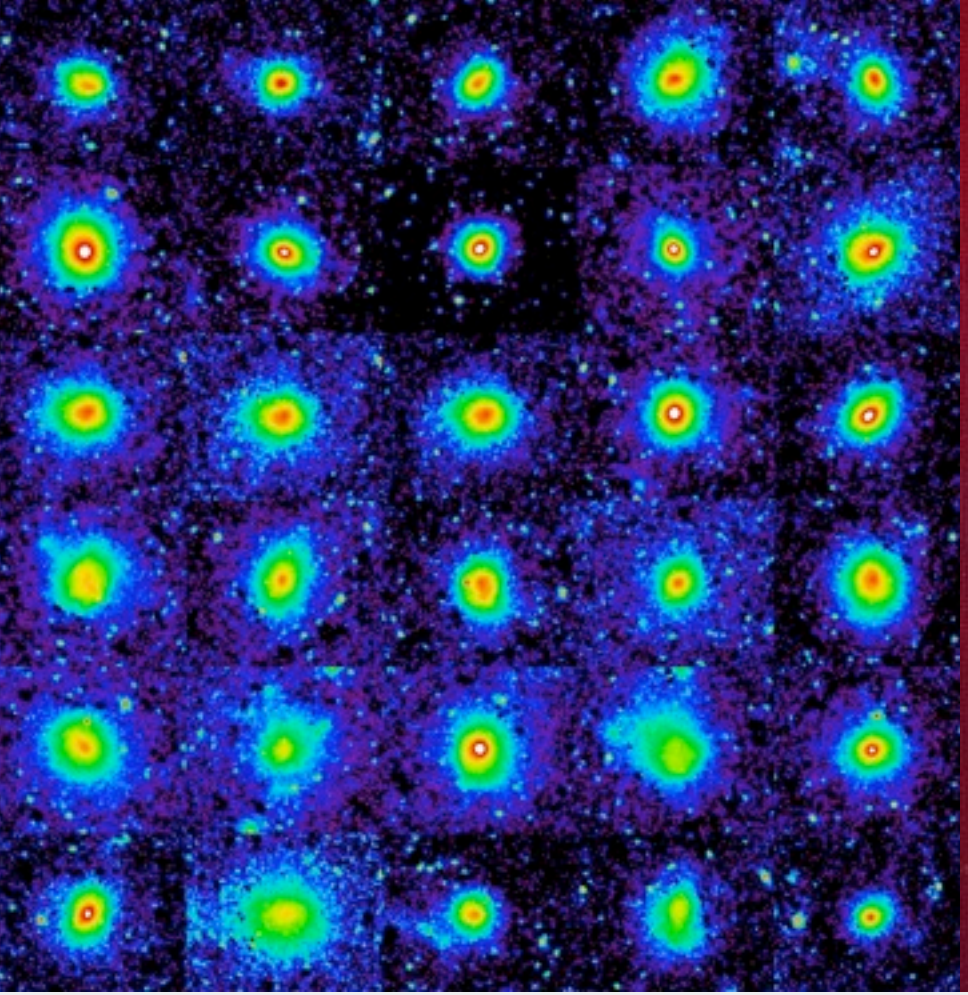
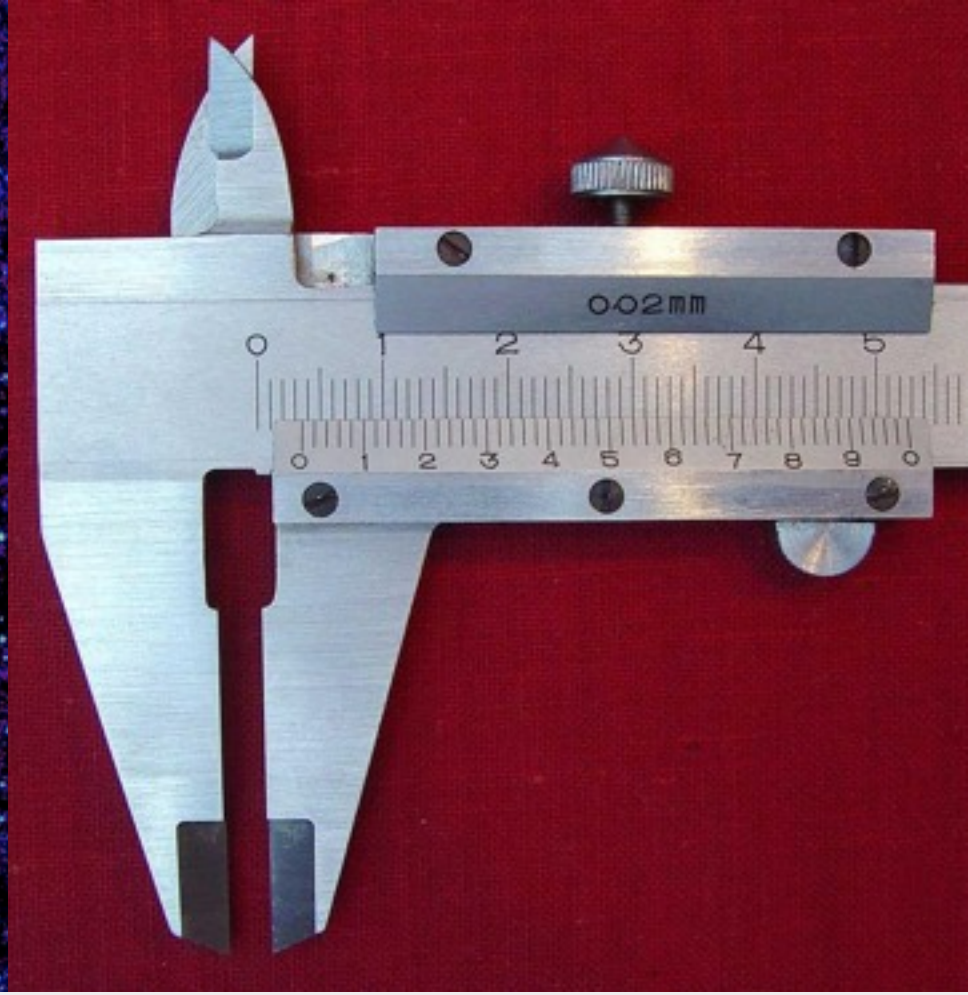




Clusters as calibration tools

S. Molendi (IASF-MI/INAF)

Motivation

- To what level can we trust the calibration of our instruments?
- How far can we push spectral modelling before we end up fitting instrument systematics rather than astrophysically relevant features?

The final frontier?

This is a frontier that is worth exploring, major future X-ray missions are not around the corner, need to make the most of currently active missions.

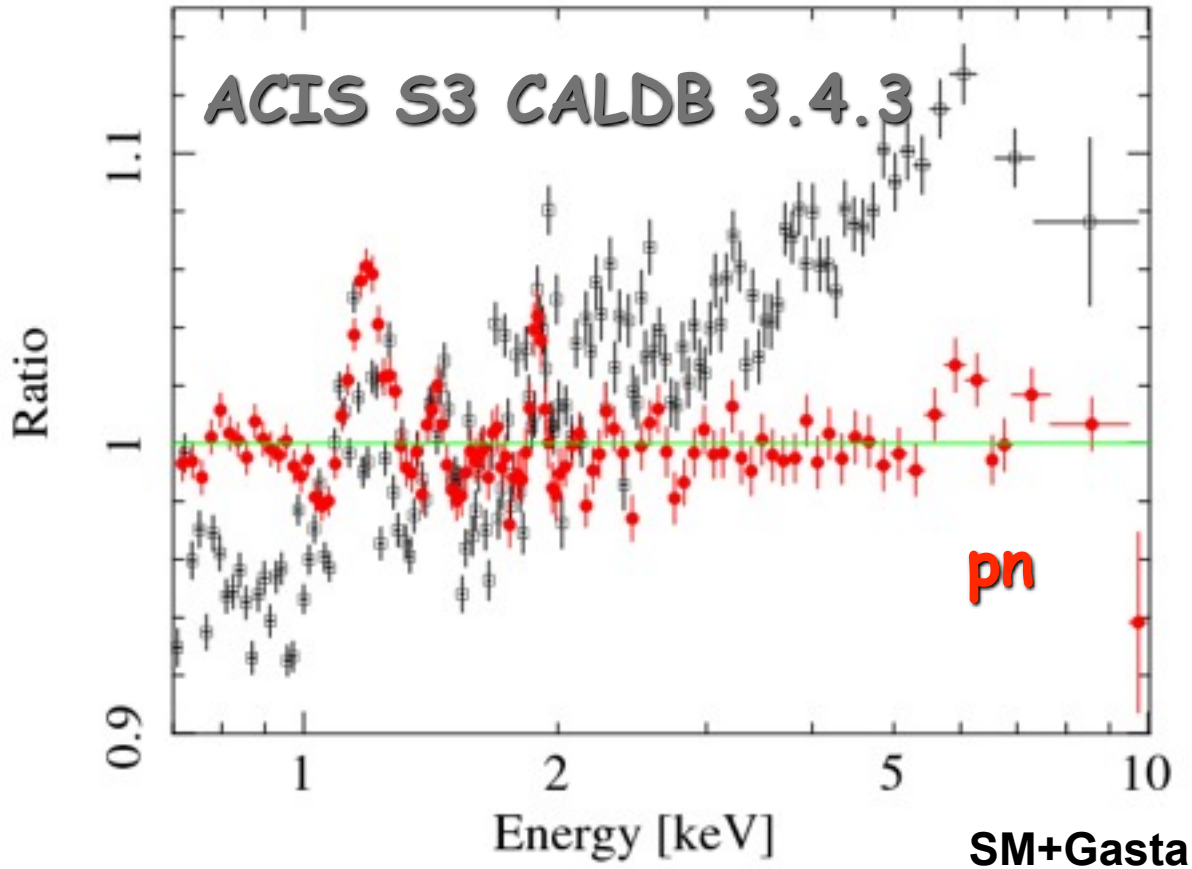
Calibration with Clusters

- Has enjoyed some success
- Lots of photons and no pile-up!
- No need for simultaneous observations
- Spectrum is not a simple power-law however at the level of precision we are dealing with are there any pure pl spectra in the X-ray sky?
- Background can be a limitation

Perseus core

Residuals in the form of ratio data/model for pn and ACIS data on pn best fitting model.

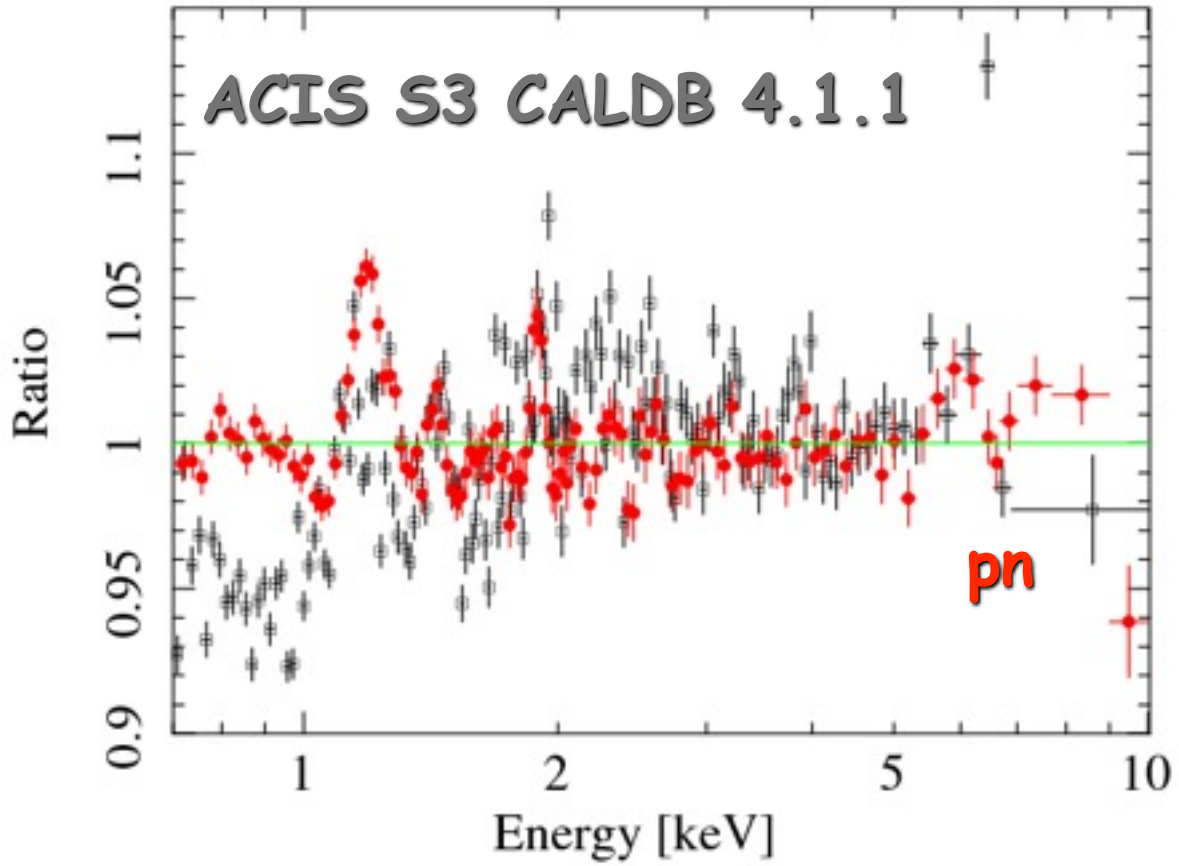
Renorm applied to match spectra at 1.5 keV



SM+Gastaldello 09

Perseus core

Residuals in the form of ratio data/model for pn and ACIS data on pn best fitting model.



Metal Abundances

De Grandi+SM 09

- Measured Si, Fe and Ni for a sample of 21 nearby bright CC clusters
- Used hard band 1.8-10 keV

mekal model			
Metal X	$(X_{MOS1} - X_{MOS2})/X_{MOS2}$	$(X_{MOS1} - X_{pn})/X_{pn}$	$(X_{MOS2} - X_{pn})/X_{pn}$
Fe	0.02 ± 0.01	0.07 ± 0.01	0.02 ± 0.02
+3% syst.err.	0.02 ± 0.02	0.04 ± 0.02	0.01 ± 0.02
Si	0.01 ± 0.02	0.19 ± 0.03	0.10 ± 0.03
+3% syst.err.	-0.03 ± 0.04	0.11 ± 0.04	0.08 ± 0.04
Ni	-0.12 ± 0.08	0.14 ± 0.11	0.01 ± 0.09
+3% syst.err.	-0.13 ± 0.08	0.12 ± 0.11	0.00 ± 0.10

Systematics within 3%

Plasma Codes

mekal vs apec

Fe 4%

Si 10%

Ni 16%

Plasma Codes

mekal vs apec

Fe 4%

Si 10%

Ni 16%

Systematics associated to plasma codes are comparable to or larger than those associated to the instruments.

The Sample

only EPIC to be extended to Chandra

16 observations of 13 objects

spectra selected to be:

- Observed in thin or medium filters
- high SB
- 1T
- $2 < kT < 8$
- $0.015 < z < 0.09$
- long exposures

The Sample

only EPIC to be extended to Chandra

16 observations of 13 objects

spectra selected to be:

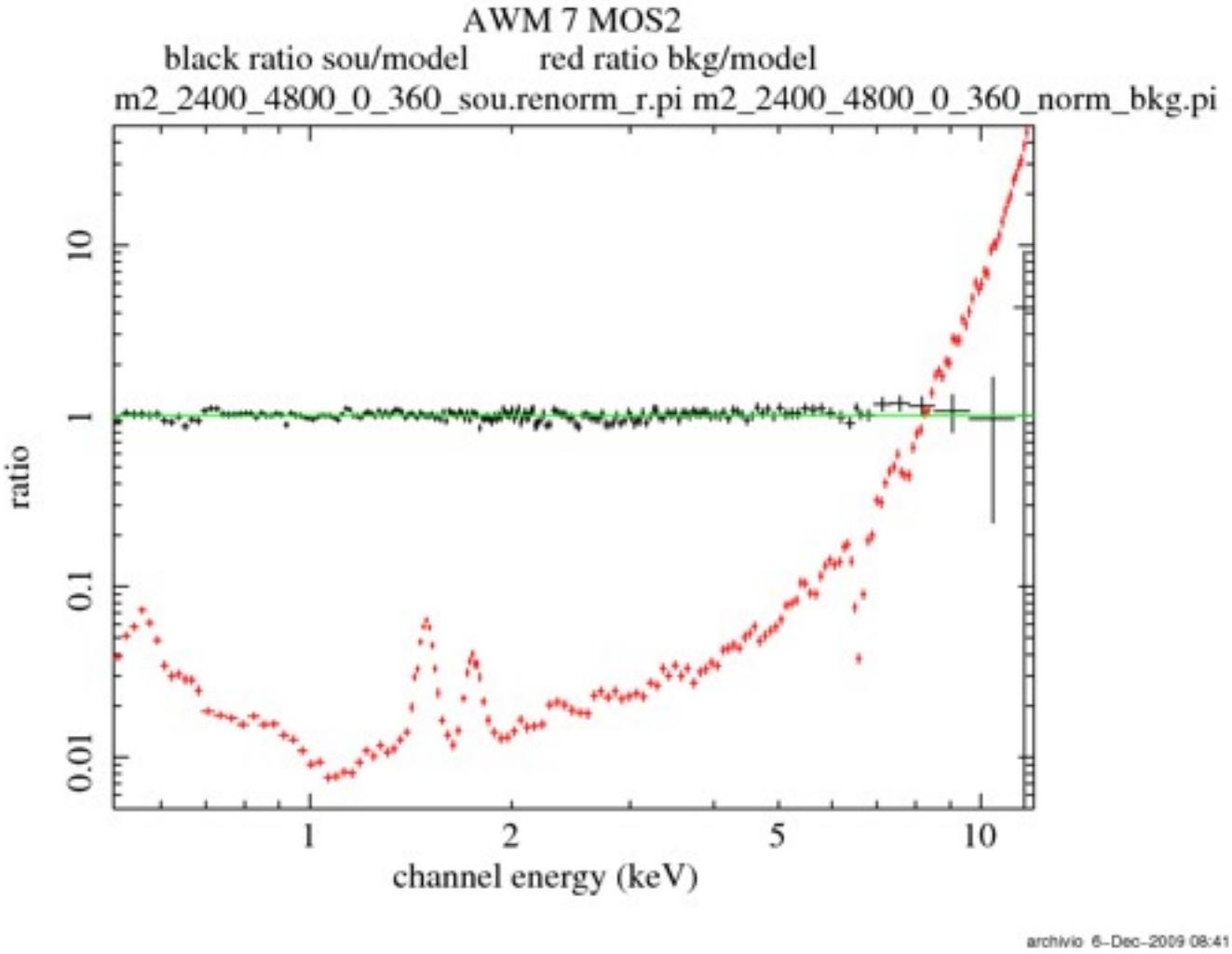
- Observed in thin or medium filters
- high SB
- 1T
- 2 < kT < 8
- 0.015 < z < 0.09
- long exposures

WORK IN PROGRESS

The Sample

source	ring		T	SB	Z	Nev
	arcmin		keV	erg cm^{-2} s^{-1} $amin^{-2}$	Sol Units	
2A0335	2	5	3.2	5.0e-13	0.46	
A86	3	5	6.0	4.5e-13	0.39	*
A262	2	4	2.2	3.0e-13	0.31	*
A478	2	5	6.5	5.7e-13	0.31	
A496	4	7	4.5	2.7e-13	0.31	
A1060	2	5	3.0	4.2e-13	0.46	
A1650	1	2	5.8	4.0e-13	0.35	
A1795	3	5	6.0	3.6e-13	0.30	*
A2029	2	4	7.6	7.5e-13	0.37	*
A2199	2	5	4.2	7.5e-13	0.44	*
A2597	2	4	3.7	8.9e-14	0.28	
AWM7	2	4	3.7	8.7e-13	0.28	
MKW3s	2	4	3.6	3.2e-13	0.30	*

Background


AWM 7 MOS2
black ratio sou/model
red ratio bkg/model
m2_2400_4800_0_360_sou.renorm_r.pi m2_2400_4800_0_360_norm_bkg.pi
ratio
10
1
0.1
0.01
1
2
5
10
channel energy (keV)
archivio 6-Dec-2009 08:41

Analysis

Fit spectra with 1T and 2T models

In most cases no substantial improvement with 2T, even when improvement is substantial, typically for objects with better statystics, 2T modeling is un-physical, possibly associated to systematics

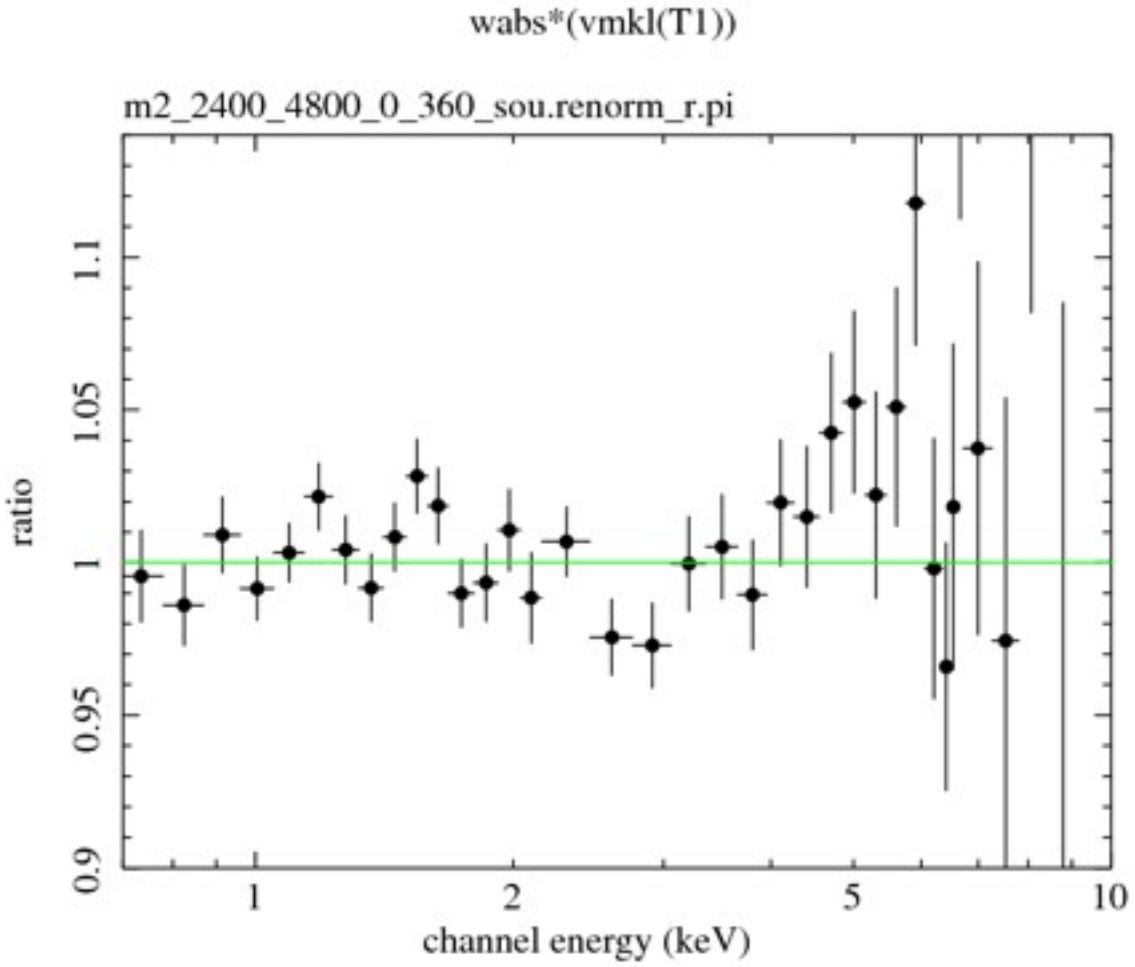
Calibration

Consider data from each camera individualy

Investigating residuals

- Explore residuals in the form of ratio data/model
- Heavily regroup data (beyond resolution limit) to achieve few % errors

2A 0335 Ratio data/model

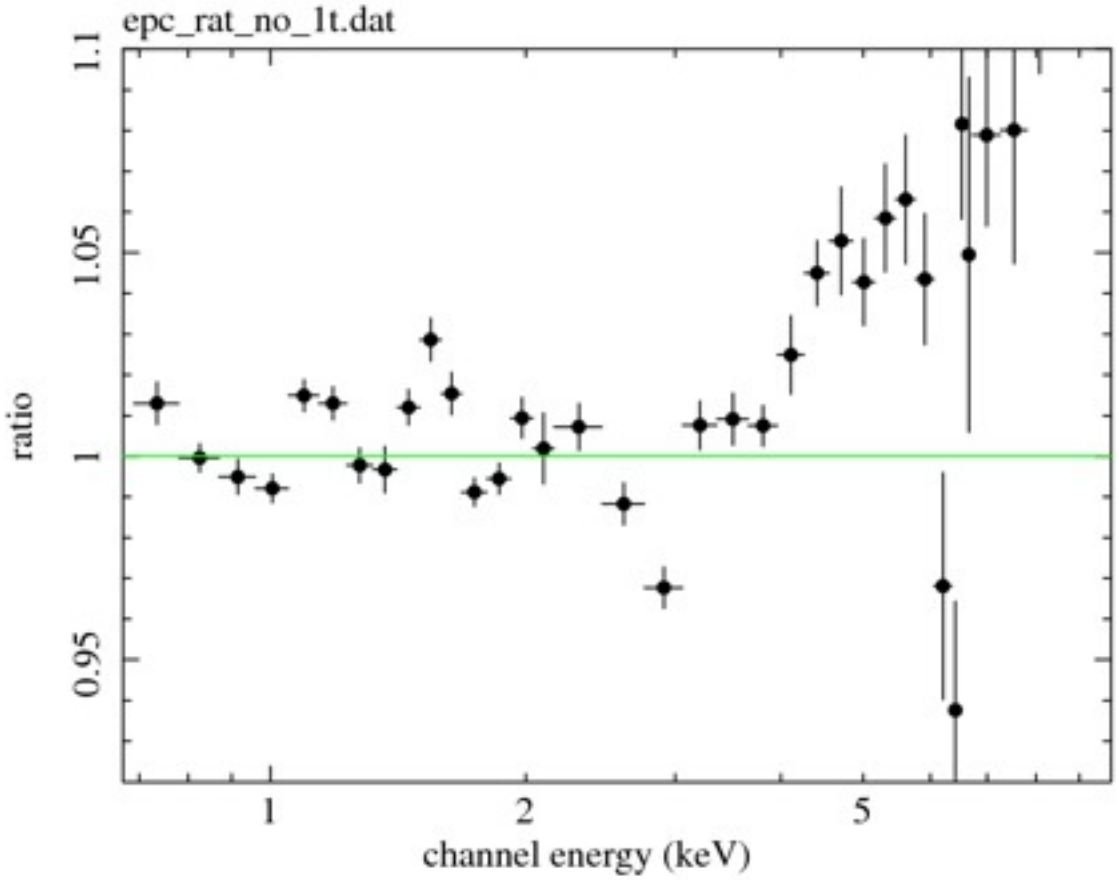


Investigating residuals

- Compute mean residuals averaged over all 16 observations
- Statistical errors are reduced, systematics should show up

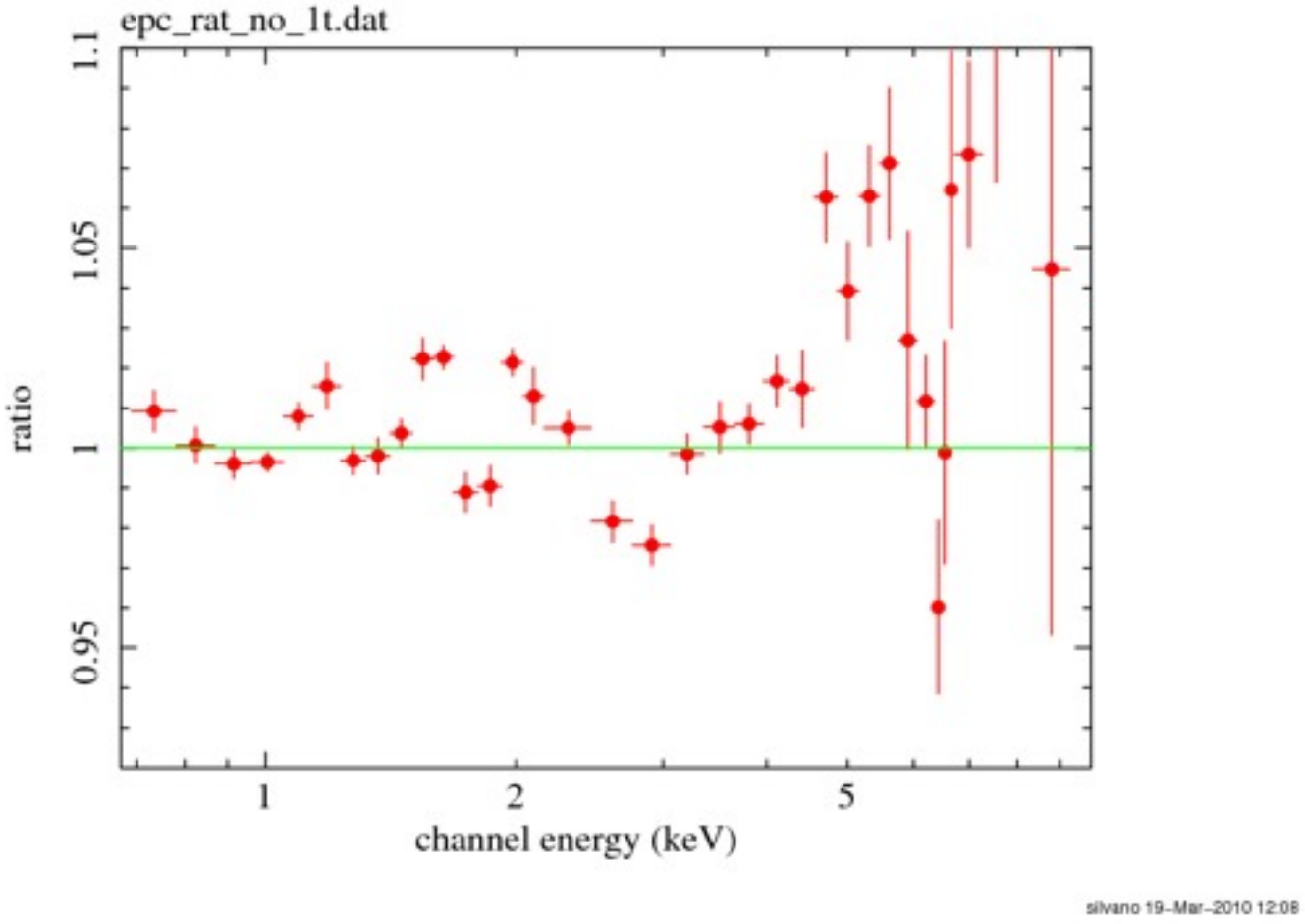
Deviations from a simple thermal model

MOS 1



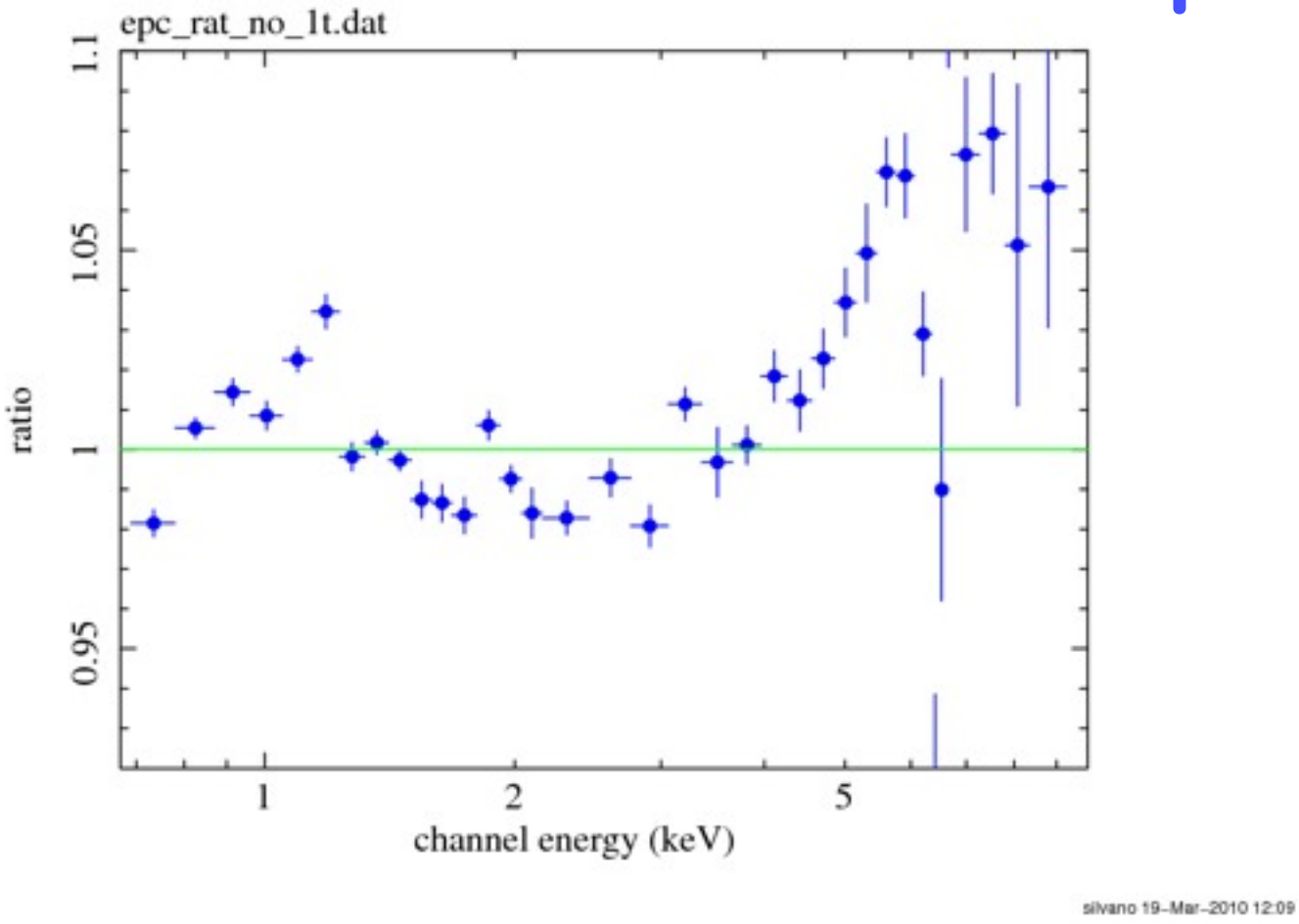
Deviations from a simple thermal model

MOS 2



Deviations from a simple thermal model

pn

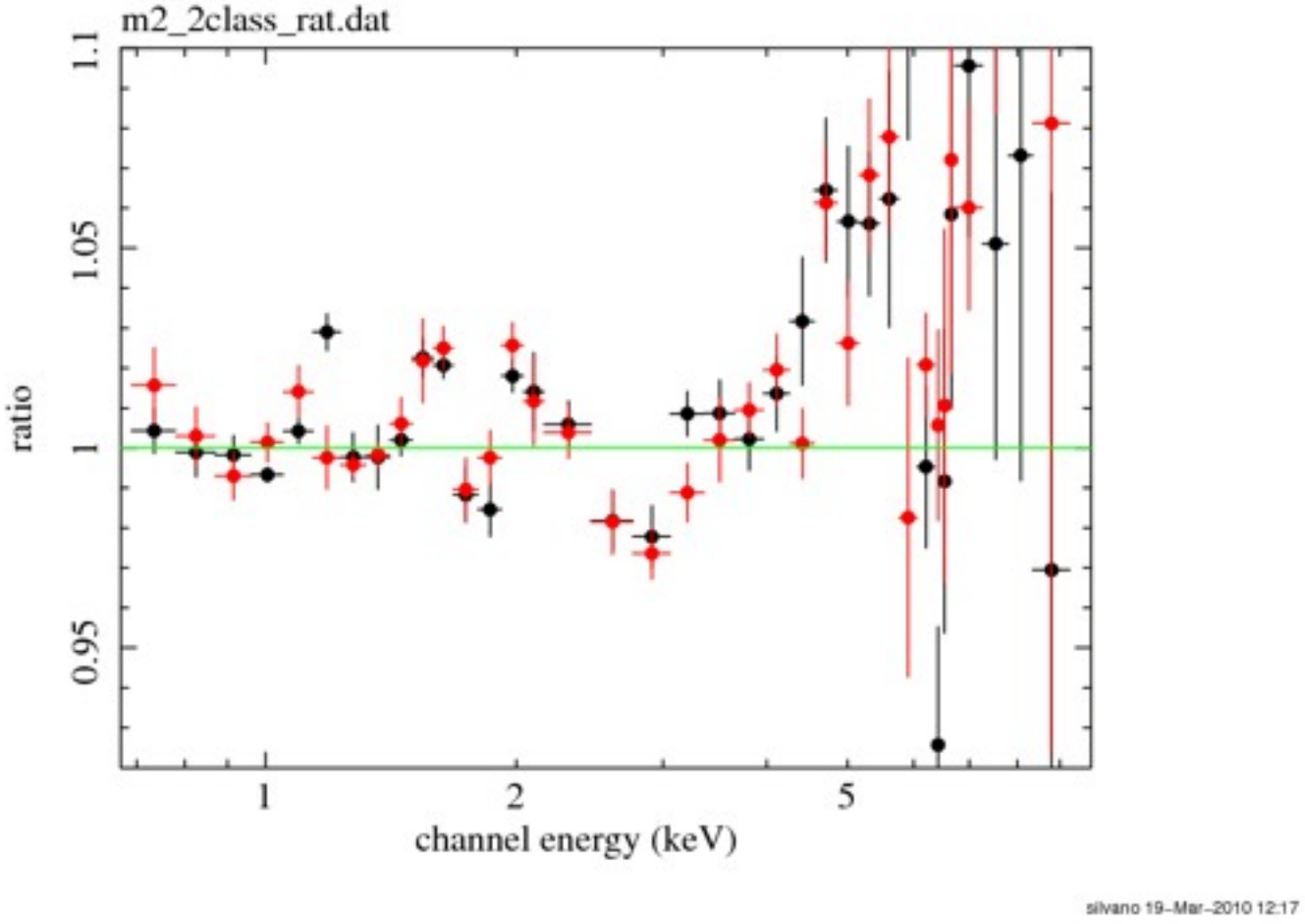


Stability of residuals

Do different objects show similar residuals?

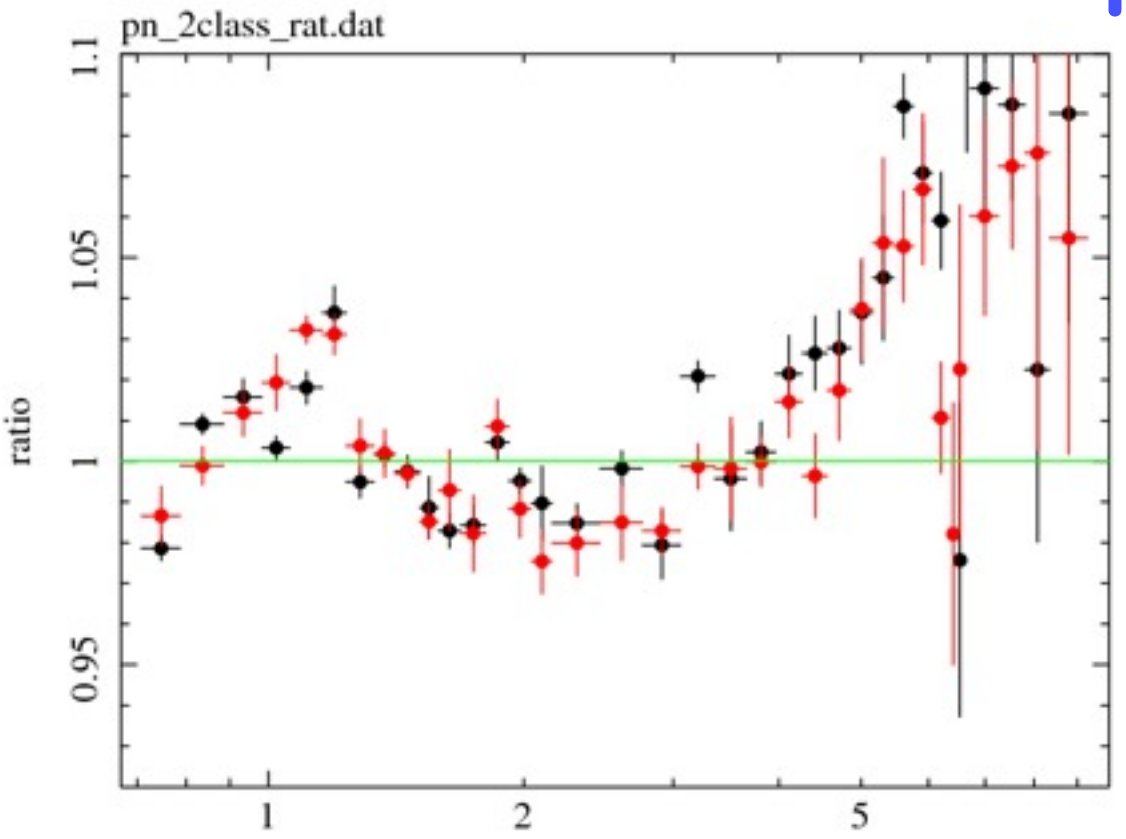
Cold vs Hot

MOS2



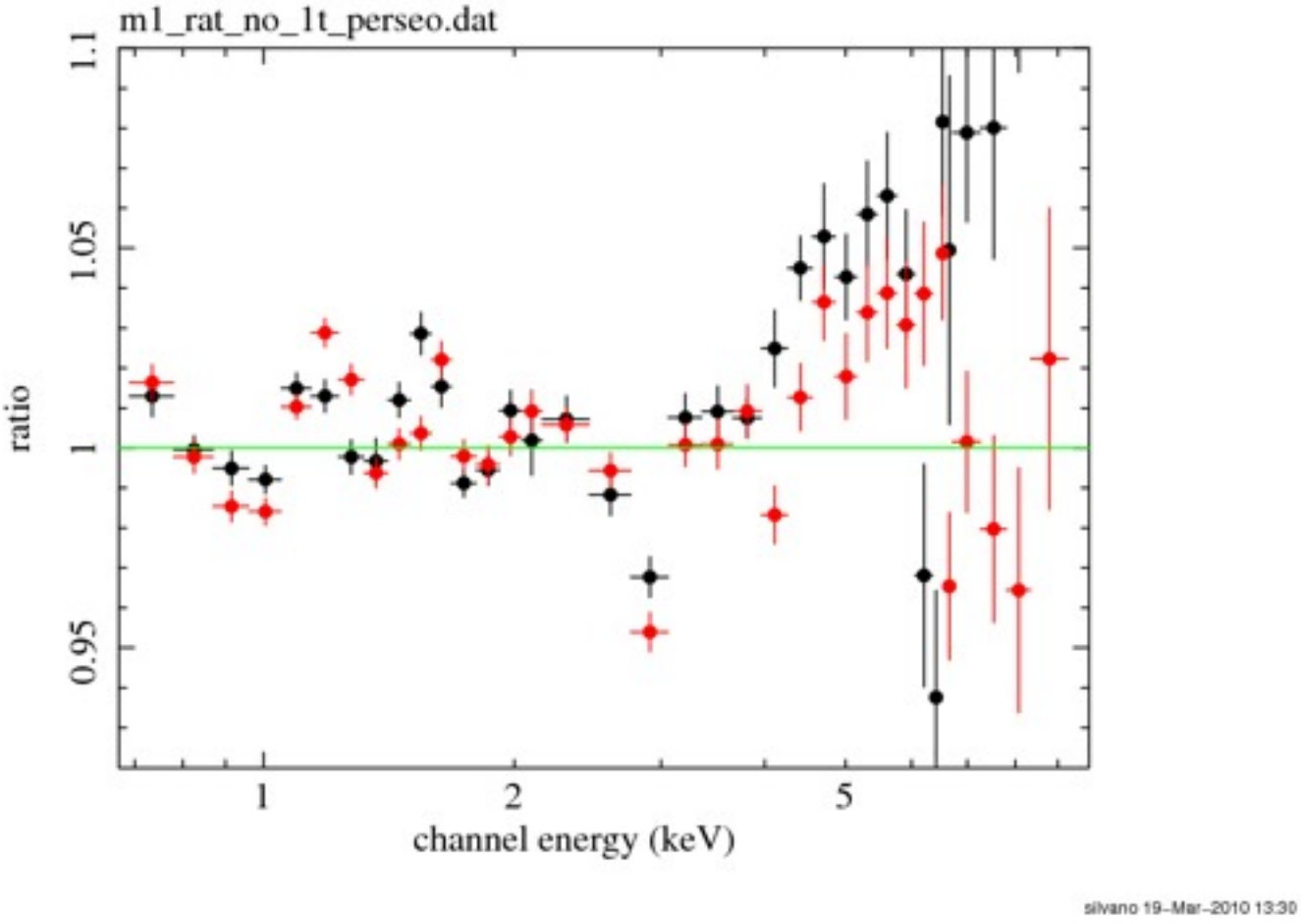
Cold vs Hot

pn



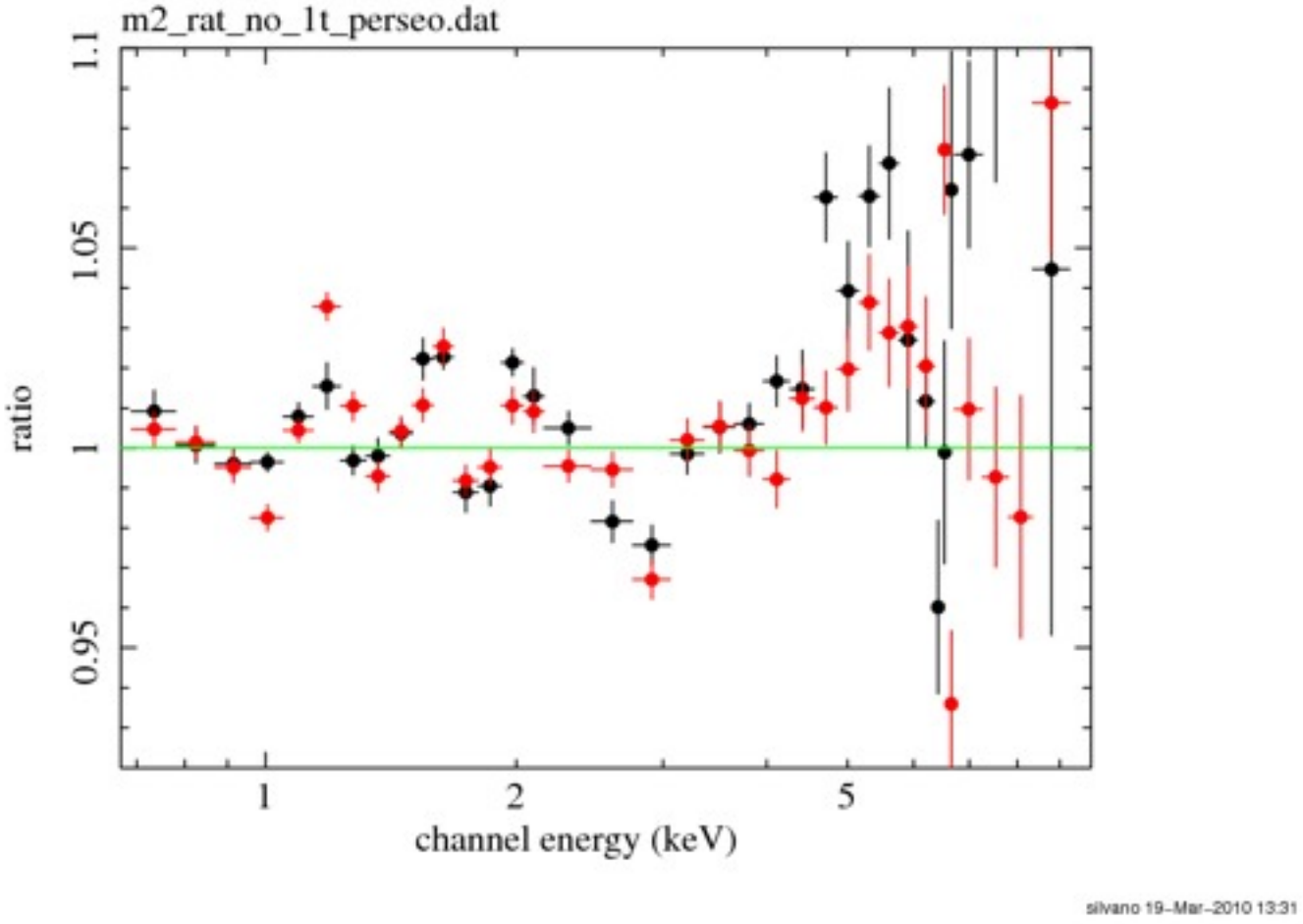
Sample vs Perseus

MOS1



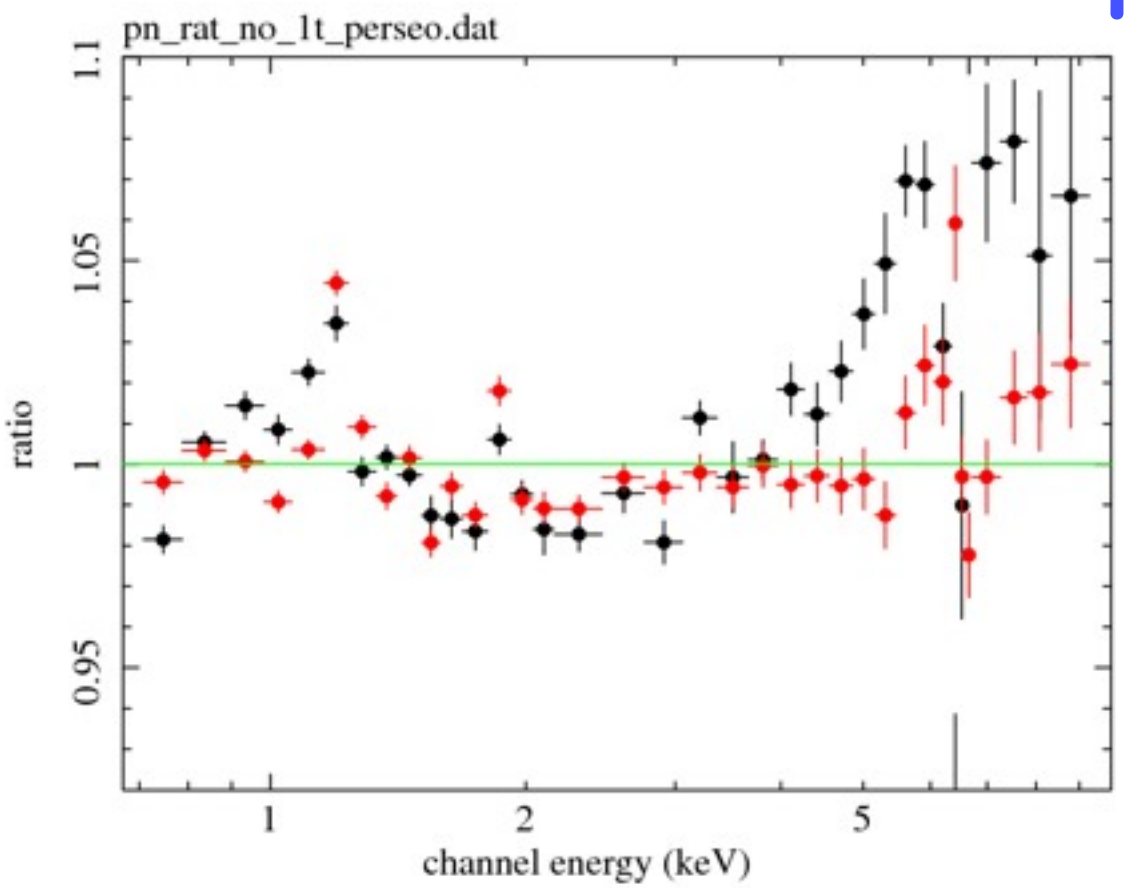
Sample vs Perseus

MOS2



Sample vs Perseus

pn



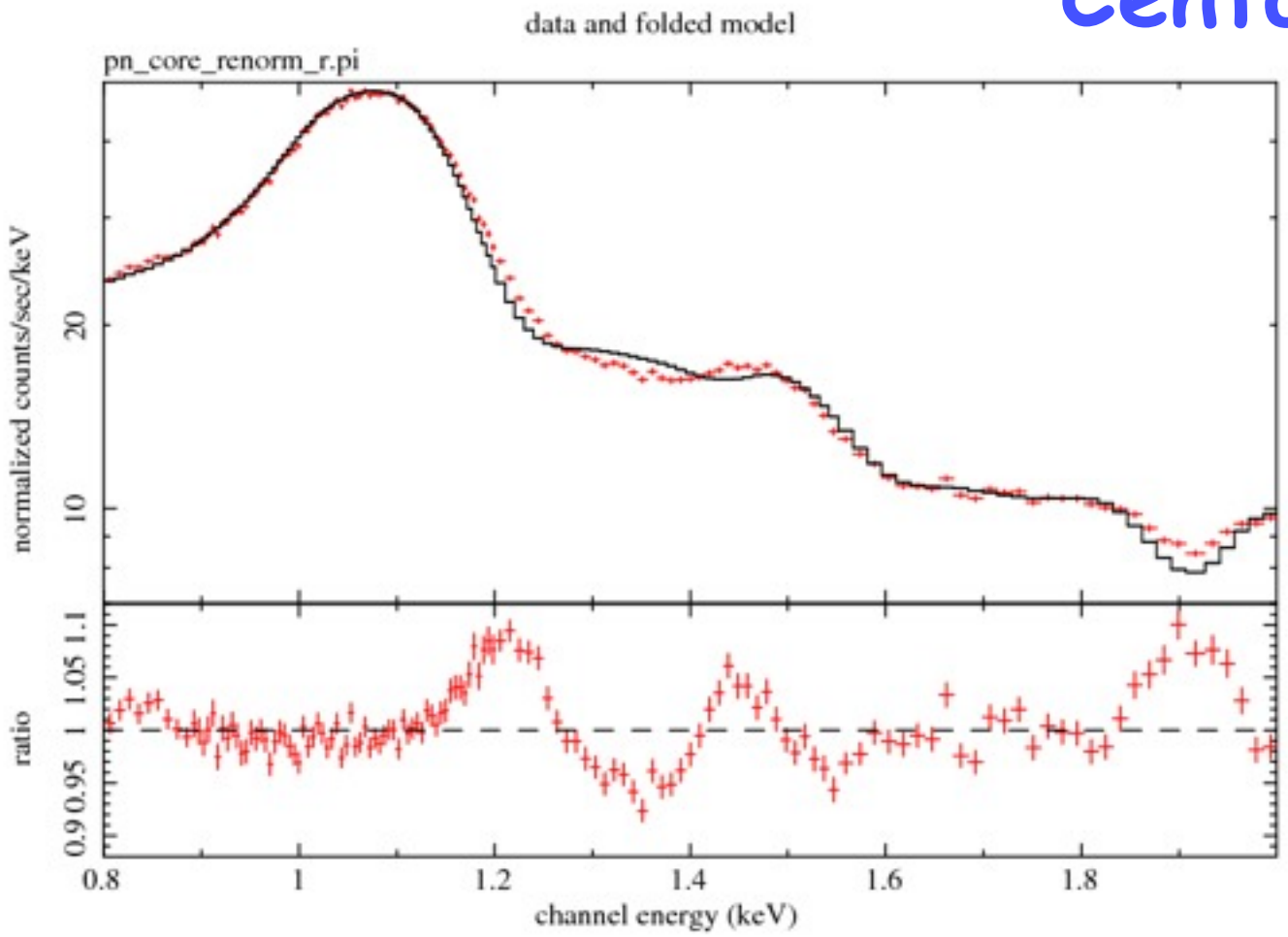
Investigating residuals

- Residuals at least in some instances appear to be similar in different objects
- Spectral model 1T, hot cold, 4T for Perseus -- unlikely

  - Redistribution -- rmf
  - Effective Area -- arf

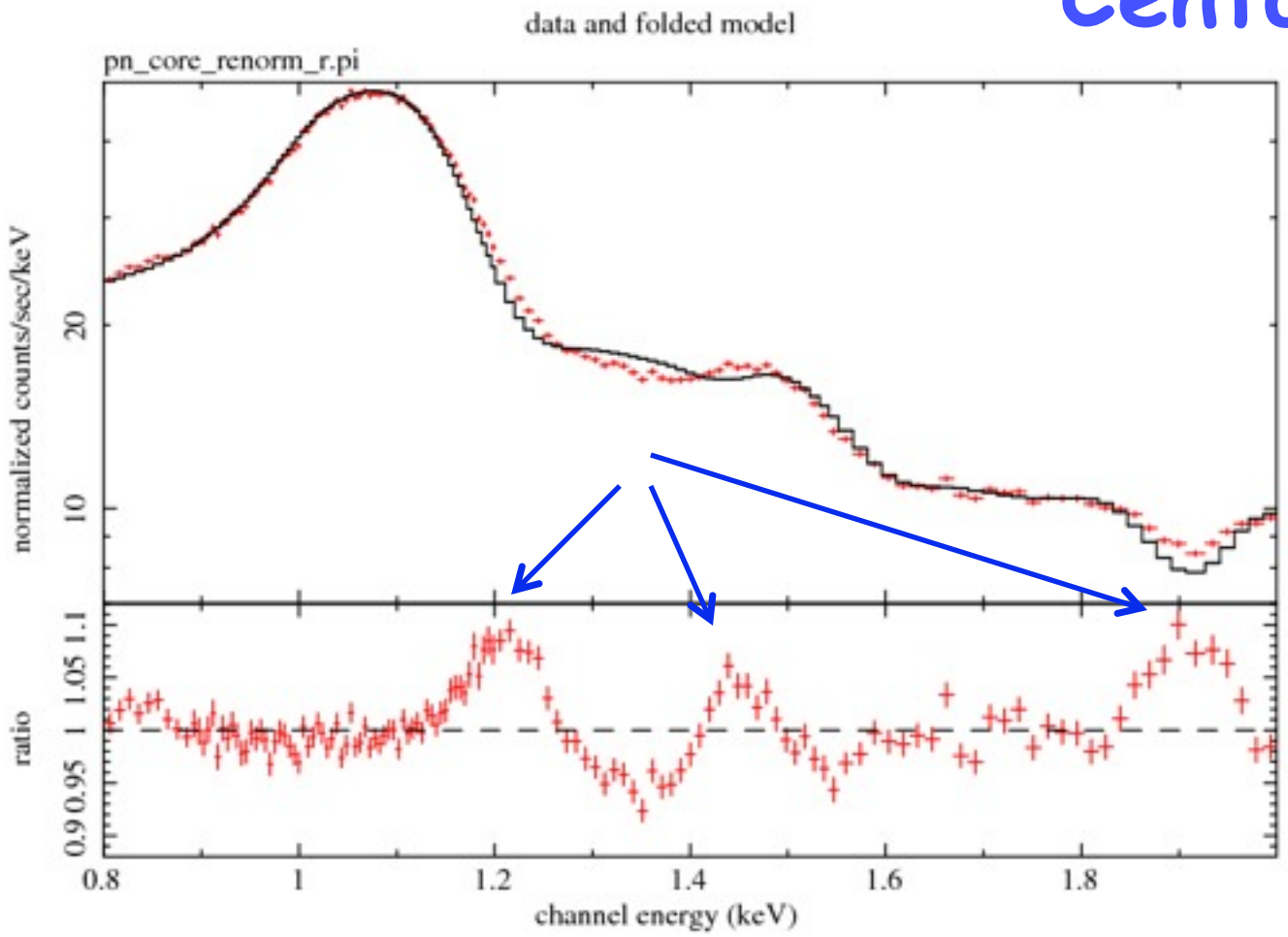
pn soft band residua

Centaurus



pn soft band residua

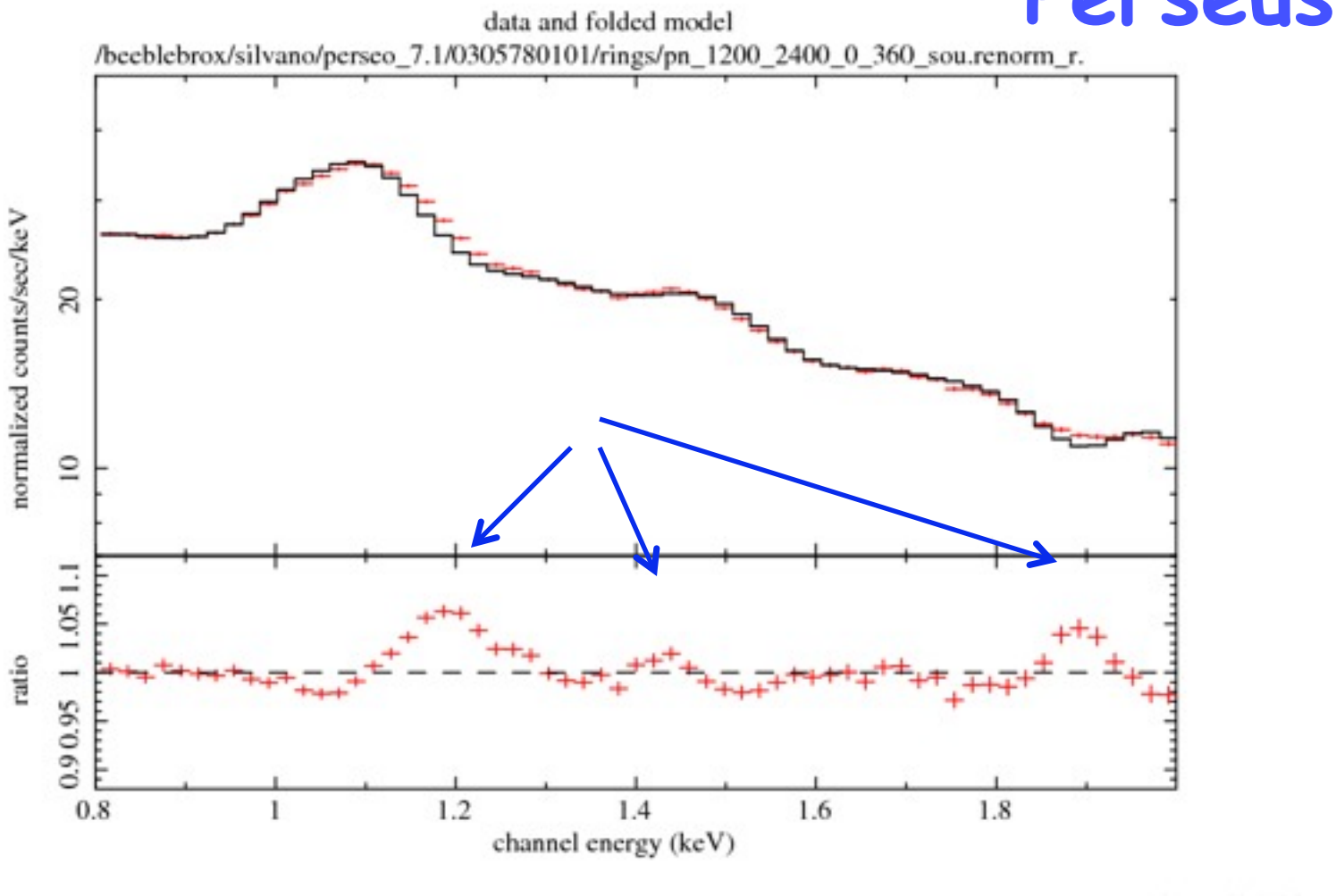
Centaurus



silvano 20-Mar-2010 20:57

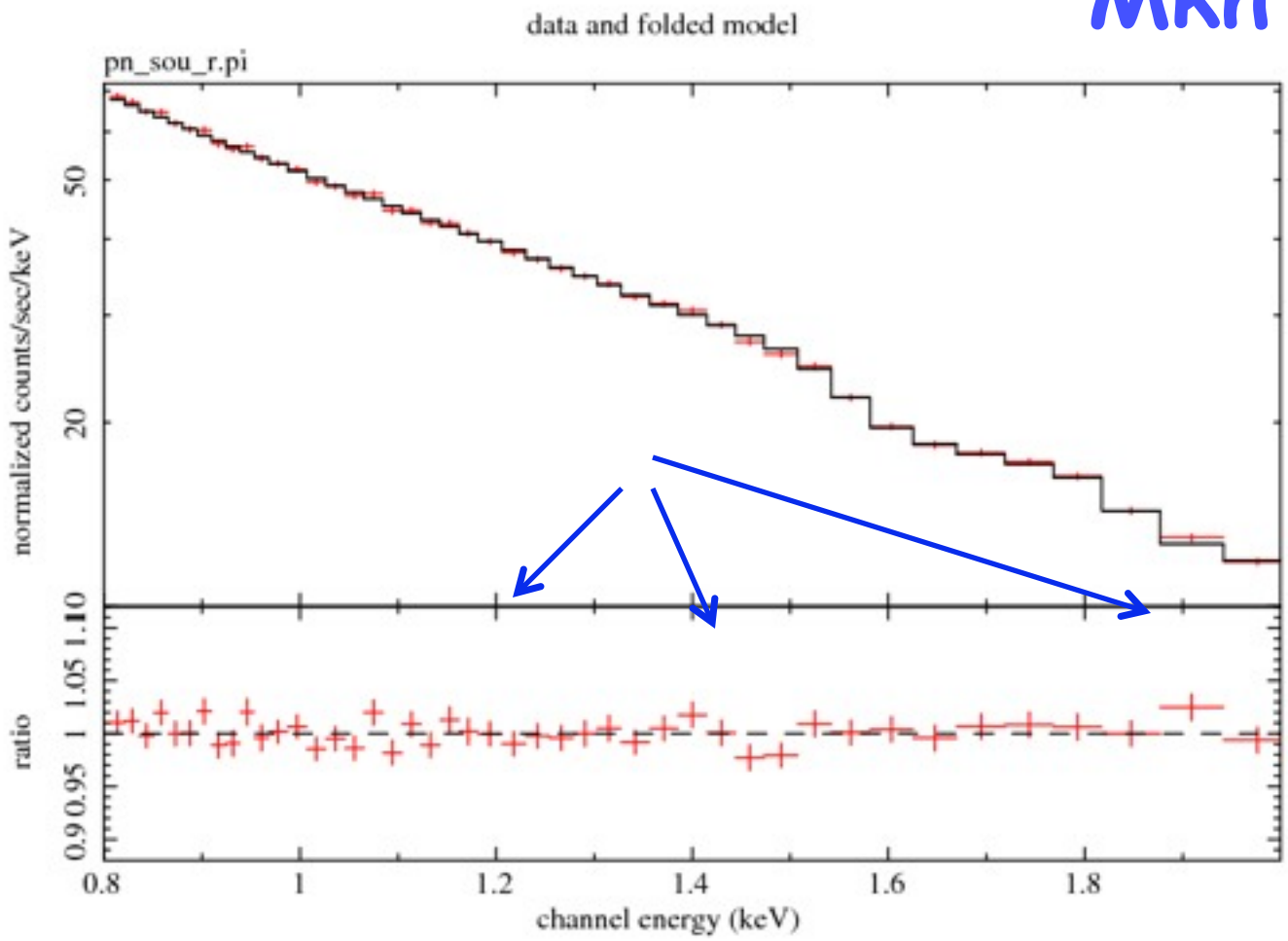
pn soft band residua

Perseus



pn soft band residua

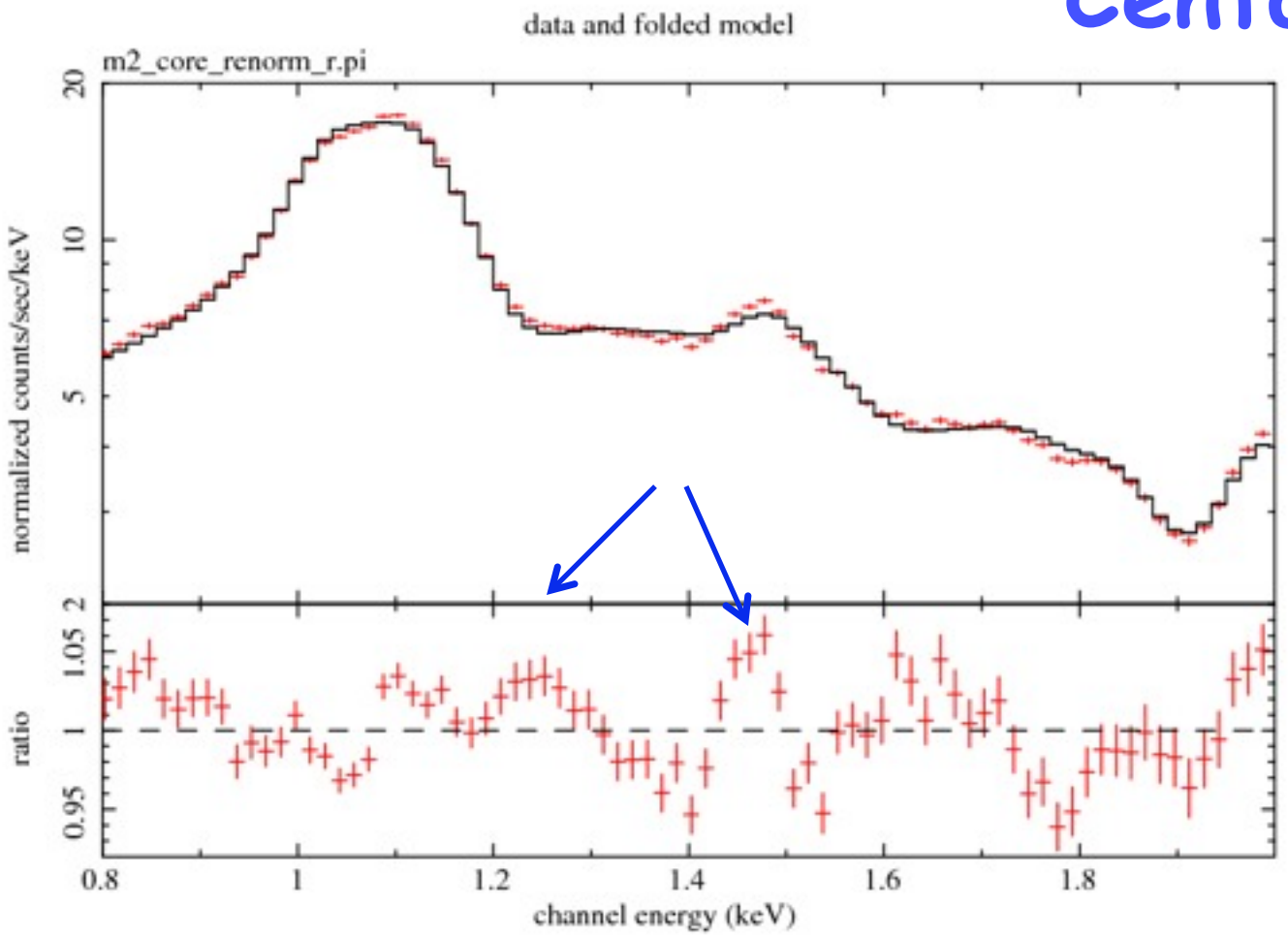
Mkn 421



silvano 20-Mar-2010 21:34

mos soft band residua

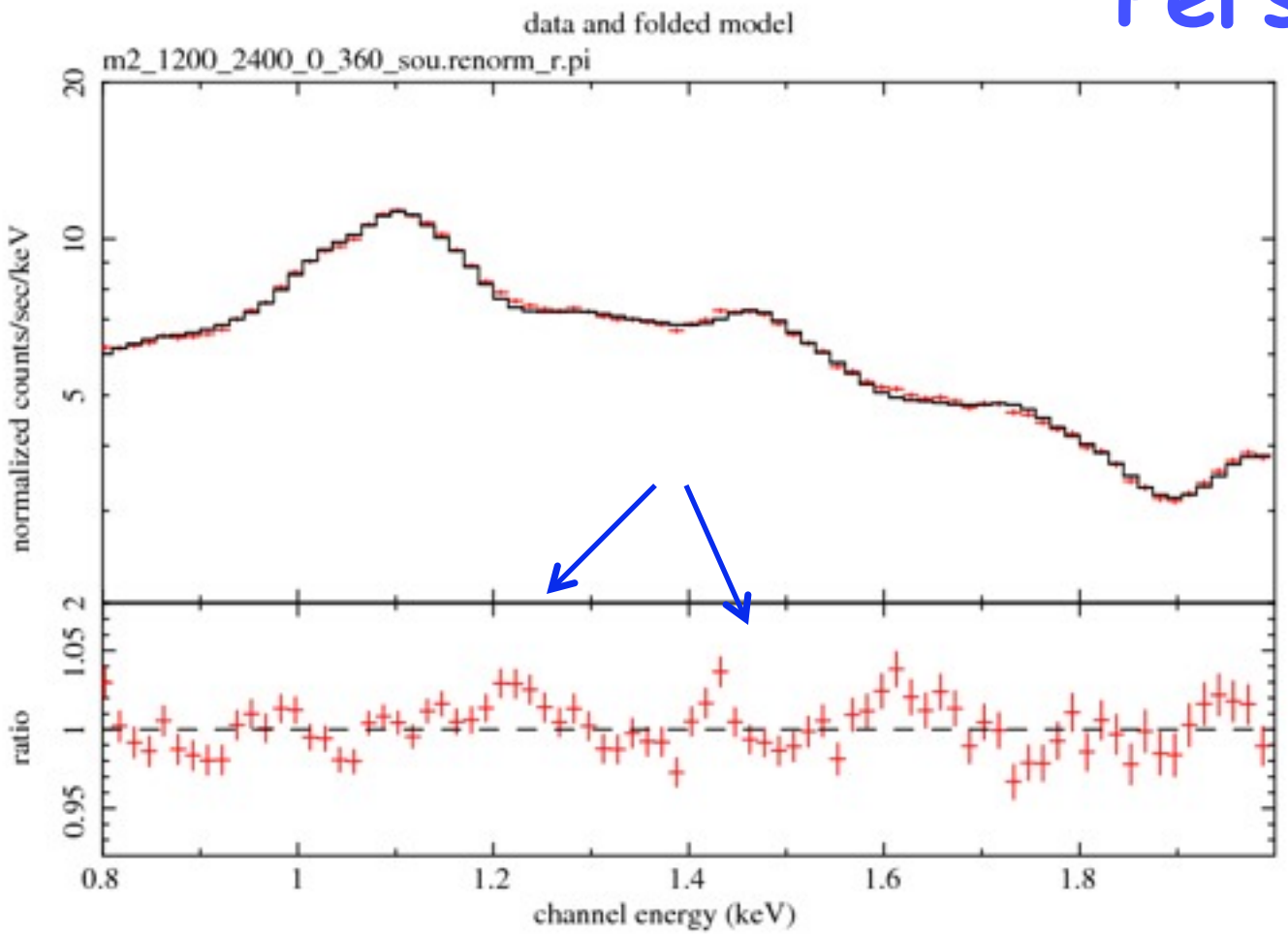
Centaurus



silvano 21-Mar-2010 16:50

mos soft band residua

Perseus



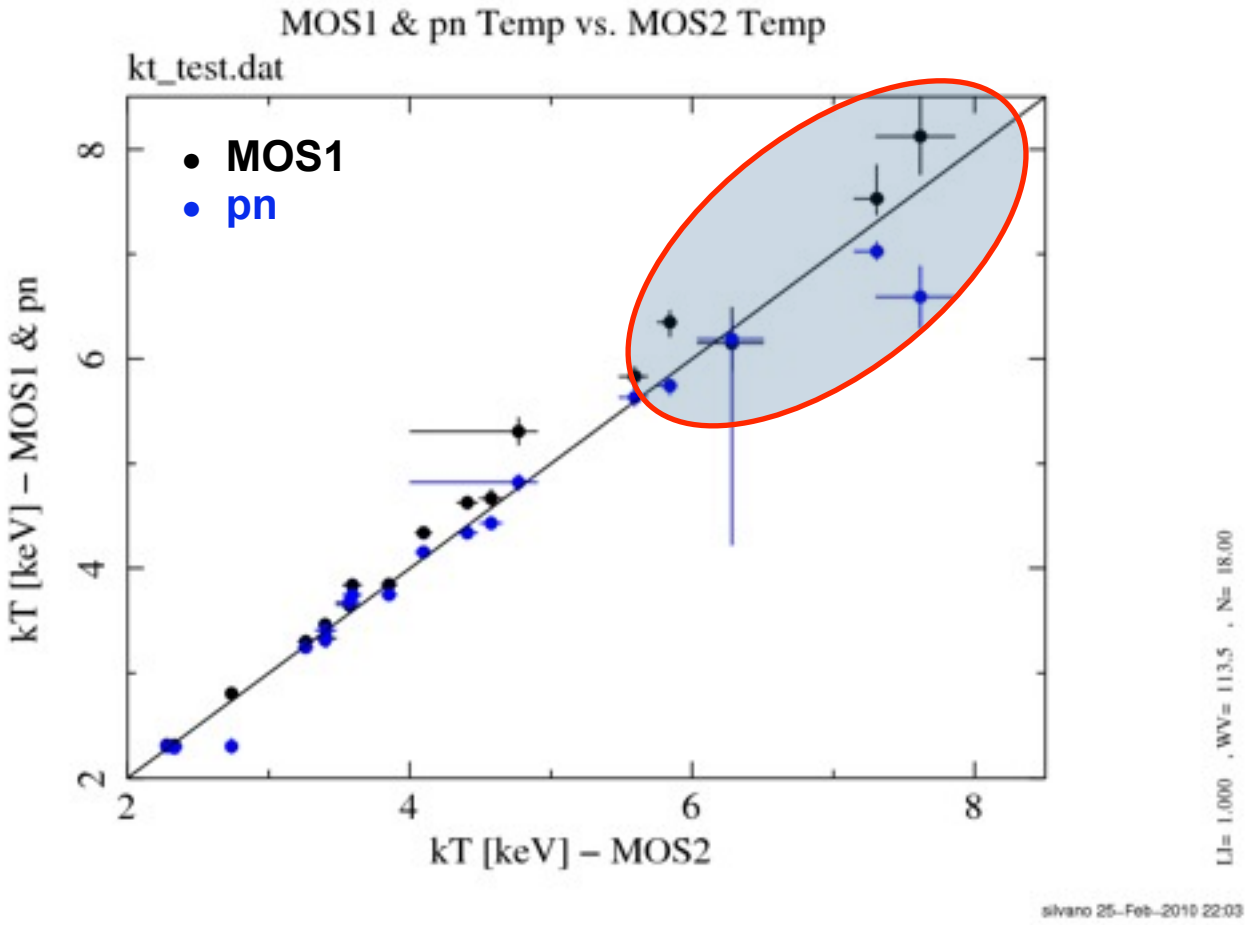
Implications

- Systematics likely related to rmf, particularly true for pn
- MOS less certain

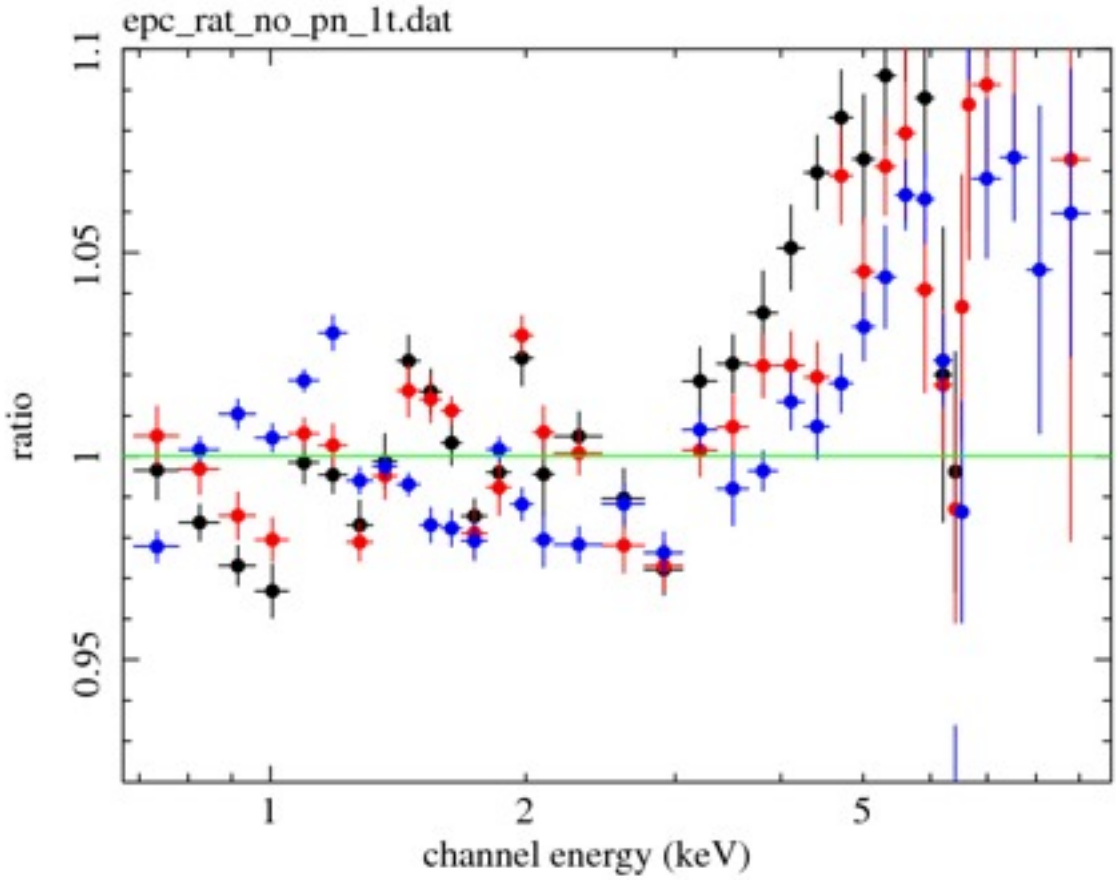
Cross-Calibration

Compare different instruments

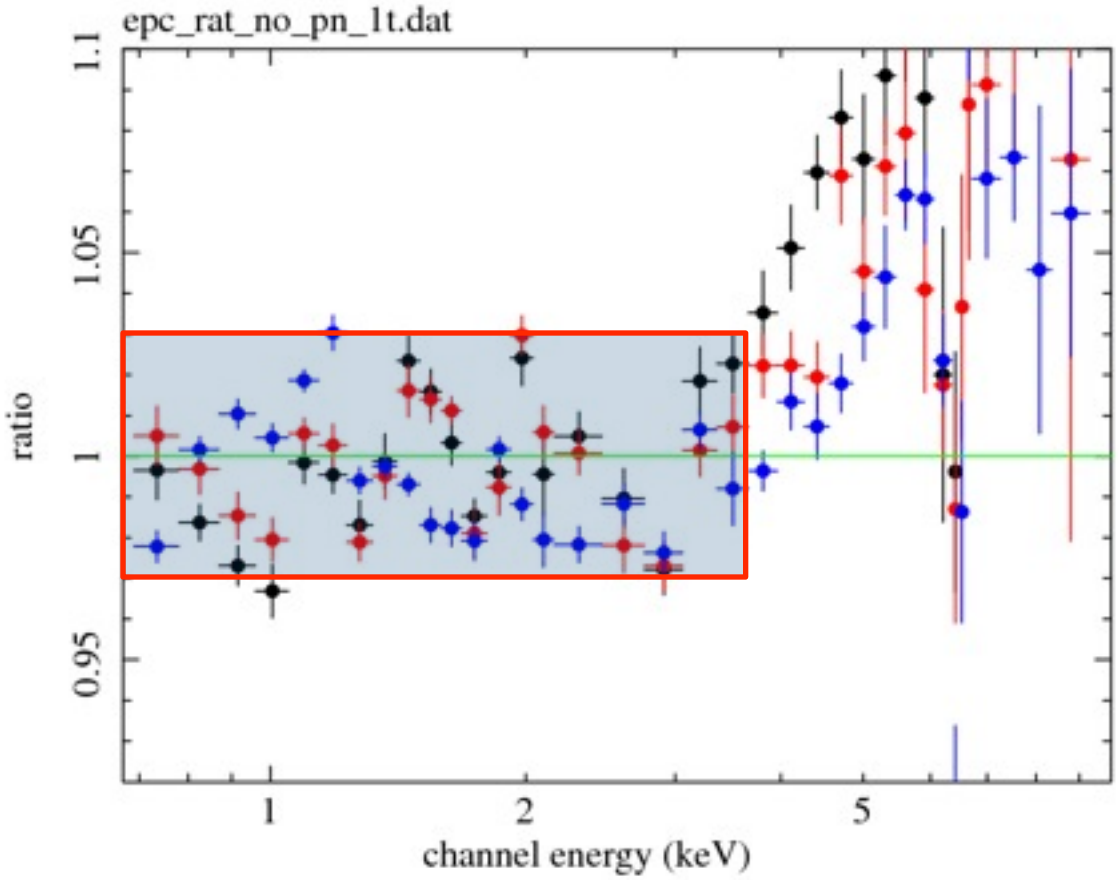
MOS1 & pn kT vs MOS2 kT



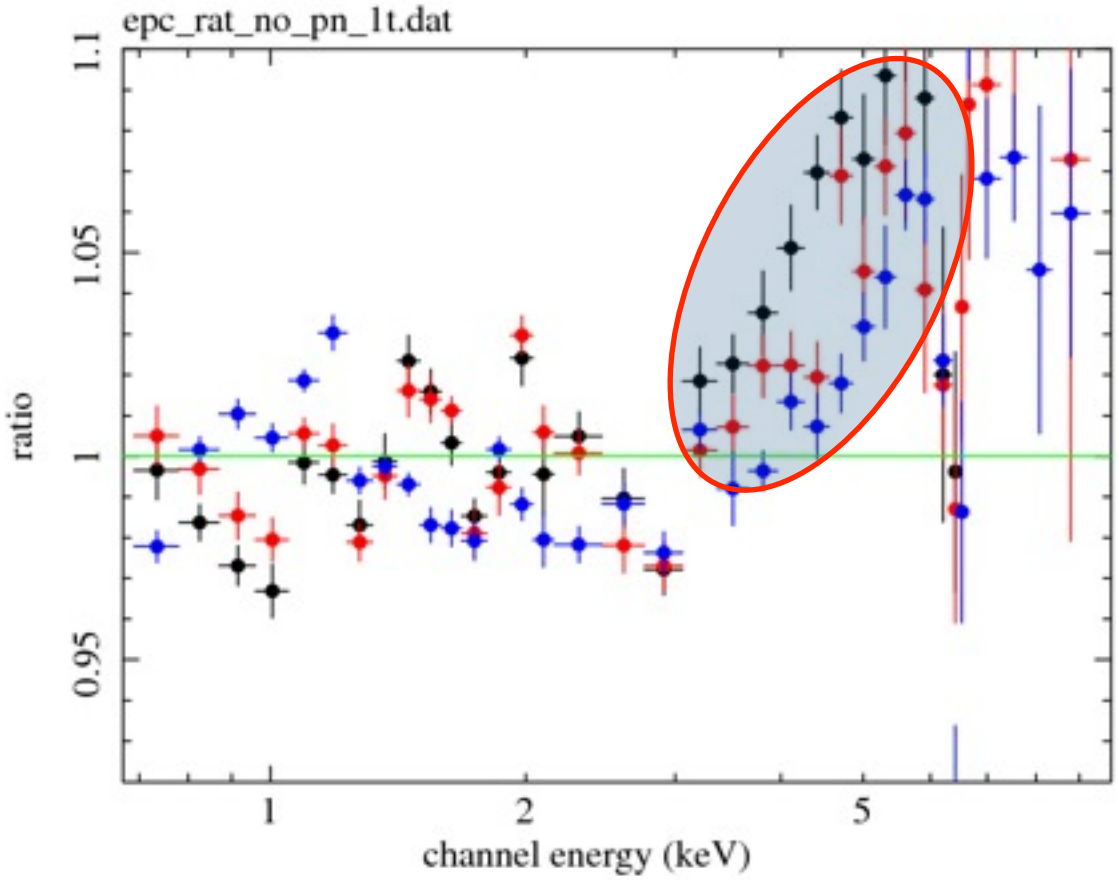
MOS1, MOS2 & pn vs pn model



MOS1, MOS2 & pn vs pn model



MOS1, MOS2 & pn vs pn model



Summary

Calibration

- Redistribution problem on pn
- MOS, if there is one it's smaller
- Medium vs high energies A_{Eff} missmatch

Cross-calibration

- Good to 3% in 0.7-3.5 keV band
- problem with A_{Eff} at high energies