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INTEGRATED ACTIVITIES FOR THE HIGH-ENERGY ASTROPHYSICS DOMAIN



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# Cross-calibration consensus forum



Jukka Nevalainen  
13<sup>th</sup> IACHEC meeting, Italy, 2018



- ★ Action initiated in 2016 IACHEC meeting
- ★ A forum for dedicated discussion between the different working groups
- ★ Utilise the collective experience of IACHEC to go beyond the WG tasks
- ★ Attempt to understand the instruments as a whole
- ★ Verify that WGs are consistent
- ★ Ask and answer questions like:
  - How do the analyses of different types of objects look when put together?
  - Are the residuals btw two given instruments similar, independent of the object type? Should they be similar?
- ★ Experts on the calibration of different instruments could try to understand the cross-cal patterns. Find and test different sources of calibration problems. (Complementary to Concordance Calibration, PyBLocks)



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# Agenda for today

## 1) Consistence

1.1) Blazars v.s.clusters

1.2) Annual review of Stack Residuals Spectra

1.3) Comment round btw WG chairs before submission

## 2) Crab absolute flux measurement



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**1) Do we have a  
consistent picture?**



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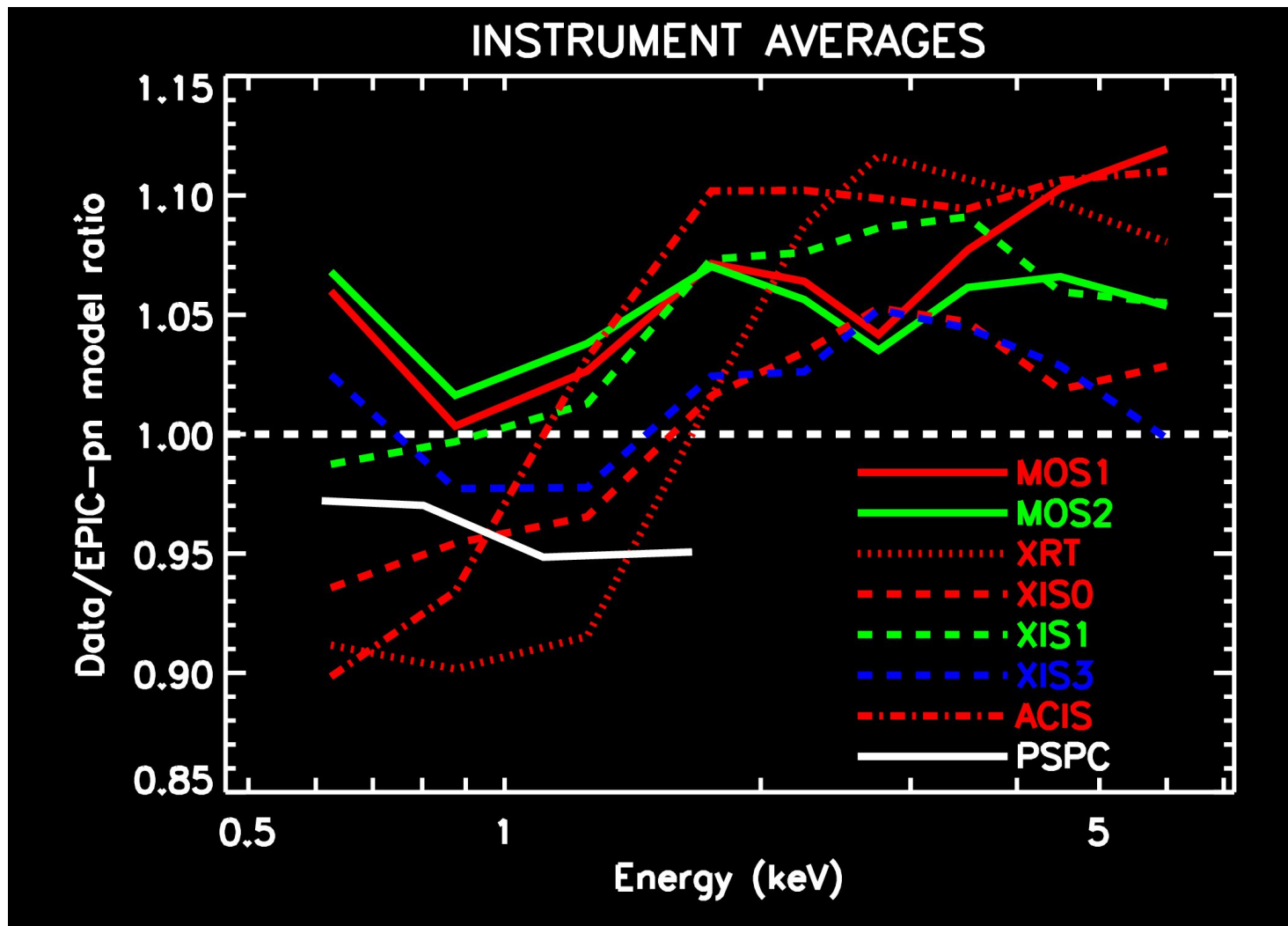
# 1.1) Blazars v.s. clusters

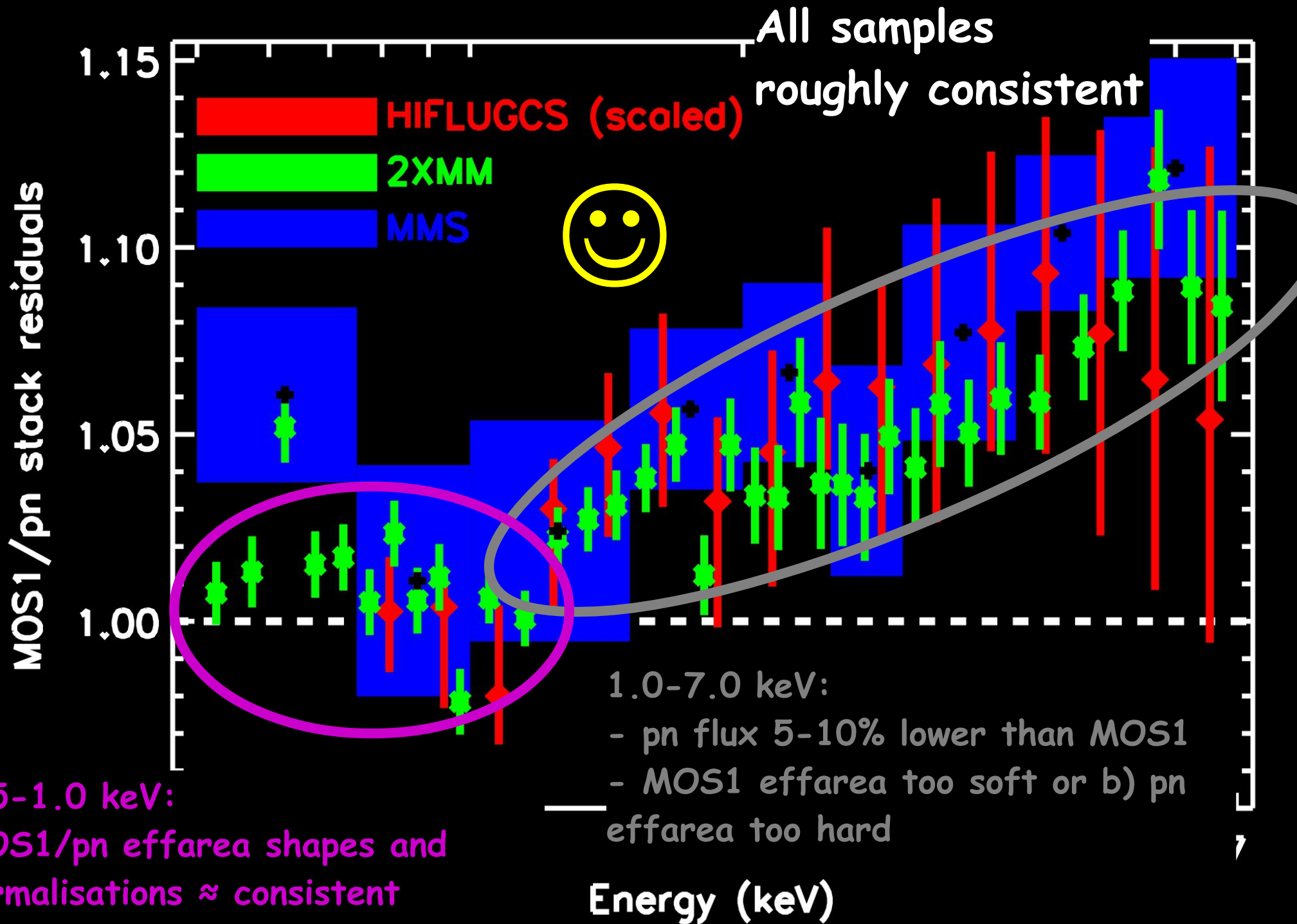


- Read et al., 2014, *A&A*, 564, 75 (**2XMM**): **Cross-calibration of the XMM-Newton EPIC pn and MOS on-axis effective areas using 2XMM sources**
- Schellenberger et al. 2015, *A&A*, 575, 30 (**HIFLUGCS**): **XMM-Newton and Chandra cross-calibration using HIFLUGCS galaxy clusters. Systematic temperature differences and cosmological impact**
- Madsen et al., 2017, *AJ*, 153, 2: **IACHEC cross-calibration of Chandra , NuSTAR , Swift , Suzaku , and XMM-Newton with 3C 273 and PKS2155-304.**
- Nevalainen+2018 (**MMS**), preliminary

# Multi Mission Study (4 clusters)

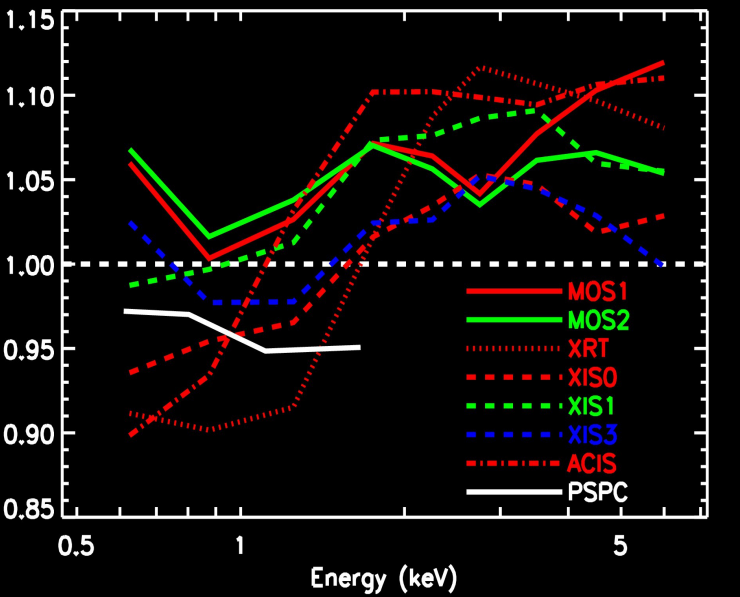
$$R_{i|ref} = \frac{data_i}{model_{ref} \otimes resp_i} \times \frac{model_{ref} \otimes resp_{ref}}{data_{ref}}$$





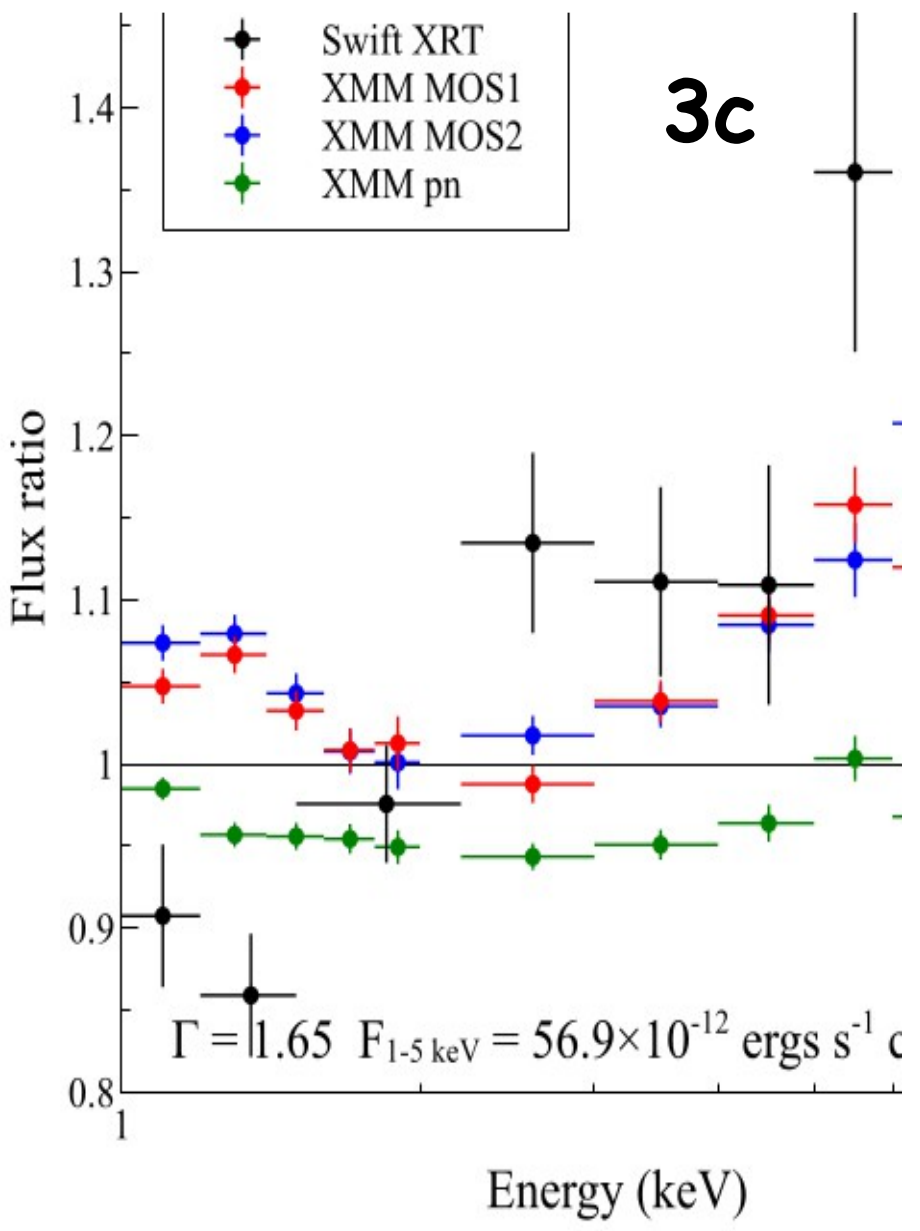
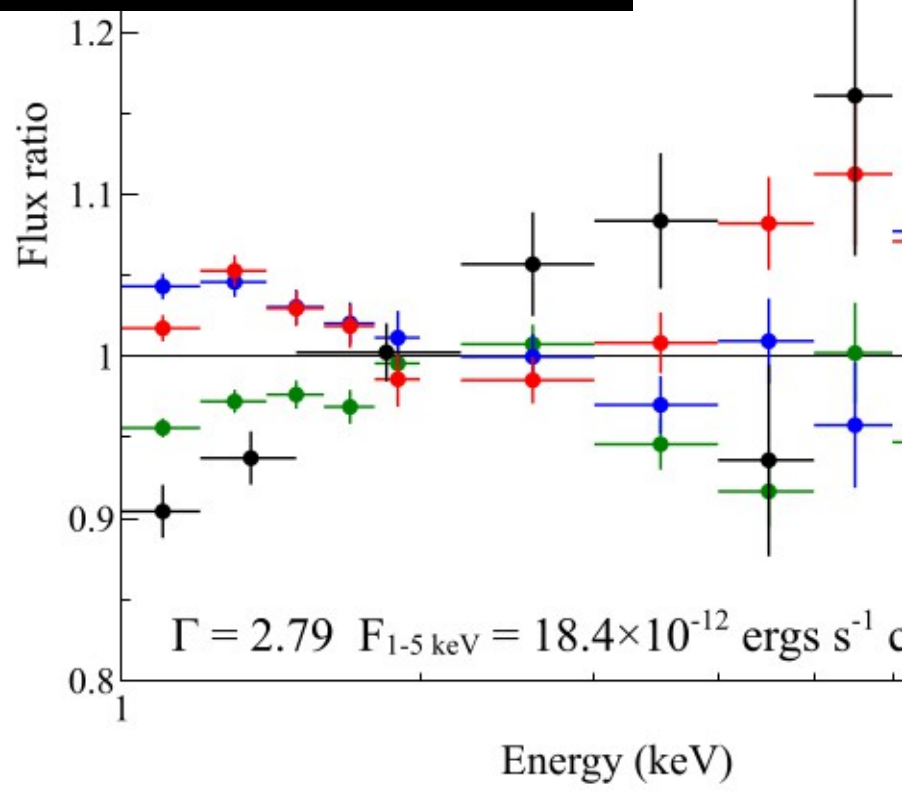


INSTRUMENT AVERAGES

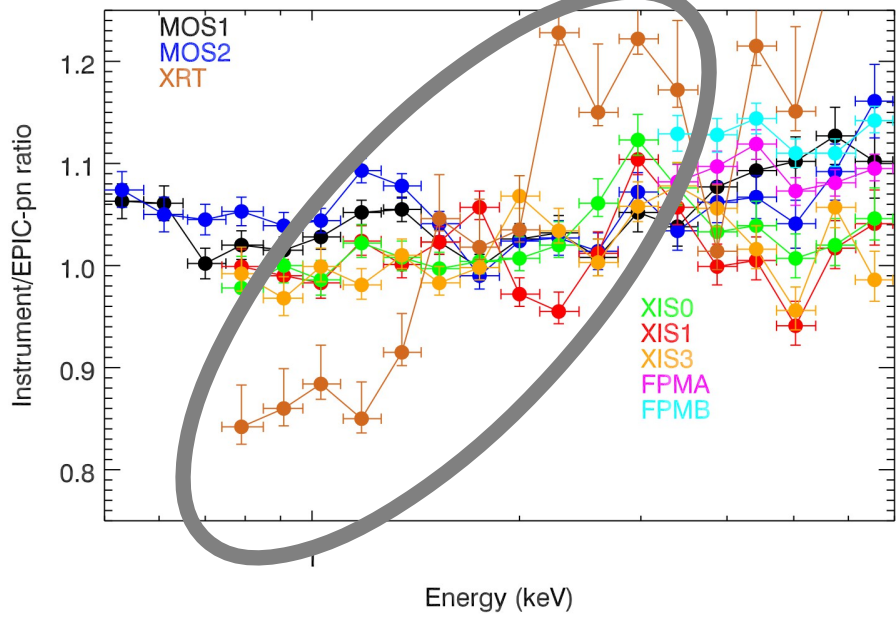


pn 1-6 keV flux 5-10% lower than MOS. OK  
 Swift/XRT 1-6 keV spectrum harder than pn. OK

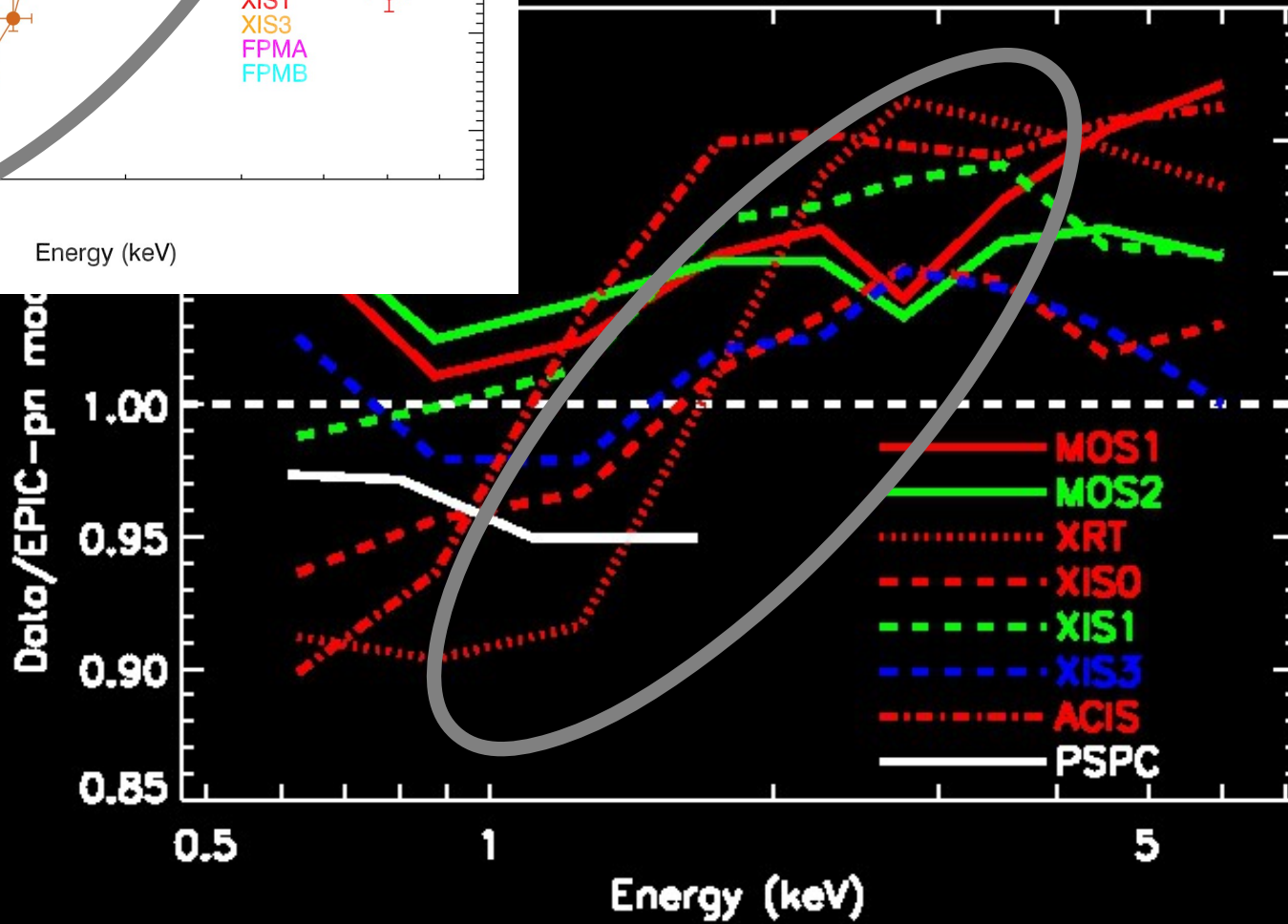
PKS



# Swift-XRT



## INSTRUMENT AVERAGES





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# 1.2) Annual review of Stack Residuals Spectra



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- Hard to compare in detail stack residuals spectra and flux ratios
- JN commits to perform an annual SRS review in this forum (if new results available)
- Requires the data and responses. Heritage data base...



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**1.3) Comment round  
btw WG chairs before  
submission of a new  
IACHEC paper**



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- To ensure a consistent message outside the IACHEC
- If agreed, how to implement?



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## 2) Crab absolute flux measurement



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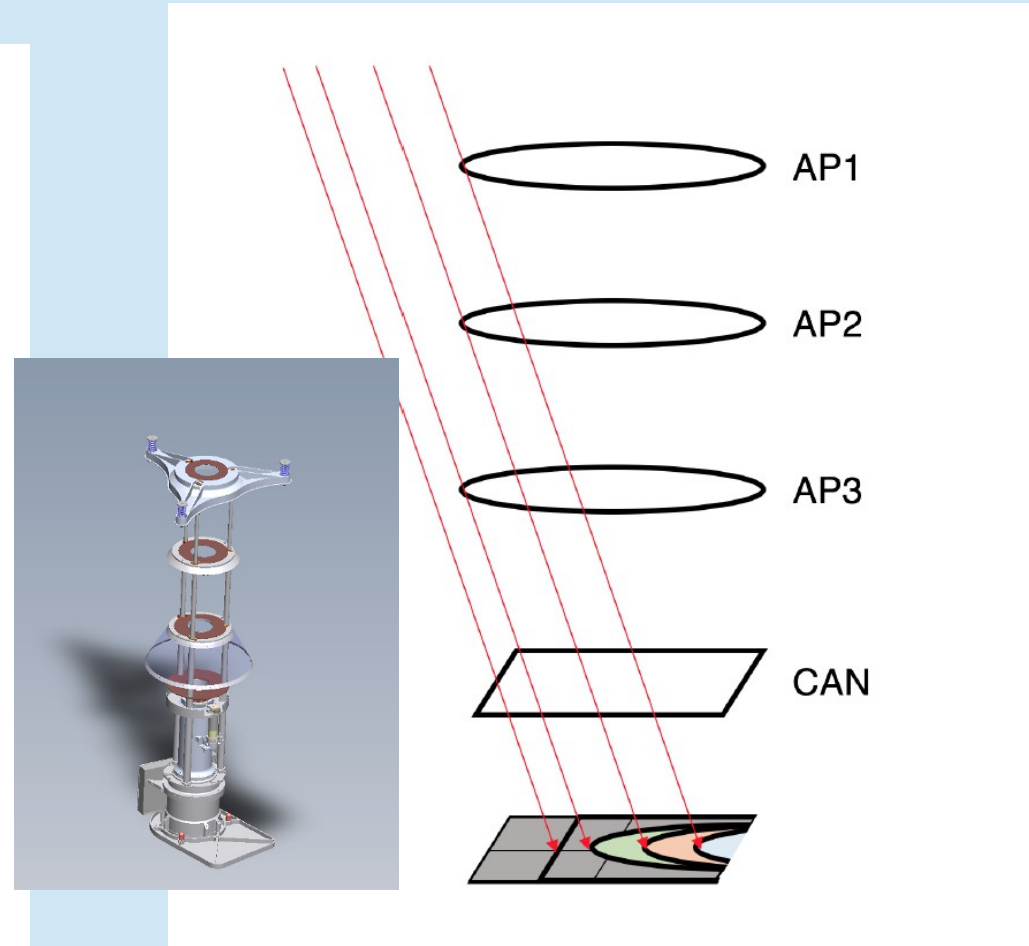
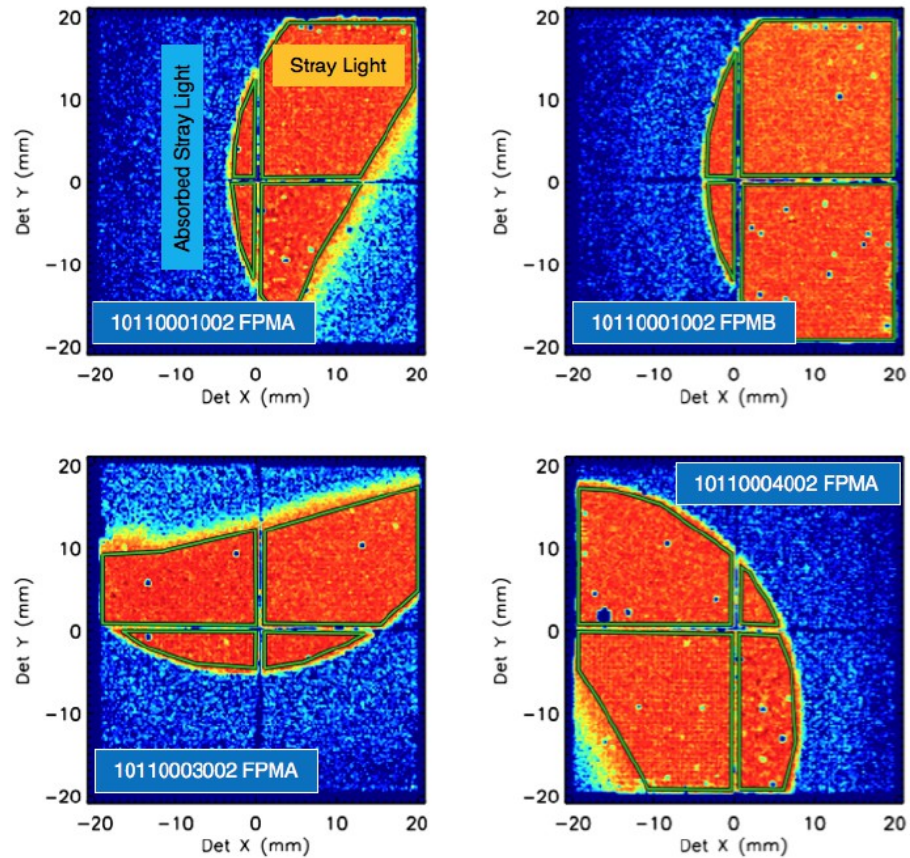
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- **Stray light NuSTAR measurement of Crab (Madsen+17) bypasses the mirror → less complicated path → easier to model very accurately**



# NuSTAR stray light observations

Paper submitted and accepted in ApJ.



# Response

- Area on detector (1%)
- Be window (1%)
- 100 nm with a throughput of 92% at 5 keV and 98% at 10 keV.
- RMF (1%)
  - 98% between 4 - 40 keV and understood to  $< 1\%$

# Spectrum

- Nuabs \* Tbabs \* powerlaw
- $NH = 2.2 \times 10^{21} \text{ cm}^{-2}$ 
  - At 4 keV the absorption of this column is 1% and if the column was increased to  $4 \times 10^{21} \text{ cm}^{-2}$  the absorption at 4 keV would be 2%.
  - With the best fit detector absorption parameters frozen,  $NH$  has for these observations a 90% confidence limit of  $1.1 \times 10^{21} \text{ cm}^{-2}$ .
- **Nuabs** is fitted. It is somewhat degenerate with NH.



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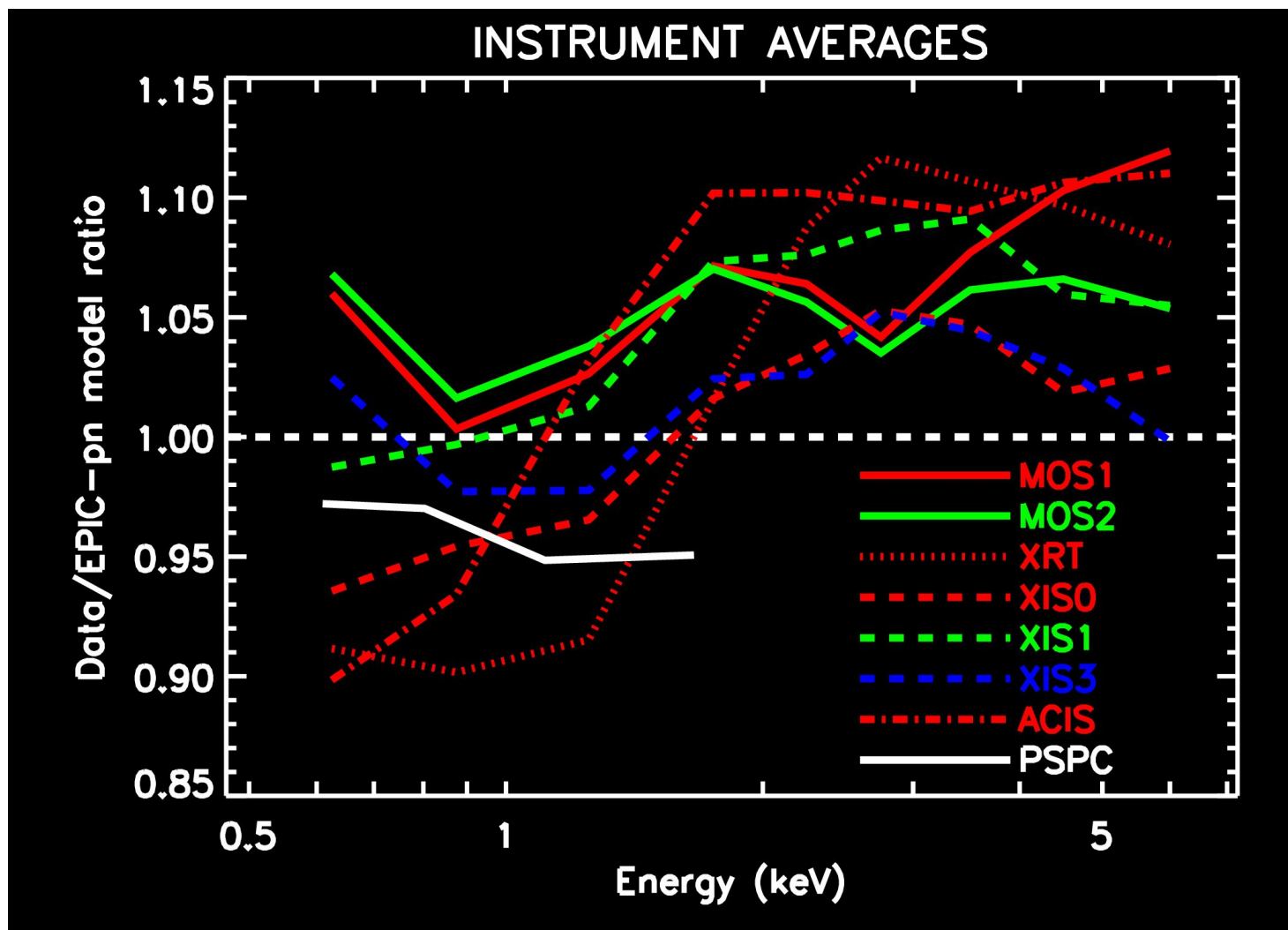


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- Nuabs fitted together with the Crab model. **Model parameters differ by 50% from Madsen15a+. No problem.**
- 2015 and 2016 off-axis 3-7 keV flux (the true flux) is 12% higher than in NuSTAR focused **SIMULTANEOUS?** (YES) observation →
- Nustar mirror effective area too high in the 3-7 keV band. **WHY?**
- Lowering NuSTAR mirror effective area by 12% increases the NuSTAR flux and decreases the instr/NuSTAR flux ratios by 12%
- 3-7 keV pn/NuSTAR flux ratio = 0.95 (PKS2155 and 3C237, Madsen15b+)
- Assuming the stray light flux measurement is absolutely correct, pn/Nustar flux ratio decreases to 0.85
- pn 3-7 keV flux too low by 15%, let's increase pn flux by 15%. What happens to clusters?

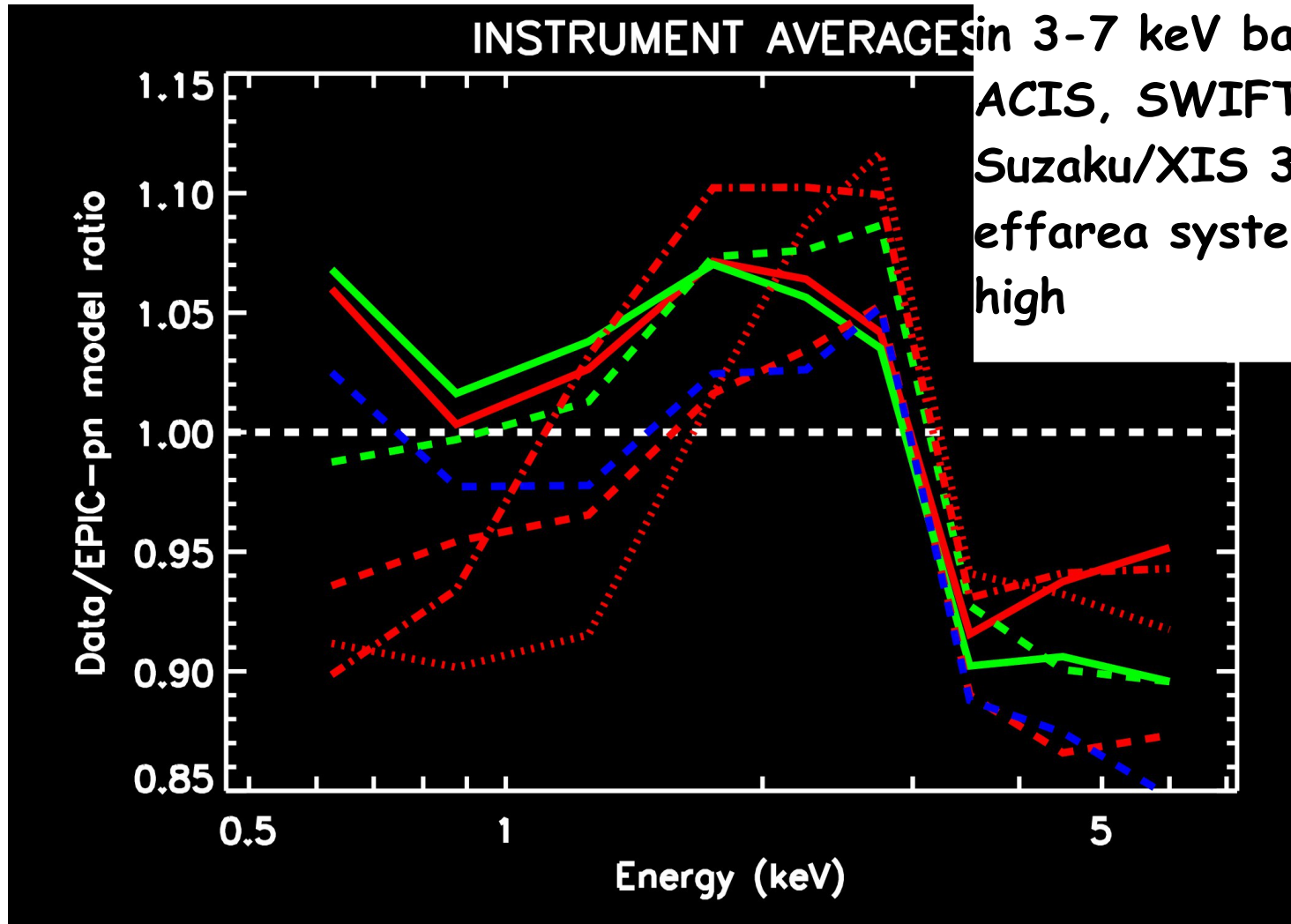
# Multi Mission Study (4 clusters)

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



# Multi Mission Study (4 clusters)

pn 3-7 keV band flux *scaled up by 15%*



if pn effarea now correct  
in 3-7 keV band, MOS,  
ACIS, SWIFT/XRT and  
Suzaku/XIS 3-7 keV  
effarea systematically too  
high

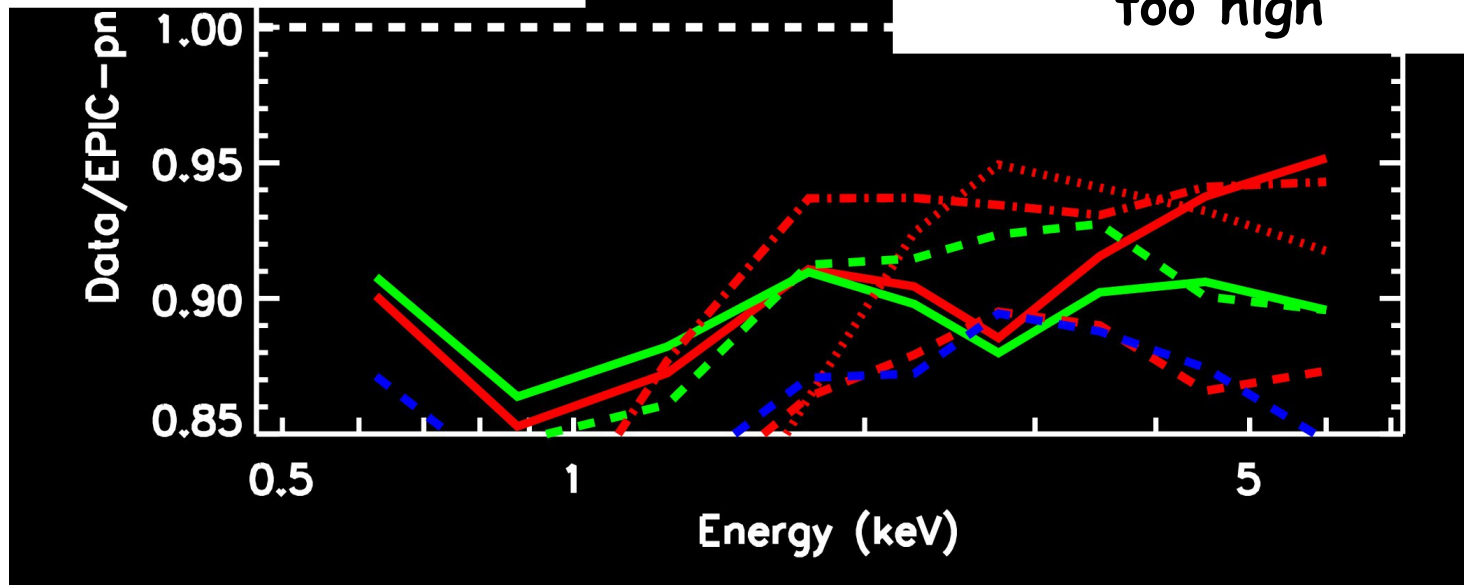
# Multi Mission Study (4 clusters)

pn **0.5-7 keV** band flux *scaled up by 15%*

In particular, the good consistence btw MOS1 and pn below 1 keV is lost.

STRUMENT A

if pn errarea now correct in 0.5-7 keV band, MOS, ACIS, SWIFT/XRT and Suzaku/XIS 0.5-7 keV effarea systematically too high



# Action items

- Andy B. will investigate the Swift/XRT giving harder 1-2 keV band spectra
- JN commits to perform an annual SRS review in this forum (if new results available). Published in the IACHEC meeting report in arXiv.
- Eric implements a page on Wiki where each IACHEC author is encouraged to post a submitted paper for comments
- JN and I. Valtchanov will keep track at plans of calibrating EPIC-pn with NuSTAR absolute Crab flux measurement