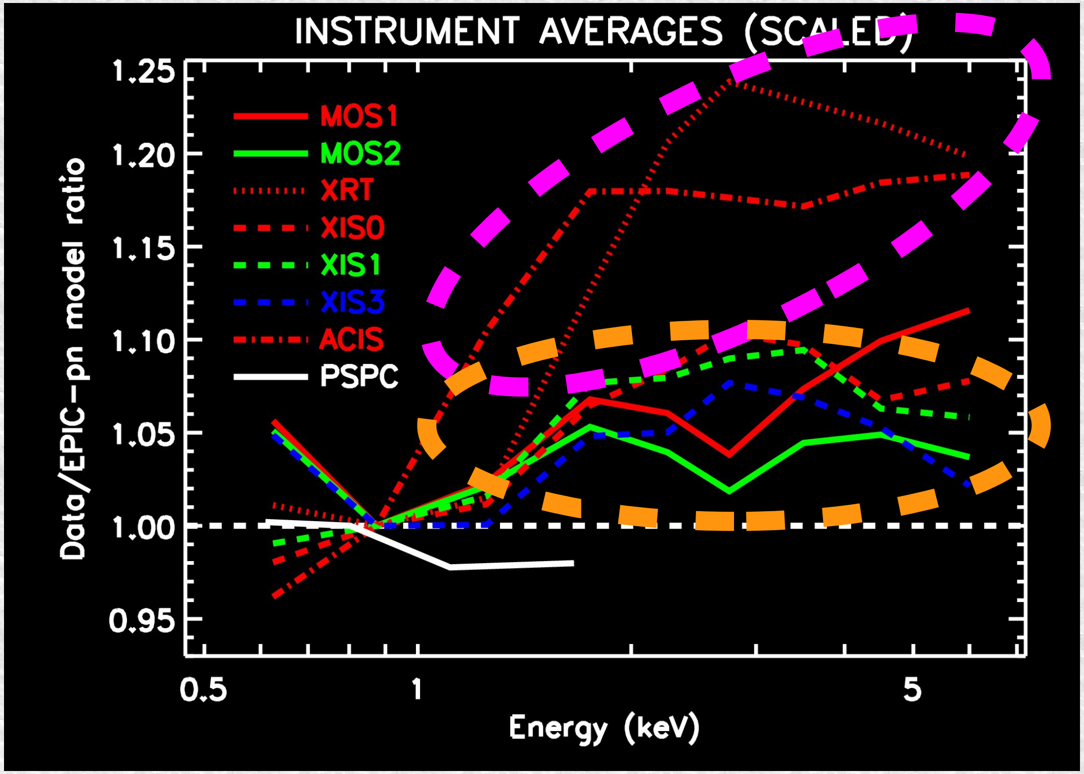
1) XMM/MOS and Suzaku/XIS similar: 10% increase at 1-2 keV

2) Swift/XRT and Chandra/ACIS similar: 20% increase at 1-2 keV gradient

➔ Not a single instrument is quilty

Scaled residuals ratios

Request to IACHEC community: explain why there are the two groups.



A) Chandra/ACIS + Swift/XRT

B) EPIC/MOS + Suzaku/XIS

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

I.e. is (are) there some element(s) of the effective area instrumentation or calibration that is (are) common within the groups, but different btw. the groups?

6) Action items

IACHEC Clusters of Galaxies WG Action items April 2015

1) HIFLUGCS Fe and S emission line ratio spectroscopy ***(Gerrit, JN)***
2) HIFLUGS data to WIKI ***(Gerrit, JN)***
3) Multi Mission Study ***(JN...)***
4) Residual ratios for simultaneous XMM/Chandra blazar observations ***(JN, M. Smith, H. Marshall)***
5) Astro-H AO ***(JN)***
6) AstroSat calibration time / AO ***(JN, K. Mukerjee)***
7) NuSTAR AO ***(JN, Karl Forster)***
8) HXMT Coma simulations ***(JN, Song Liming)***

7) Final answer to whether Chandra or XMM is right

Chandra v.s. XMM