4) Gravitational lensing v.s. X-ray masses
Clusters of galaxies WG report

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

Spline parameters for stack residuals ratio = effective area cross-cal uncertainty
\[
\log \left( \frac{kT_{pn}}{1 \text{ keV}} \right) = 0.836 \times \log \left( \frac{kT_{ACIS}}{1 \text{ keV}} \right) + 0.016
\]

Scaling between ACIS and pn 0.7-7.0 keV band temperatures
Schellenberger et al, 2014 v.s. Nevalainen et al., 2010

\[ \log \frac{kT_{pn}}{1 \text{ keV}} = a \times \log \frac{kT_{ACIS}}{1 \text{ keV}} + b \]
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

$$R_{i \over pn} = \frac{\text{data}_i}{\text{model}_{pn} \otimes \text{resp}_i} \times \frac{\text{model}_{pn} \otimes \text{resp}_{pn}}{\text{data}_{pn}}$$

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%. A bit bigger at lower energies, why?
Summary of 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.
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

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

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

Indication of 15% higher NuSTAR fluxes compared to pn
NuSTAR Coma analysis
(F. Gastaldello)

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

COMPARISON T A-pn 3-10 keV

Mean of the ratio pn/A 1.185 with stdev 0.204

**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 / Mpc$^3$ hotter than 10 keV
- If pn sees 0 clusters, argument for pn eff area adjustment