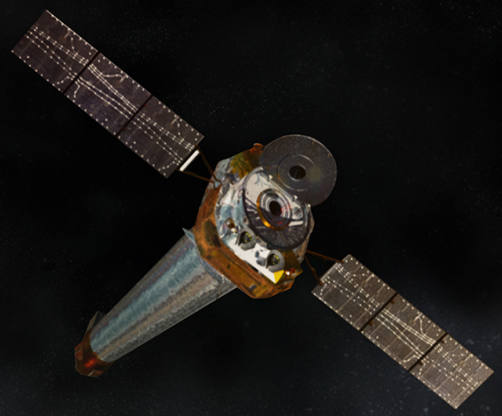


Cross Calibration using HIFLUGCS Galaxy Clusters

Gerrit Schellenberger

10th IACHEC Meeting Cluster Working Group Beijing – 20.4.2015

IMPRS astronomy & astrophysics Bonn and Cologne

bcgs Bonn-Cologne Graduate School of Physics and Astronomy

Argelander-Institut für Astronomie

Outline

XMM-Newton – Chandra cross calibration

temperature differences – stacked residuals – tests – cosmology

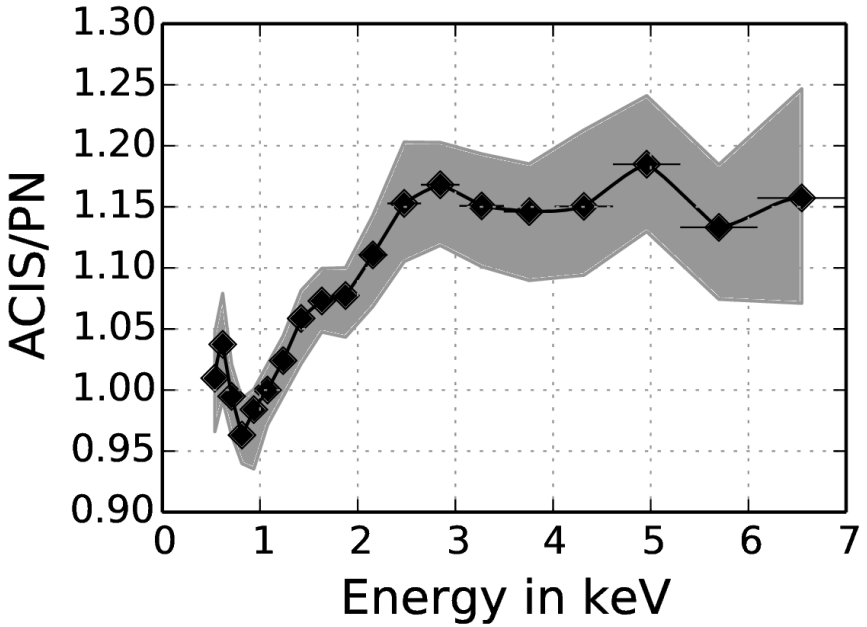
new ACIS contamination model

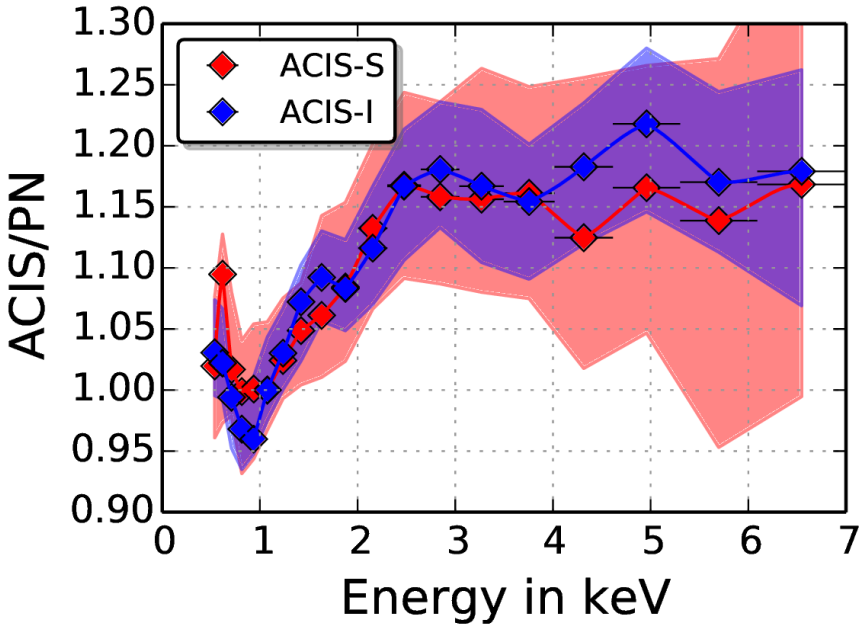
Updated XMM calibration

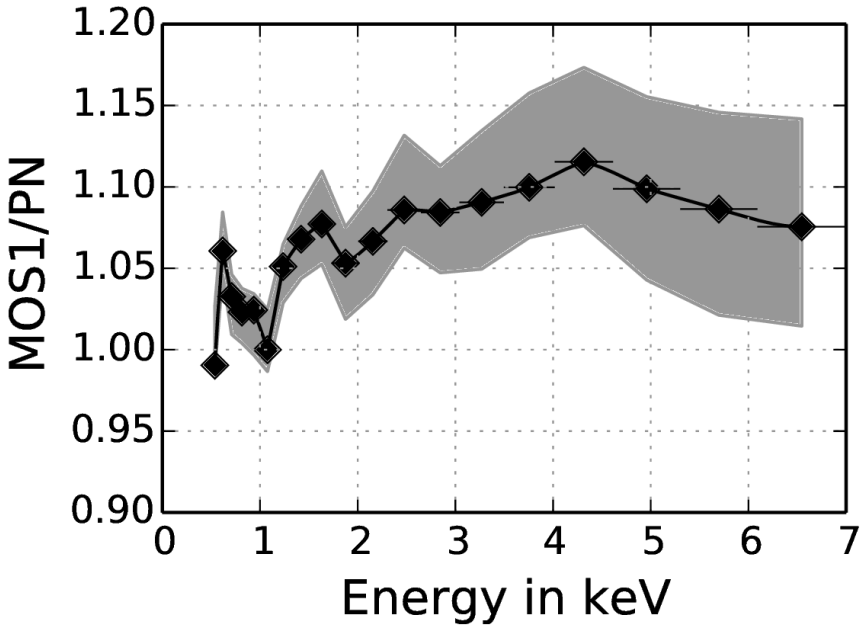
Line ratio temperatures

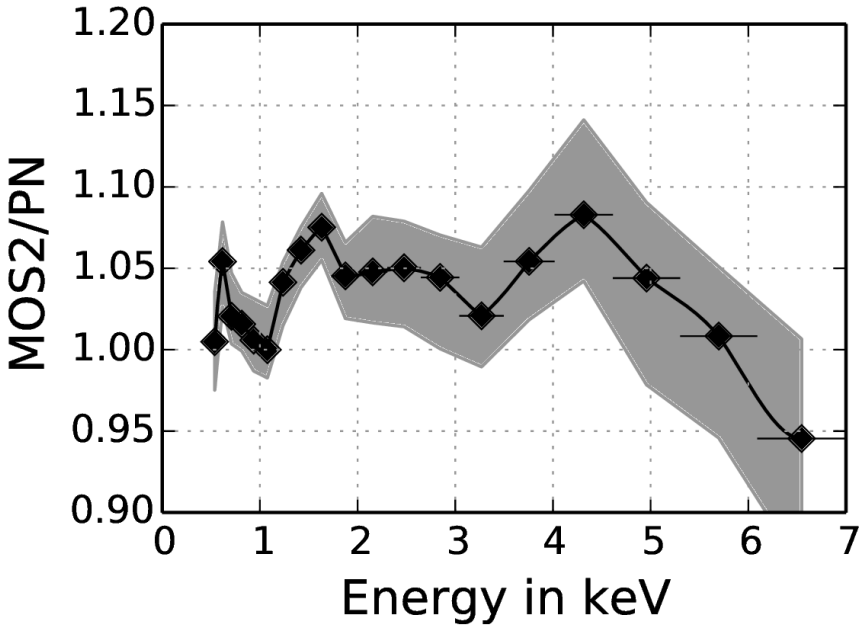
Time variability of calibration tested with galaxy clusters

Chandra – XMM residuals

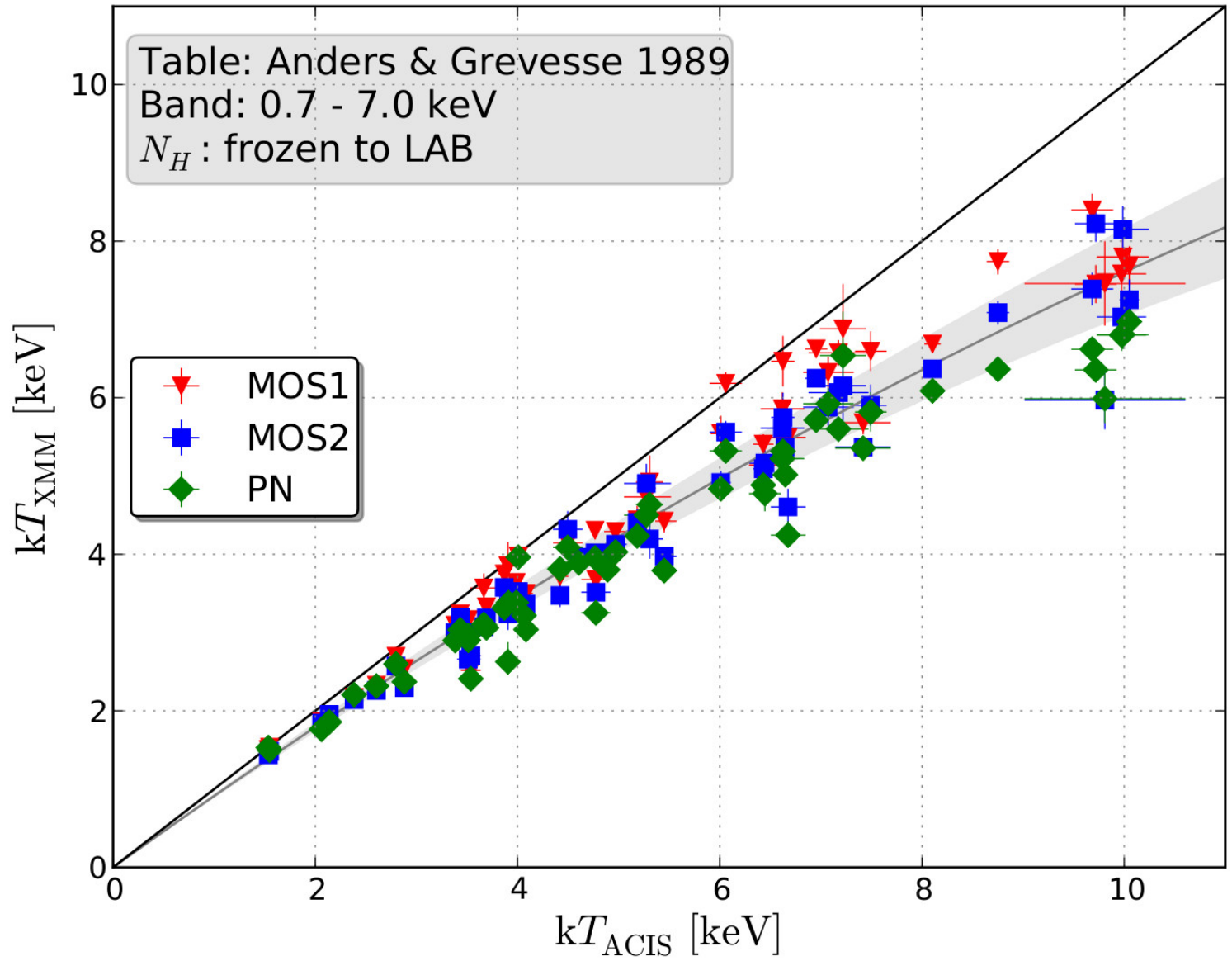


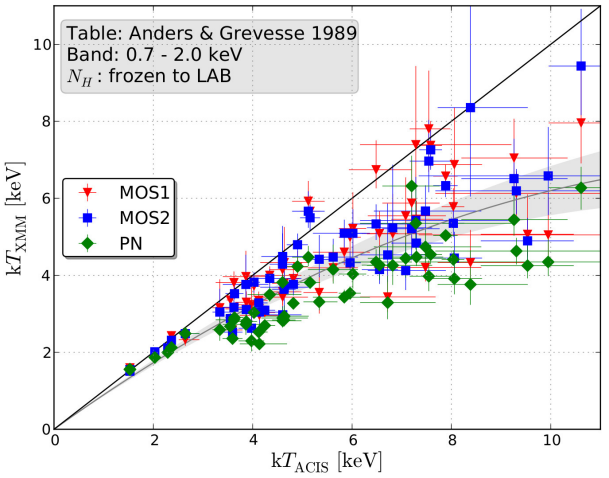


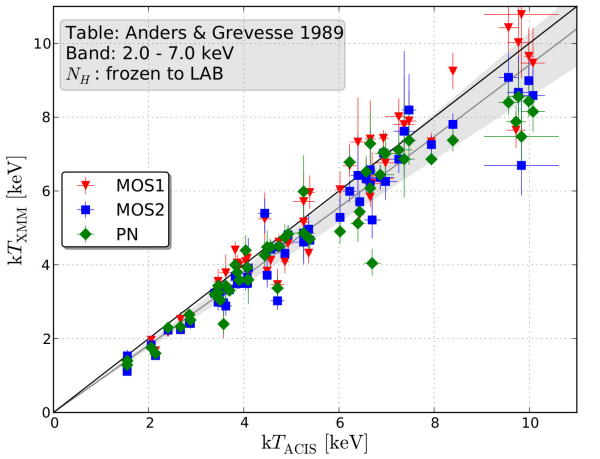




Temperature bias



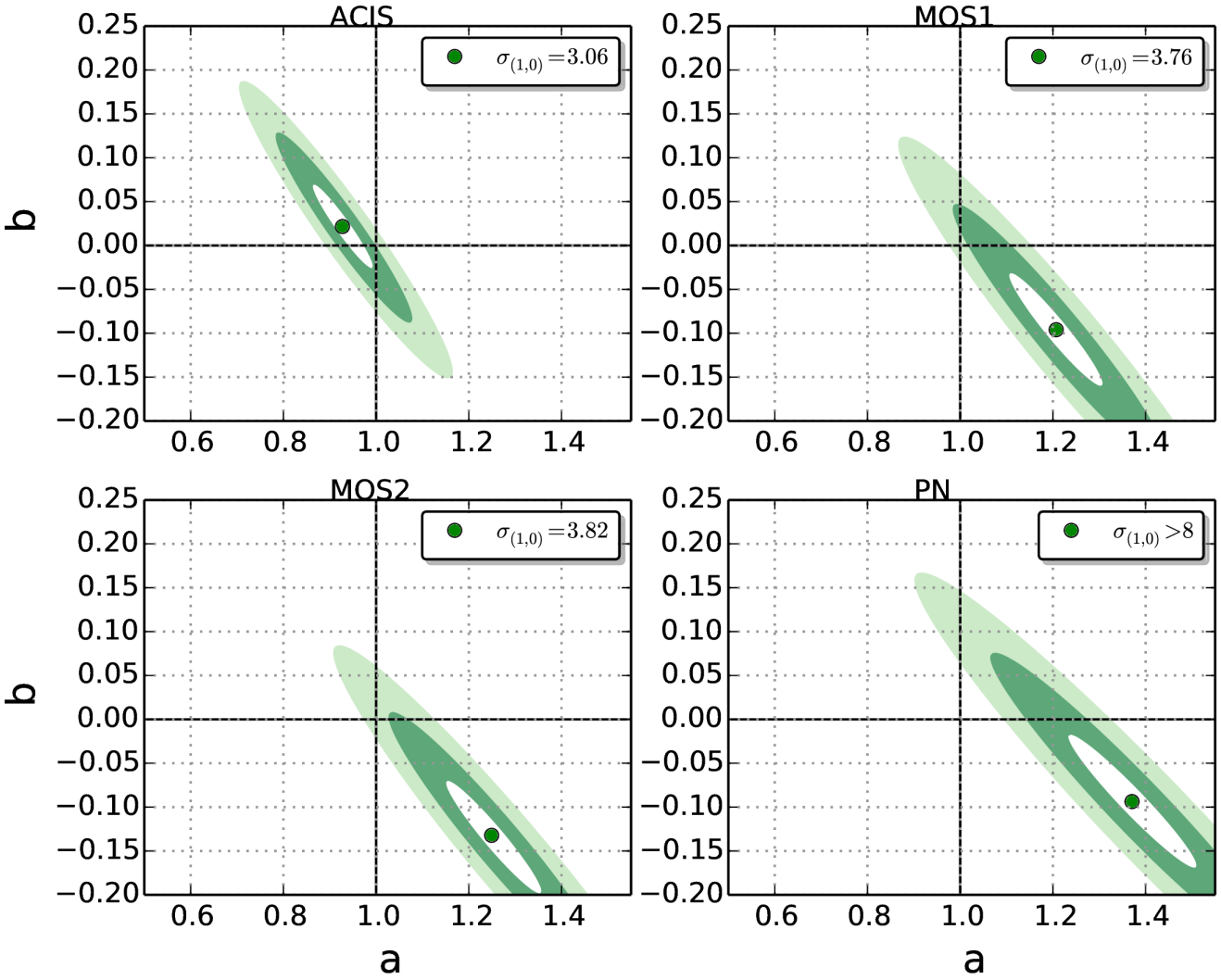




Aim

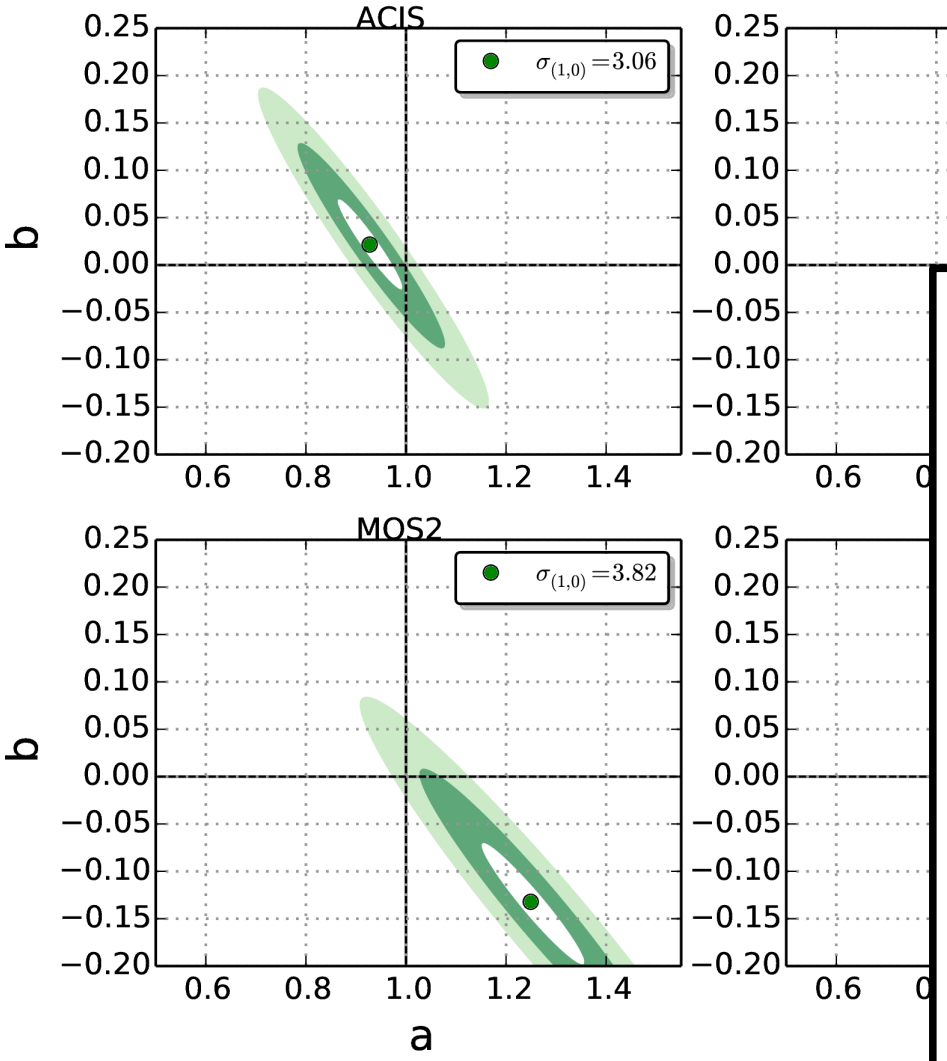
Test for “absolute” calibration

tests

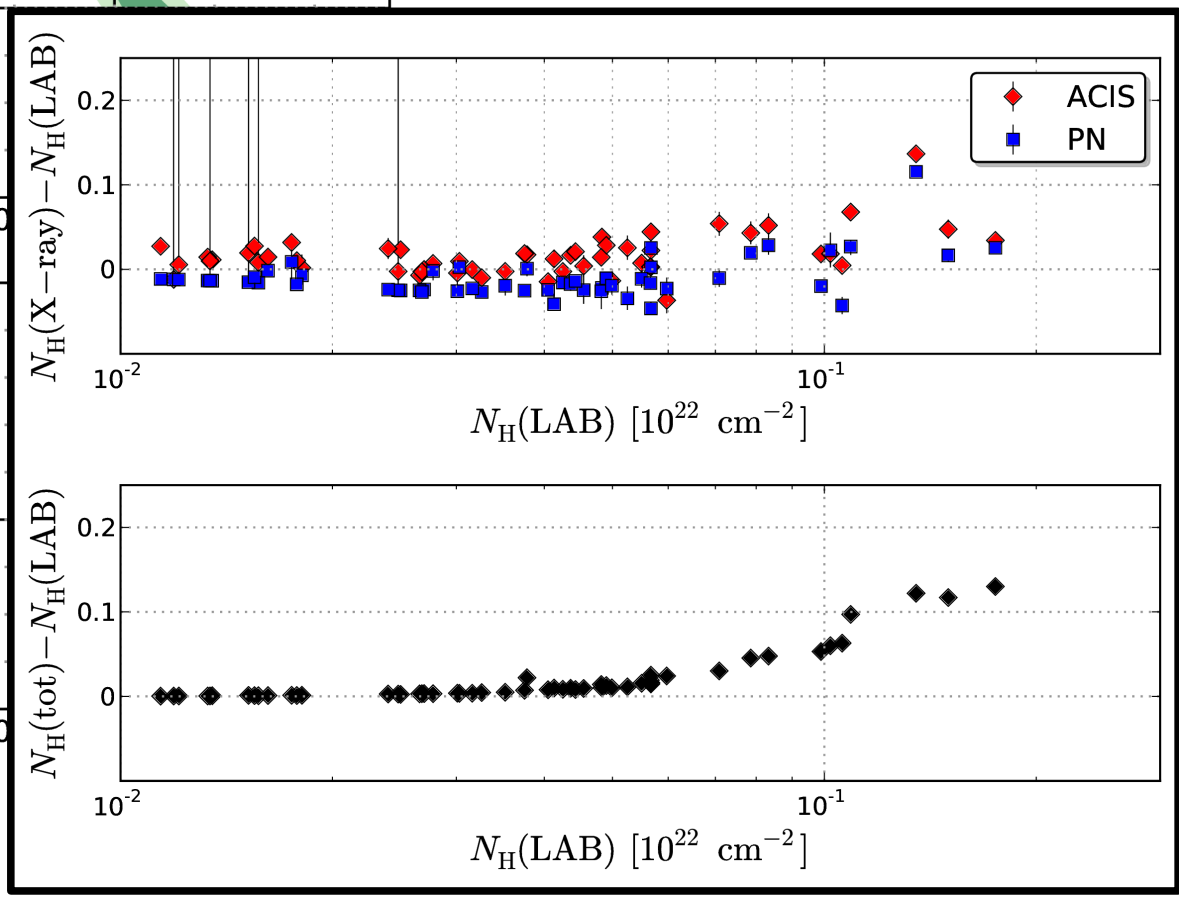


Self-consistent test:
Soft vs. hard band of the same instrument

tests

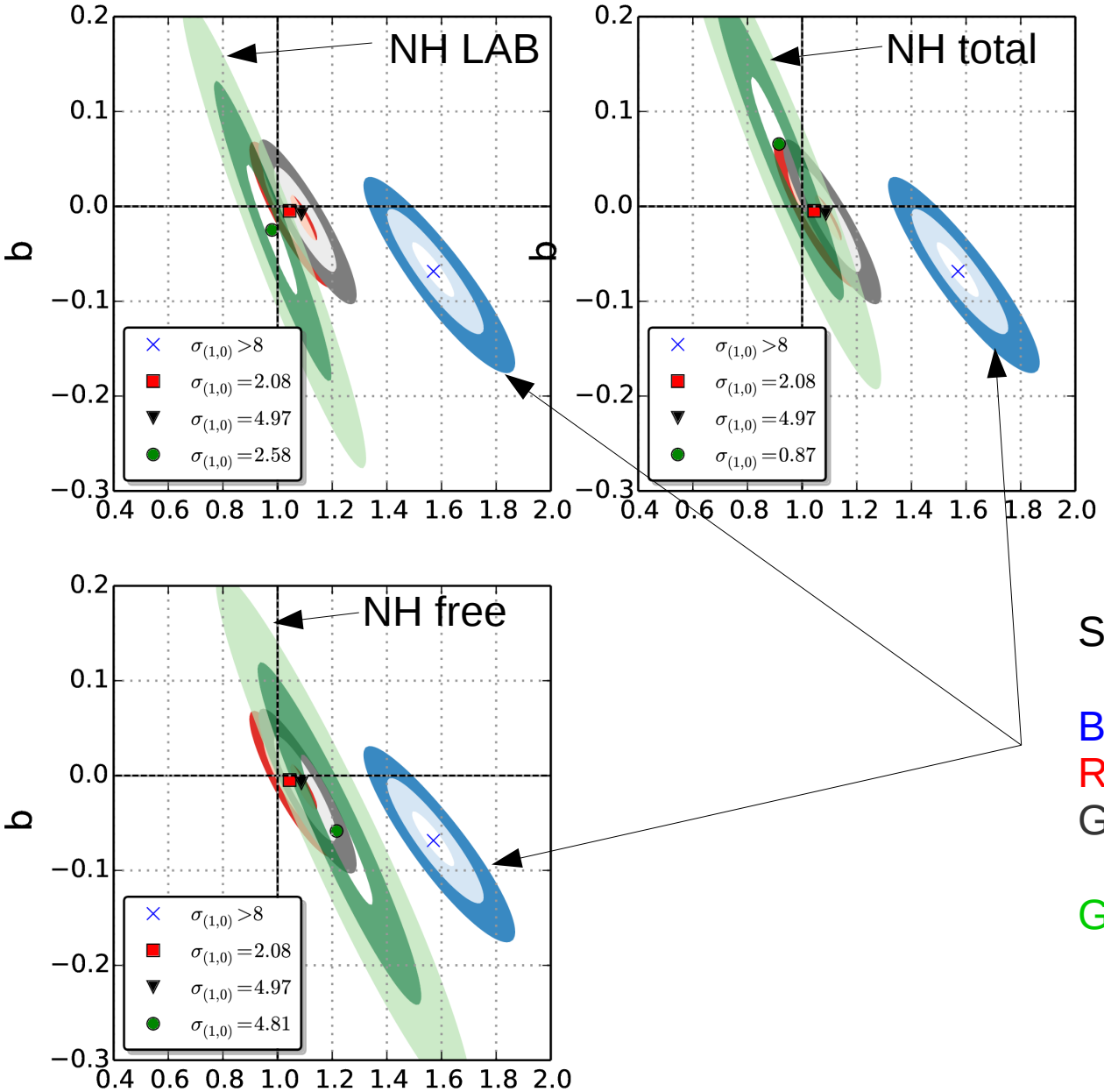


Self-consistent test:
Soft vs. hard band of the same instrument



Free-NH test

self consistency test



Deviation expected from Multiphase ICM

Test: Latest ACIS Calibration
+NH Free/total

Simulations

Blue: T_cold = 1keV; EMR = 0.05
Red: T_cold = 2keV; EMR = 0.05
Gray: T_cold = 1keV; EMR = 0.01

Green: Observations

Emission lines

- Possible to measure individual lines from ICM emission of galaxy clusters
- Important lines we see:

Iron-L Complex ~1keV	Magnesium ~1.4 keV
Sulfur Lines ~2.5 keV	Neon ~ 1 keV
Iron-K Lines ~6.8 keV	Oxygen ~0.6 keV
Silicon Lines ~1.9 keV	Nitrogen ~0.5 keV

- Intensity of lines depends on the plasma temperature and abundance
- Two lines of same element with different peak temperature

  → Ratio is independent of abundance
- Possible to determine plasma state (CIE)

Emission lines

- Iron-K Lines:
  - H-like Iron (FeXXV): at 6.7keV, with peak at 5.4keV
  - He-like Iron (FeXXVI): at 6.97keV, with peak at 10.85keV
  - He-like Iron (FeXXV): at 7.89keV, with peak at 5.4keV
  - Perfect candidate for high temperature regions
  - Iron highly abundand metal
  - Close together (Calibration), but not too close (can be identified)
- Sulfur Lines:
  - S-XV at 2.46keV, with peak at 1.4keV
  - S-XVI at 2.62keV, with peak at 2.17keV
  - For low temperature regions
  - Sulfur not so abundant

No calibration problems in this range expected
→ Still useful for consistency test

Emission lines

- Iron-L Complex:
  - FeXXIV, FeXXIII, FeXXII, FeXXI, FeXX, FeXIX, FeXVIII,FeXVII
  - All between 0.8 and 1.2 keV
  - Sensitive to very low temperatures (< 2.5 keV)
  - Many lines at different energies → Position of the complex can be used

- Silicon Lines:
  - SiXIV at 2 keV, peak temperature 1.37 keV
  - SiXIII at 1.85 keV, peak temperature 0.86 keV

No calibration problems in this range expected
→ Still useful for consistency test

Emission lines

Energy band: 5.8 – 7.2 keV

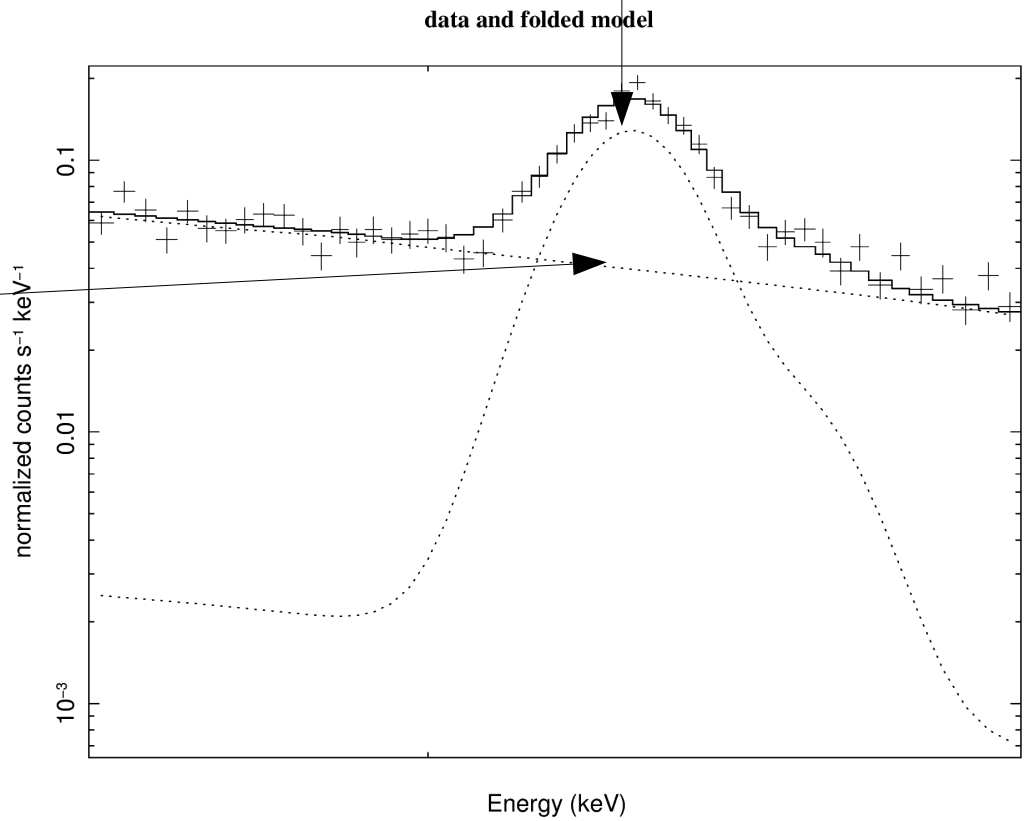
vapec + vapec

Free parameters:
- Temperature
- Fe (up to 1E6)

Frozen:
- Normalization = 1E-8
- Redshift
- All other elements = 0

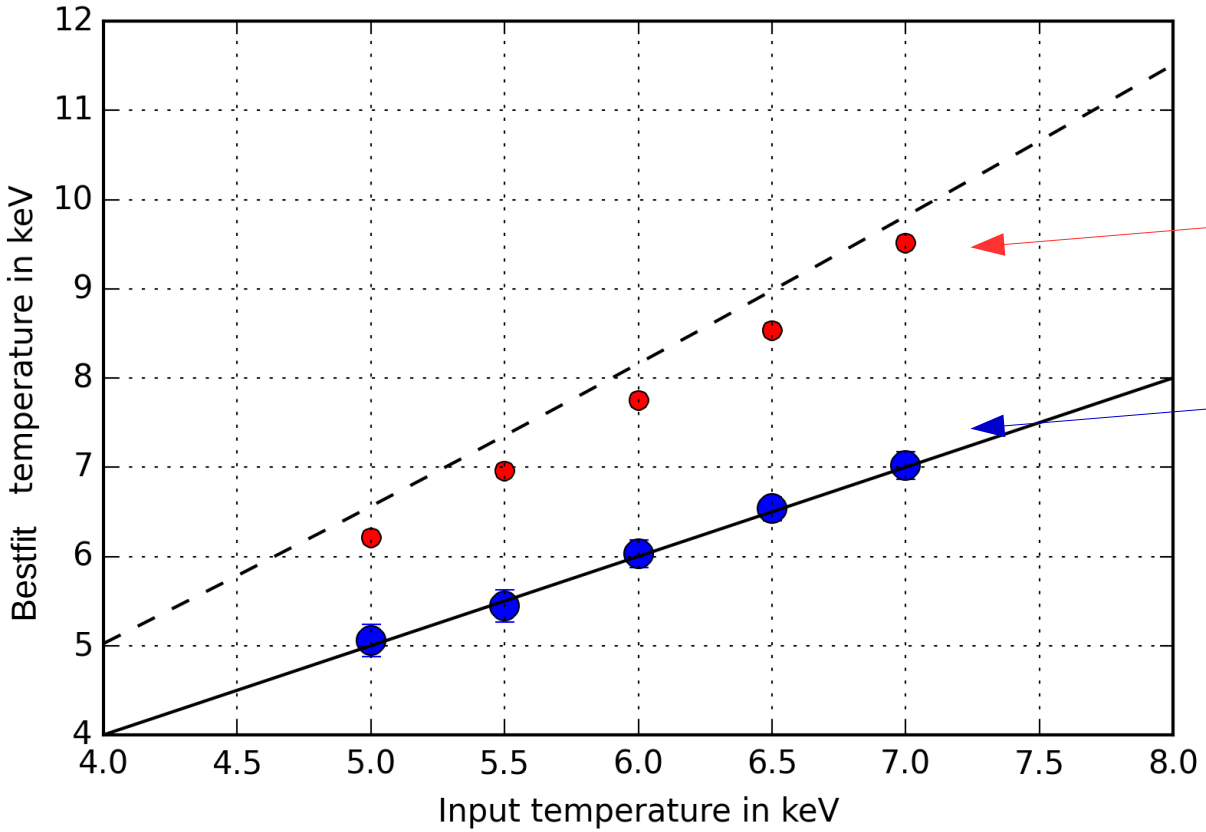
Free parameters:
- Temperature
- He (all other abundances linked except Fe)
- Norm

Frozen:
- Fe (to 0)
- Redshift



Emission lines – Simulations

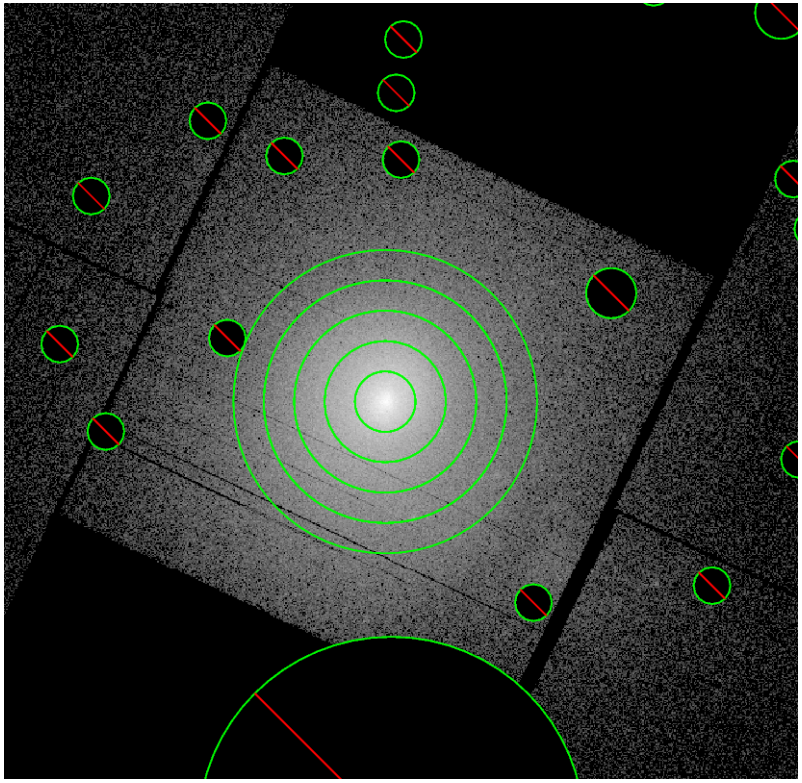
- PN response used to create fake spectra
- PN response converted to Chandra response using modarf-tool
- Broad band and lines of fake spectra are fitted using fake-Chandra response



Broad band

Line temperature

Emission lines

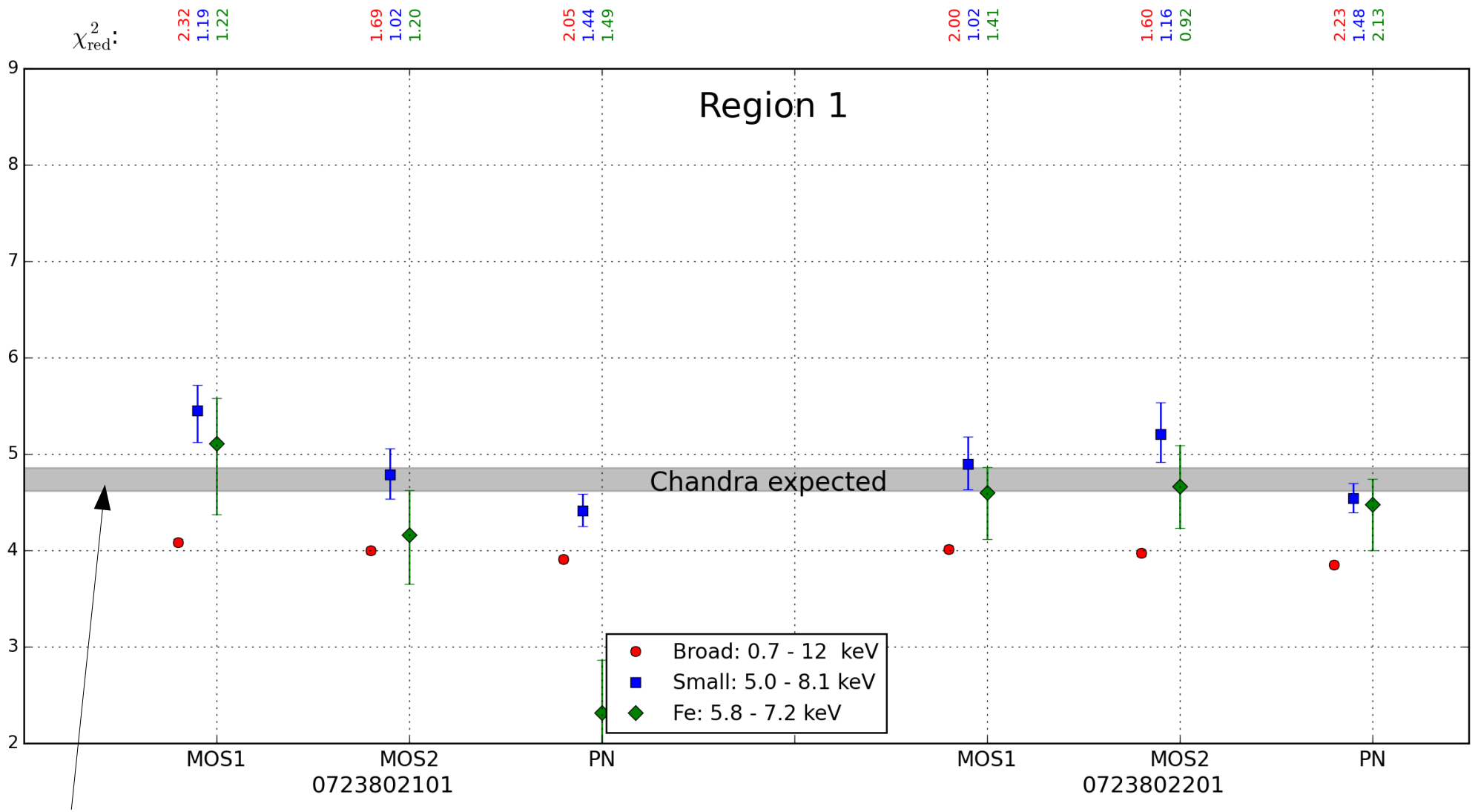


Regions:

1: 0 – 40 arcsec
2: 40 – 80 arcsec
3: 80 – 120 arcsec
4: 120 – 200 arcsec ←Outside cool core
5: 200 – 280 arcsec

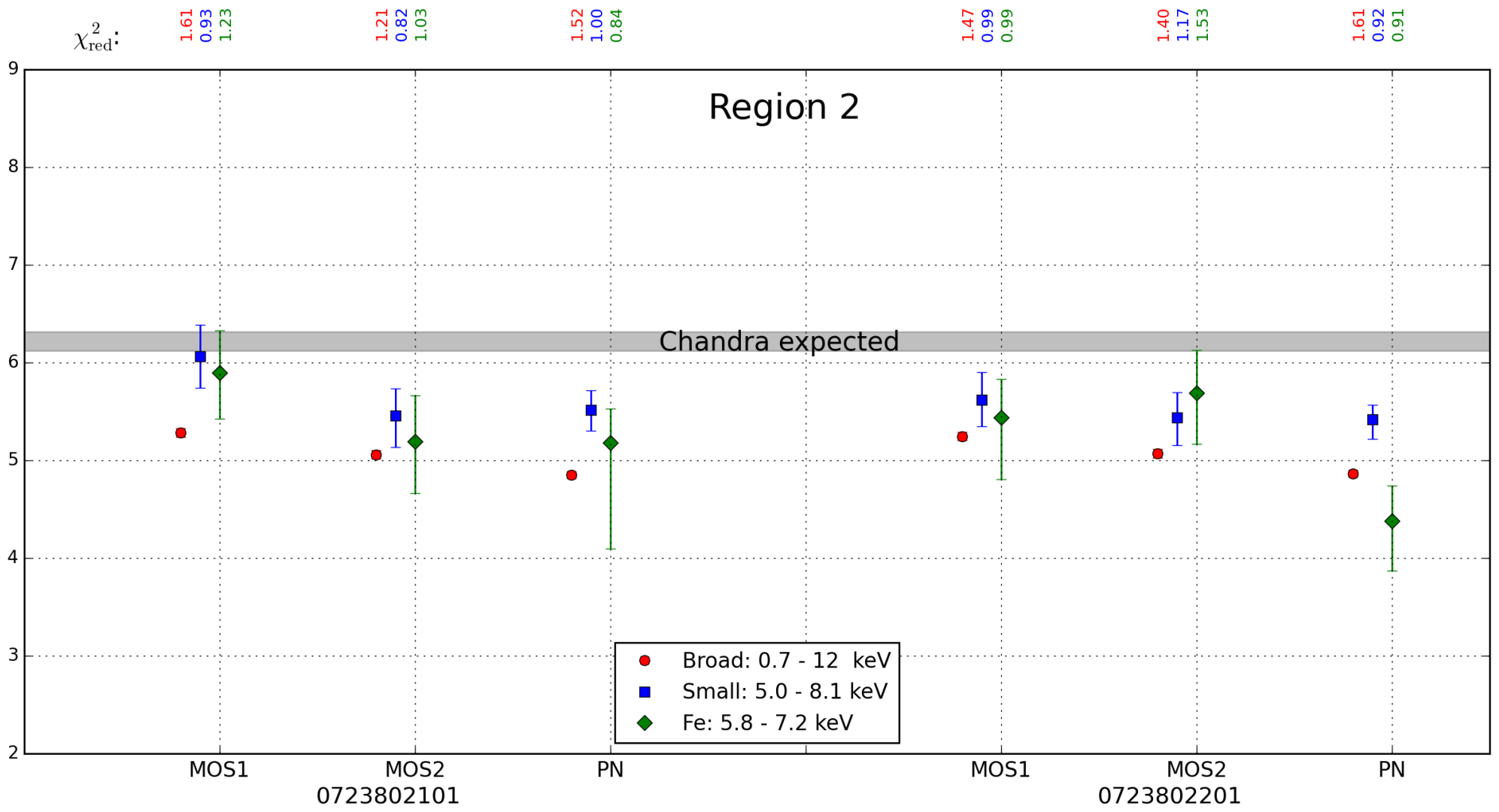
→ Background 2-3 orders below source

Emission lines

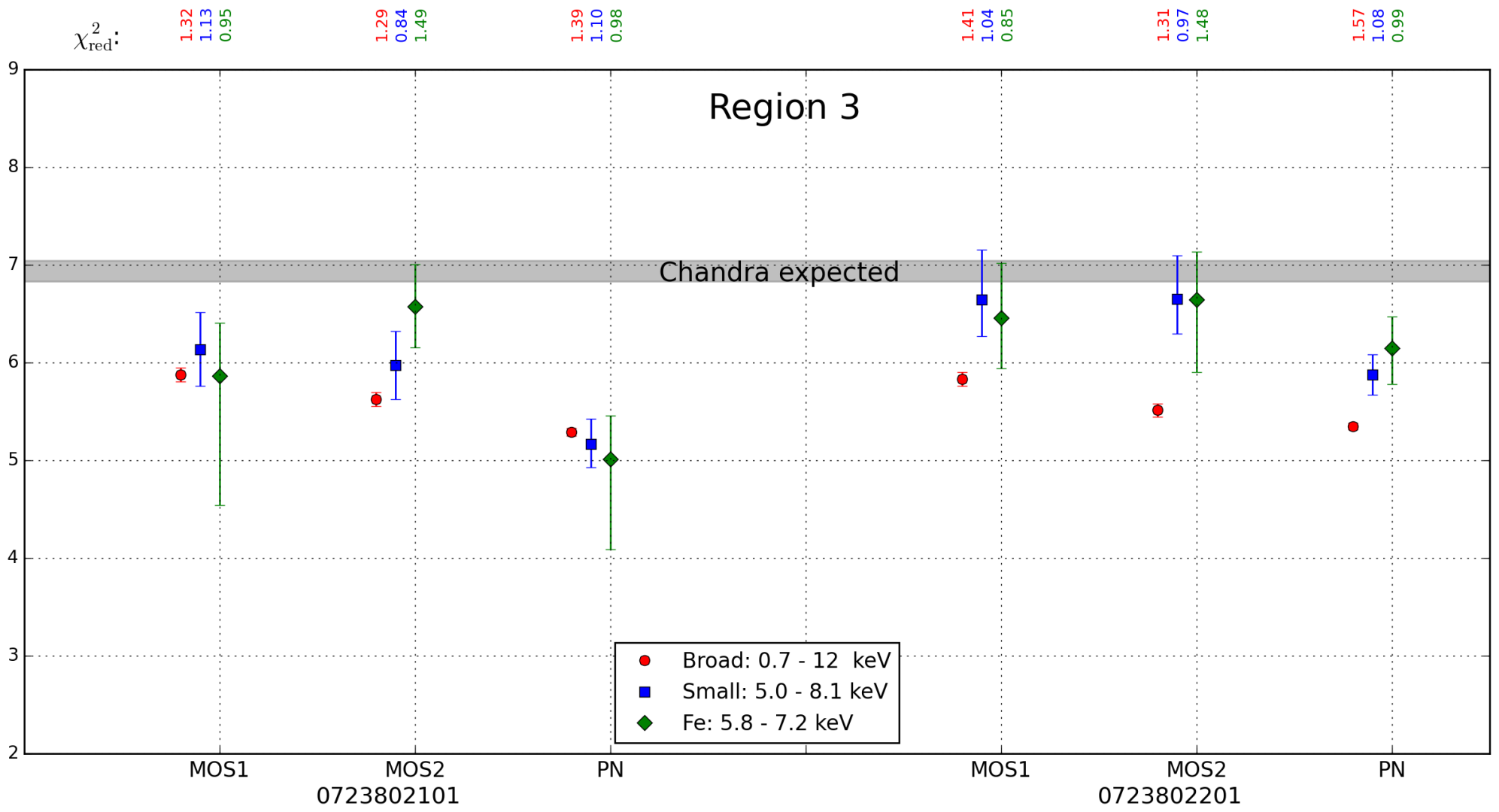


Broad band temperatures converted to Chandra by using fitting formulas from Schellenberger+15

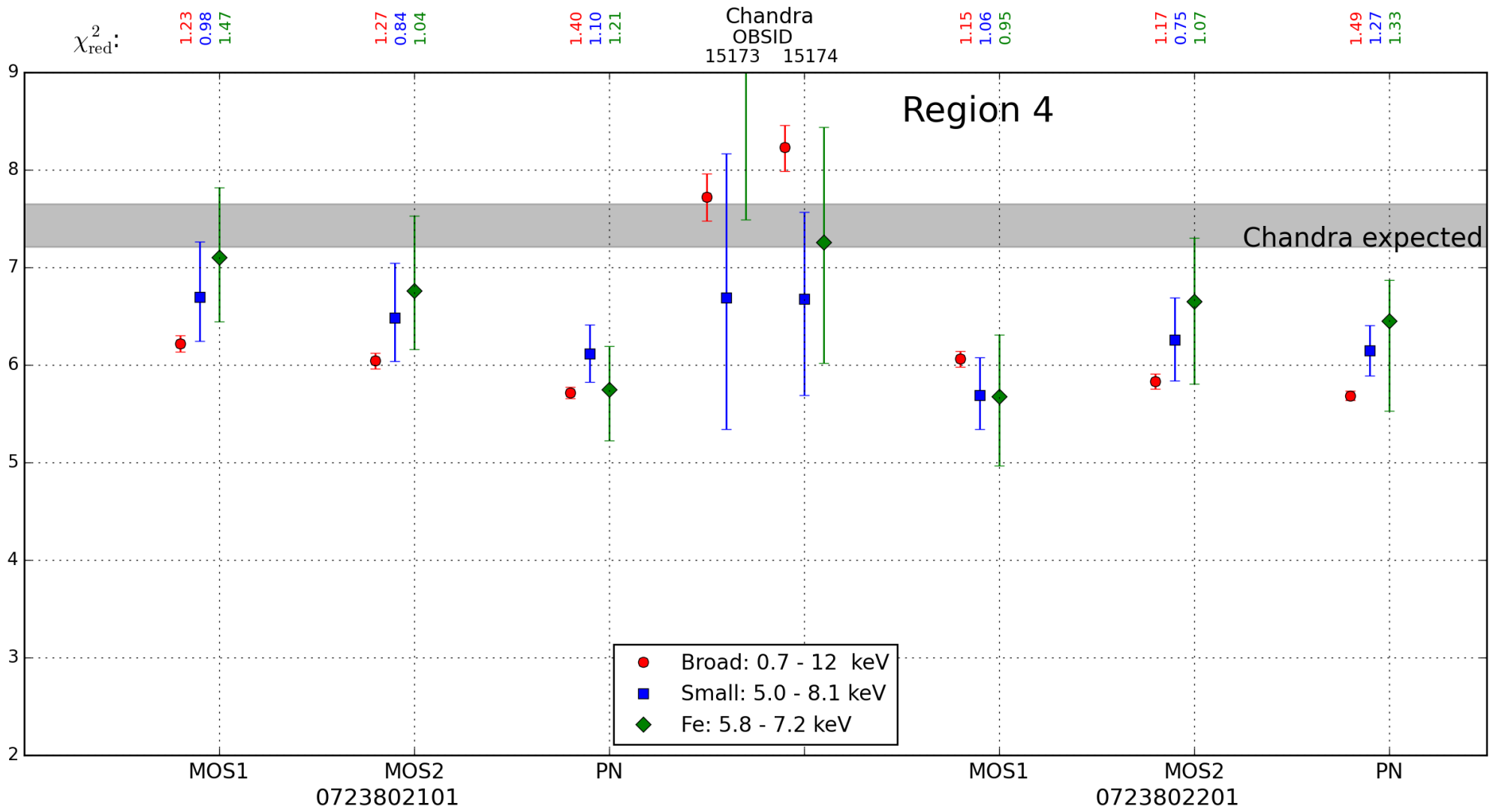
Emission lines



Emission lines



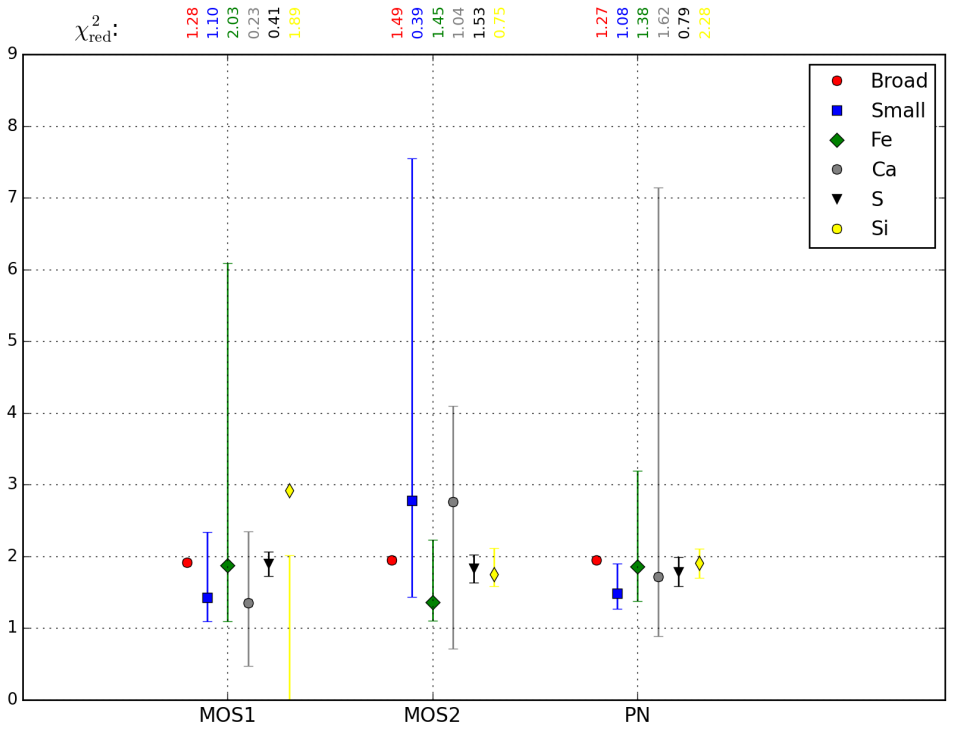
Emission lines



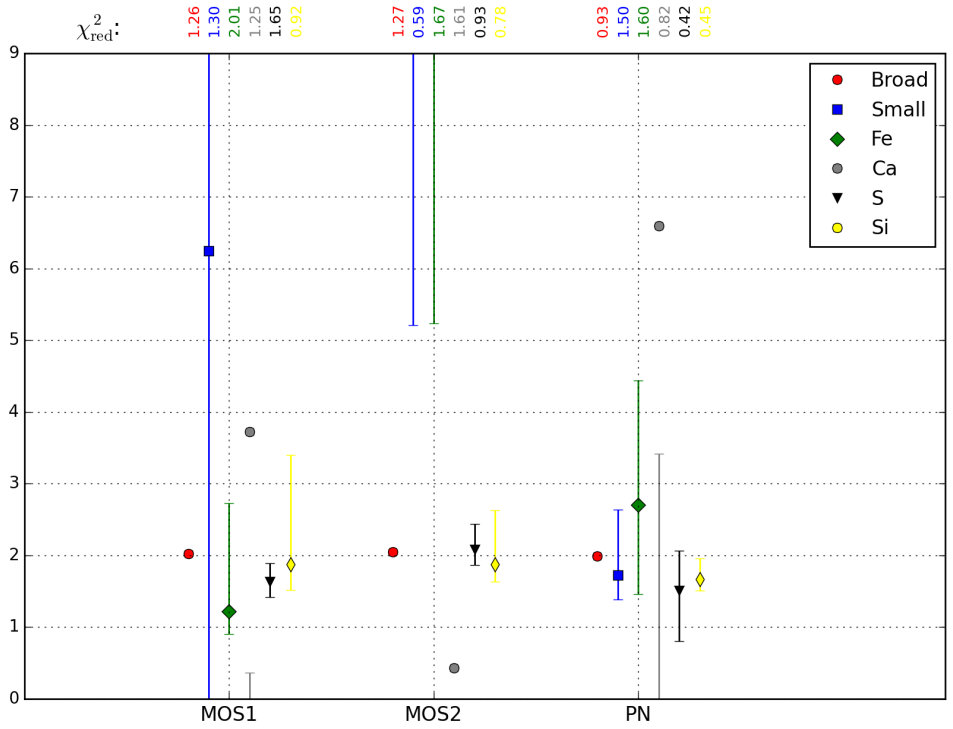
Low kT → consistent?

MKW4

Region 1



Region 2



New ACIS contamination model

Present Calibration Activities

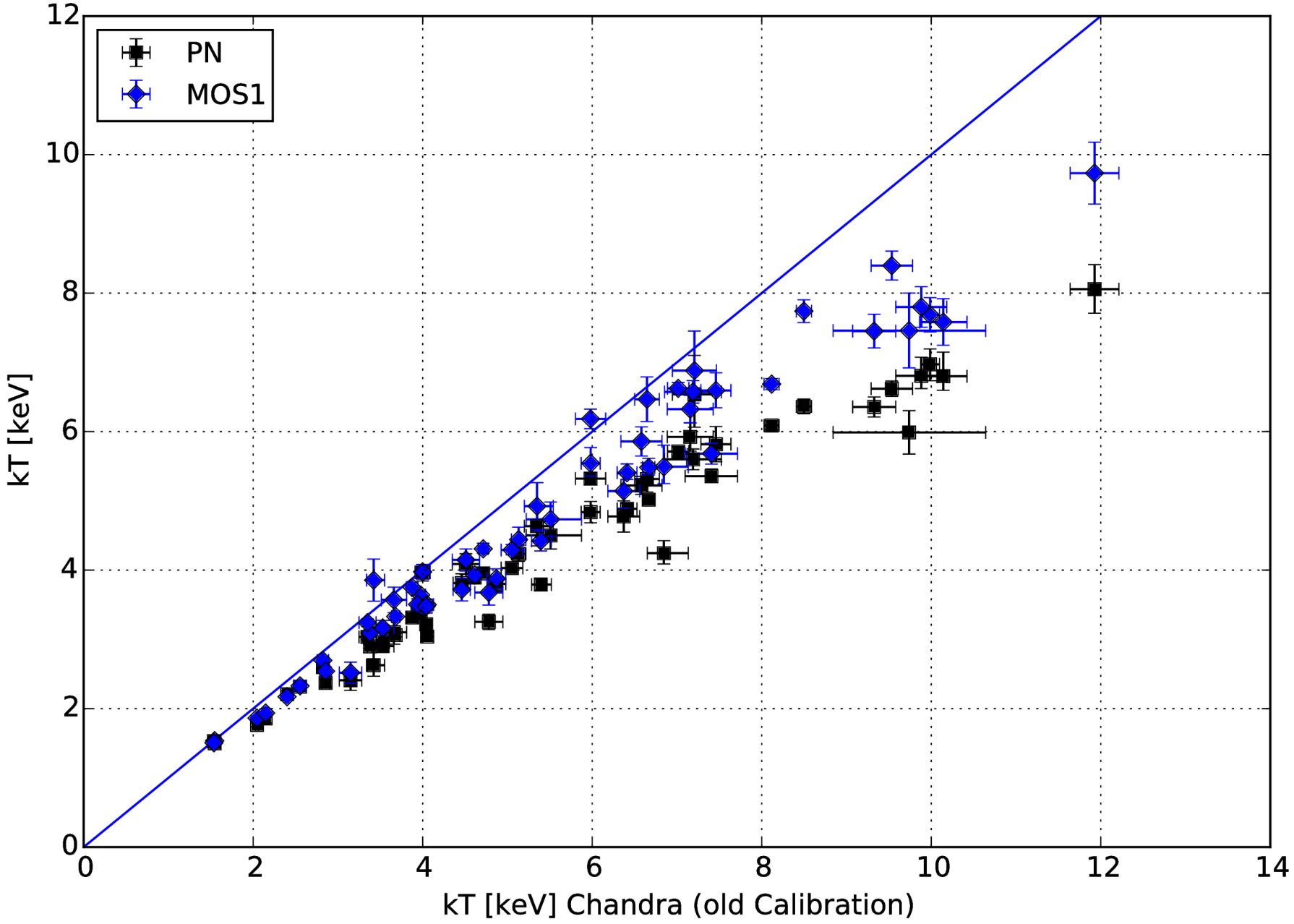
- Update ACIS contamination model, including: new time-dependence, elemental ratios, spatial gradients for each element and possibly a N component.

IACHEC2014 Talk by L. David

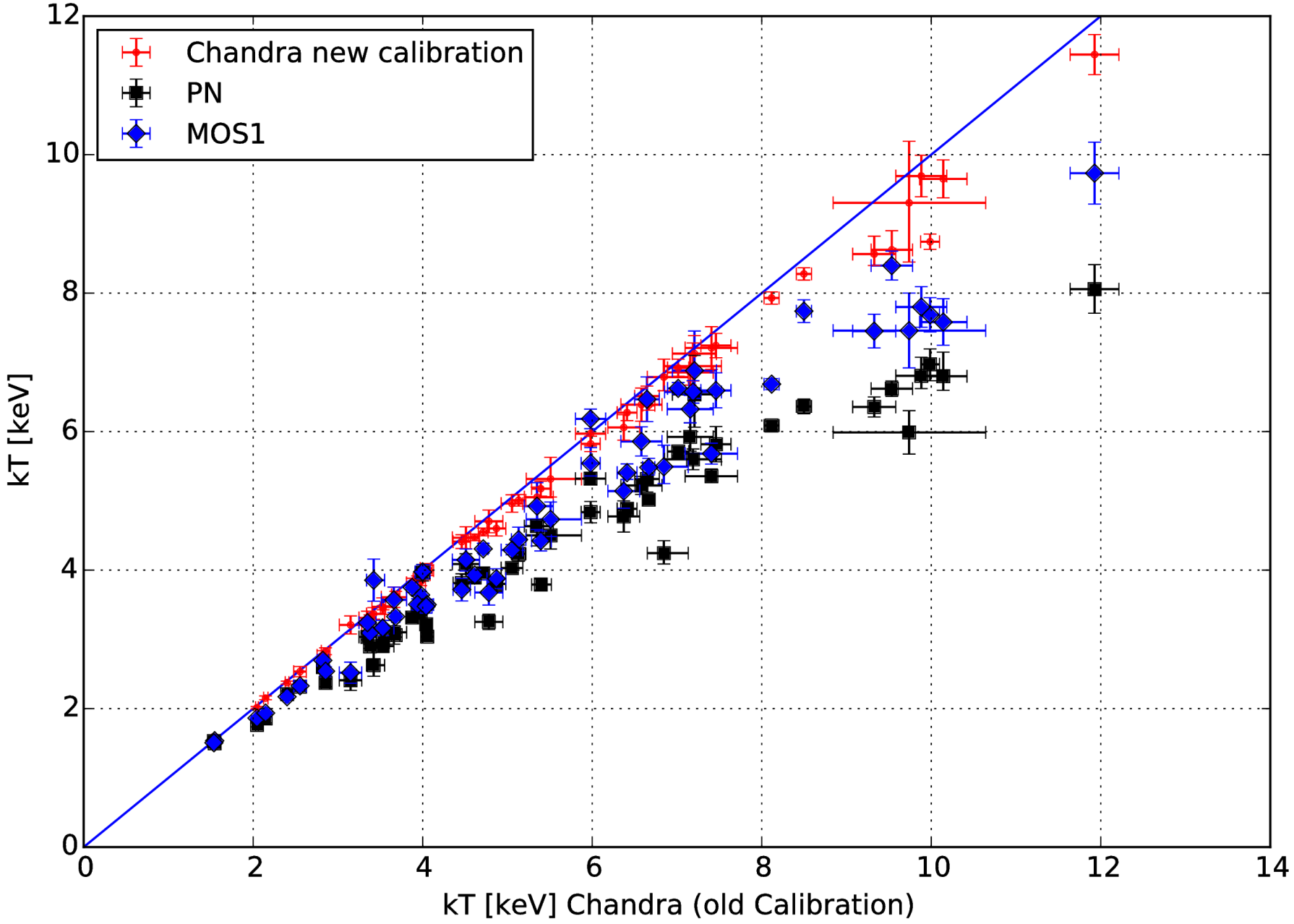
The version **N0008 model**, released in CALDB 4.5.9, provides a **more realistic model** of the contaminant—without use of an artificial "fluffium" component as in previous models—resulting in a **more accurate representation** and prediction of current and future effective ACIS QE. Subsequently, there is a significant loss of effective area for present and future observations using the model as compared to previous models; however, **early- and mid-mission effective areas are not much affected** by the new model.

http://cxc.harvard.edu/ciao/why/acisqecontam.html

New ACIS contamination model

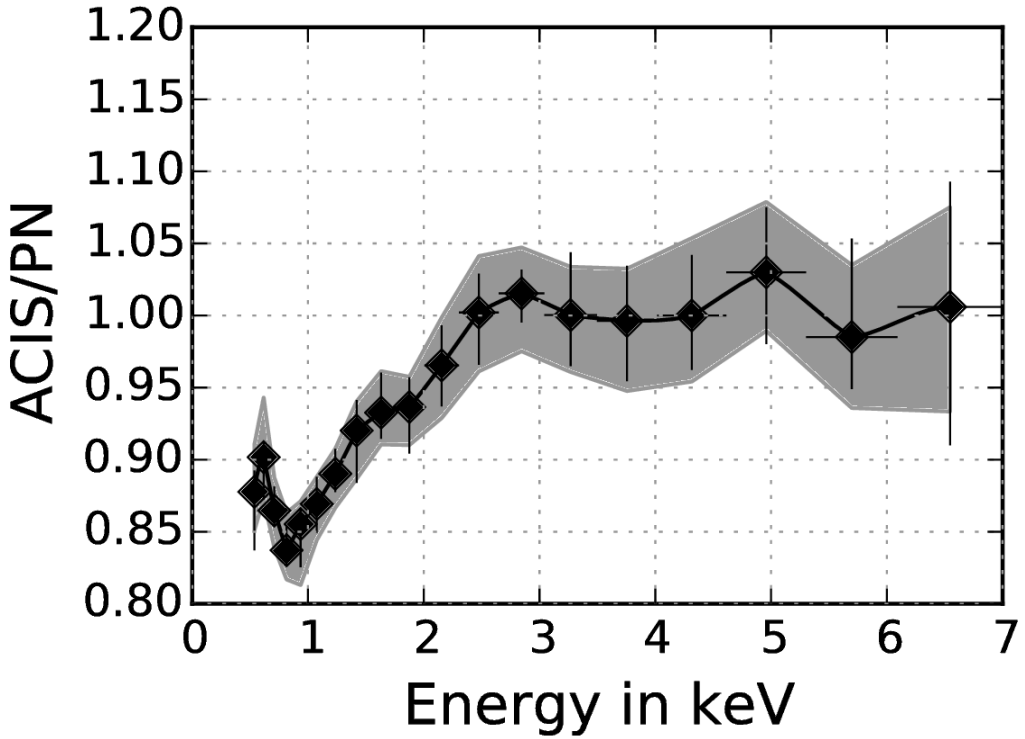


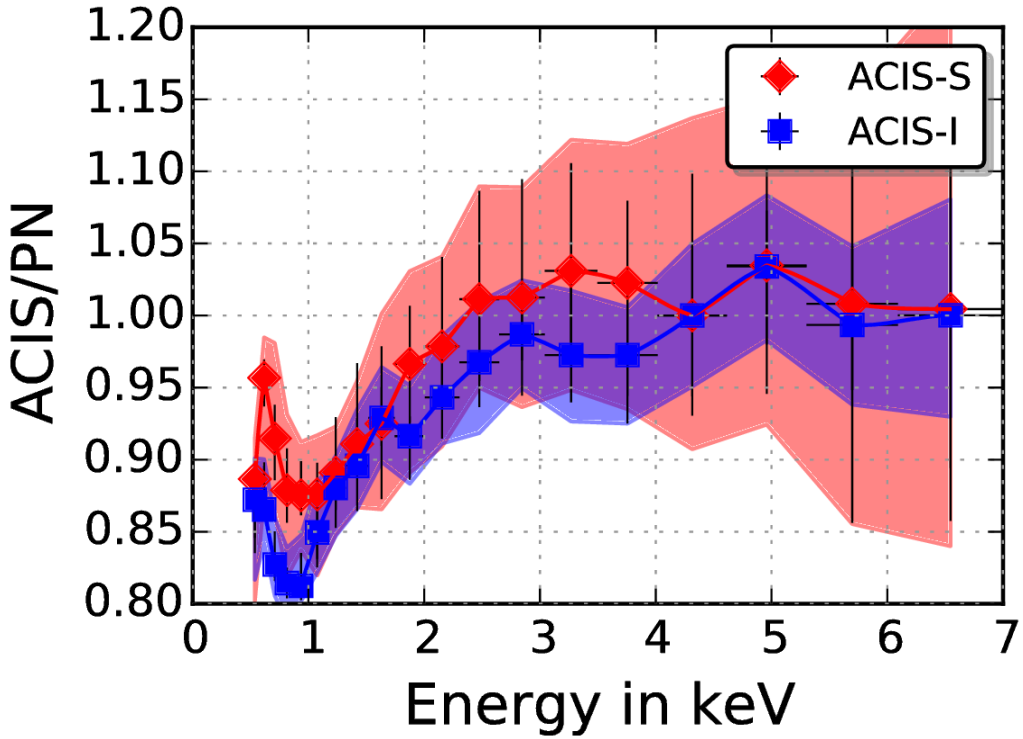
New ACIS contamination model



New ACIS contamination model

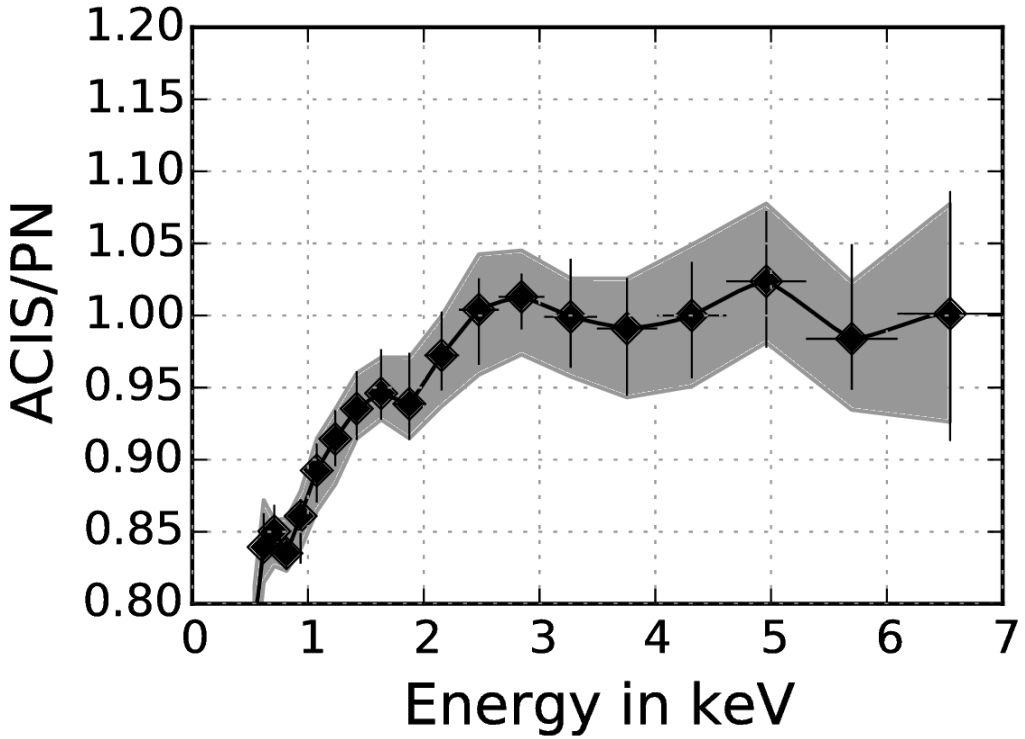
Old contamination model

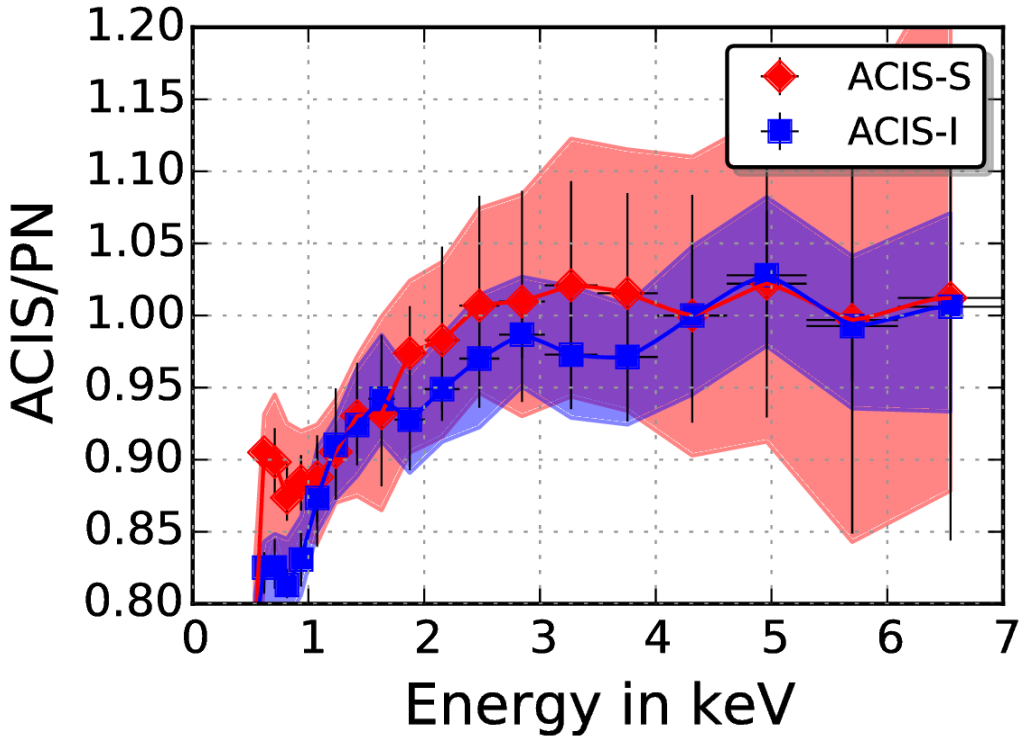




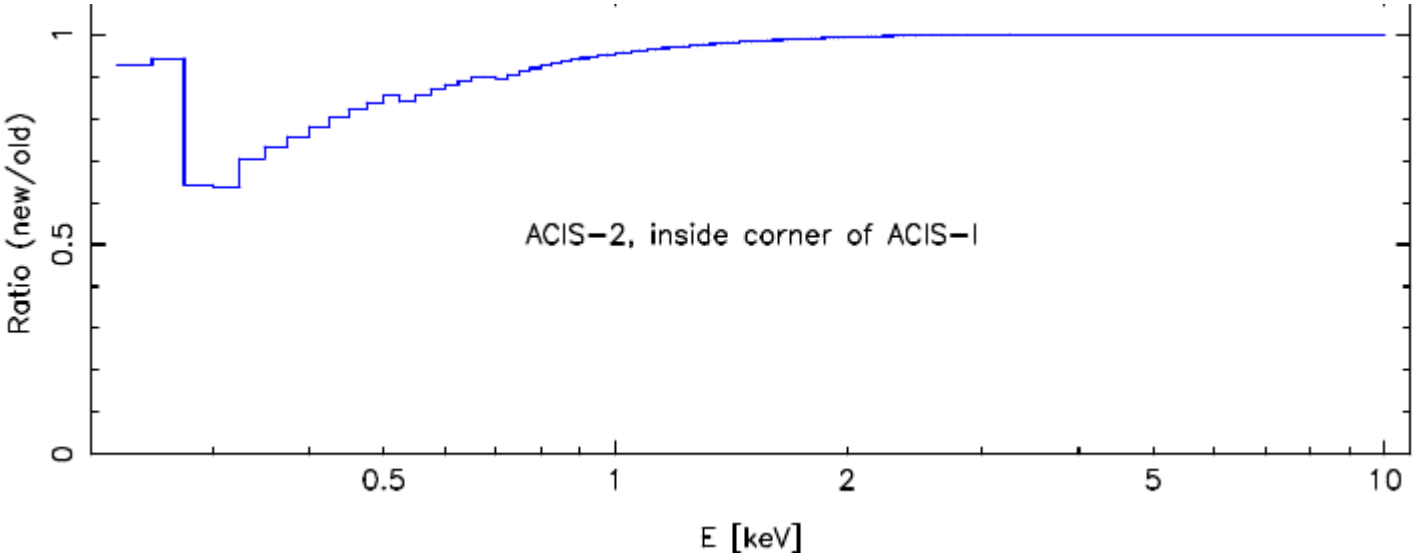
New ACIS contamination model

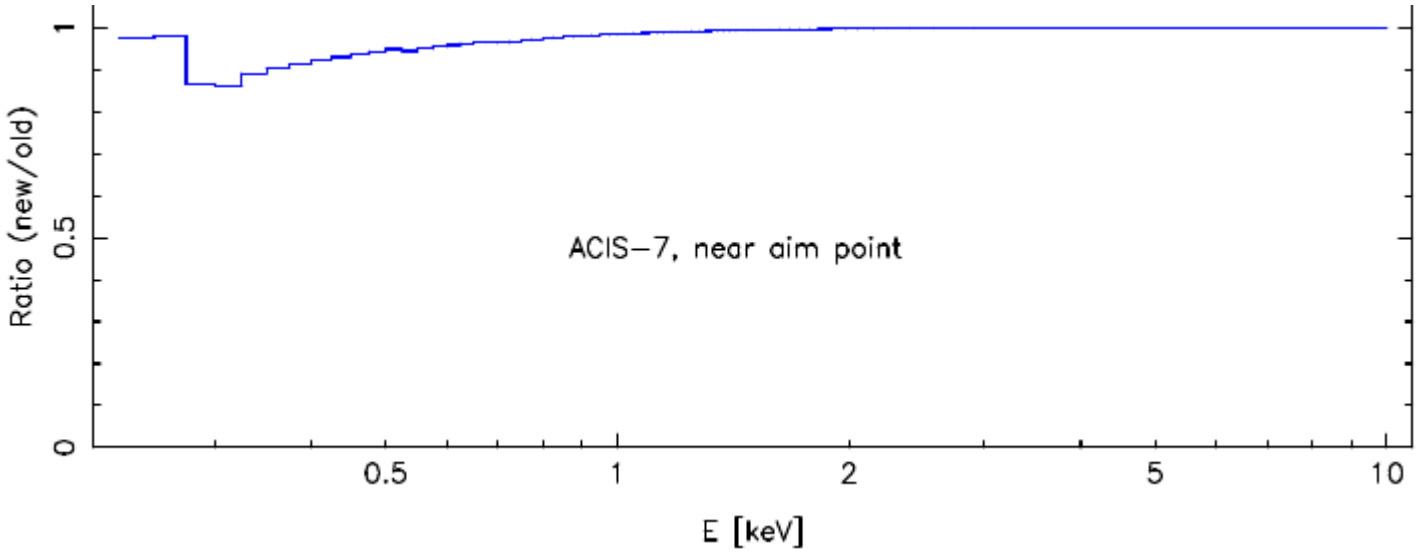
New contamination model





New ACIS contamination model



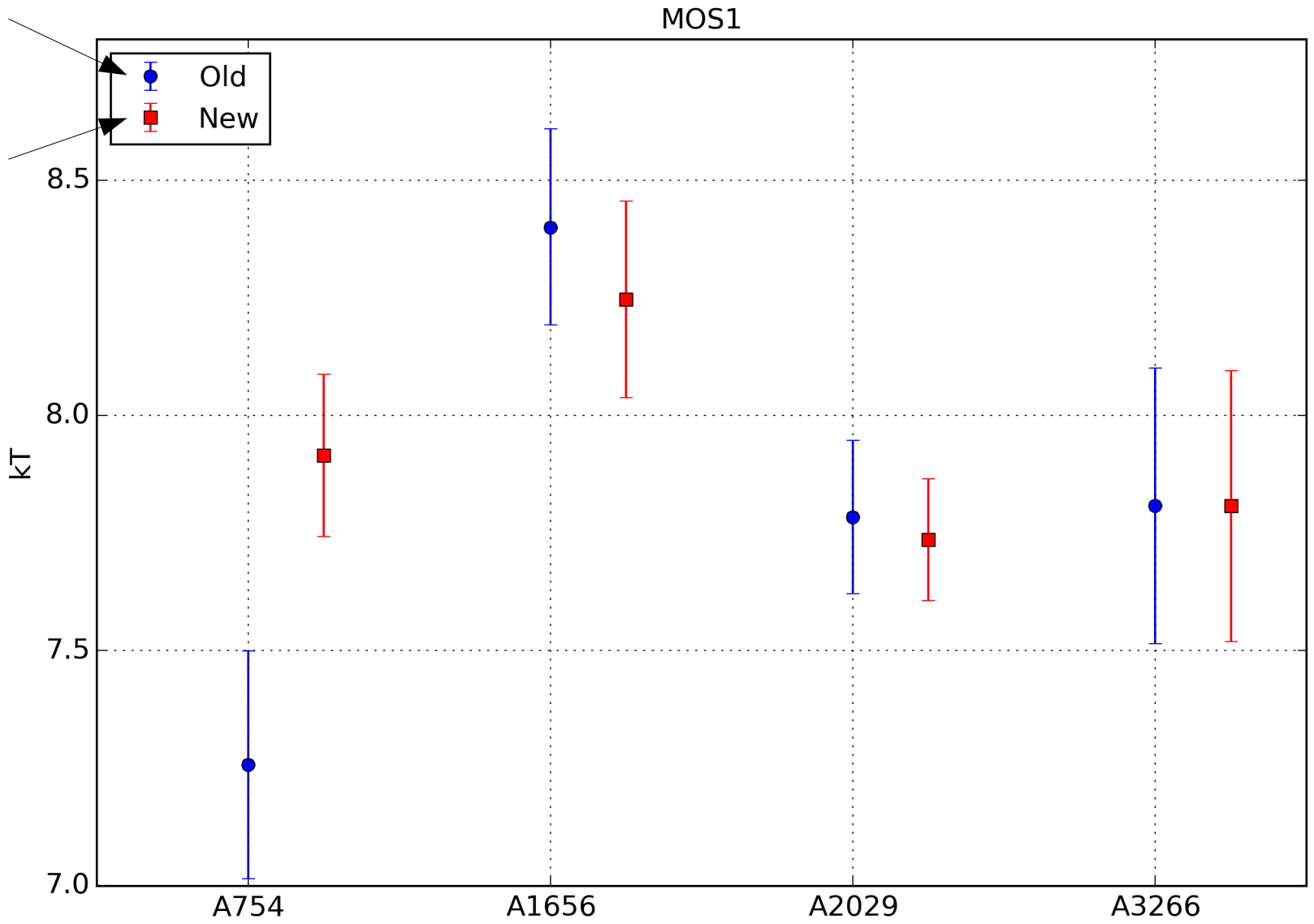


→ smaller changes for ACIS-S

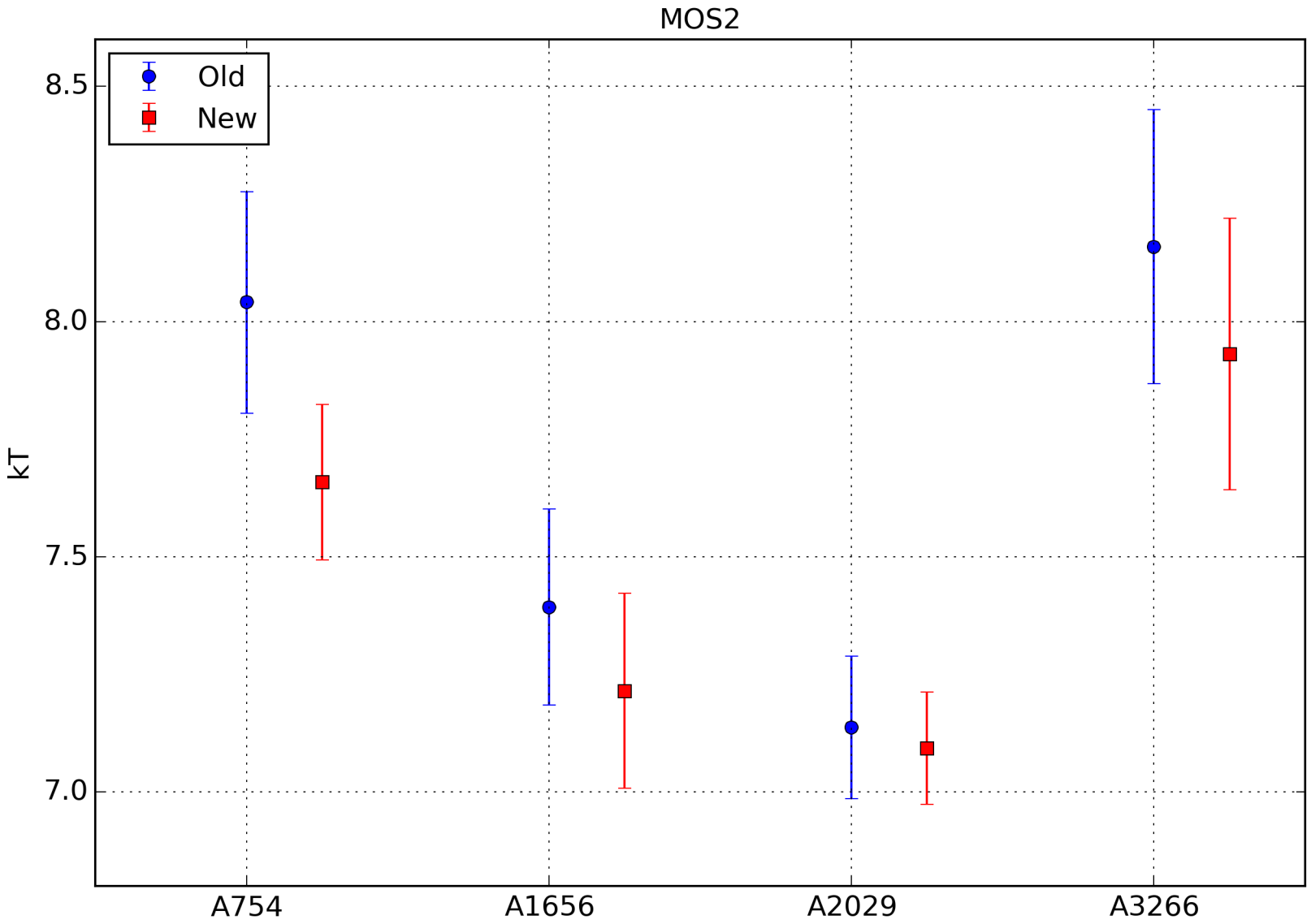
Testing recent XMM calibration

SAS12
Dec2012

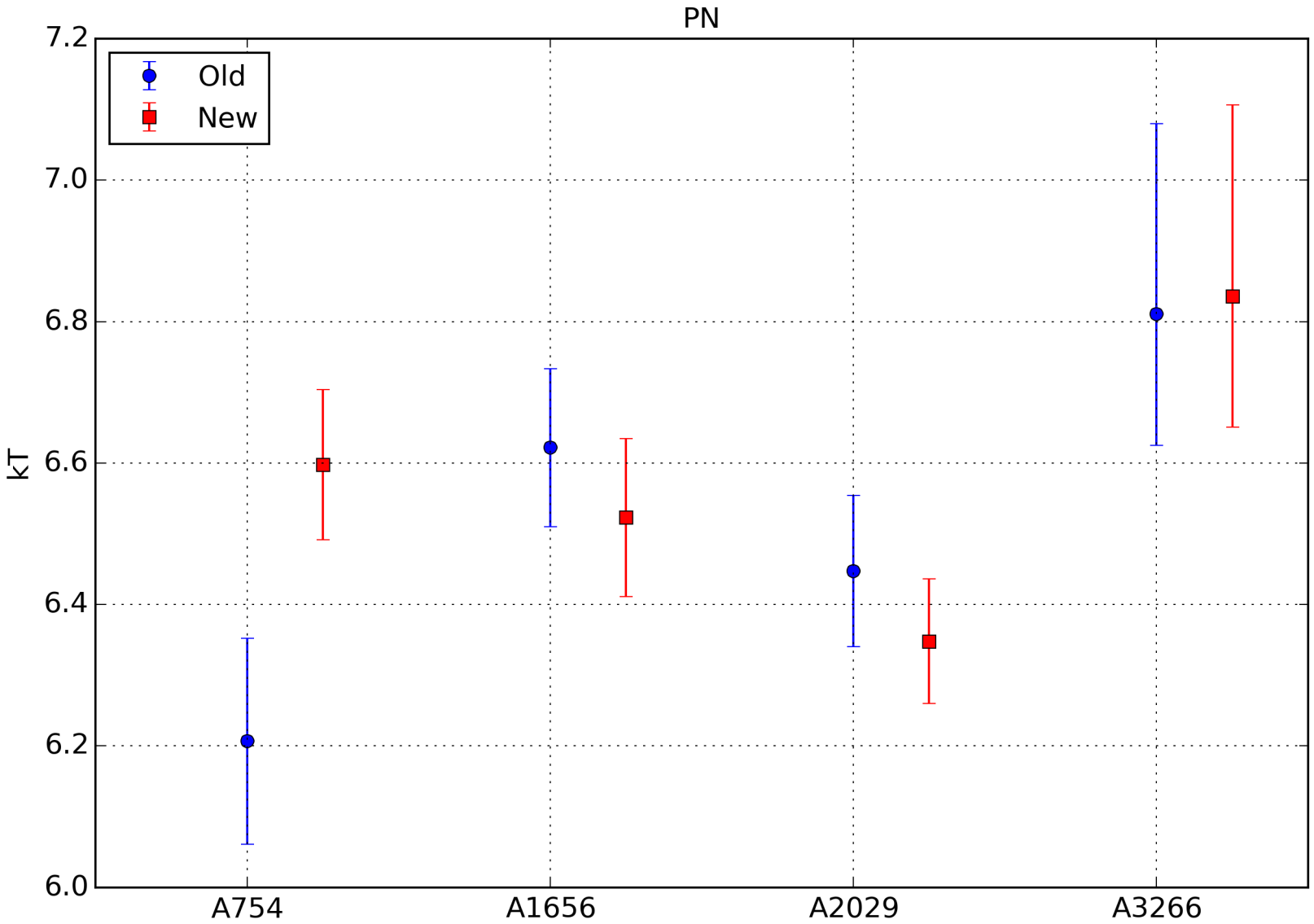
SAS14
Mar2015



Testing recent XMM calibration



Testing recent XMM calibration



Time variability

Up to now the time dependends of the calibration uncertainties was ignored

Future project
→ Study cluster residuals function of time / different epochs

Is there enough data available?

→ Cluster catalog Piffaretti+11

1743 objects

160SD, 400SD, BCS, CIZA, EMSS, MACS, NEP, NORAS/REFLEX, SGP, SHARC, WARPS
(homogenized) luminositiy & redshift

(k-corr.) fluxes & temperatures calculated
(Pratt+09/Reichert+11 scaling relations)

Chandra / XMM archive for all objects

→ At least 10ks observations
→ At least observations in a certain number of years

Time variability

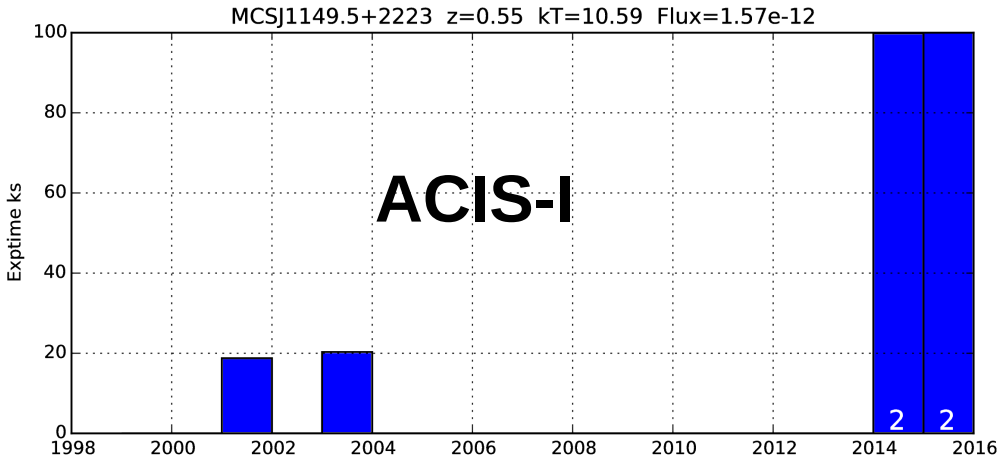
Having observations in at least **4** different years:

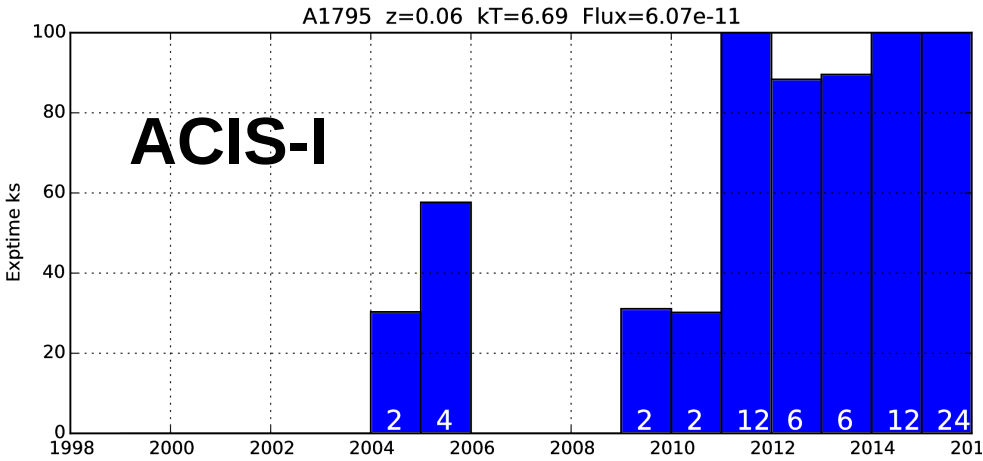
- 3 Cluster for ACIS-I
- 3 Cluster for ACIS-S
- 10 Cluster for ACIS
- 14 Cluster for XMM

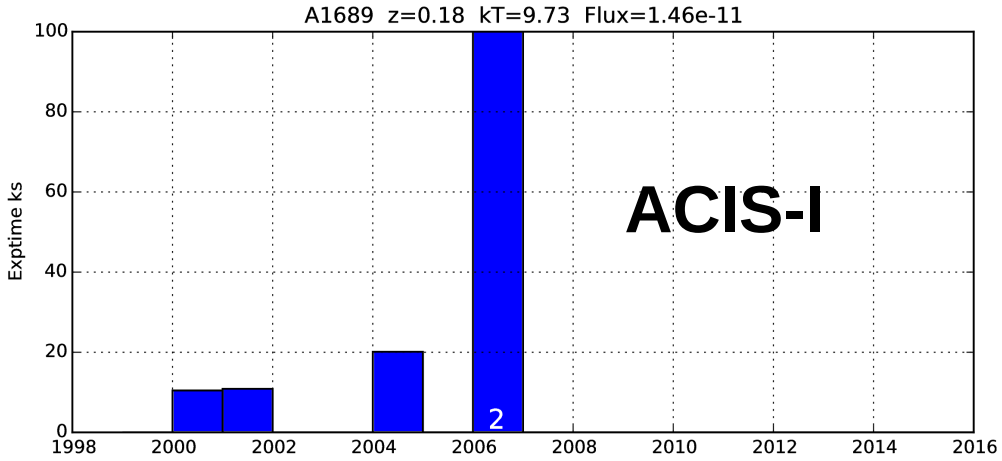
Having observations in at least **4** different years and **kT > 5keV**:

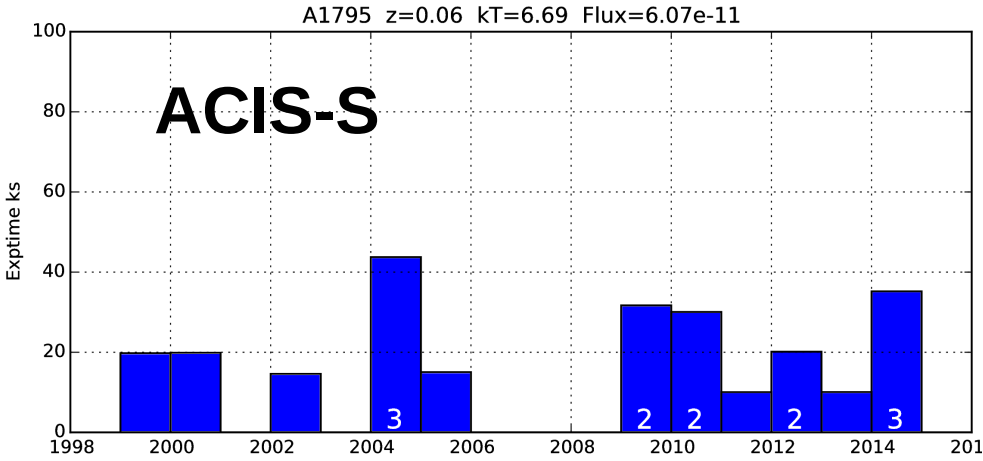
- 3 Cluster for ACIS-I
- 1 Cluster for ACIS-S
- 6 Cluster for ACIS
- 3 Cluster for XMM

Time variability – ACIS

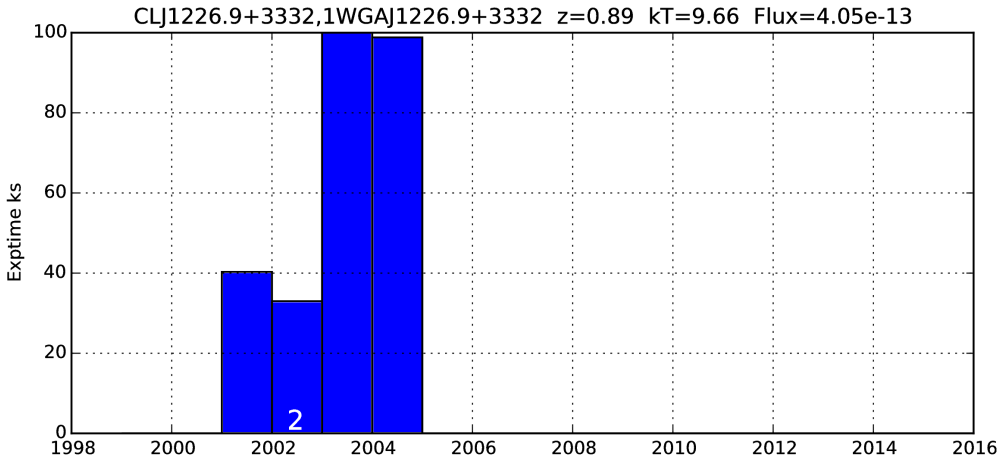


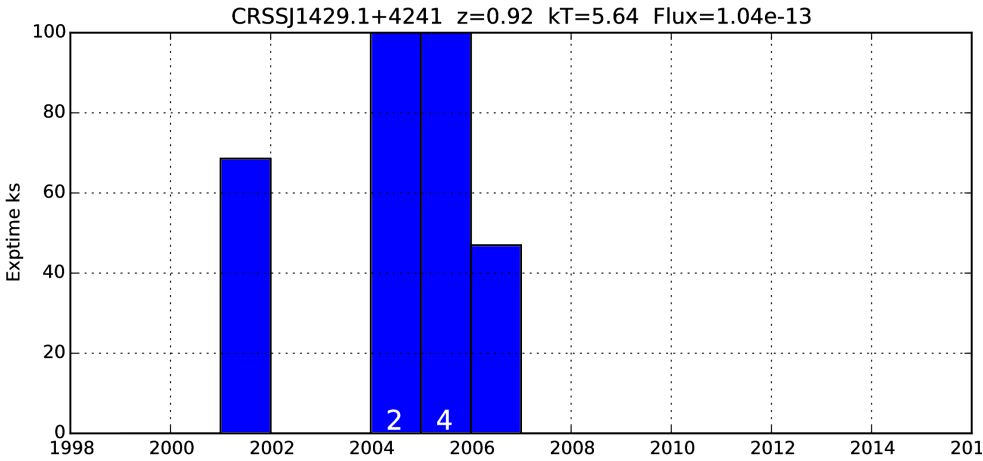


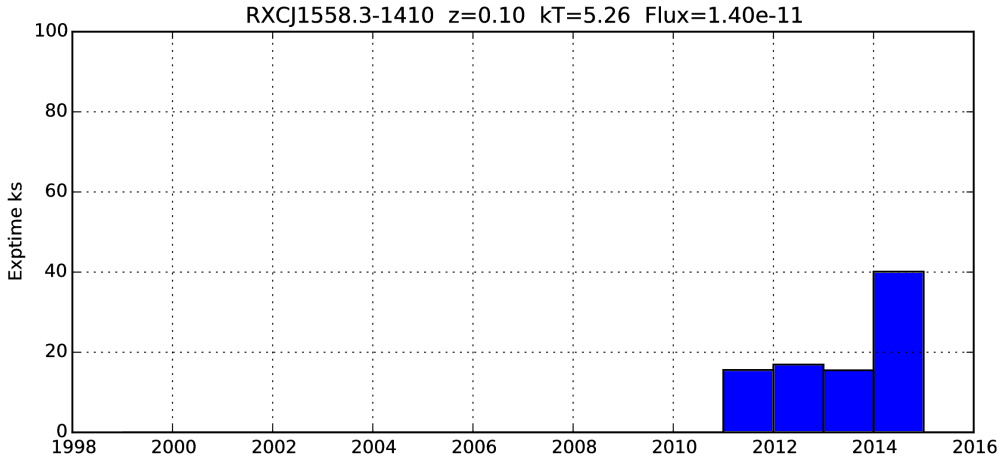




Time variability – XMM







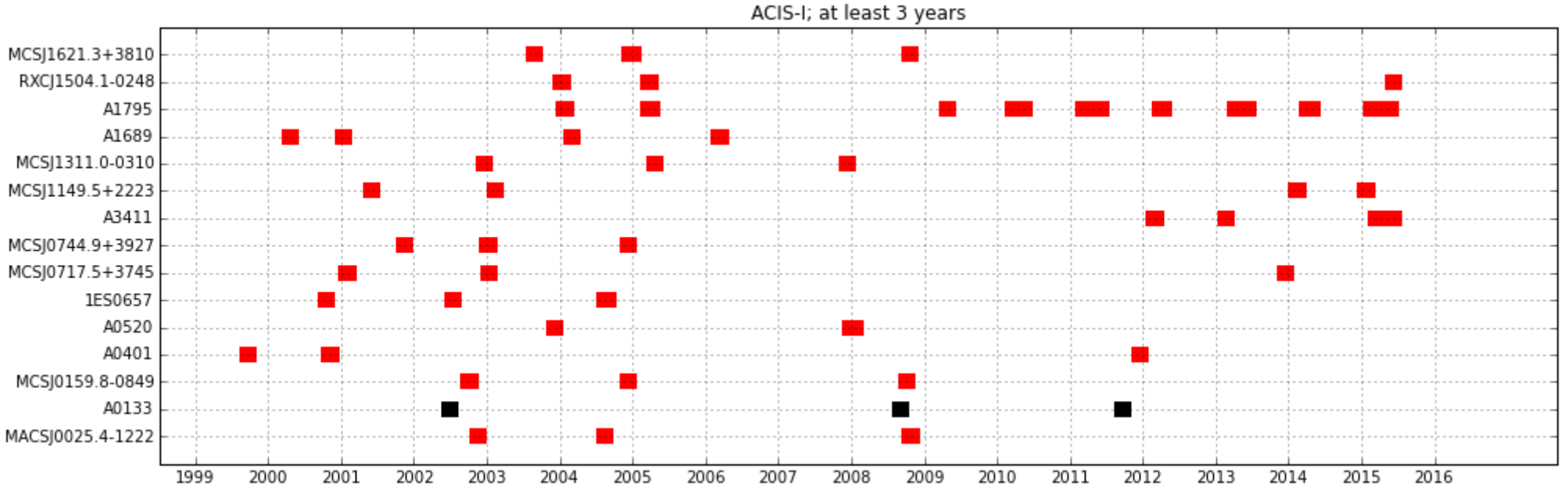
Time variability

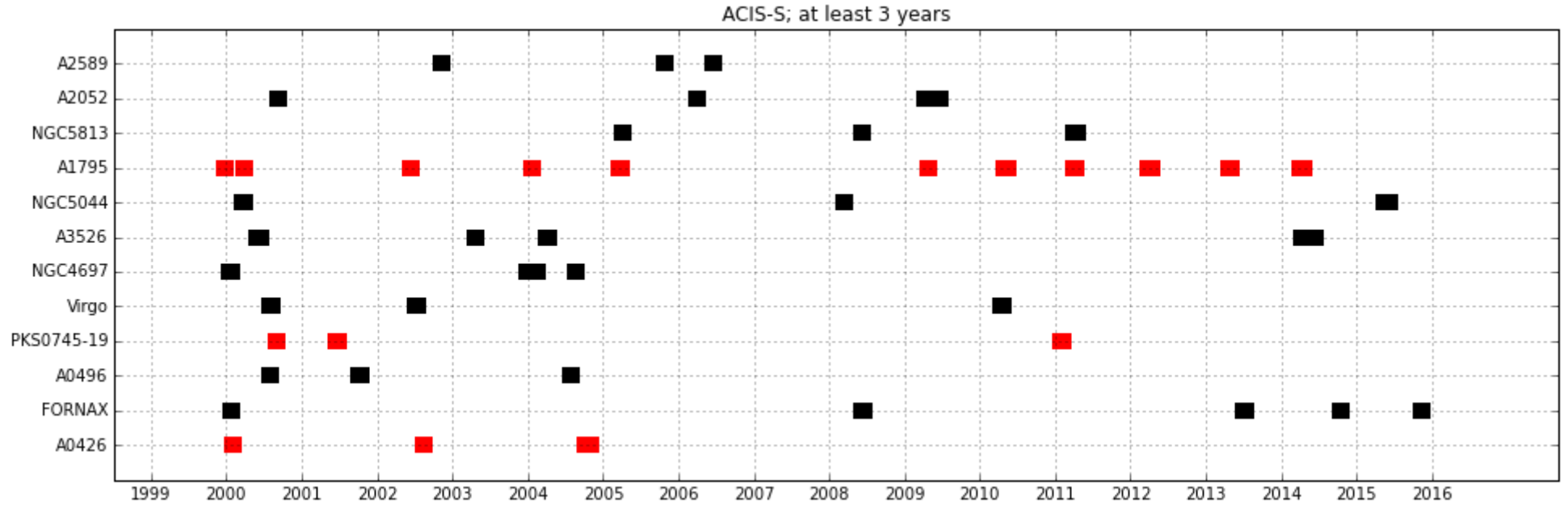
Having observations in at least **3** different years:

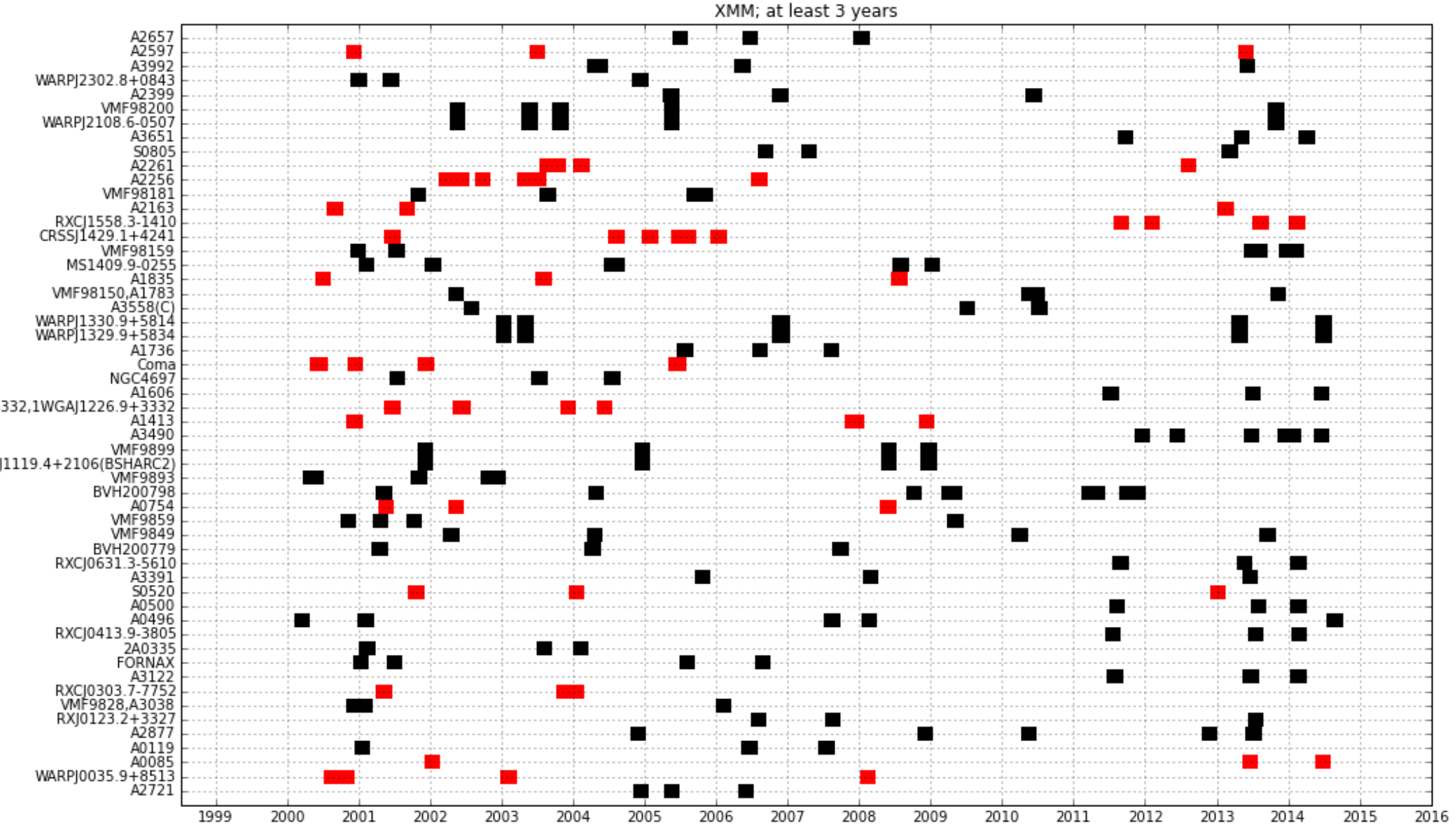
- 15 Cluster for ACIS-I
- 12 Cluster for ACIS-S
- 36 Cluster for ACIS
- 54 Cluster for XMM

Having observations in at least **3** different years and **kT > 5keV**:

- 14 Cluster for ACIS-I
- 3 Cluster for ACIS-S
- 25 Cluster for ACIS
- 15 Cluster for XMM

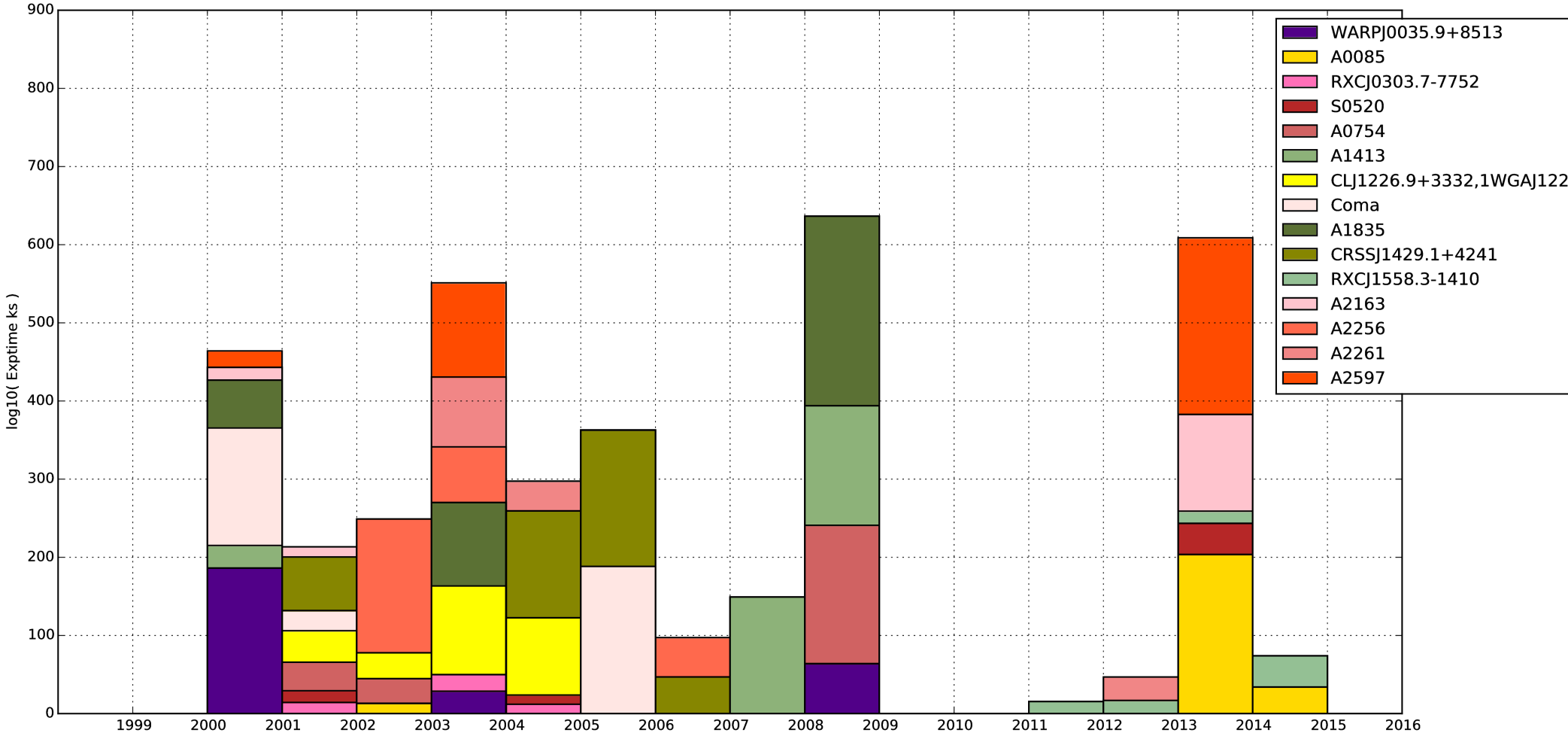

ACIS-I; at least 3 years
MCSJ1621.3+3810
RXCJ1504.1-0248
A1795
A1689
MCSJ1311.0-0310
MCSJ1149.5+2223
A3411
MCSJ0744.9+3927
MCSJ0717.5+3745
1ES0657
A0520
A0401
MCSJ0159.8-0849
A0133
MACSJ0025.4-1222
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016


ACIS-S; at least 3 years
A2589
A2052
NGC5813
A1795
NGC5044
A3526
NGC4697
Virgo
PKS0745-19
A0496
FORNAX
A0426
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016


XMM; at least 3 years
A2657
A2597
A3992
WARPJ2302.8+0843
A2399
VMF98200
WARPJ2108.6-0507
A3651
S0805
A2261
A2256
VMF98181
A2163
RXCJ1558.3-1410
CRSSJ1429.1+4241
VMF98159
MS1409.9-0255
A1835
VMF98150,A1783
A3558(C)
WARPJ1330.9+5814
WARPJ1329.9+5834
A1736
Coma
NGC4697
A1606
332,1WGAJ1226.9+3332
A1413
A3490
VMF9899
J1119.4+2106(BSHARC2)
VMF9893
BVH200798
A0754
VMF9859
VMF9849
BVH200779
RXCJ0631.3-5610
A3391
S0520
A0500
A0496
RXCJ0413.9-3805
2A0335
FORNAX
A3122
RXCJ0303.7-7752
VMF9828,A3038
RXJ0123.2+3327
A2877
A0119
A0085
WARPJ0035.9+8513
A2721
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016

Time variability

XMM – kT > 5keV – at least 3 years



Time variability

XMM – kT > 5keV – at least 3 years