# IACHEC: a resource for the future

Matteo Guainazzi
(XMM-Newton EPIC Calibration Scientist & IACHEC Chair)

# OUTLINE

- What is the IACHEC?
- Why is IACHEC useful?
- How does IACHEC work?
- What's there still to do (*i.e.*: cross-calibration status)?
- Lessons learned
- IACHEC and future missions

IACHEC is a truly collective undertaking. Special contributions to this presentation by *D.Jerius* (SAO), *J.Nevalainen* (Tartu Un.), and *S.Sembay* (Leicester Un.) are gratefully acknowledged

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# IACHEC in a nutshell

- The IACHEC is the *International Astronomical Consortium for High-Energy Calibration*
- Founded in 2006 on impulse by Marcus Kirsch (ESA) and Steve Sembay (University of Leicester).
- It is a shared undertaking among high-energy calibrators to coordinate (and therefore strengthen) our work
- It acts as a forum where astronomers involved in calibration of past, operational, and future missions work together to:
  - Define calibration standards
  - Document (=publish) calibration and cross-calibration status
  - Improve the cross-calibration among their instruments
- Not directly funded by any Agencies or institutions. Individual projects/missions contribute through the work and mission budget of their calibration teams
- **Strongly endorsed** by the *XMM-Newton* and *Chandra* User's Group

`http://web.mit.edu/iachec/`

# The IACHEC crew

8th IACHEC Meeting picture at the (2013; Hothorpe Hall, UK): 40 participants (6 "sequestred")
The number of participants has been fairly constant (≅45) over the last 4 years

- http://web.mit.edu/iachec/meetings/2013/index.html

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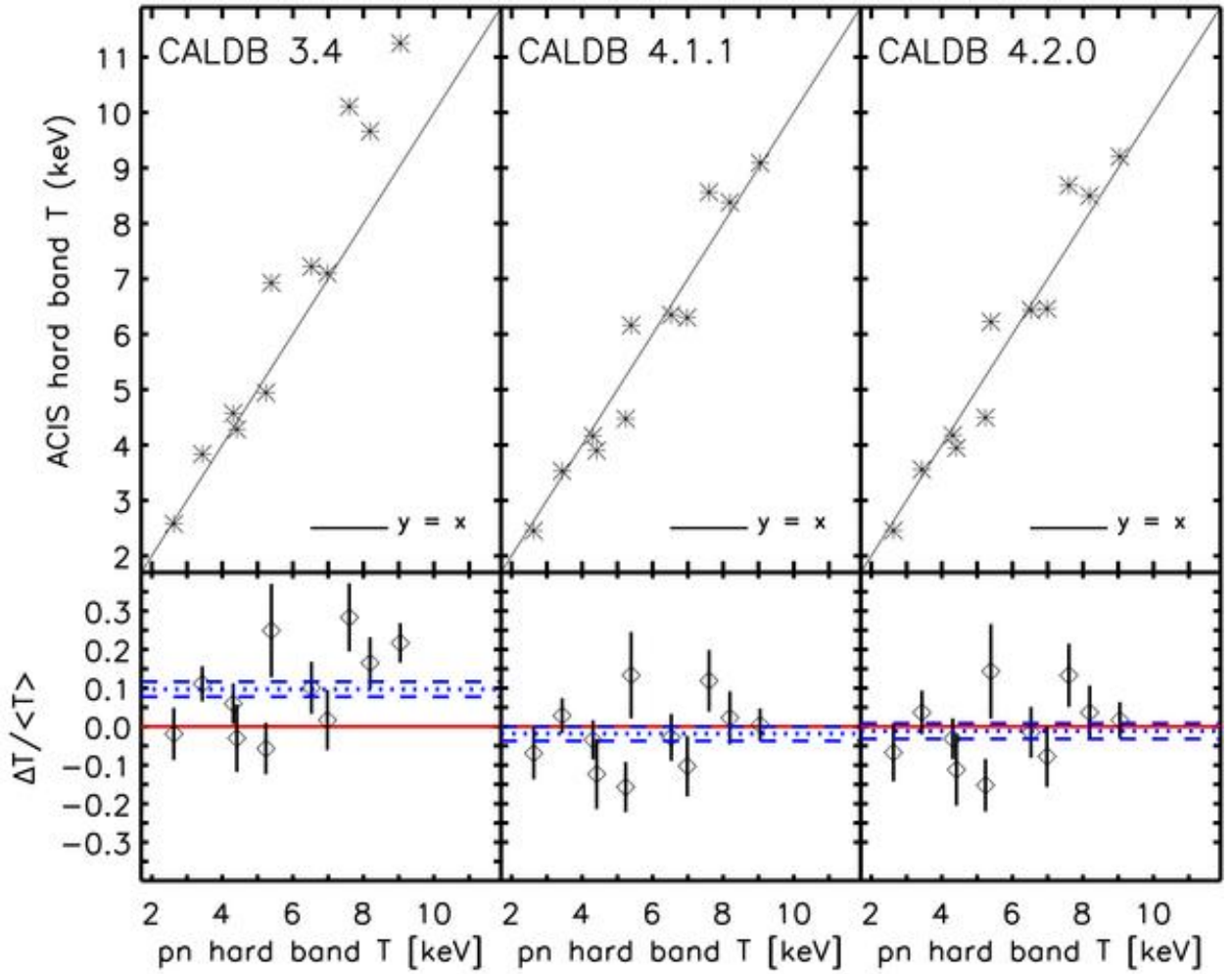
# IACHEC successes: I.

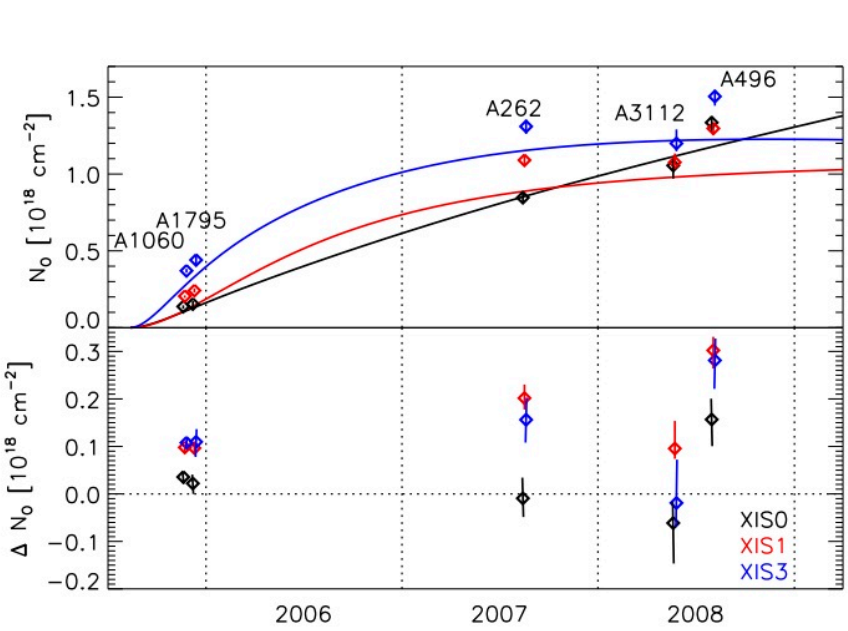
Change in the ACIS effective area inspired by IACHEC work

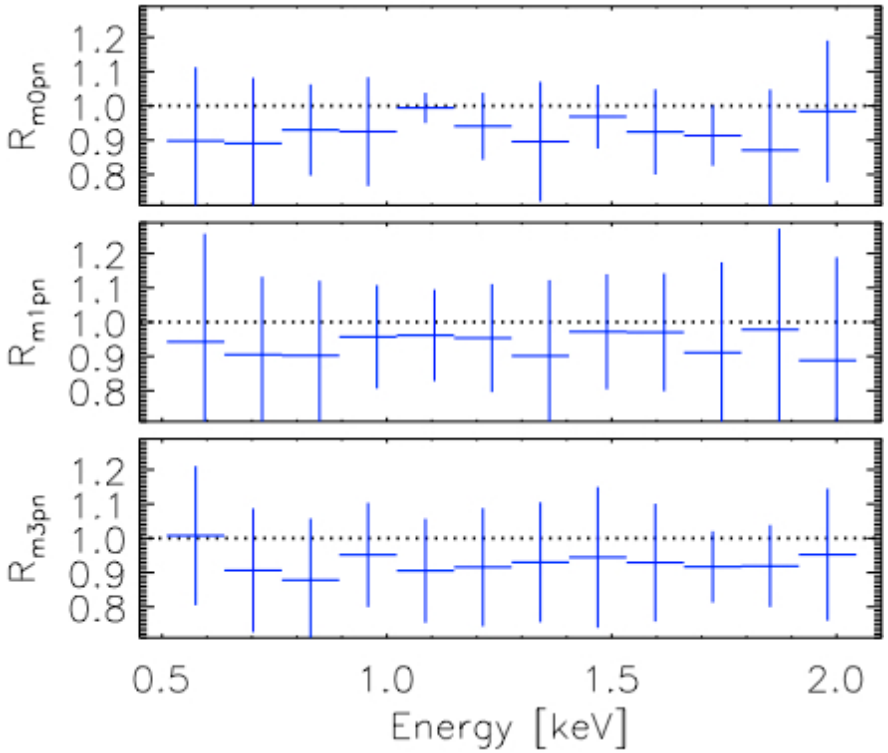



- (Nevalainen et al., 2010, A&A, 526, 22)

# IACHEC successes: II.

Study of 10 galaxy clusters observed by *Suzaku*/XIS and XMM-Newton/EPIC



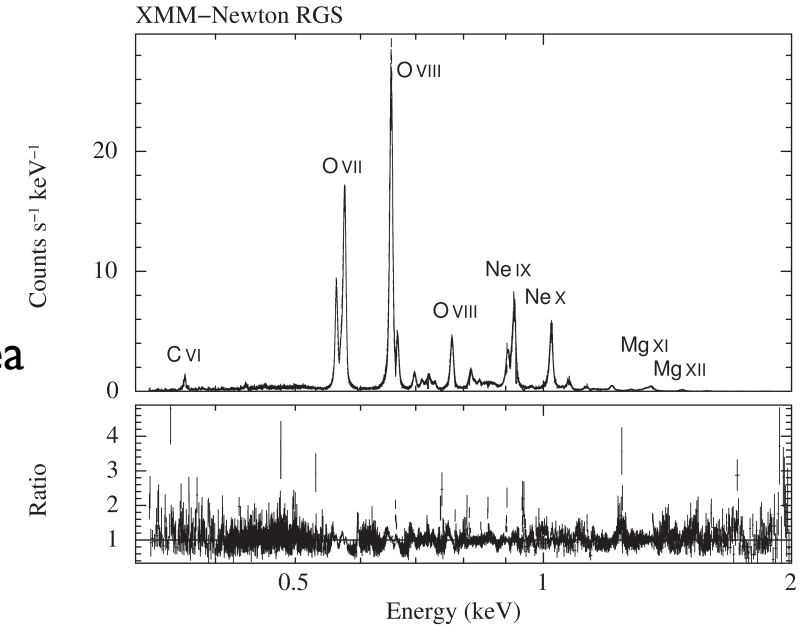



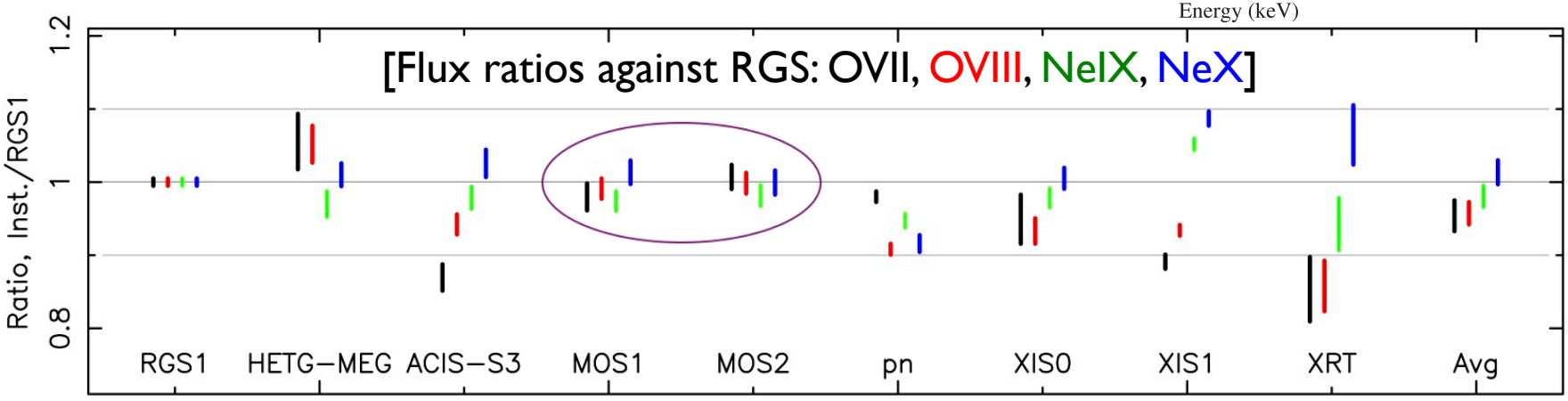

Change in the XIS contamination evolution validated against EPIC spectral fits.
Good agreement between XIS and EPIC temperatures (and *bad agreement* with ACIS)

- (Kettula et al., 2013, A&A, 552, 47)

# IACHEC successes III.

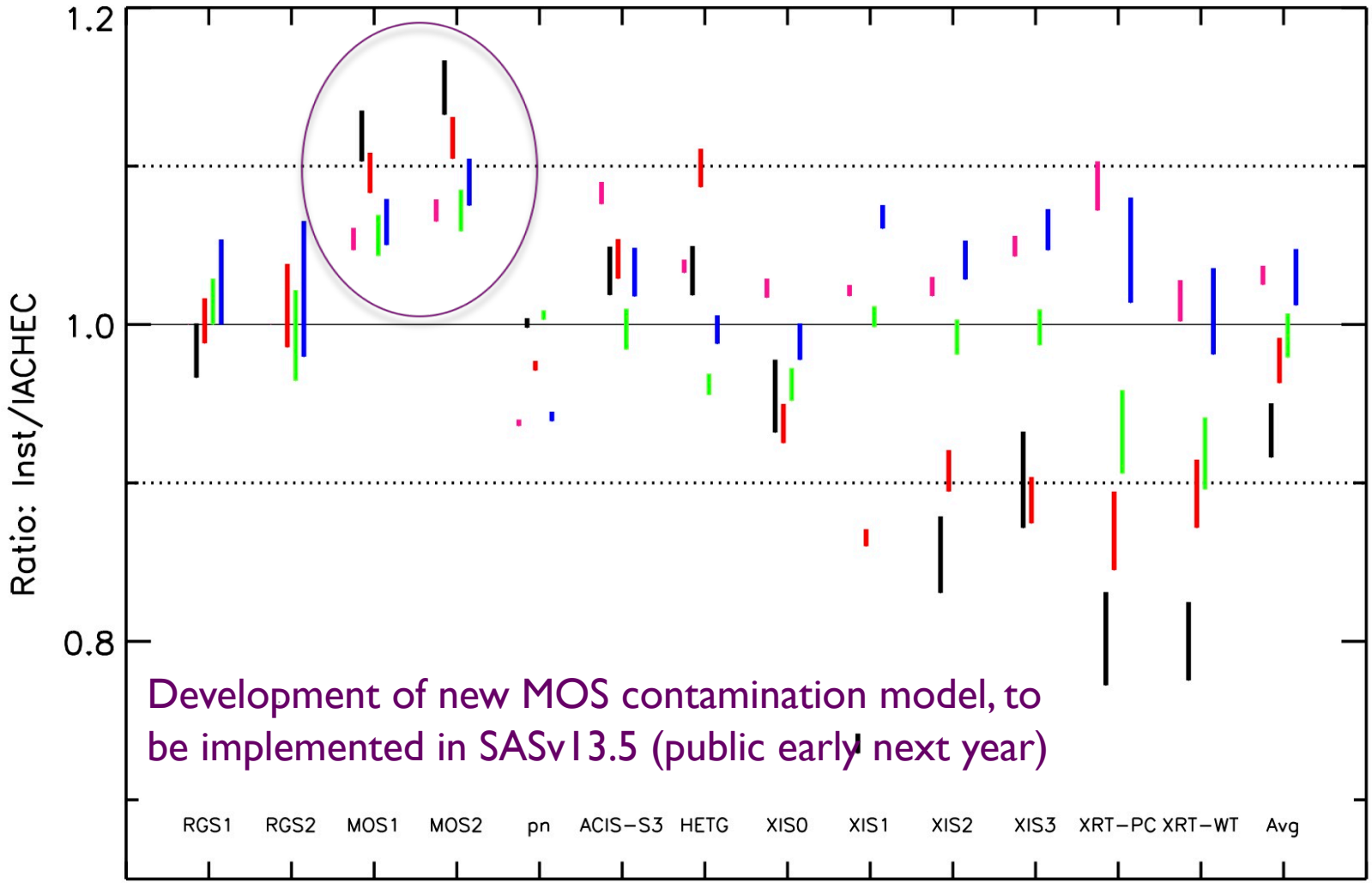
- 1E0102.72: compact (1') thermal SNR
- Astrophysical model based on RGS spectrum
- [collaboration with ATOMDB R.Smith's group]
- Reference for soft X-ray cross-calibration:
  - XIS contamination
  - EPIC-MOS redistribution and effective area
  - ACIS contamination




(Plucinsky et al., SPIE, 2008, 7112)

# IACHEC successes (?) III:




- (Plucinsky et al., SPIE, 2012, 8443)

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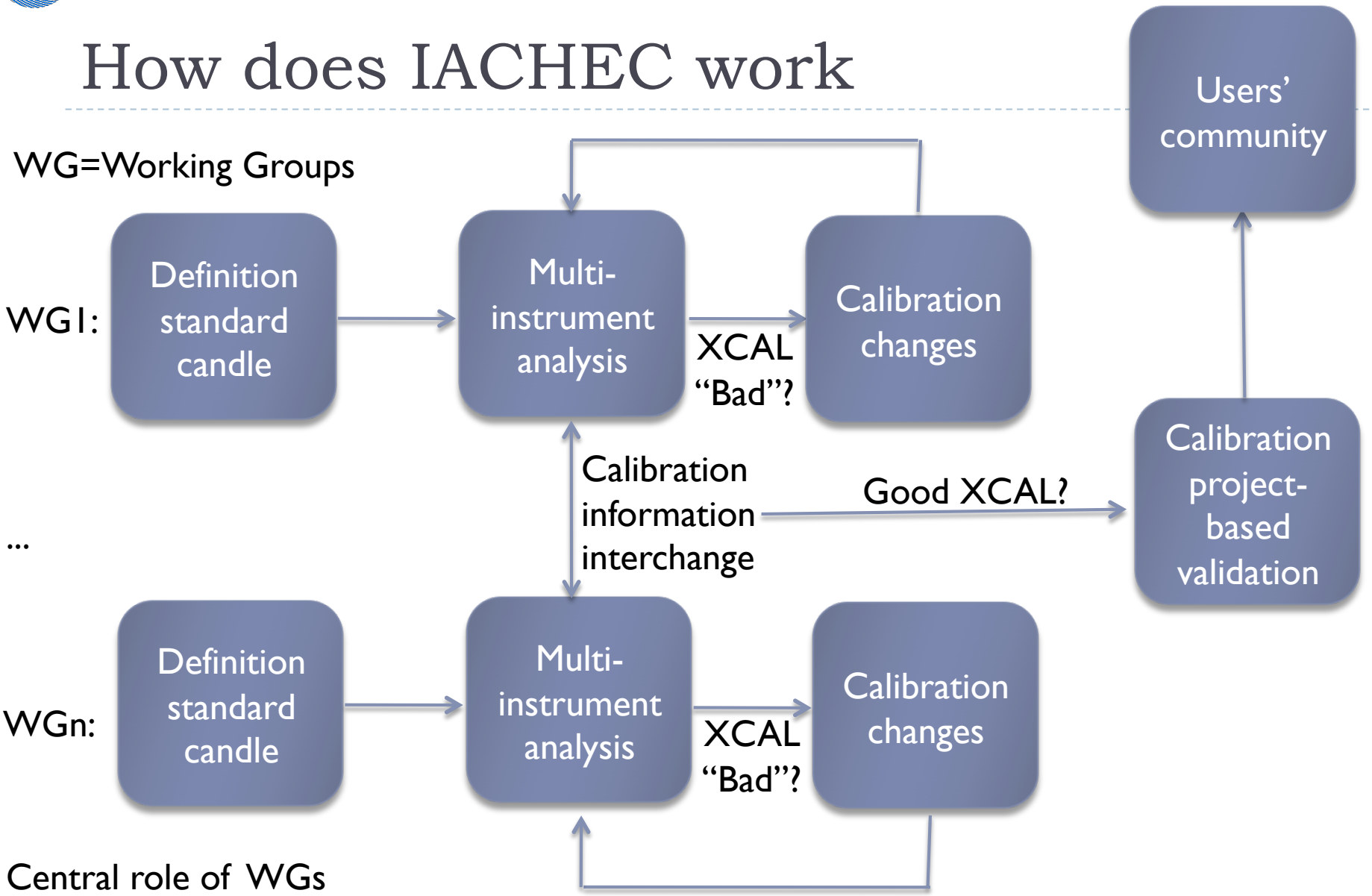
# IACHEC Working Groups

- **CCD issues** (*Chair:* *Catherine Grant*). Forum for cross-mission discussion and comparison of CCD-specific modeling and calibration issues, lessons learned, and best practices.
- **Clusters** (*Chair:* *Jukka Nevalainen*). Comparison of galaxy cluster temperatures
- **Effective area** (*Chairs:* *Manabu Ishida* and *Hermann Marshall*). Chandra, NuSTAR, *Suzaku*, Swift, and XMM-Newton cross-calibration campaign data on PKS2155-304
- **High Resolution** (*Chair:* *Andy Pollock*). Complete census of emission lines in the RGS and LETG spectrum of Capella.
- **Non-Thermal SNR** (*Chairs:* *Lorenzo Natalucci* and *Masahiro Tsujimoto*). Effective area cross-calibration analysis of G21.5-0.9 (mainly below 10 keV) and of the Crab Nebula (mainly above 10 keV) spectra.
- **Thermal SNR** (*Chair:* *Paul Plucinsky*): Analysis of 1E0102.2-7219 and N132D
- **White Dwarfs** (*Chair:* *Vadim Burwitz*). Compare atmospheric models in conjunction with analysis of high-resolution data.

# How does IACHEC work




Central role of WGs

Process not always smooth and linear!

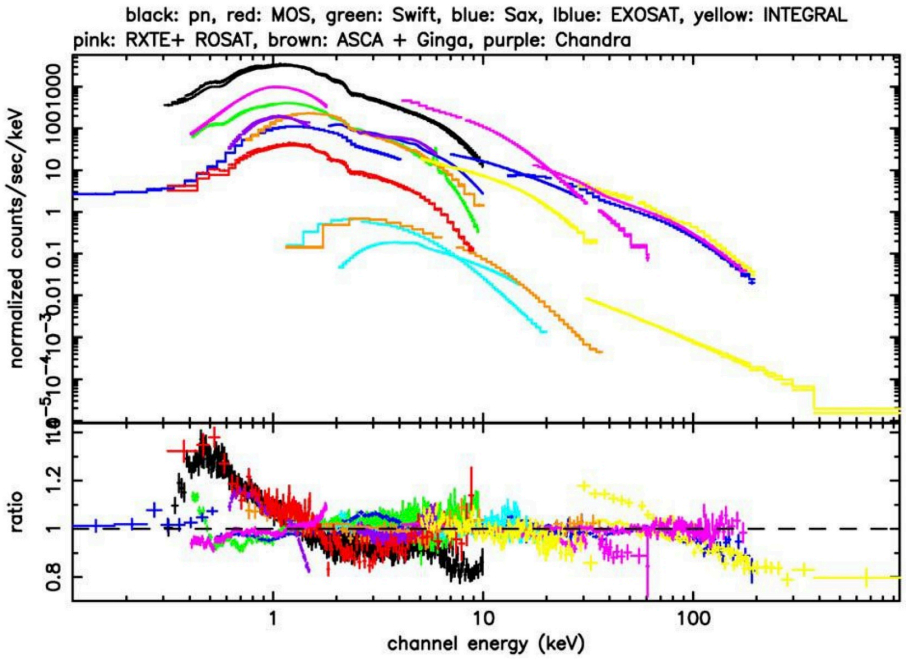
- `http://web.mit.edu/iachec/wgs/index.html`

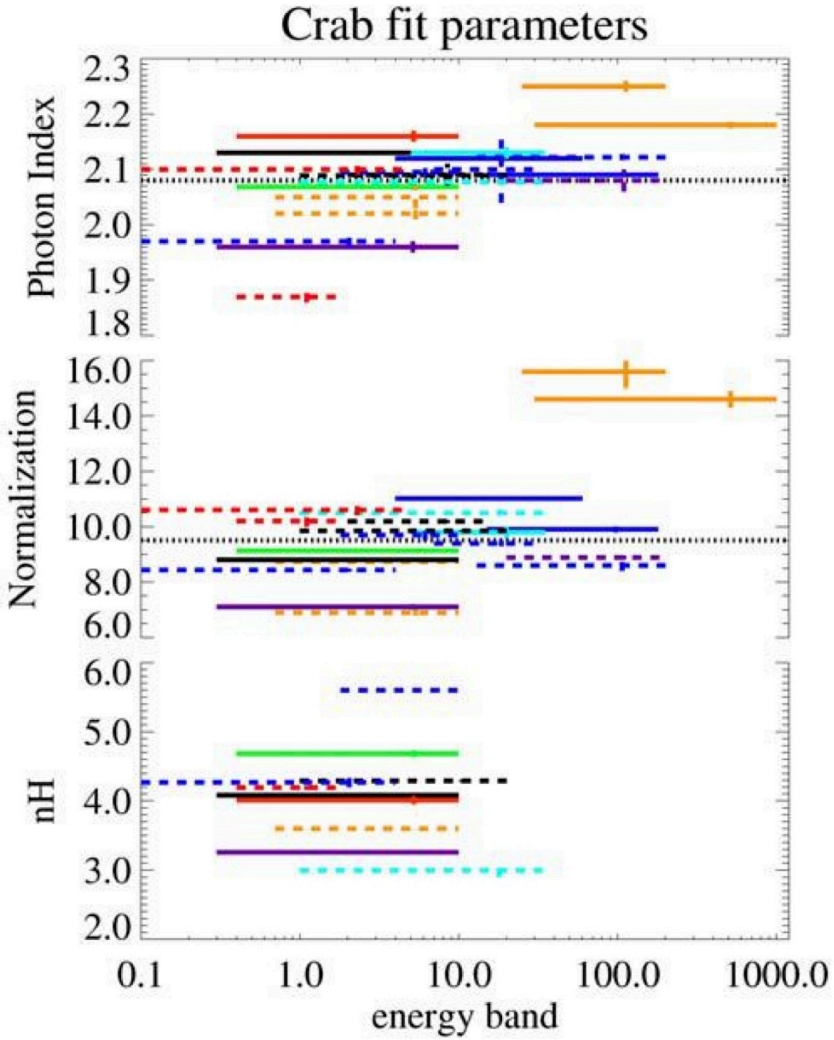
# Standard candles in high-energy astronomy

- Calibration starts from instrument models defined and calibrated before launch
- In operational phase, in-flight corrections are required and new responses are computed. Most approaches use astronomical sources known as *standard candles* (SC)
- SC are typically sources of non-thermal continuum and line fluxes in a broad band, or provide thermal soft X-ray spectra. They must have **non-variable** spectra and fluxes.
- The choice of a SC is driven by the wavelength band, the energy resolution of the instruments, and the source size as compared to the angular resolution
- **In the X-ray band, standard candles cannot rely on a knowledge of the absolute intrinsic source flux.** We must be content with an educated guess on their physical processes
- The main task of the IACHEC: **define a set of SCs** and their data reduction procedure, **establish** their reference **astrophysical models**, and **publish** them (ideally on refereed journals)

# A "standard candle": the Crab Nebula

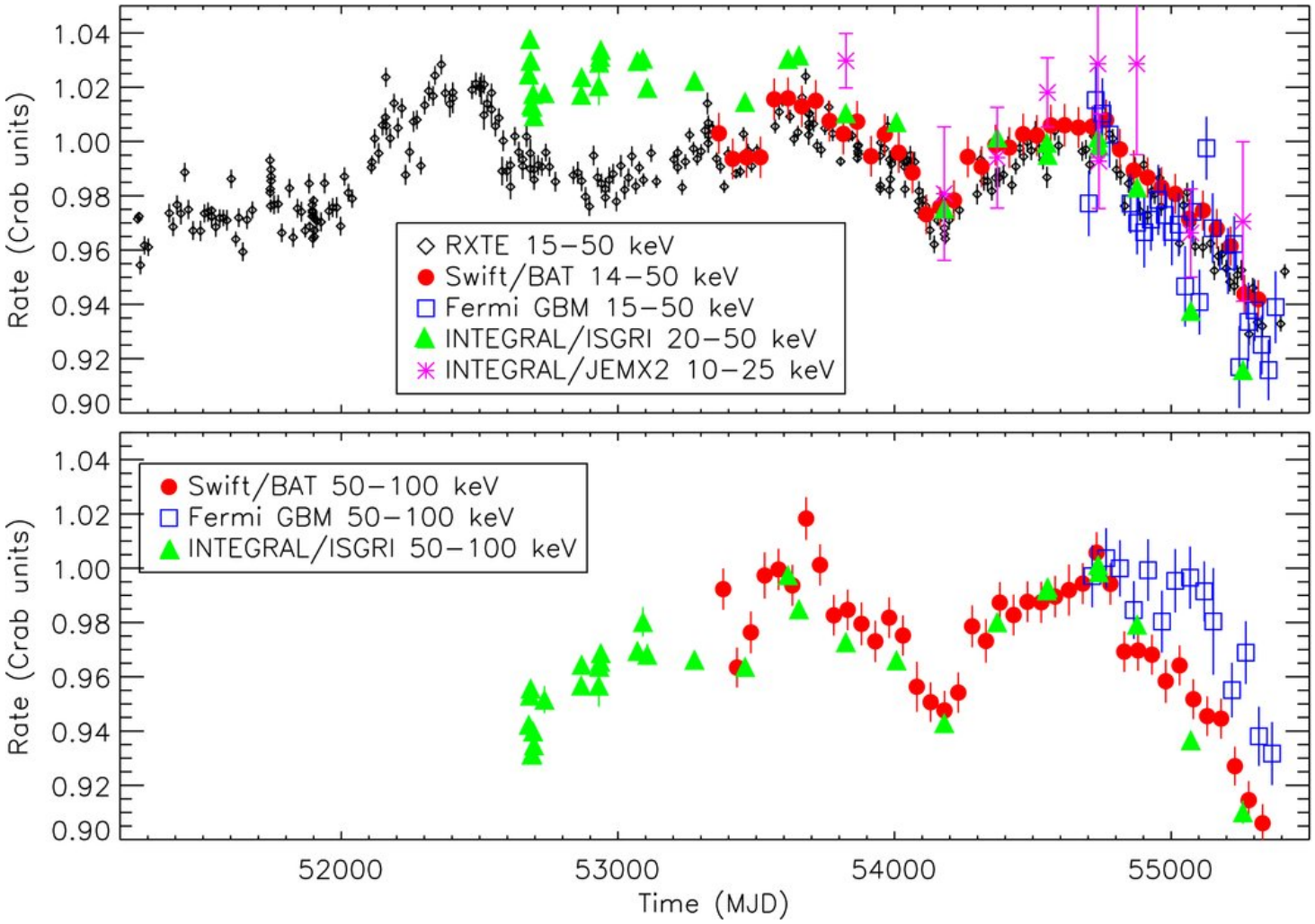
- Common fit with simple power-laws
- Rather poor agreement among instruments
- Mainly driven by wrong astrophysical modeling
  *[Weisskopf et al., 2010, ApJ, 713, 912]*




(Kirsch et al., SPIE, 2005, 5898)

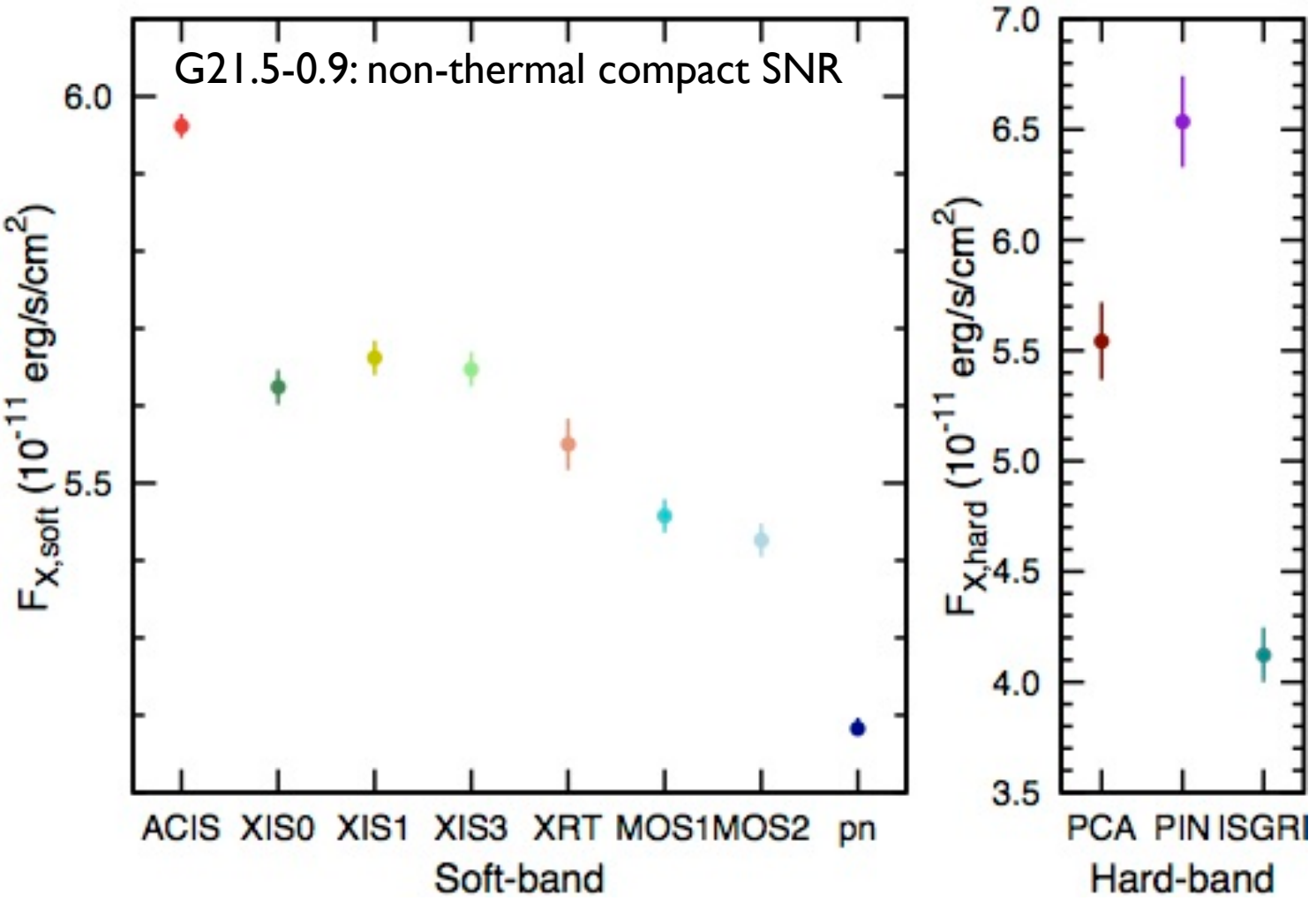
# Death of a candle




Solution: using only quasi-simultaneous observations *(Natalucci et al., in prep.)*

- (Wilson-Hodge et al., 2011, ApJ, 727, 40)

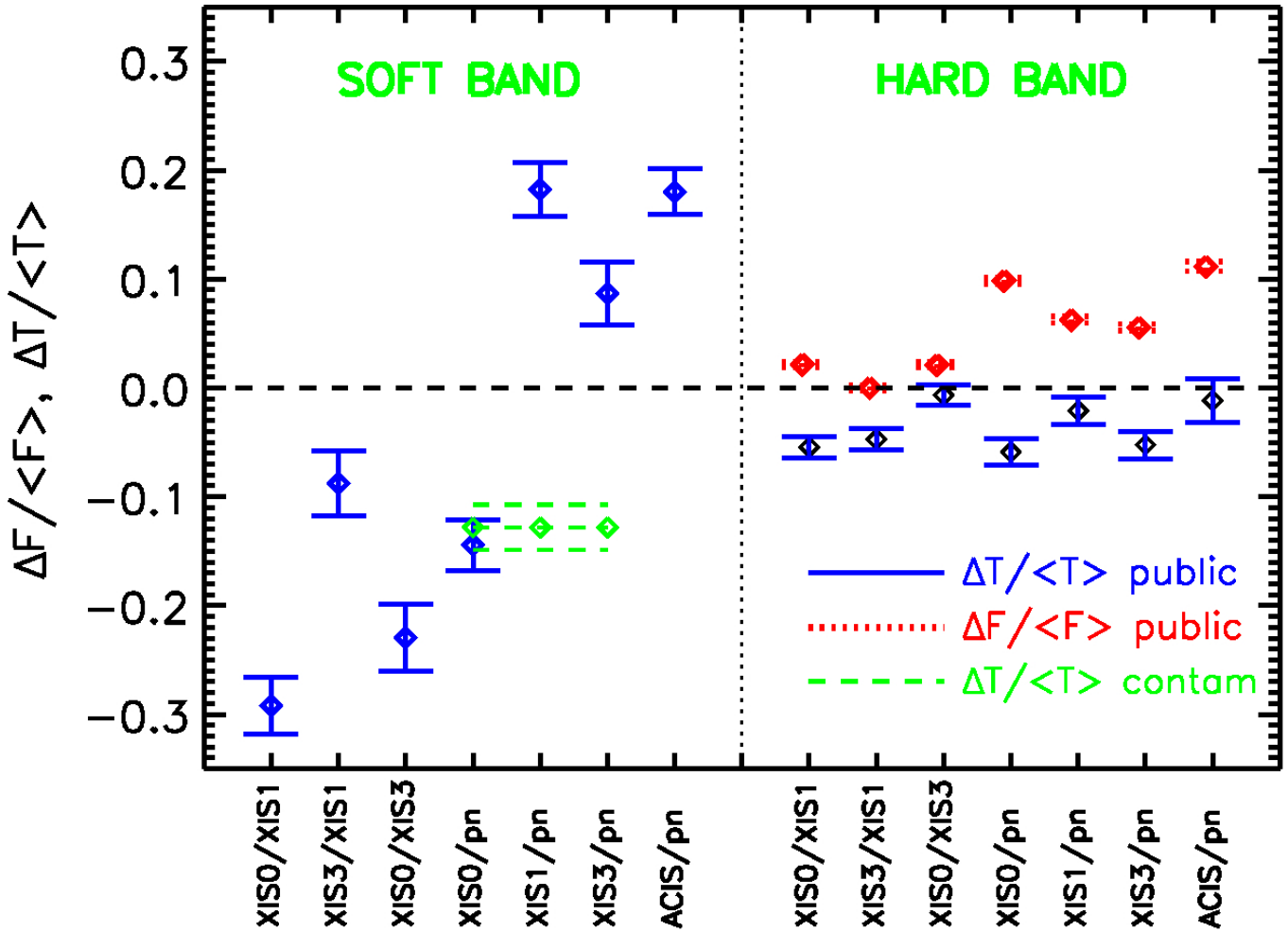
# Cross-calibration status: fluxes




Similar results obtained on PKS2155-*304* *(Ishida et al., PASJ, 2011, 63, 657)*

- (Tsujimoto et al., 2011, A&A, 525, 25)

# Cross-calibration status: spectral shape I.

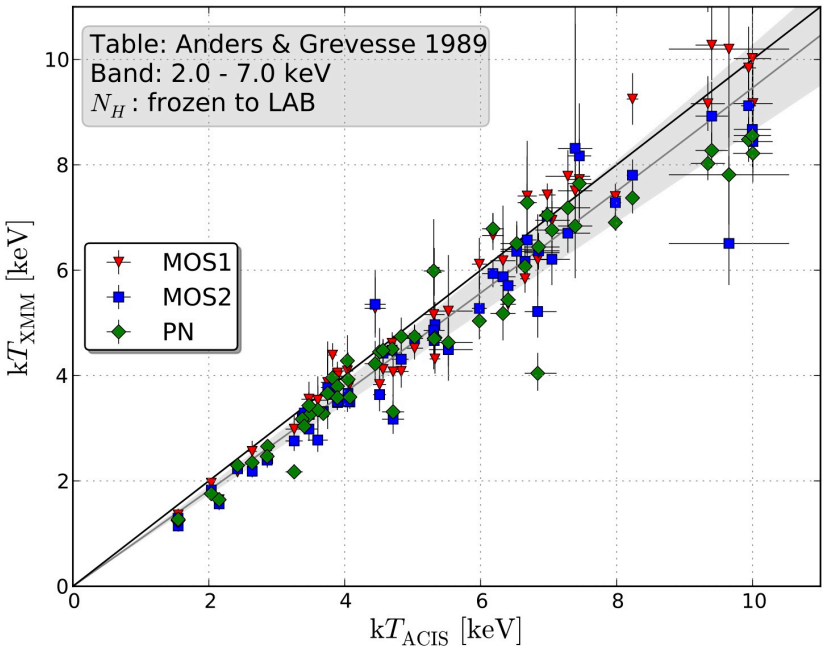



- (Kettula et al., 2013, A&A, 552, 47)

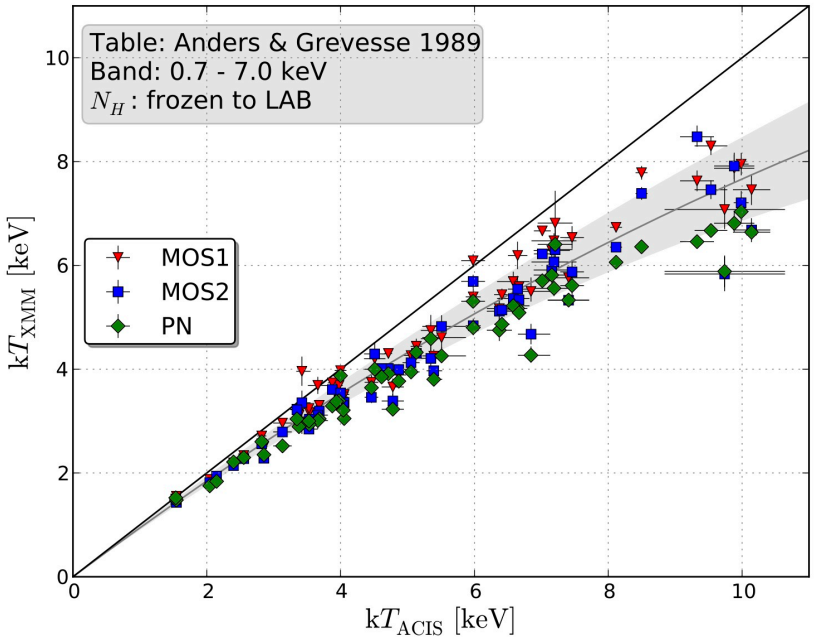
# Cross-calibration status: spectral shape II.

Sample of 63 bright galaxy clusters observed by ACIS and EPIC

Hard band: good agreement



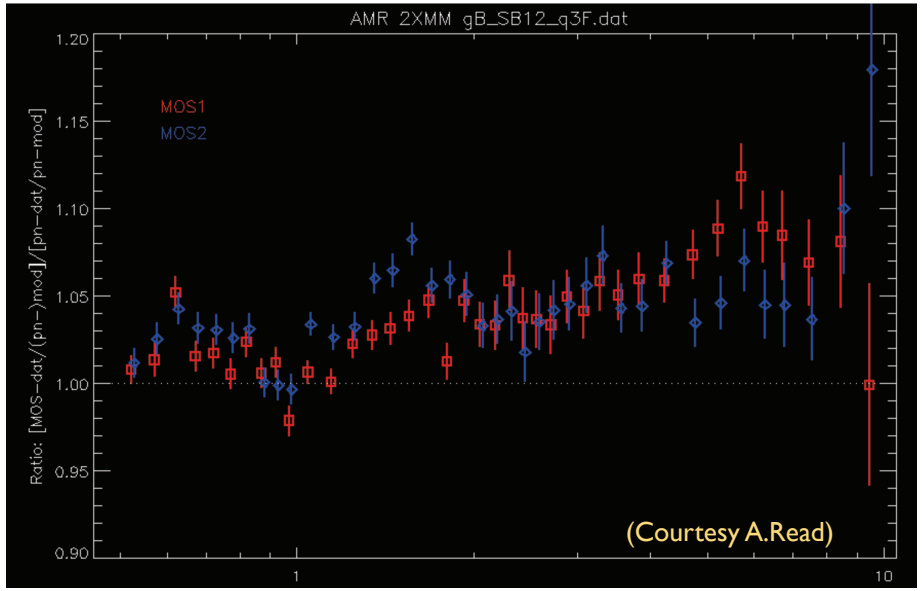

Total band: EPIC spectra harder

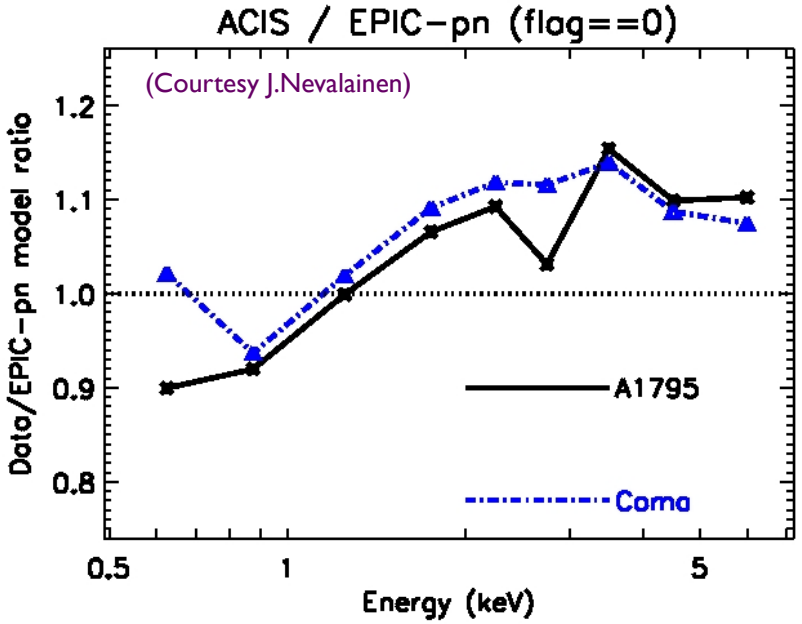


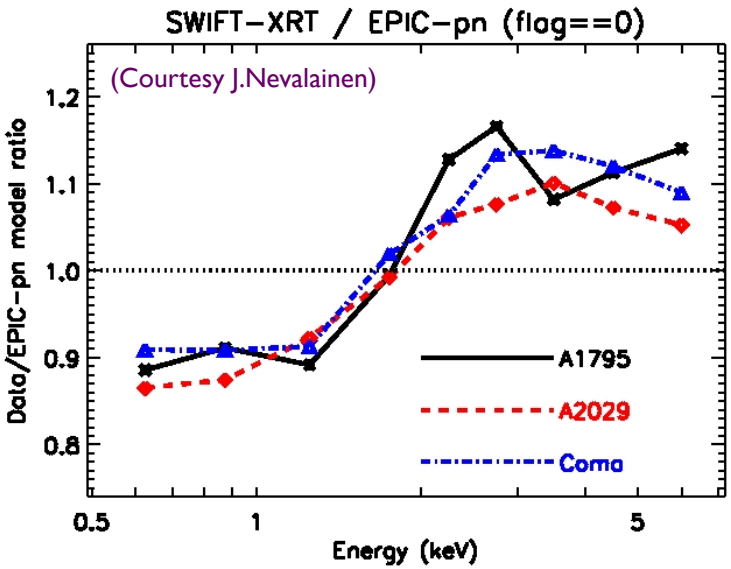

Origin of the discrepancy still unknown

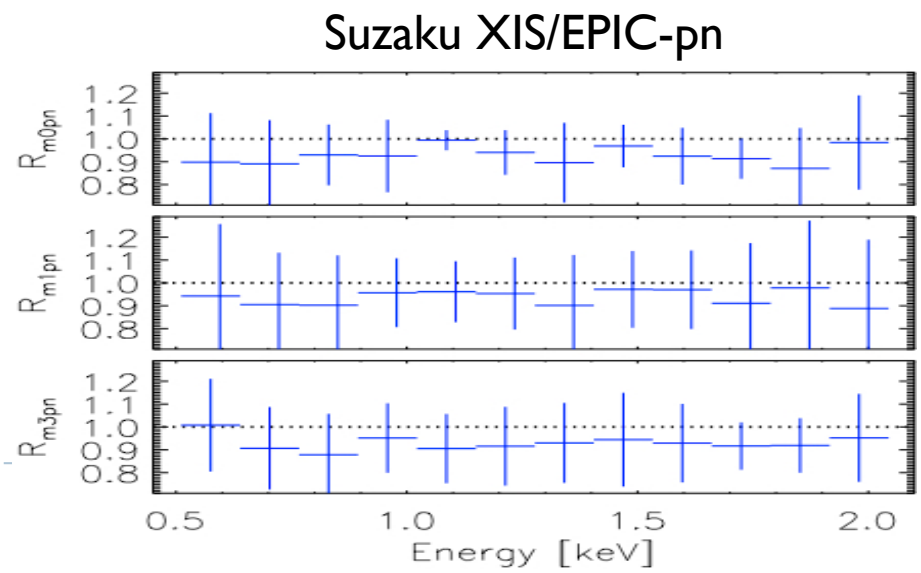
- (Schellenberger et al., submitted)

# The soft X-ray condurunum



# Pending calibration work

- ACIS contamination
- EPIC-MOS contamination
- EPIC-MOS/-pn effective area/QE
- XIS contamination
- XRT redistribution
- [... at the very least]

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- What is the IACHEC?
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- How does IACHEC work?
- What's their still to do (cross-calibration status)?
- Lessons learned (excerpt from a Special Session at the 5th IACHEC)
  - Chandra
  - XMM-Newton (plus some personal experience):
    - The "*We'll see after launch*" Syndrome
    - The "*Post-flight communication*" Syndrome
    - The "*Welcome to space*" Syndrome
- IACHEC and future missions (e.g. Astro-H)

# Calibration Transcendent

Focused on the **Observer** and **other Calibration Scientists**

In addition to the Observer focused objectives:

- Standardization of pre-CALDB products
- Publishing of pre-CALDB products, analyses, techniques
- Public availability of ground calibration data

A comprehensive public archive
of a mission's calibration history.

# Calibration and Operations Continuity

It is important to have ***continuity*** between pre-flight calibration teams and on-orbit operations and calibration teams.

Pre-flight teams include instrument teams as well as telescope teams.

What does this mean?

- On-orbit Ops/Data Center works with pre-flight calibration teams to integrate pre-flight calibration data into data archive *in a useable fashion*.
- Pre-flight Teams must be involved in on-orbit calibration planning in order to provide them with an inclusive view of the end-to-end calibration.
- Pre-flight Teams must provide *all* data products and procedures (and analysis pipelines) to Ops/On-orbit Calibration Team.

# Example: *Chandra* Optics Calibration

Things that didn't work out as well as they might have.

1. Optics Calibration Team *not* part of Data Center (existed before Chandra X-ray Center)
2. Tasked *solely* with ground calibration
3. Official archive of ground-calibration data done with little input from calibration team
   - No way to correct data in archive
   - Measurement meta-data not part of archive
   - Archive never used by Calibration Team
   - Everyone had their own databases w/ personal "fixes" – very difficult to synchronize
4. Spectral analysis pipelines – fragile and only operable by one person

Some things were unavoidable, but quite a few weren't

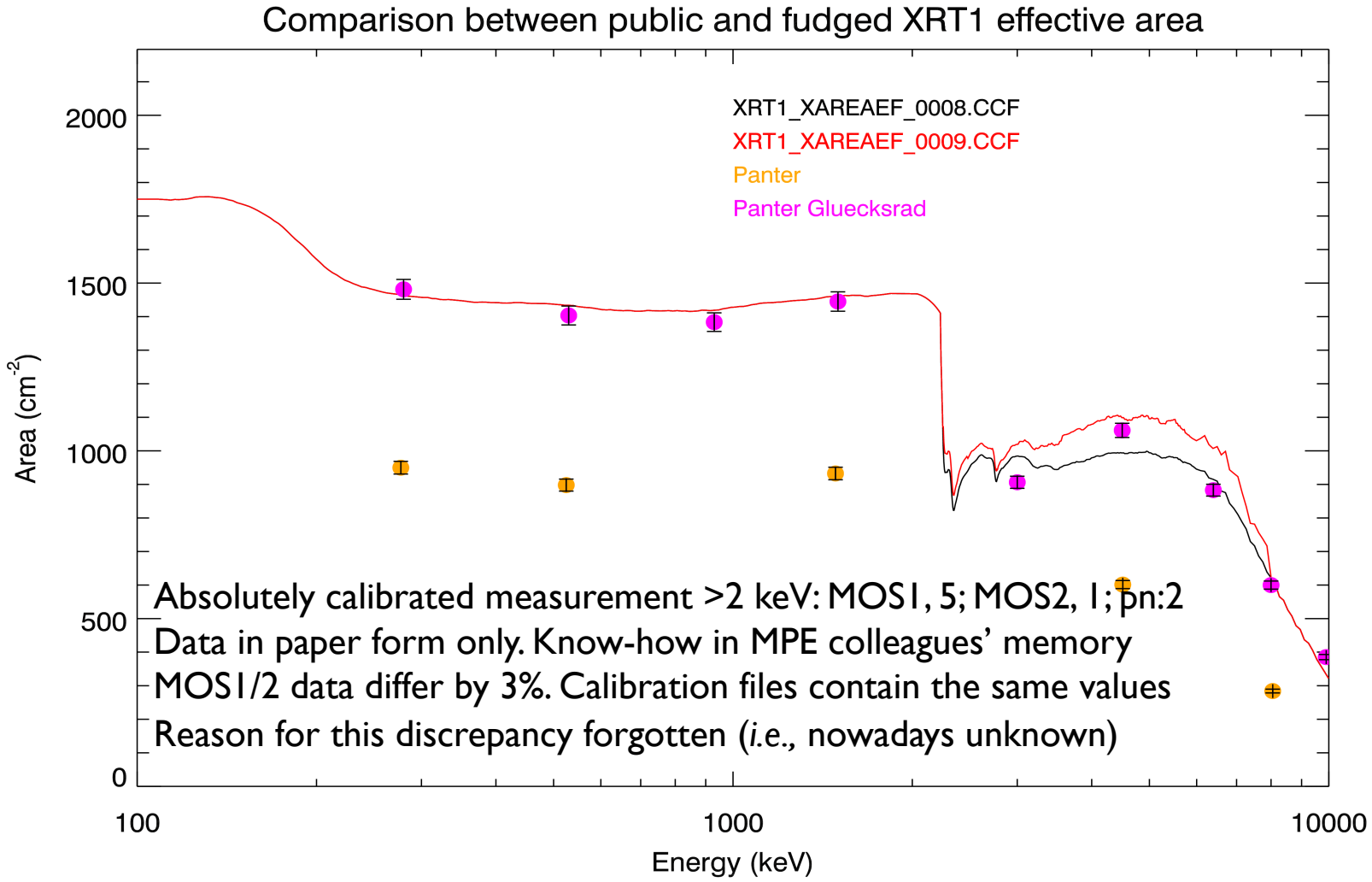
# Example: *Chandra* Optics Calibration

**Things that did go right.**

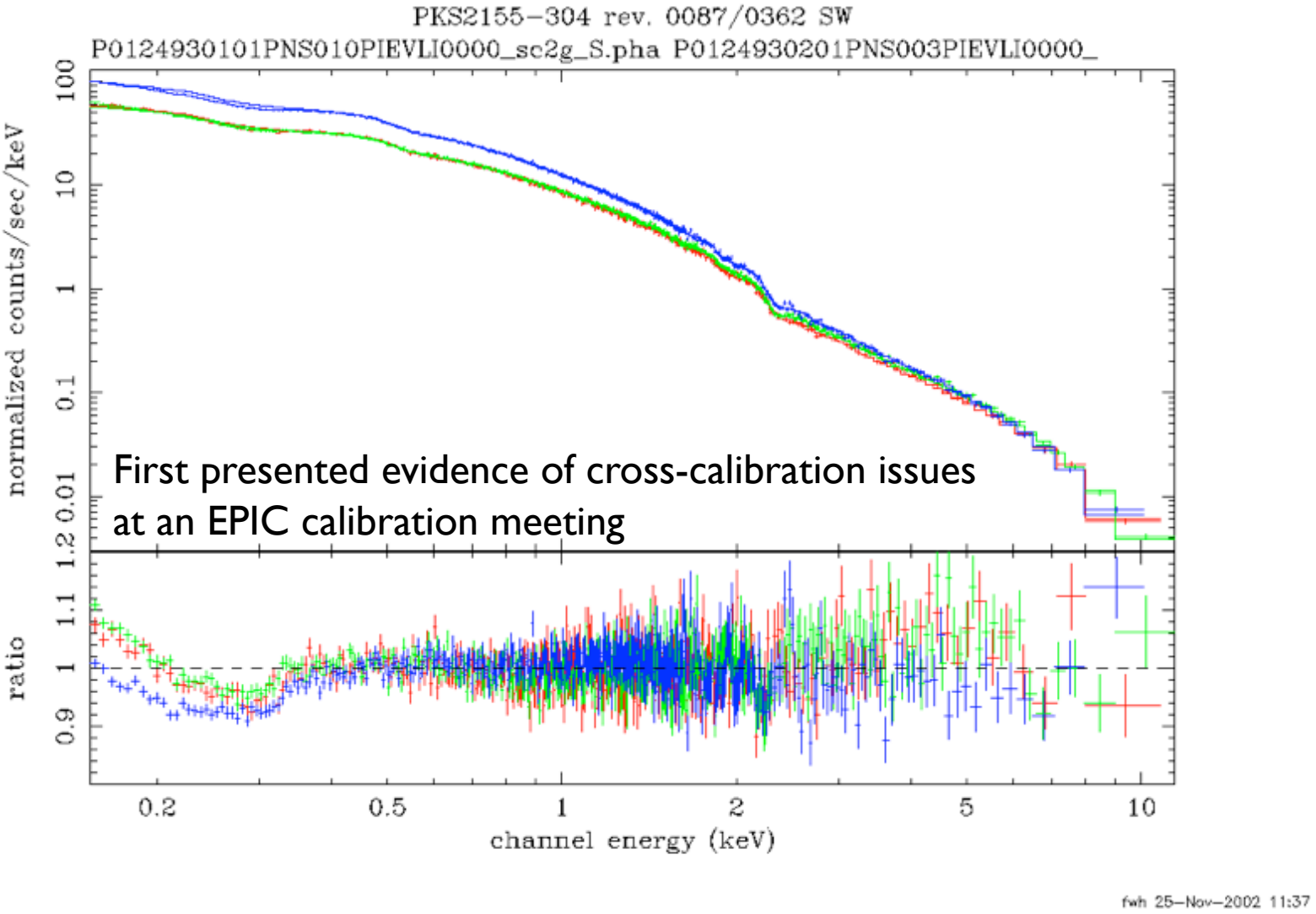
1. Same personnel on pre-flight and on-orbit Calibration Teams
2. No catastrophic disk failures
3. Our memory isn't as bad as it might be.

**In many ways we were very lucky**

# The "*we'll see after launch*" Syndrome

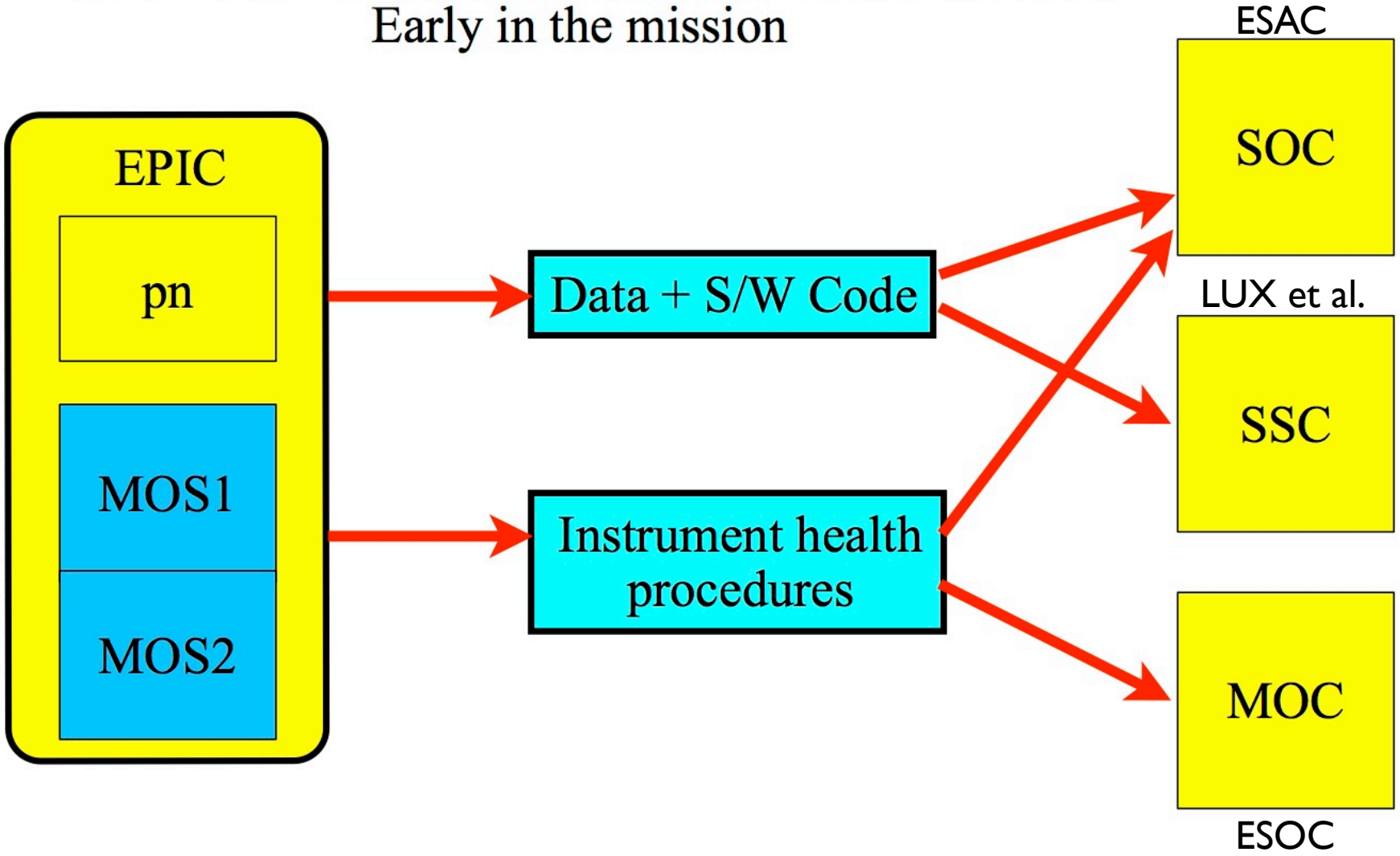


# The "*Post-Flight Communication*" Syndrome




- (from a presentation by F.Haberl in **2002**)

# XMM-Newton: Communication (MOS perspective)
## Early in the mission



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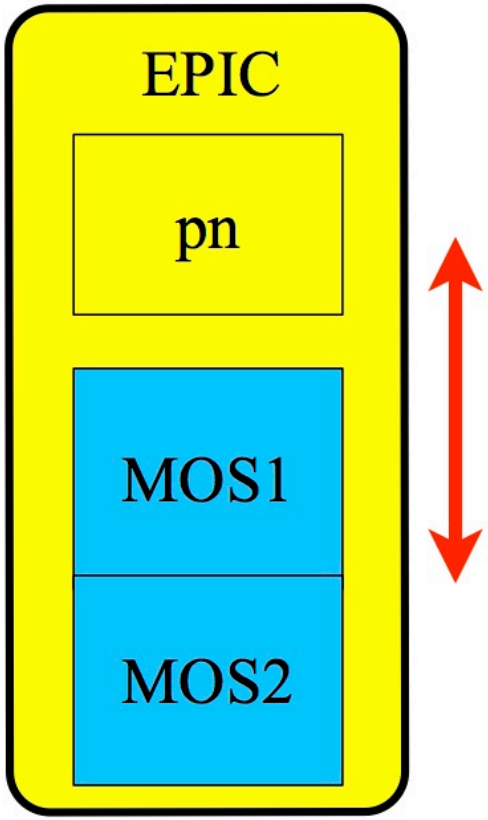



Calibration information flow between MOS and pn teams largely in form of presentations at Consortium Meetings.

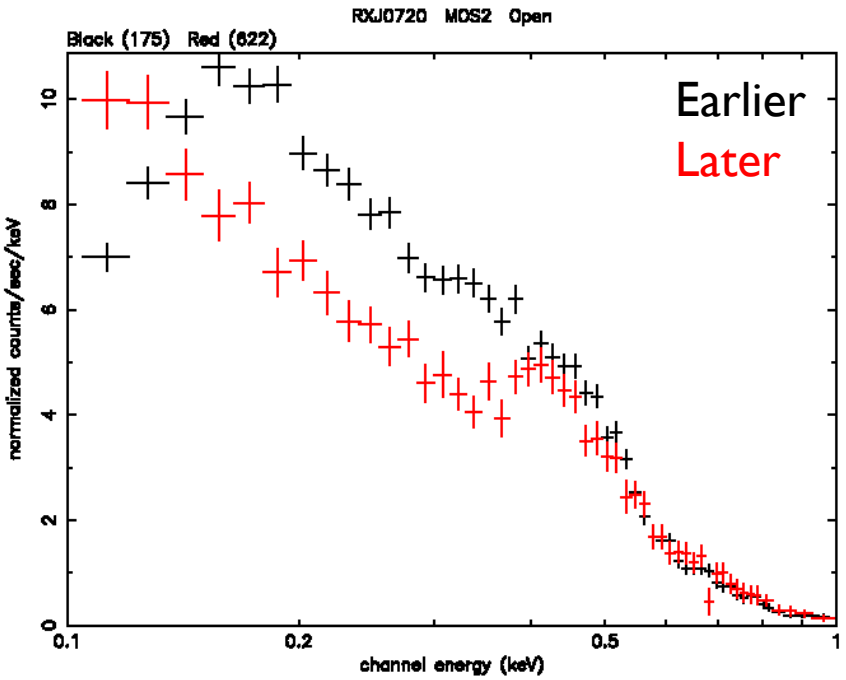
Early in the mission, presentations tend to put the best spin on the current status....politics/human nature.

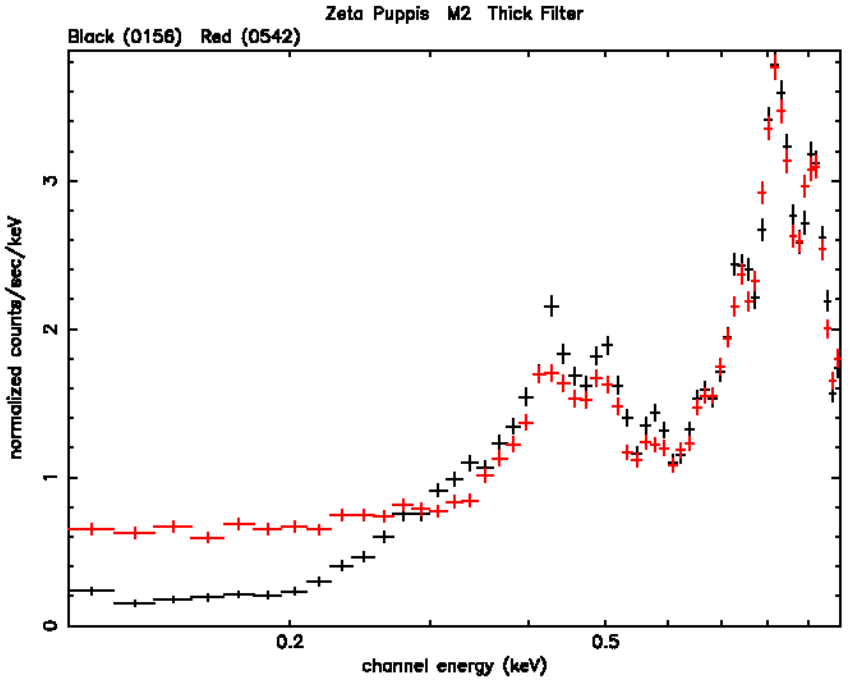
Reluctance to present negative results on your own instrument.

Extreme reluctance to analyse data on other instruments within the consortium, let alone present negative results.

# The "*Welcome to Space*" Syndrome

Discovery of a "redistribution patch" at the MOS boresight position




Too cumbersome to model it with the instrument physical model ➔ Switch to an empirical description of the MOS redistribution based on a reanalysis of ground-based data

- (Sembay et al., 2010, XMM-CCF-REL-267)

# 10 **Golden Rules** of calibration

1. **Think of a mission as a single instrument** [credit: S.Sembay]
2. Ground calibration is never sufficient ...
3. ...one might end-up needing recalibrate everything
4. Integrate calibration data in "CALDB" as early as possible
5. Integrate calibration procedures in science analysis s/w
6. Establish *before launch* a cross-calibration working team
7. Facilitate communication among Instrument Teams since $T_{0,ops}$
8. Allow ITs access to all data
9. Do not neglect the potential help of the community
10. Do not hesitate to rely on colleagues from the IACHEC

- 11. There is no golden rule, of course

# What can IACHEC offer to Astro-H

- A list of standard sources
- A standard astrophysical model for each source
- Observational data and CALDB
- Expertise, experience and support
- Actions from the 8th IACHEC meeting on the IACHEC Chair (me; unfortunately overdue ...) :
  - Draft a charter of a "IACHEC Legacy Working Group"
  - Prepare an observational proposal to systematize the database of calibration observations. This proposal shall be submitted to the "mission managers" of operational missions (and endorsed by those of future ones)

- `http://web.mit.edu/iachec/meetings/2013/index.html`