Clusters of galaxies WG report

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11th IACHEC meeting, 2016, IUCAA, India

IACHEC Clusters of Galaxies WG Action items from 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) eROSITA

1) Multi-Mission Study

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

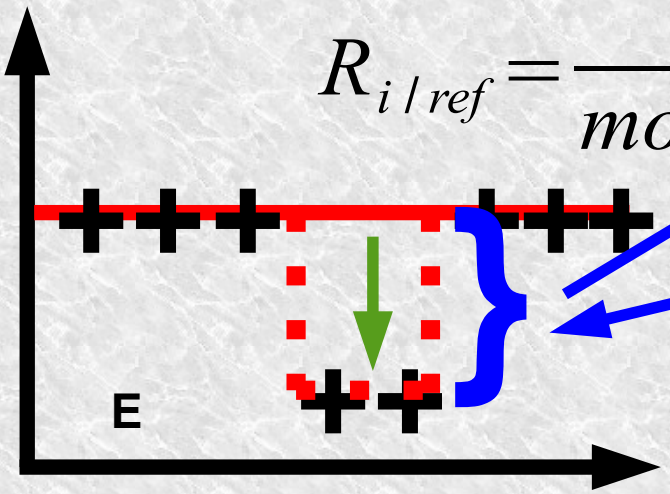
11th IACHEC meeting 2016, Pune, India

1.1) Method for evaluating cross-cal uncertainties

Stack residuals method

- A phenomenological mathematical model that fits the data is OK for cross-cal
- Since we know the relative difference between the data ref and model ref, we can use this info to correct the model prediction to match the data (fudge factor kind of thing)
- A second term on the R formula does exactly that

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

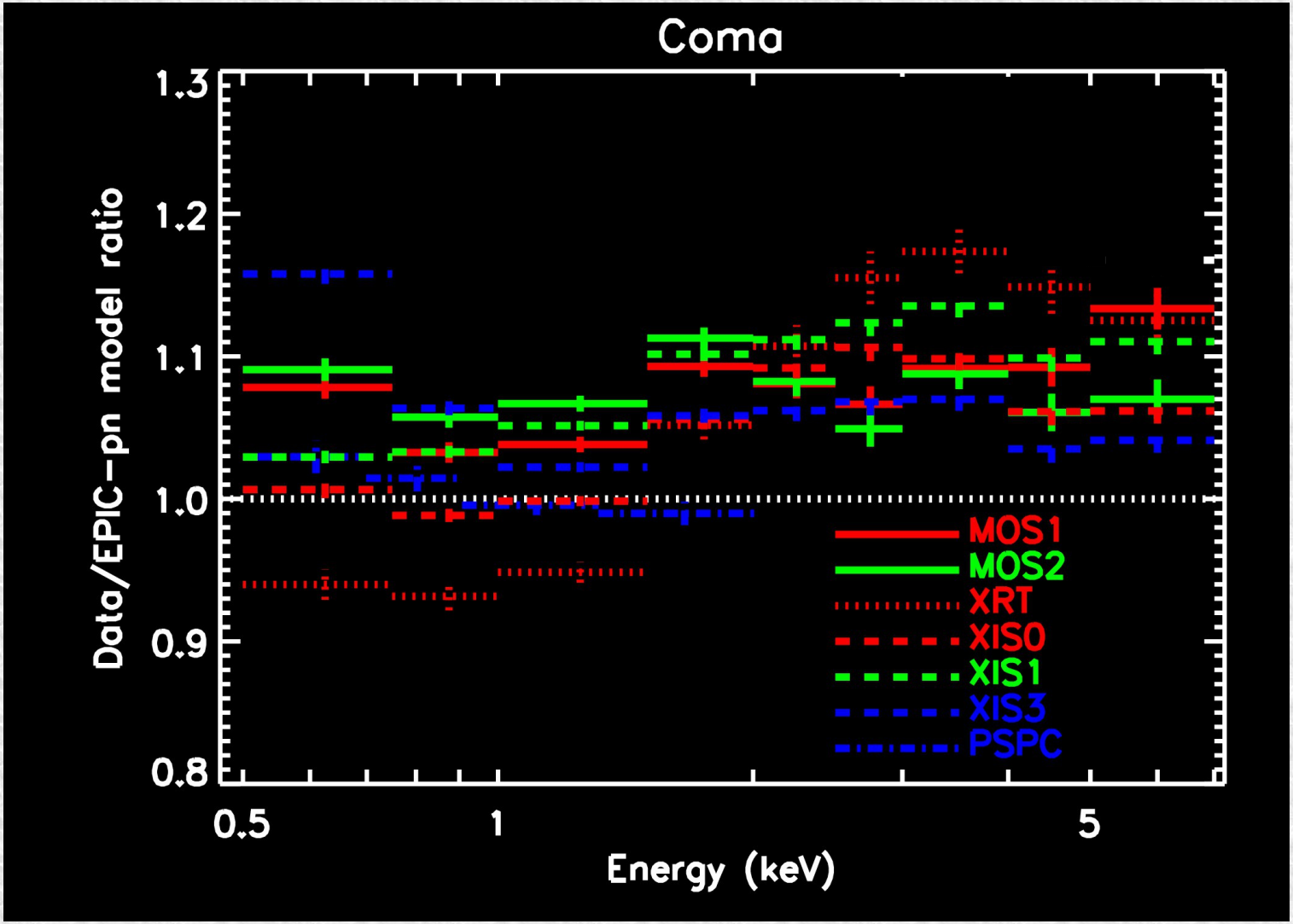


Define extraction region

- So it is OK to use mergers and cool cores and fit them with whatever model ➔ extract spectra from clustercentric circle with extraction radius r_{ext}
- Lower limit of r_{ext} affected by requirements of
  - a few% statistical precision in small enough spectral bins
  - At the moment we use 9 bins ➔ need 100000 counts

Statistical precision

- Coma r_{ext} = 6' : 17 ks EPIC exposure, 1% statistical precision in 9 bins in 0.5-7.0 keV band

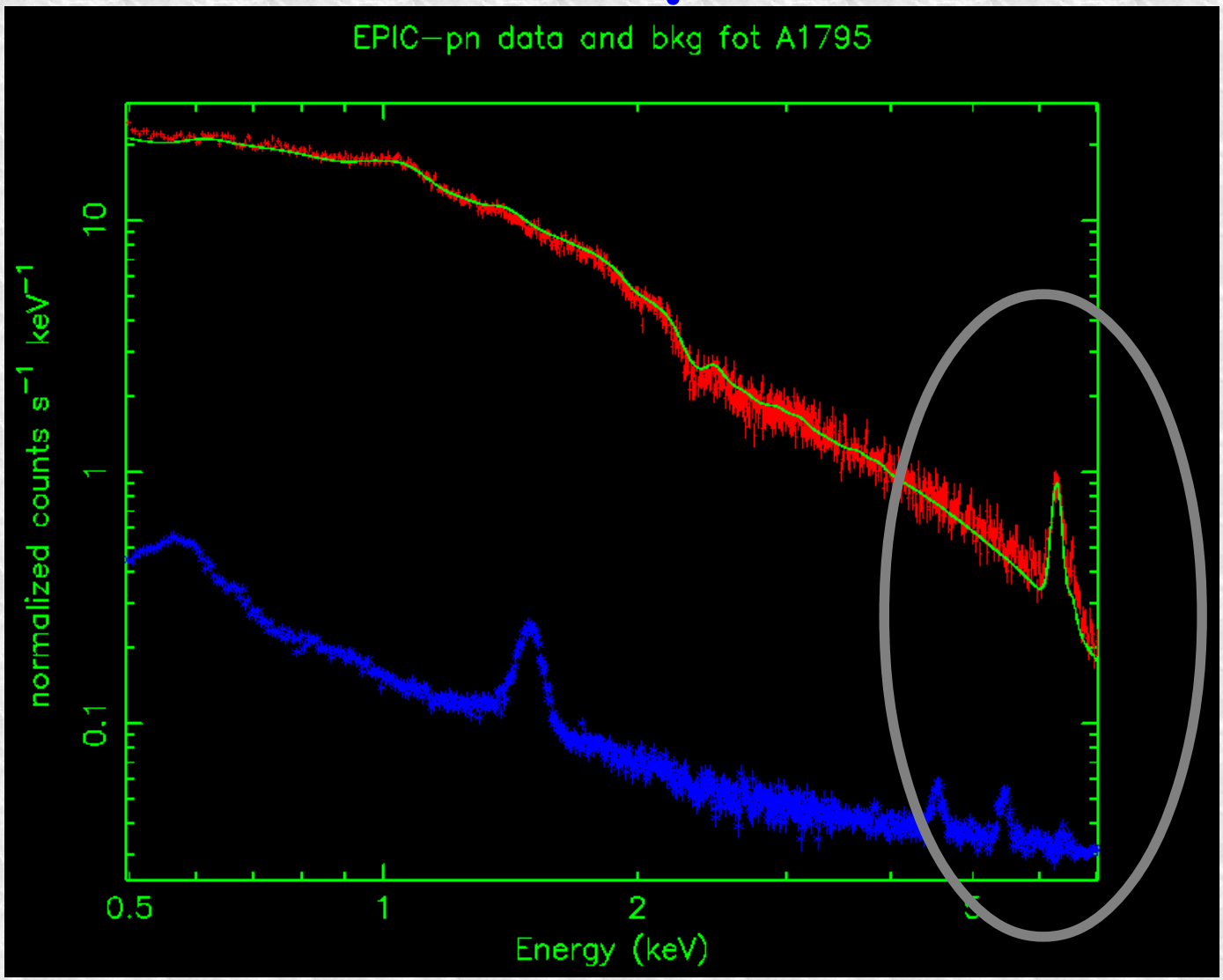


Define extraction region

- Upper limit of r_{ext} affected by requirements of
  - Bkg below 10% of signal in the 0.5-7 keV range
- At the moment we use r_{ext} = 6 arcmin

Bkg/source signal for A1795 with XMM-Newton pn

- r_{ext} > 6' makes things worse at E = 7 keV
- KT < 6 keV makes things worse at E = 7 keV



1.3) Cluster selection

Cluster selection criteria

- Hot enough so that we
  - have enough counts at the highest energies *(Perseus is an exception, perhaps a few more* ***TBD****)*
  - minimise the 1 keV line emission (we are studying the effective area, not RMF nor energy scale calibration), i.e kT > ≈ 6 keV

1.4) Current sample

Sample

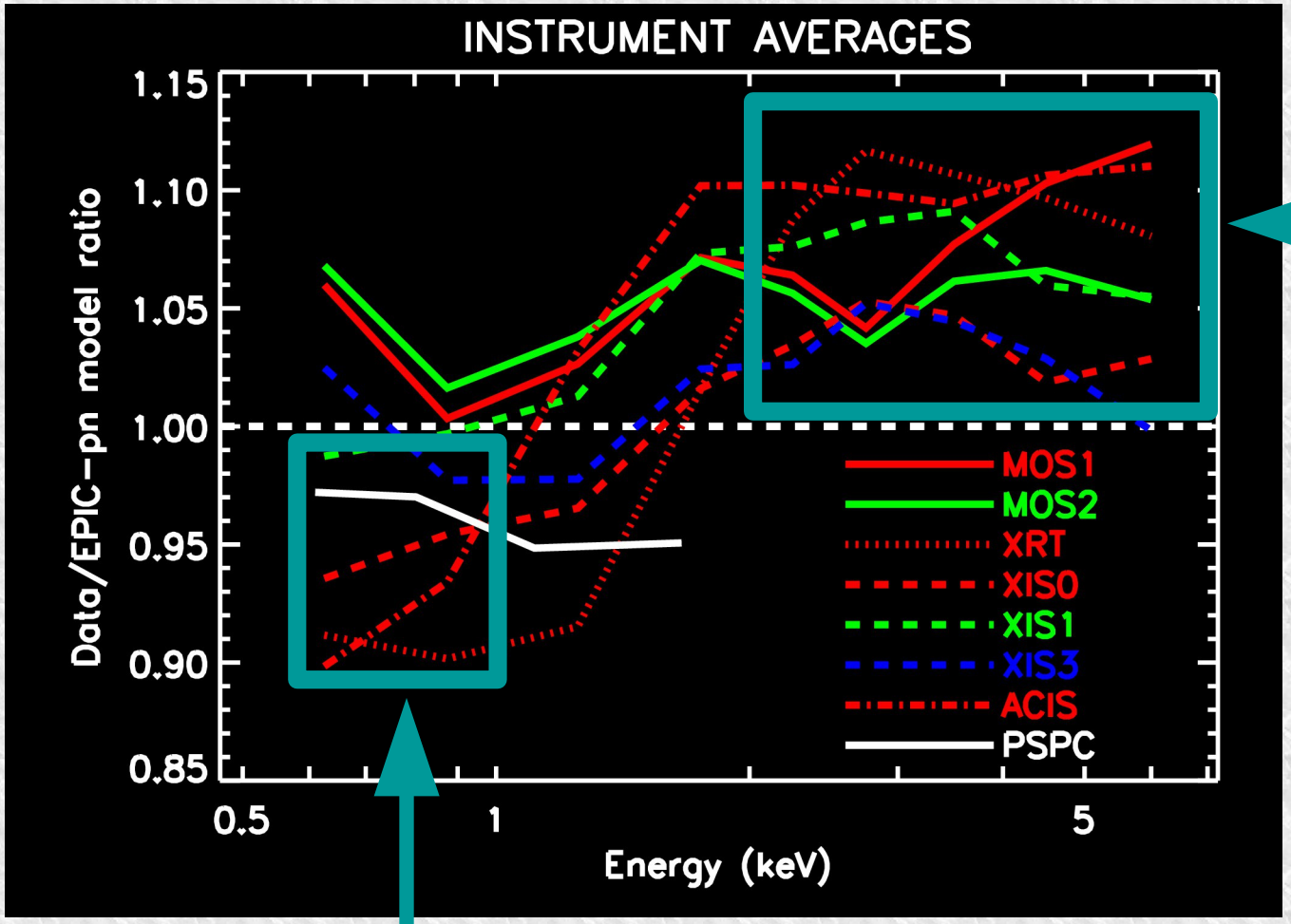
- Currently the sample consists of

  A1795, A2029, Coma and PKS 0745-19

1.5) Preliminary results from the 4 clusters sample

Residuals ratios

The average instr/pn residual ratio of each pair



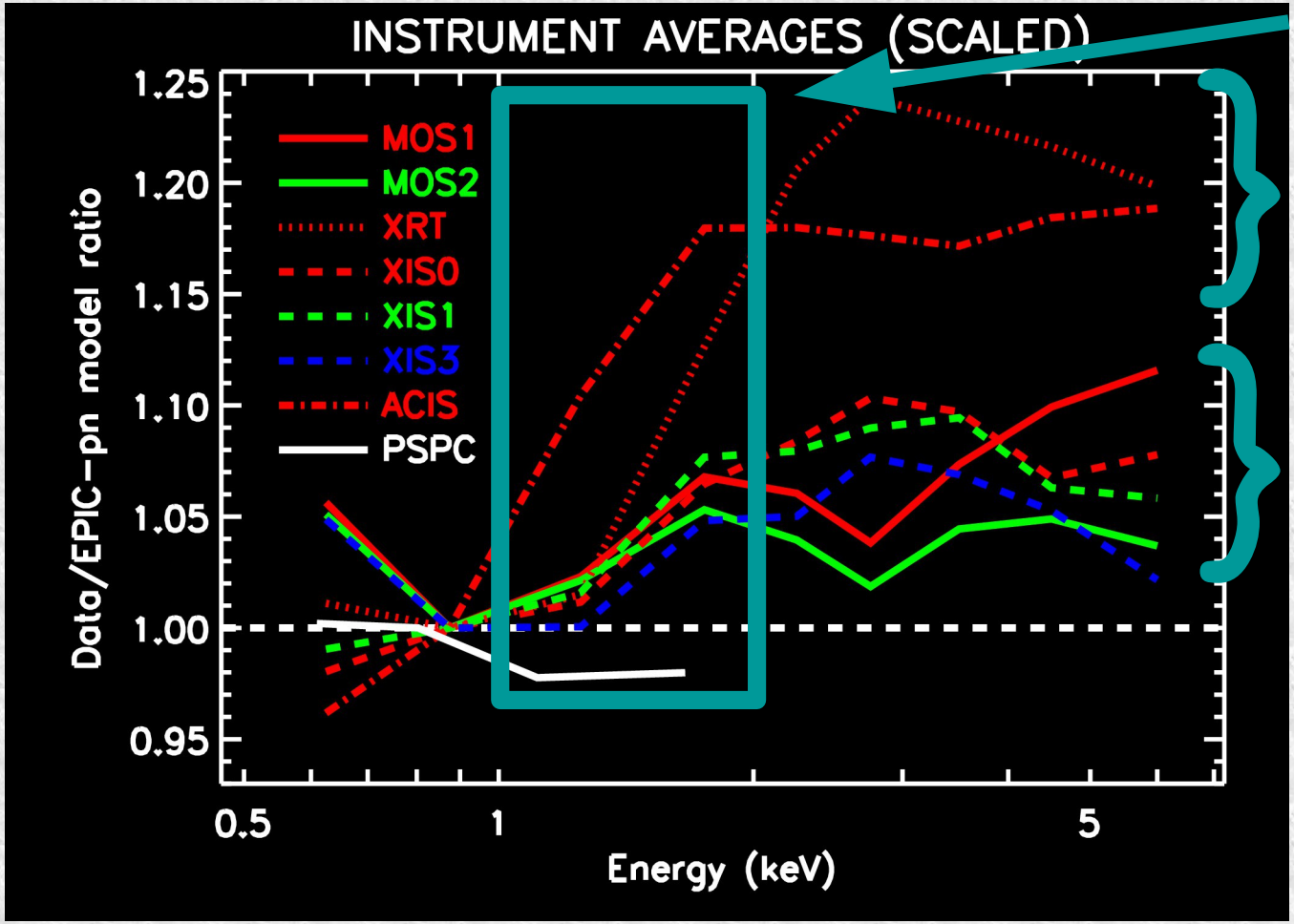
All instruments show higher flux than pn at > 2 keV, but with a varying degree (0-15%)

Most instruments show lower flux than pn at < 1 keV, but with a varying degree (0-10%)

Request 1 to IACHEC community: Are the evidence convincing enough to make conclusions about EPIC-pn calibration?

Scaled residuals ratios

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



The 1-2 keV gradient:

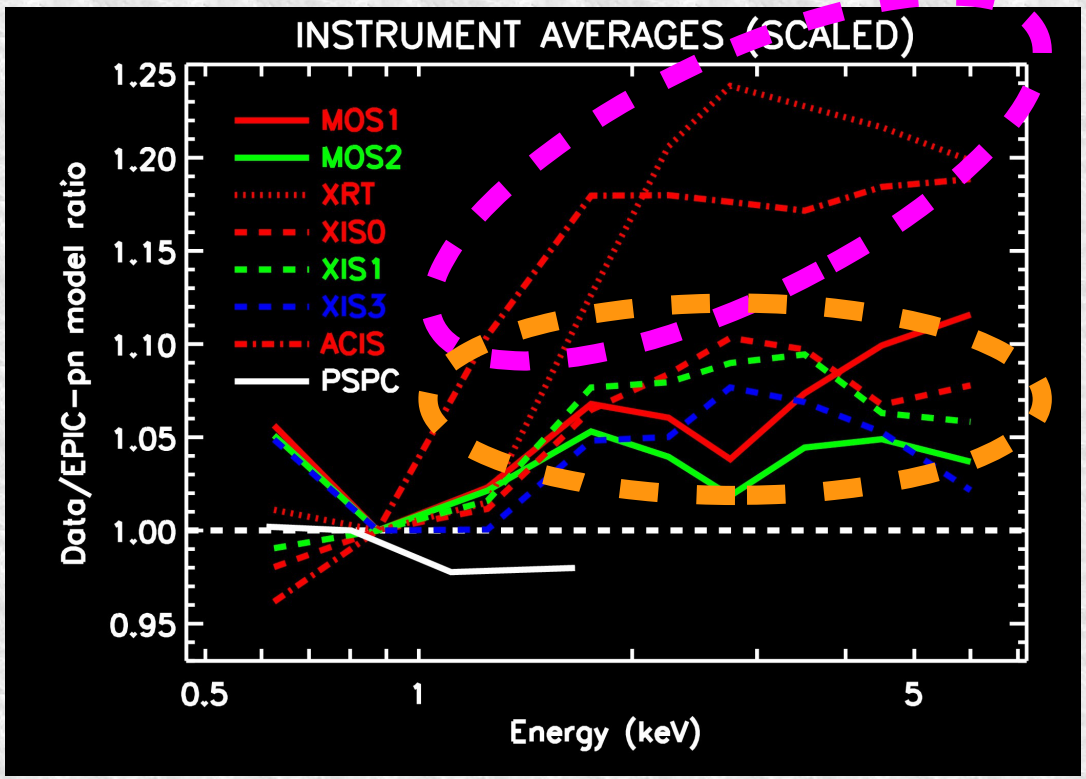
1) Swift/XRT and Chandra/ACIS similar: 20% increase

2) XMM/MOS and Suzaku/XIS similar: 5% increase

➔ Not a single instrument is guilty

Scaled residuals ratios

Request 2 to IACHEC community: explain why there are the two groups



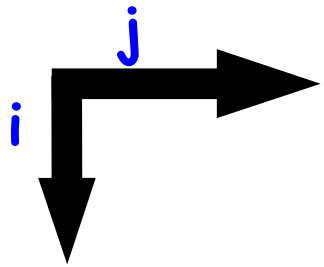
The average instr/pn residual ratio of each pair, scaled to unity at 0.75-1.0 keV

A) Chandra/ACIS & Swift/XRT

B) EPIC/MOS & Suzaku/XIS

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

1.6) More satellites/instruments



Current data base

	A1795	A2029	Coma	PKS 0745-19
XMM	☺	☺	☺	☺
Chandra	☺	☺	☺	☺
Suzaku	☺	☺	☺	☺
Swift	☺	☺	☺	☺
Rosat	☺	☺	☺	☺
NuSTAR	😐	😐	☹	😐
eRosita	😐	😐	😐	😐
AstroSat	☺	😐	😐	too short
Astro-H	☹	☹	☹	☹

2) Increase the current cluster sample

More clusters

- Need more clusters to be able to derive statistically robust conclusions (e.g. when applying Prof. Meng's method)
- Following list consists hot nearby clusters from HIFLUGCS sample, following these criteria:
  - kt > 6 keV, except for Perseus
  - Offset btw. the cluster center and pointing FOV center < 3 arcmin
  - Exposure > 10 ks in the available data

X: XMM/EPIC

C: Chandra/ACIS

R: ROSAT/PSPC

SW: Swift/XRT

SU: Suzaku/XIS

AS: Astrosat/SXT

A1835?

cluster	X	C	R	SW	SU	AS
A85	☺	☺	☺	☹	☹	☹
A119	☺	☺	☺	☹	☹	☹
A399	☺	☺	☺	☹	☹	☹
A401	☺	☺	☺	☺	☹	☹
A478	☺	☺	☺	☹	☹	☹
A754	?	☺	☹	☹	☹	☹
A644	☺	☺	☺	☹	☹	☹
A1413	☺	☺	☺	☹	☹	☹
A1650	☺	☺	☹	☹	☹	☹
A1651	☺	☺	☺	☺	☹	☹
Coma	☺	☺	☺	☺	☺	☹
A1689	☺	☺	☺	☹	☹	☹
A1795	☺	☺	☺	☺	☺	☺
A1914	☺	☺	☺	☹	☹	☹
A2029	☺	☺	☺	☺	☺	☹
A2065	☺	☺	☹	☹	☹	☹
A2142	☺	☺	☺	☹	☹	☹
A2163	?	?	☹	☹	☹	☹
A2204	☺	☺	☺	☹	☹	☹

cluster	X	C	R	SW	SU	AS
A2244	☺	☺	☺	☺	☺	☹
A2255	☺	☺	☺	☹	☹	☹
A2256	☺	☺	☺	☹	☺	☹
A2319	☺	☺	☹	☹	☹	☹
A3158	☺	☺	☹	☹	☹	☹
A3266	?	☺	☹	☹	☹	☹
A3391	☺	☺	☺	☹	☹	☹
A3558	☺	☺	☹	☹	☹	☹
A3571	☺	☺	☺	☹	☺	☹
A3627	?	?	☺	☹	☺	☹
A3667	?	☺	☺	☹	☺	☹
A3827	☺	☺	☹	☹	☹	☹
A3888	☺	☺	☺	☹	☹	☹
Ophiu	☺	☺	☺	4ks	☺	☹
Perse	☺	☺	☺	☺	☺	☺
PKS0745	☺	☺	☺	☺	☺	☹
RXCJ1504	?	?	?	☹	?	☹
Triang	☺	☺	☺	☹	☺	☹
ZwCl1215	☺	☺	☹	☹	☹	☹

All 5 instruments

- 6 (or 7) clusters observed with all with good enough data
  - Sample too small **(is it?)** for proper statistics (Prof Meng's method) ☹
  - Common wisdom not true: "Your clusters will eventually be observed, don't worry" ☹
  - Need to promote the cluster sample to the instrument calibration teams to be able to proceed. This is hard even with the 4 clusters. ☹
    - Try pushing the 10-20 keV band of the hottest clusters **(TBD)**
  - Calibration via science AO: contrived. Hard to make a competitive proposal by justifying scientifically the most studied bright nearby clusters ☹

    ➔ Need to pick the data if/when observed, as before ☹
  - Fortunately **ATHENA** team has cross-mission calibration early in the mission planning ☺

Subsamples of instruments

- XMM + Chandra + Swift ≈ 9 clusters
- XMM + Chandra + Suzaku ≈ 10 clusters

➔Numbers remain small

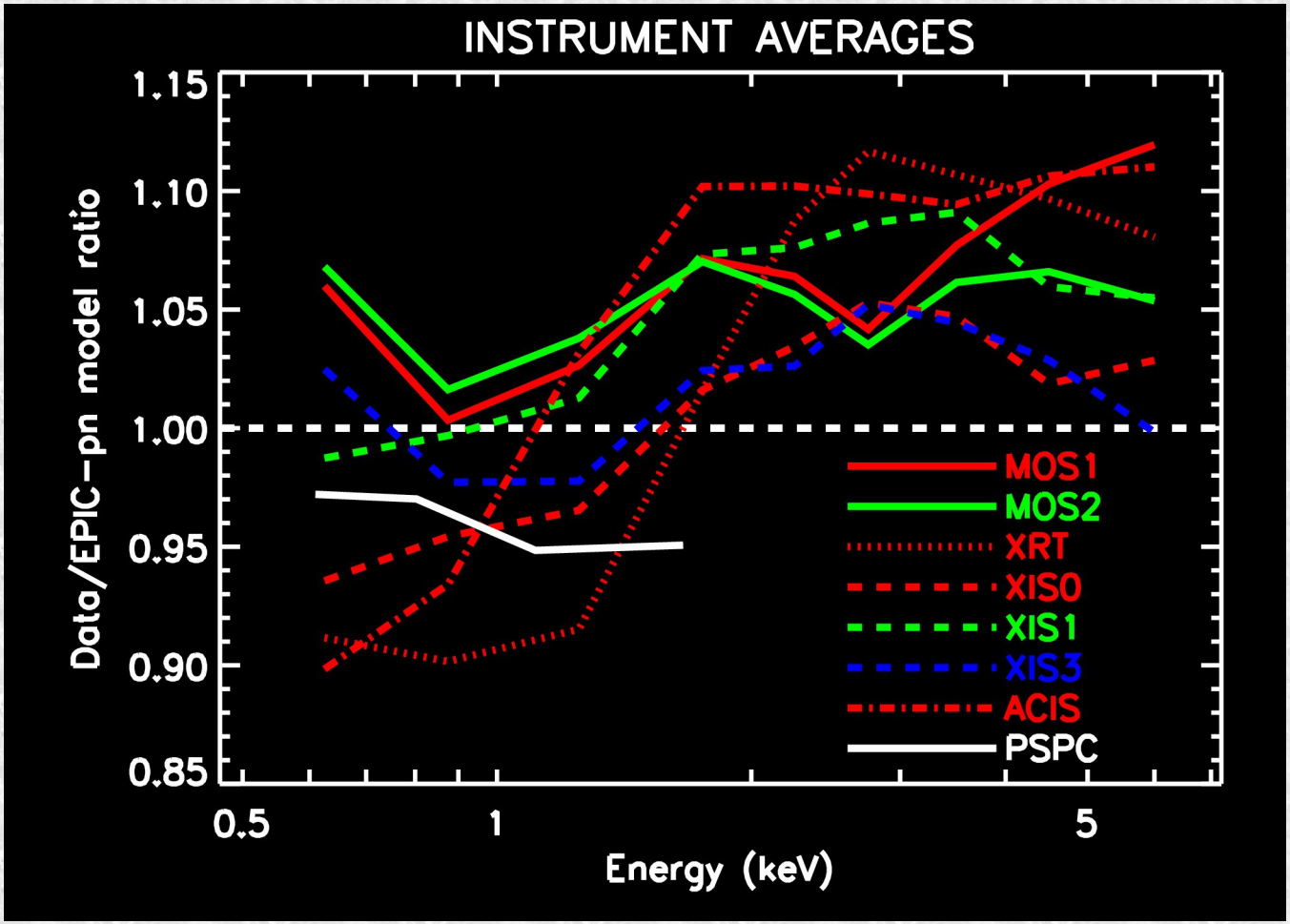
Subsamples of instruments

- XMM + Chandra + ROSAT : 25 clusters
  - This is currently the only statistically useful sample
  - Requires 250 ks of XMM time, i.e
  - Similar eROSITA time **(is this feasible?)**
  - Ms ASTROSAT time **(not feasible)**
  - Ms AstroH time **(not feasible)**
  - 25 ks of ATHENA time **(piece of cake, right?)**

- Add cooler very nearby clusters, which might have enough counts up to E=7 keV (like Perseus)

So?

- Let's add the available data XMM, Chandra, ROSAT, Swift, Suzaku) into sample, relaxing some of the criteria, and proceed for a publication

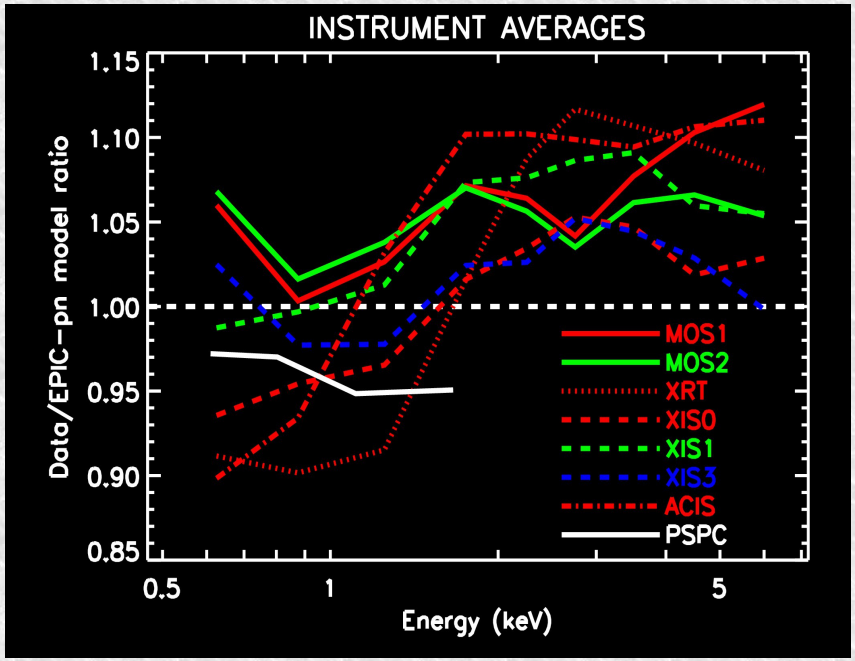


Let me be provocative

I know how to get τ values for Concordance Calibration

$R_{i,ref}$ = XMM-Newton/pn

- Stack residuals ratio $R_{i,ref}$ can be used to rank the instruments by their accuracy of A_{eff} calibration and thus to get the τ values
- If one instrument has problem with A_{eff} calibration and all others are right, the set of $R_{i,wrong}$ curves should be similar, i.e. the deviation between the curves is minimised
- Compute a set of $R_{i,ref}$ curves for each instrument as ref in turn
- For each set of $R_{i,ref}$ calculate the "accuracy parameter" J_{ref}
- Seriously: let's calculate $R_{i,ref}$ for each instr. and see how it looks



$$J_{ref} = stdev\left(R_{(i,ref)}(E)\right)$$

$$\tau = \frac{\left(J_{ref}\right)}{\left(max\left(J_{ref}\right)\right)}$$