

***Chandra/XMM cross-calibration:  
Temperatures and soft X-ray  
fluxes of galaxy clusters with  
ACIS/EPIC***

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**CHANDRA CALIBRATION WORKSHOP 2004  
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## OUTLINE

1. ACIS-S AND EPIC TEMPERATURES OF FOUR CLUSTERS: COMA, A1795, A3122 AND AS1101
2. SOFT X-RAY FLUXES (0.3-2 KeV) COMPARISON
3. CHANDRA, XMM AND ASCA COMPARISON FOR A SAMPLE OF 38 CLUSTERS ( $z=0.15-0.9$ )
4. SUMMARY OF RESULTS

# 1. TEMPERATURES OF FOUR CLUSTERS

## 1.1 THE DATA

Cluster	XMM ID.	Obs. Date	Filter	Livetime	Chandra ID	Obs. Date	Livetime
AS1101	0147800101	2002-11-20	Thin	120 ks	1668	2001-08-13	10 ks
A3112	0105660101	2000-12-24	Medium	23 ks	2216	2001-05-24	7 ks
					2516	2001-09-12	17 ks
A1795	0097820101	2000-06-26	Thin	50ks	3666	2002-06-10	15 ks
Coma	0124711401	2000-05-29	Medium	20ks	1086	1999-11-04	10 ks

- ◇ All clusters have reported soft excess emission
- ◇ Used only 2-4 arcmin data for AS1101, A3112 and A1795 (cooling flow)
- ◇ Background is from low- $N_{\text{H}}$  blank-sky fields (Chandra: files provided with CIAO software – XMM: files of Lumb et al. 2002)

## 1.2 DATA REDUCTION

### ACIS:

- \* CIAO 3.1, CALDB 2.26/CALDB 2.28
- \* `acis_process_eventson` Level 1 event file
- \* `grade=0,2,3,4,6` `status=0` and standard GTI
- \* lightcurve in 0.5-5 keV to remove background flare
- \* `acispec` to extract spectra
- \* QE calibration: N0005 (2.28) or N0003 (2.26)
- \* ACIS contaminant: `acisD1999-08-13contamN0003.fits`
- \* Spatial dependence of contaminant (`calcarf` tool)

## EPIC:

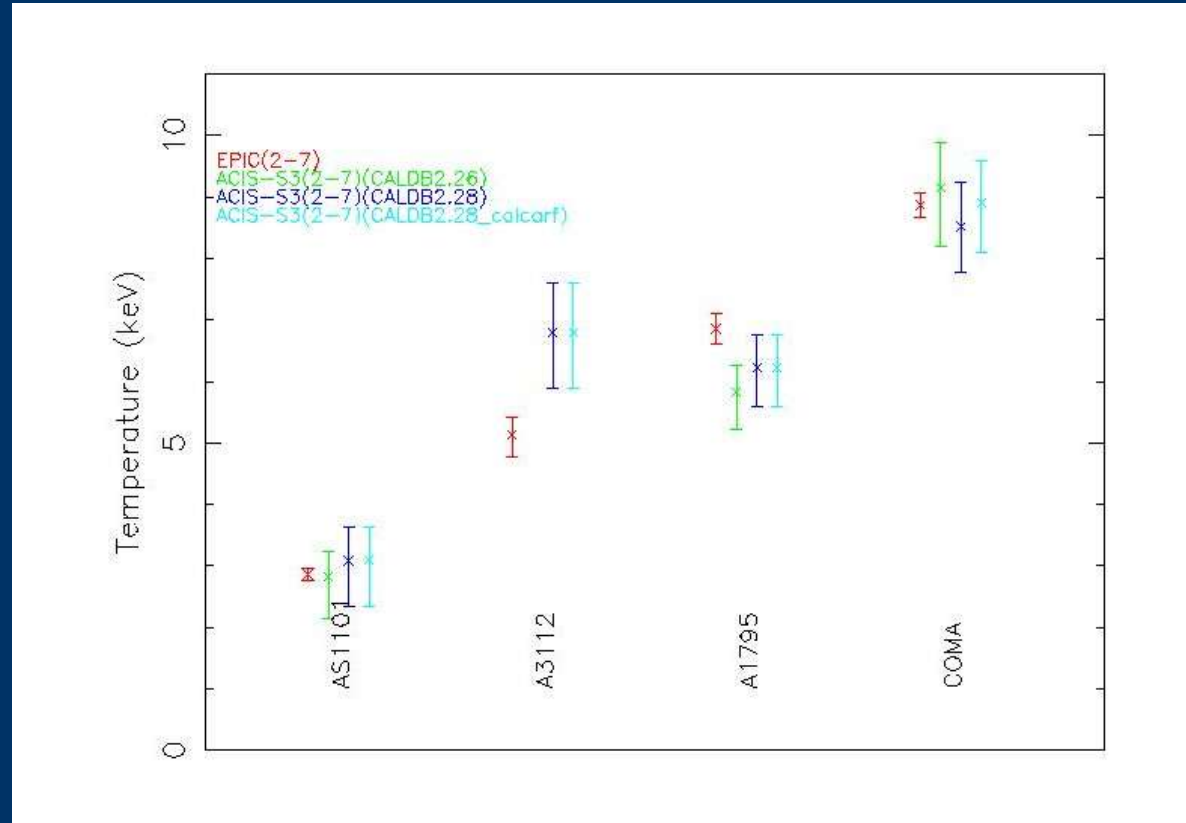
- \* SAS 6.0
- \* emchain, epchain on raw ODF data from archive
- \* MOS: pattern $\leq$ 12 flag=0
- \* PN: pattern=0 flag=0
- \* Lightcurve at  $E > 10$  keV from full field to remove flares  
Threshold: MOS1, MOS2=108, 112 c/(500 s)  
PN=168 c/(500 s)
- \* arfgen to generate arf files, canned rmfs

## 1.3 FITTING TECHNIQUE

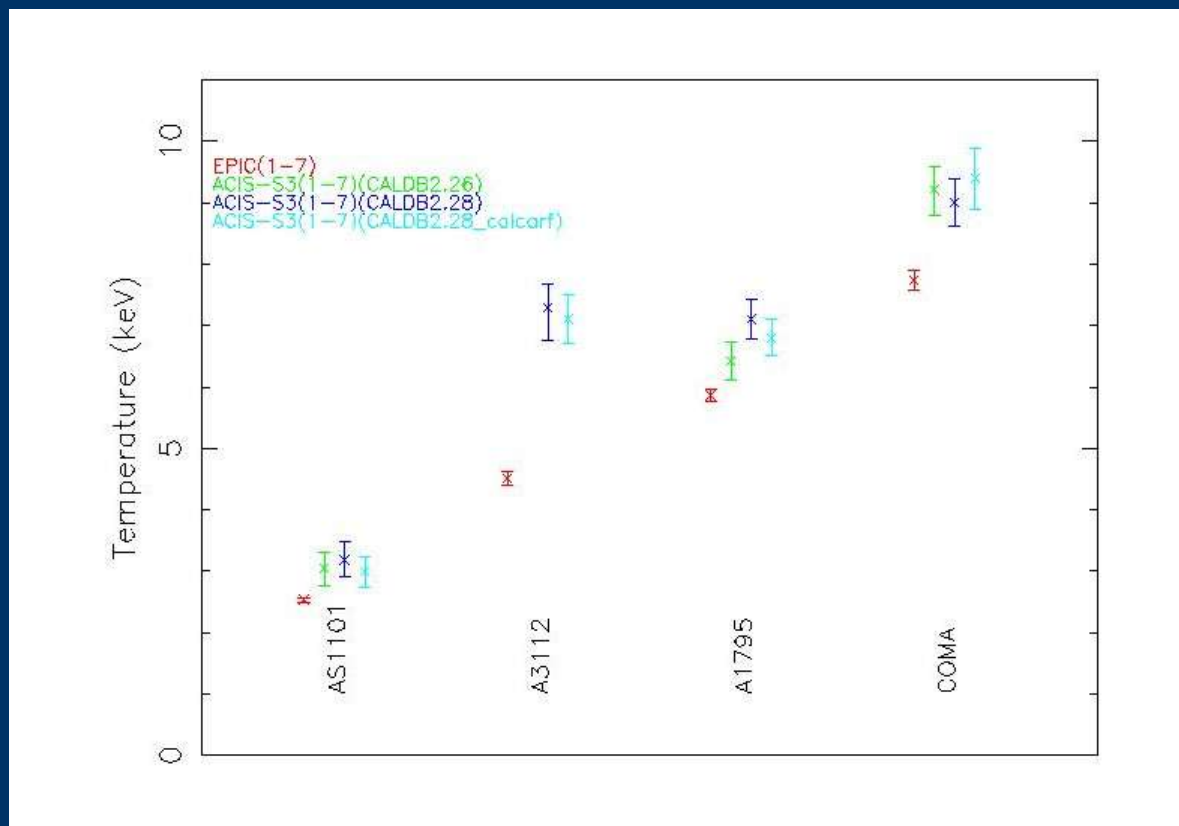
- ◇ wabs\*mekal in XSPEC 3.1
- ◇ Galactic NH
- ◇ Fit the 2-7 keV or 1-7 keV data

# 1.4 RESULTS

## 2-7 keV fit

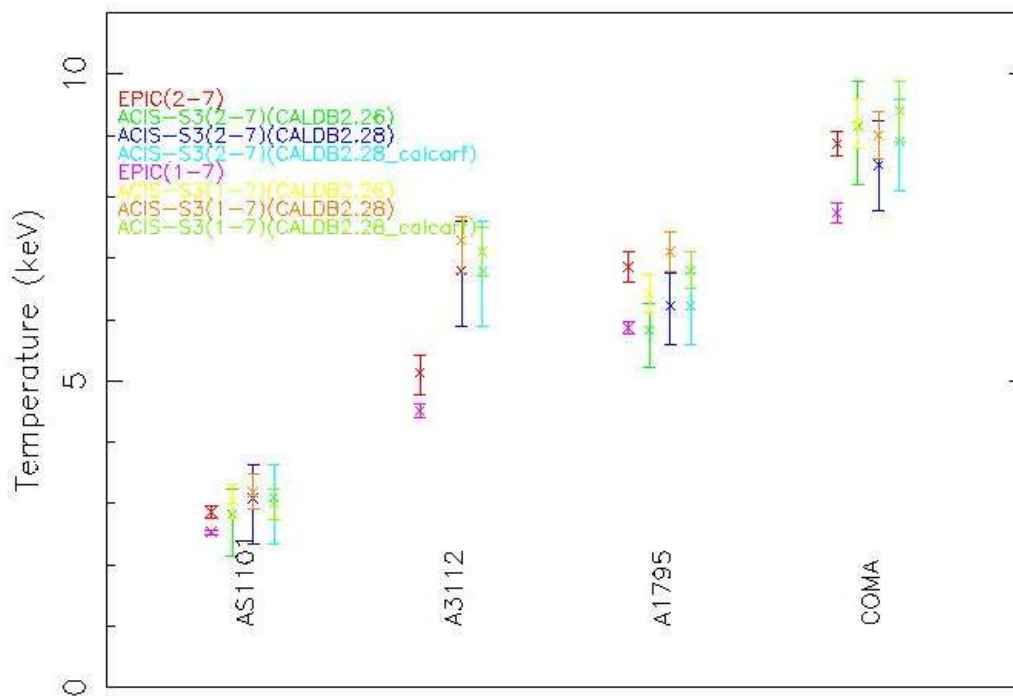


## 1-7 keV fit

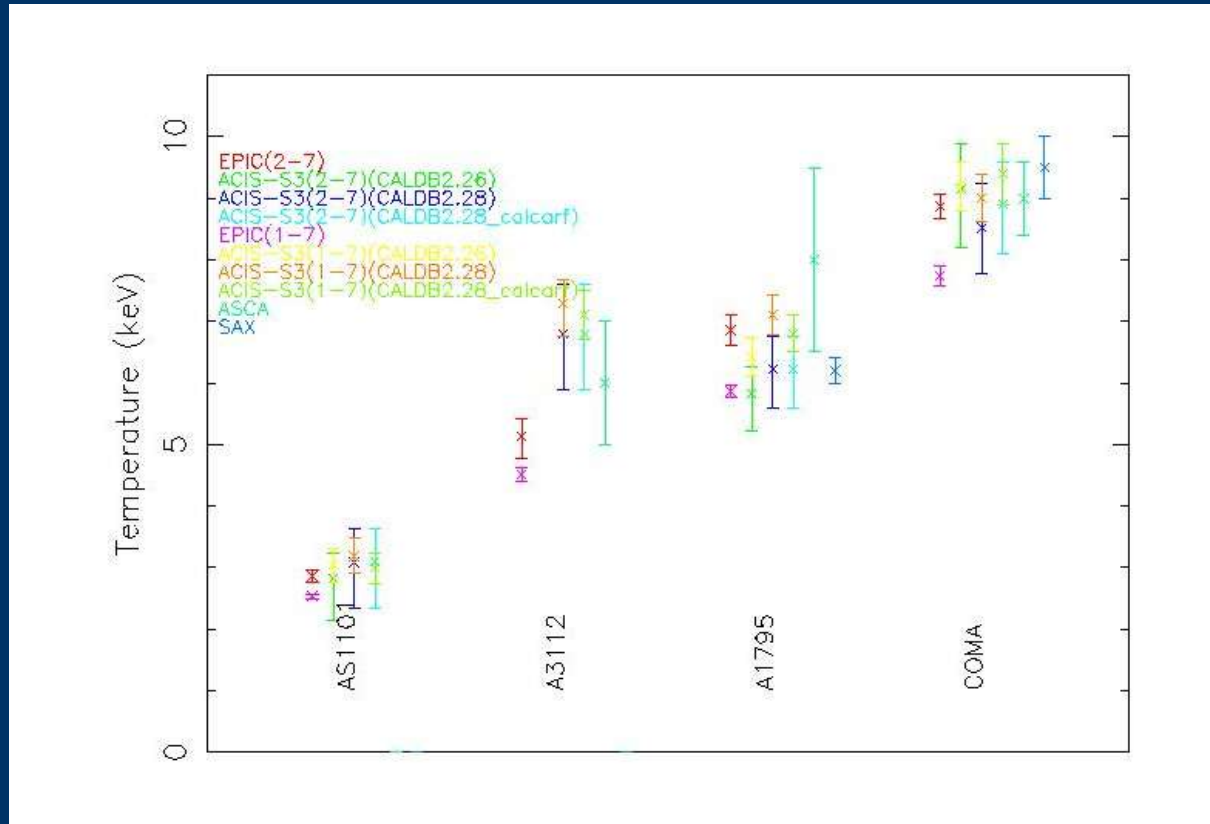




## 1-7 keV and 2-7 keV summary



## Summary with ASCA and BeppoSAX data

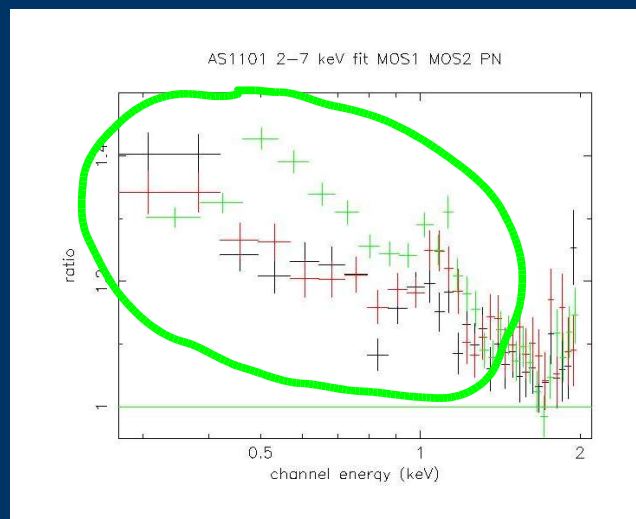


## 2. SOFT X-RAY FLUXES

- \* Extrapolate best fit models down to 0.3 keV
- \* Check for presence of soft excess emission

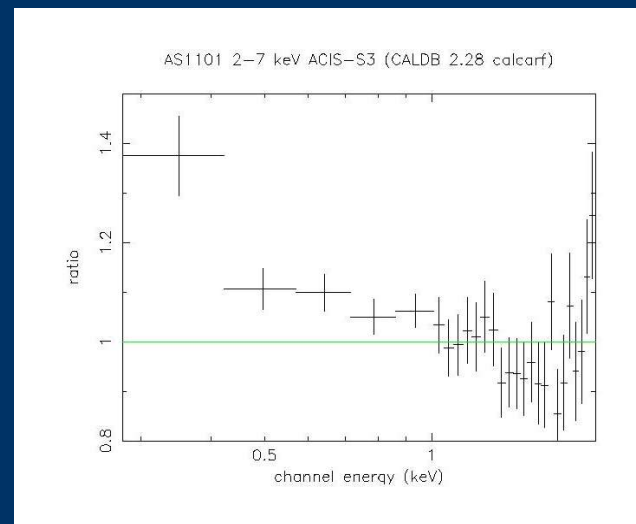
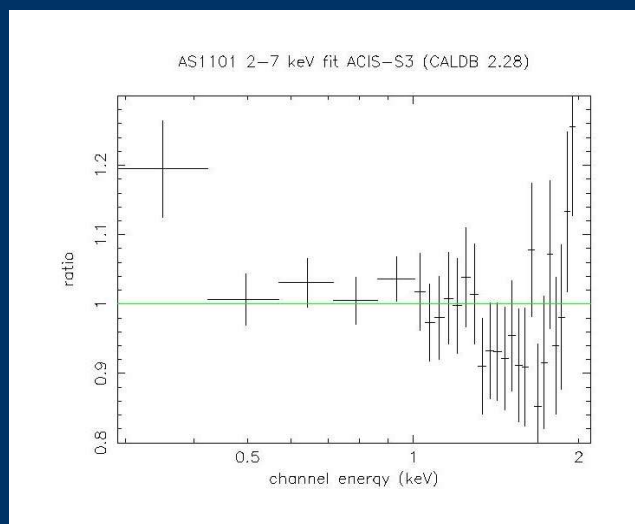
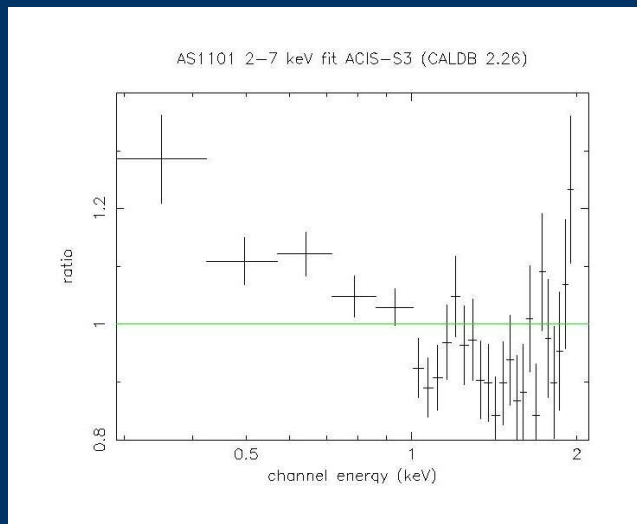
## 2.1 2-7 keV model

AS1101



EPIC

# AS1101

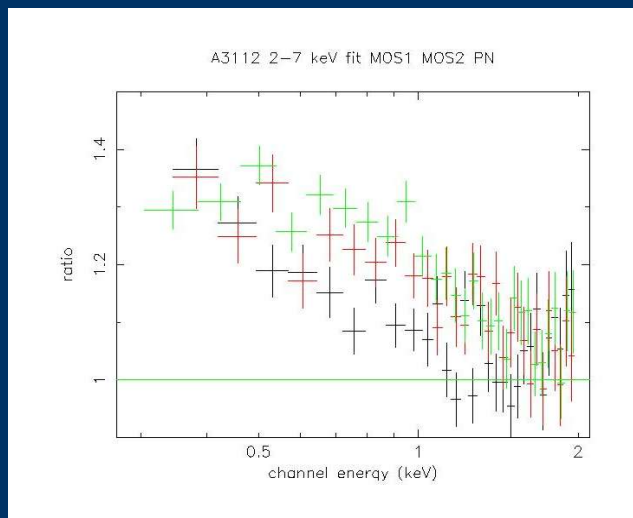


ACIS-S3 (CALDB 2.26)

ACIS-S3 (CALDB 2.28)

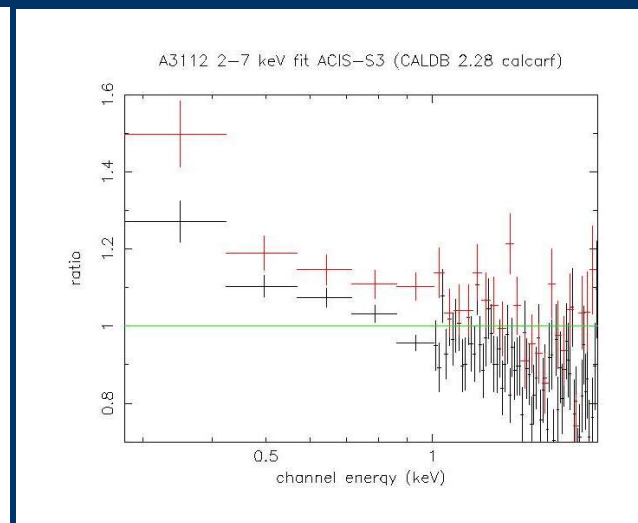
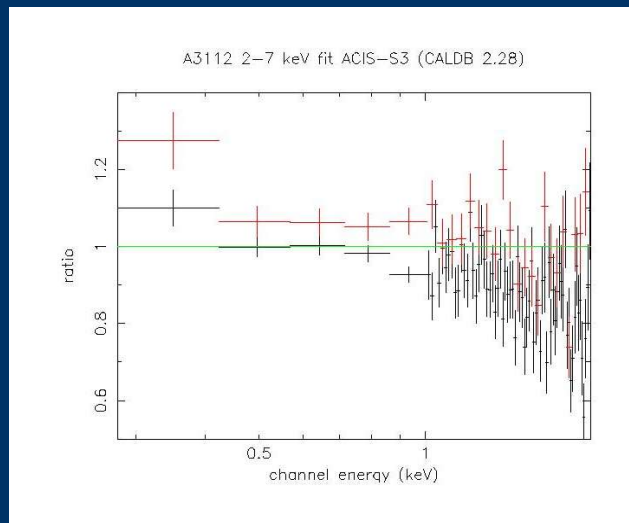
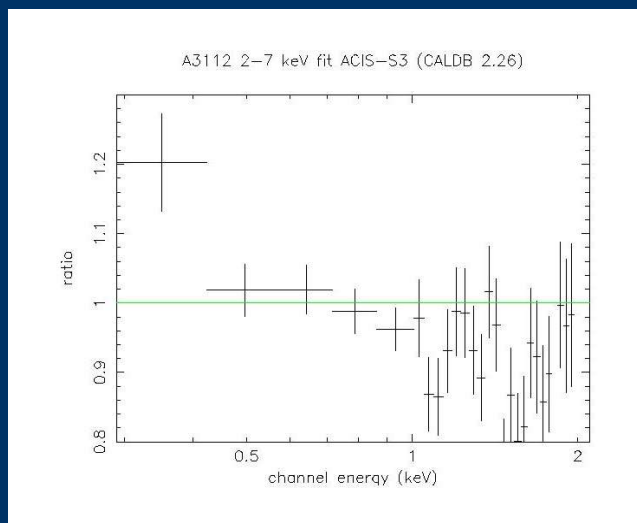
ACIS-S3 (CALDB 2.28)  
calcarf

A3112



EPIC

# A3112



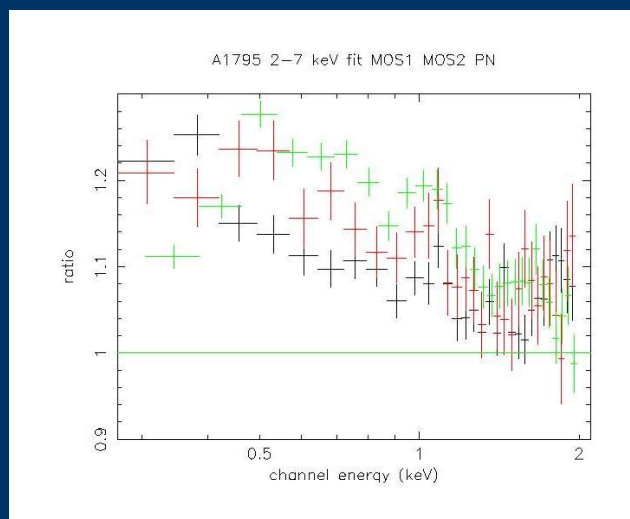
ACIS-S3 (CALDB 2.26)

ACIS-S3 (CALDB 2.28)

ACIS-S3 (CALDB 2.28)

calcarf

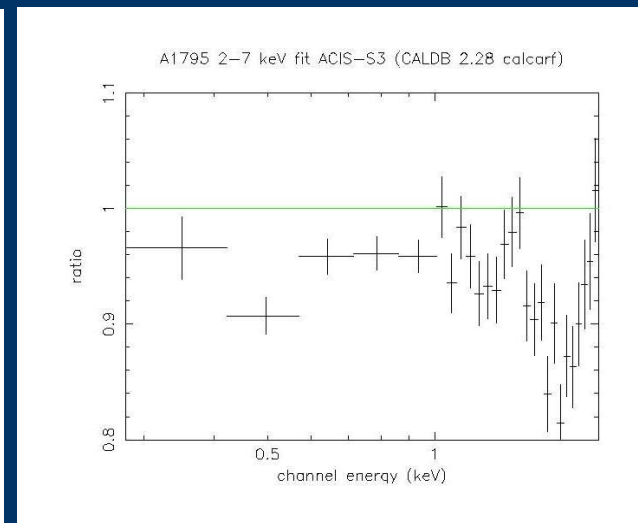
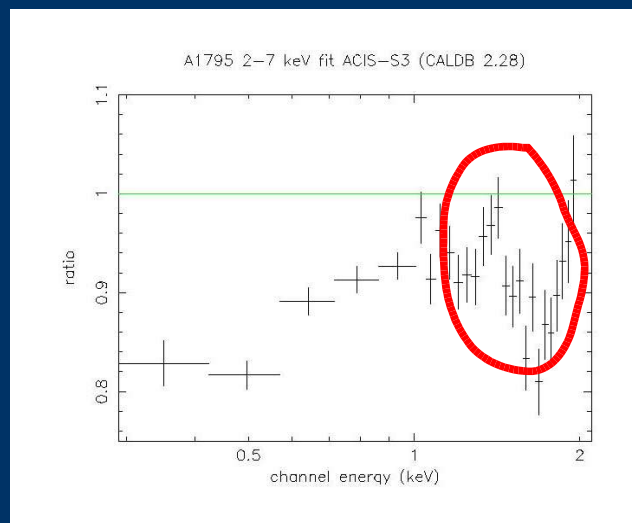
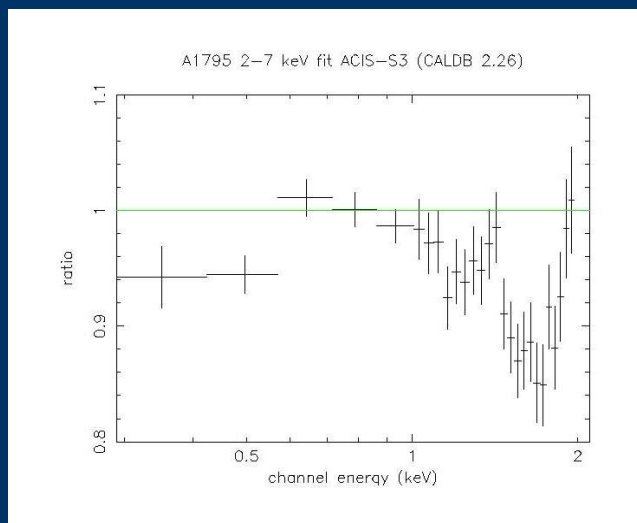
A1795



EPIC

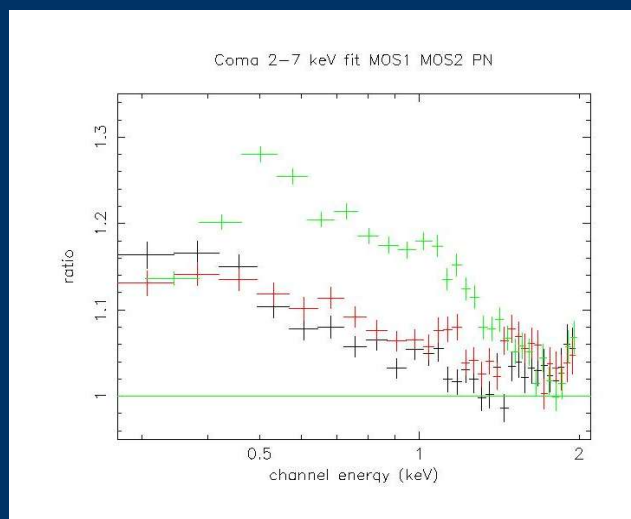


# A1795



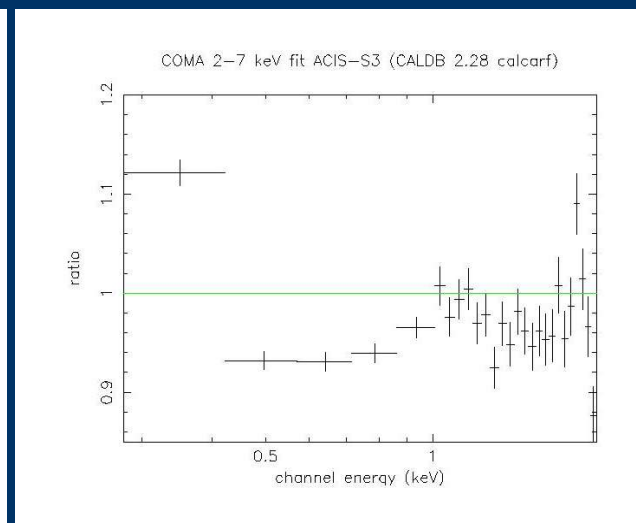
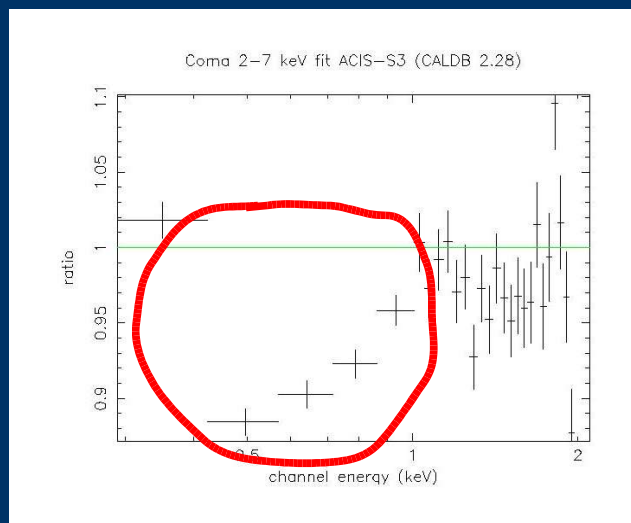
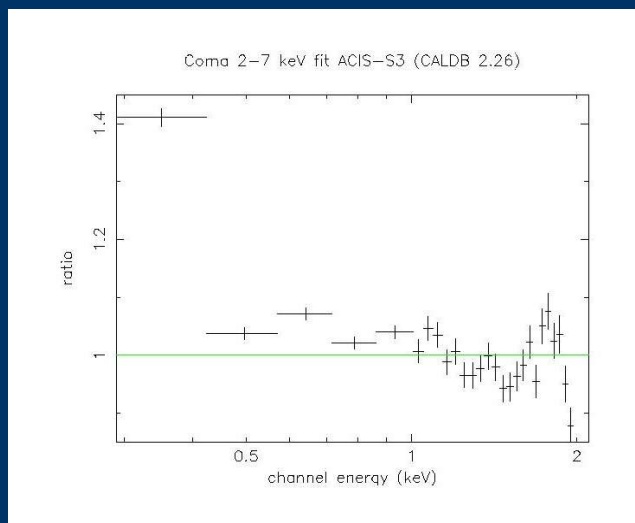
ACIS-S3 (CALDB 2.26) ACIS-S3 (CALDB 2.28) ACIS-S3 (CALDB 2.28)  
calcarf

# COMA



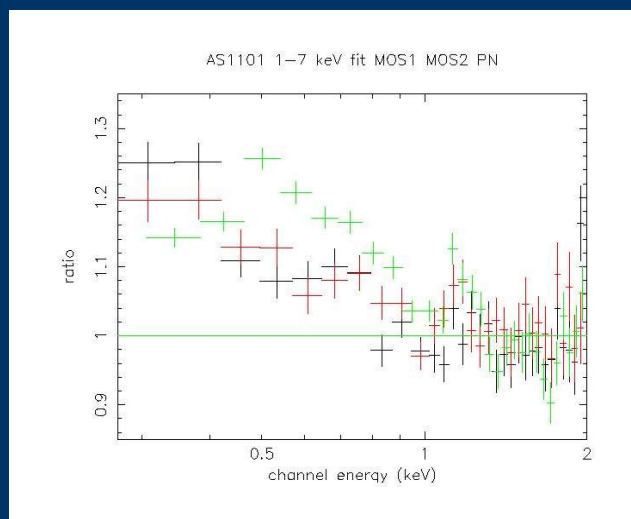
EPIC

# COMA



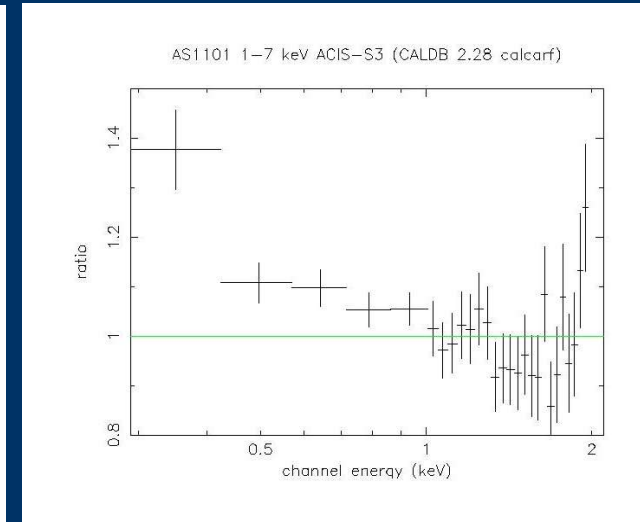
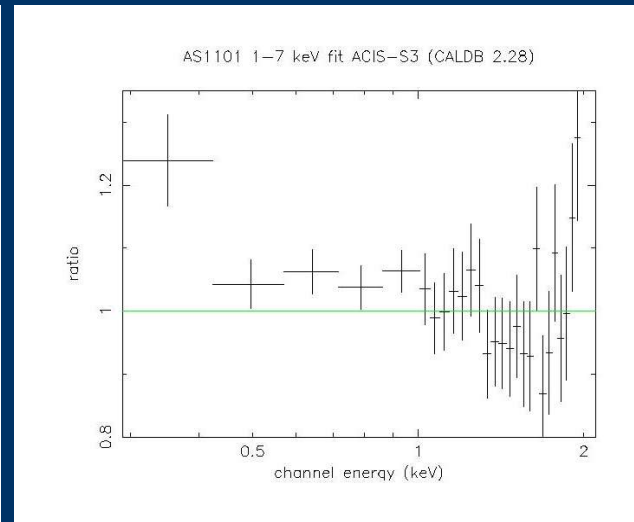
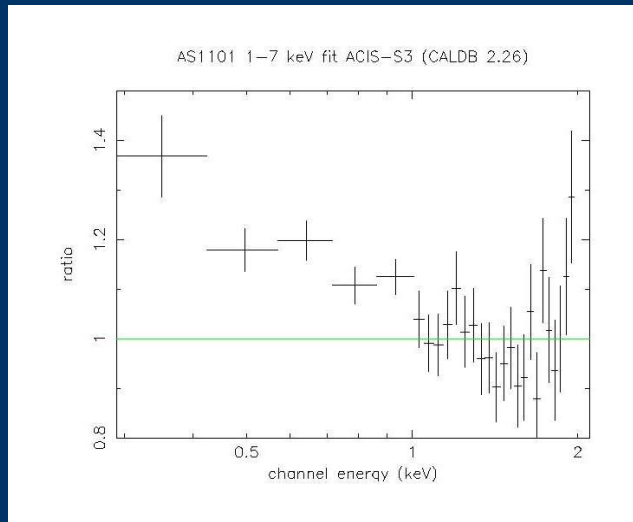
ACIS-S3 (CALDB 2.26) ACIS-S3 (CALDB 2.28) ACIS-S3 (CALDB 2.28) calcarf

## 2.2 1-7 keV FIT AS1101



EPIC

## 2.2 1-7 keV FIT AS1101

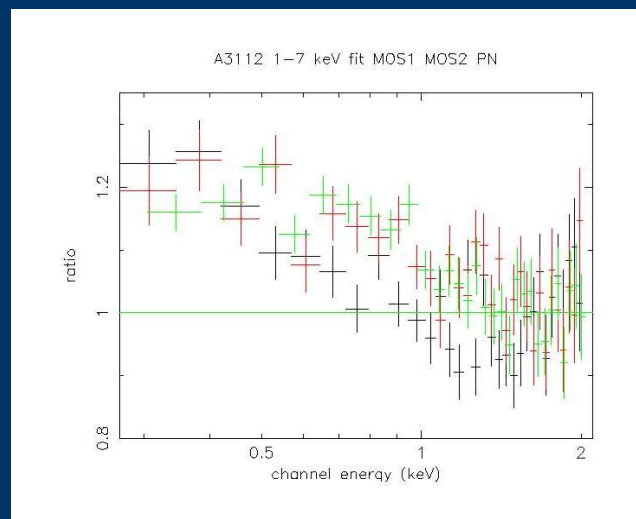


ACIS-S3 (CALDB 2.26)

ACIS-S3 (CALDB 2.28)

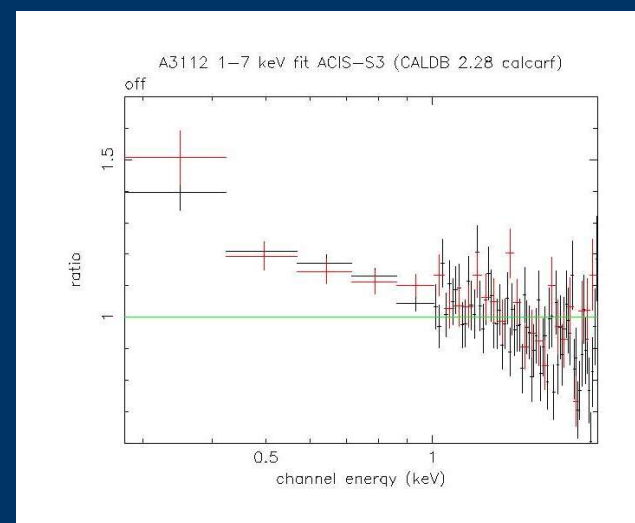
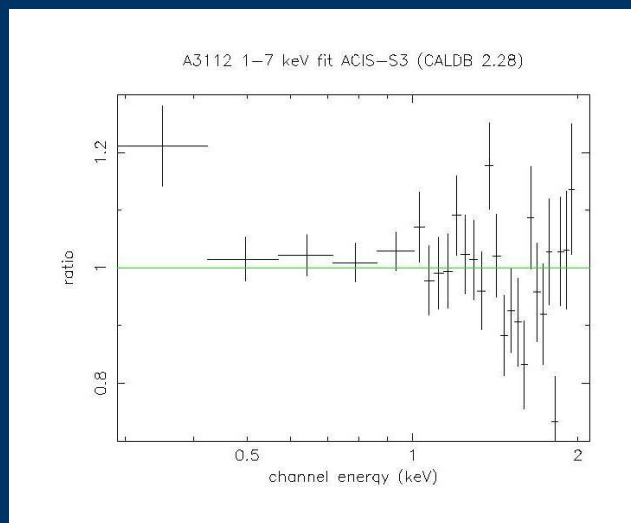
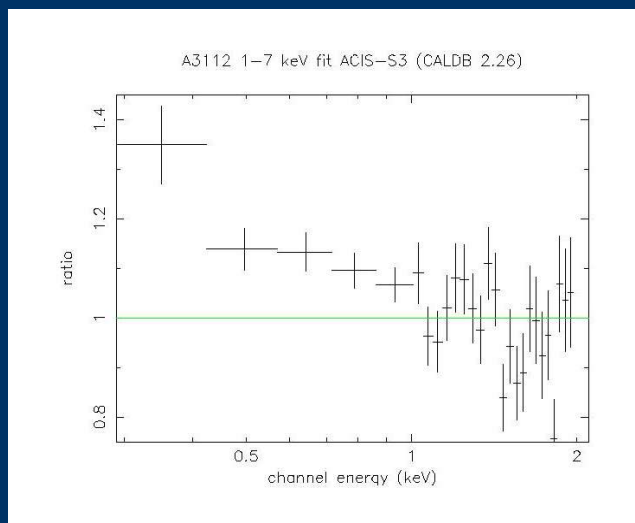
ACIS-S3 (CALDB 2.28)  
calcarf

A3112



EPIC

# A3112



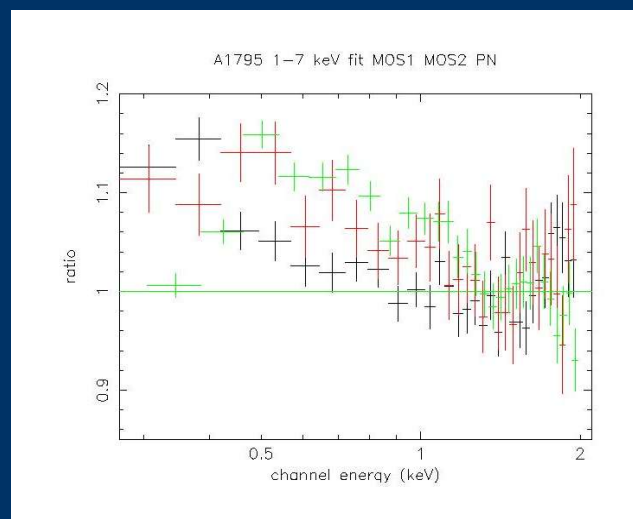
ACIS-S3 (CALDB 2.26)

ACIS-S3 (CALDB 2.28)

ACIS-S3 (CALDB 2.28)

calcarf

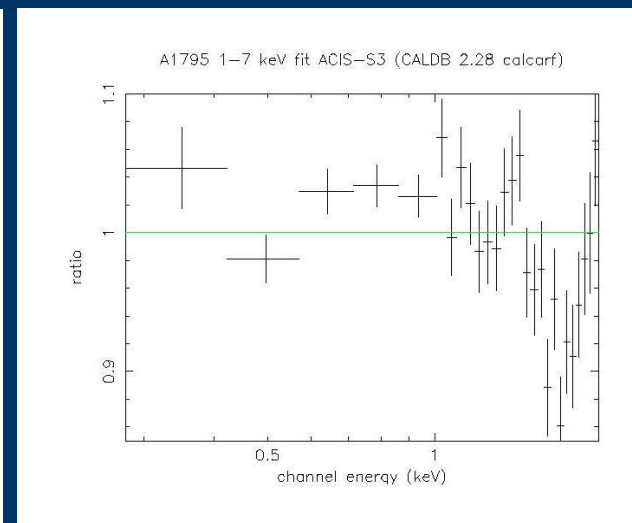
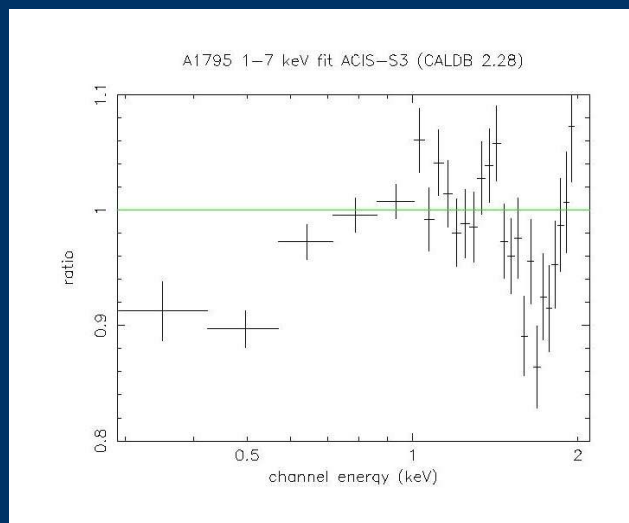
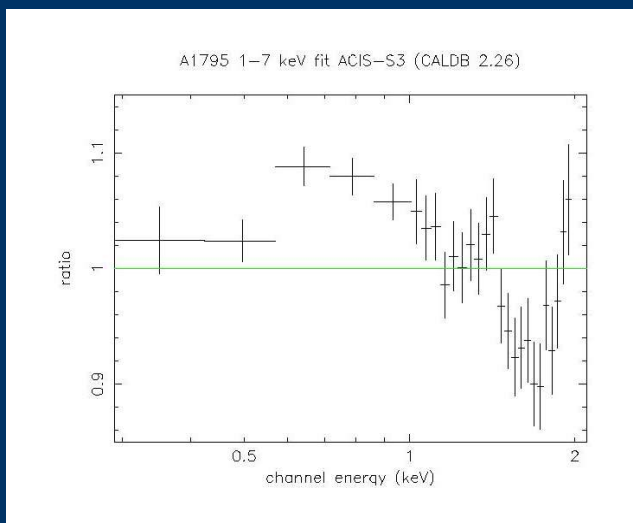
A1795



EPIC



# A1795



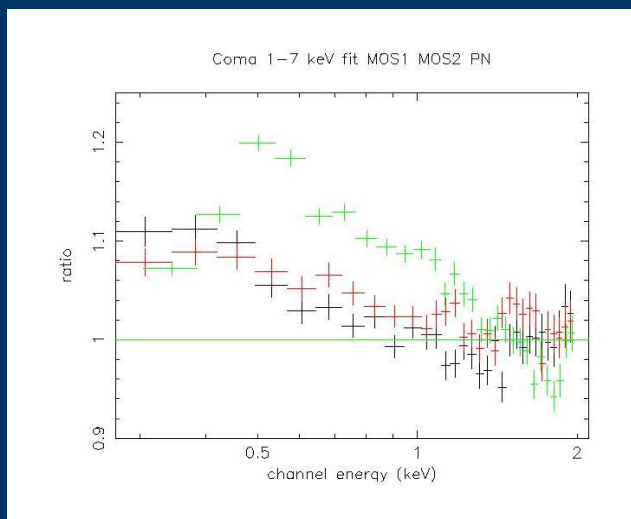
ACIS-S3 (CALDB 2.26)

ACIS-S3 (CALDB 2.28)

ACIS-S3 (CALDB 2.28)

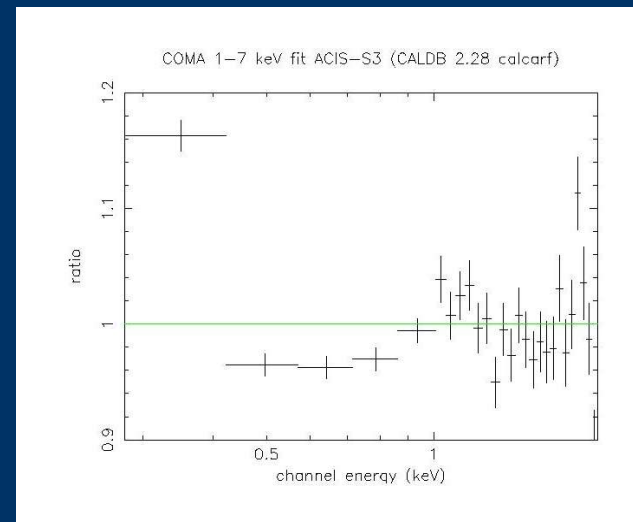
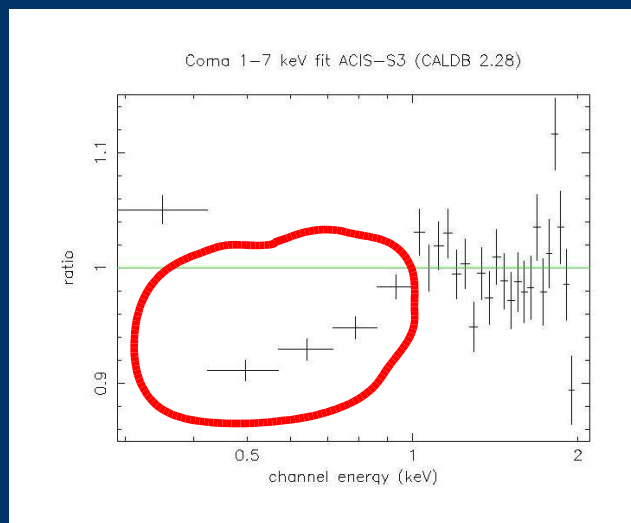
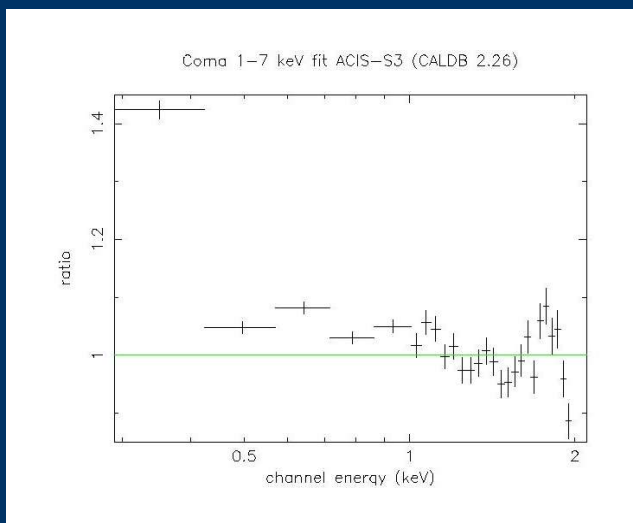
calcarf

# COMA



# EPIC

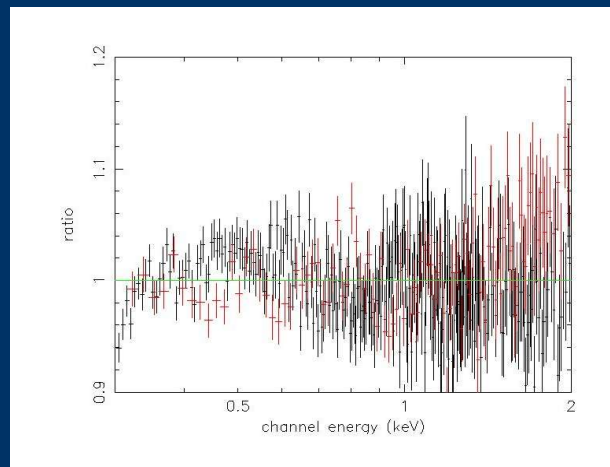
# COMA



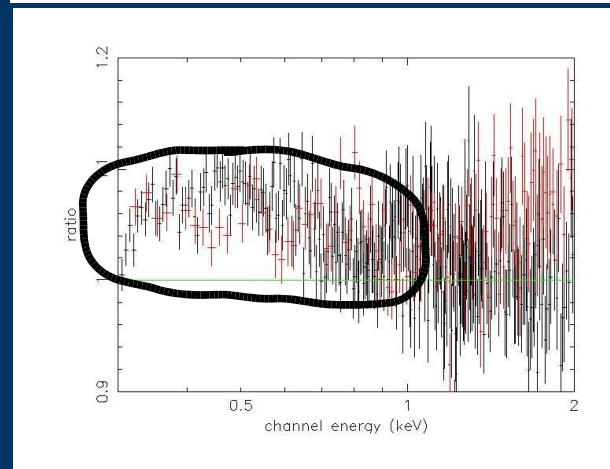
ACIS-S3 (CALDB 2.26) ACIS-S3 (CALDB 2.28) ACIS-S3 (CALDB 2.28)  
calcarf

## 2.3 XMM CALIBRATION SOURCE: PKS 2155-304

	0-3 keV fit	2-7 keV fit
<b>POWER-LAW</b> ↘		
$\alpha$	$2.793 \pm 0.004$	$2.760 \pm 0.030$
Norm. MOS	$0.0341 \pm 0.0001$	$0.033 \pm 0.001$
Norm. PN	$0.0248 \pm 0.0001$	$0.024 \pm 0.001$
red. $\chi^2$	1.23(1085)	1.03(626)



0.3-7 keV fit

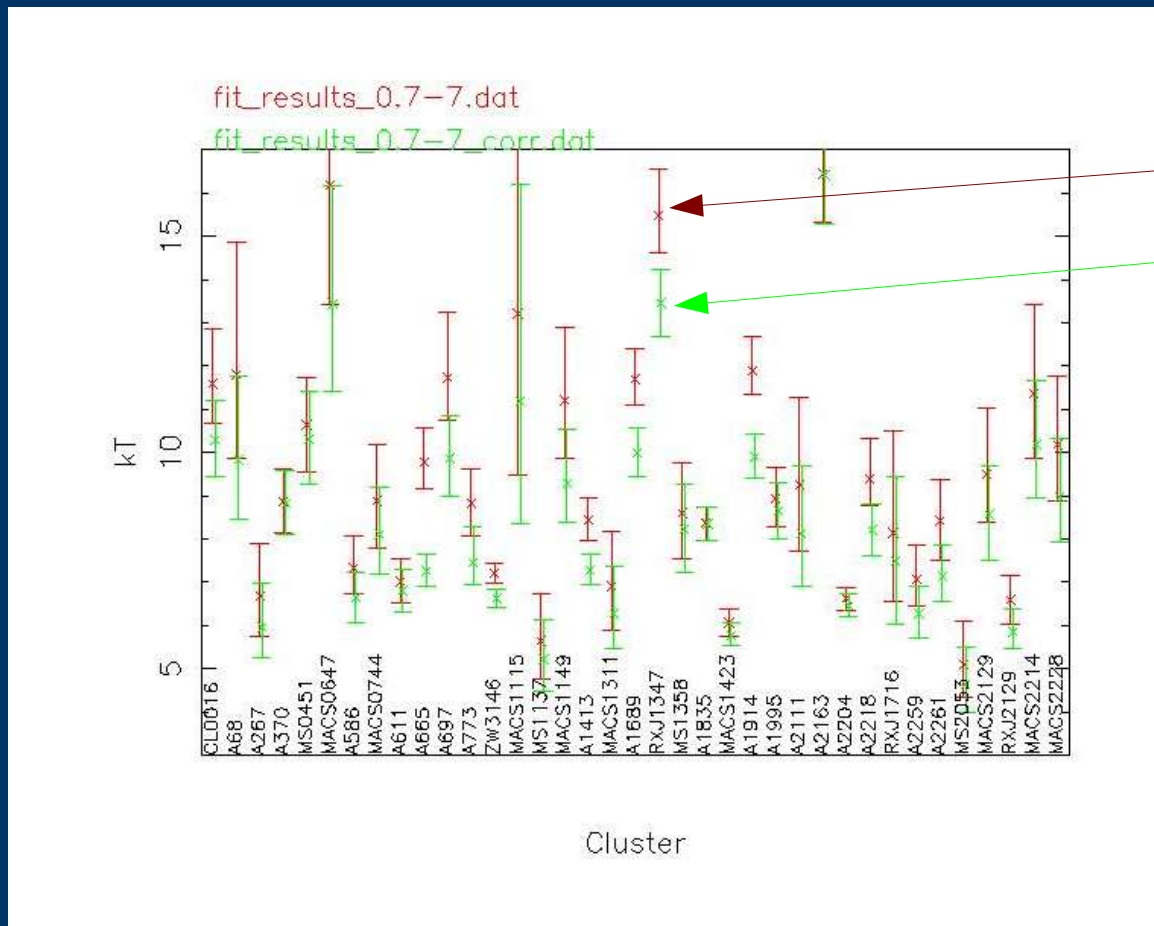


2-7 keV fit

### 3. CHANDRA/XMM/ASCA COMPARISON

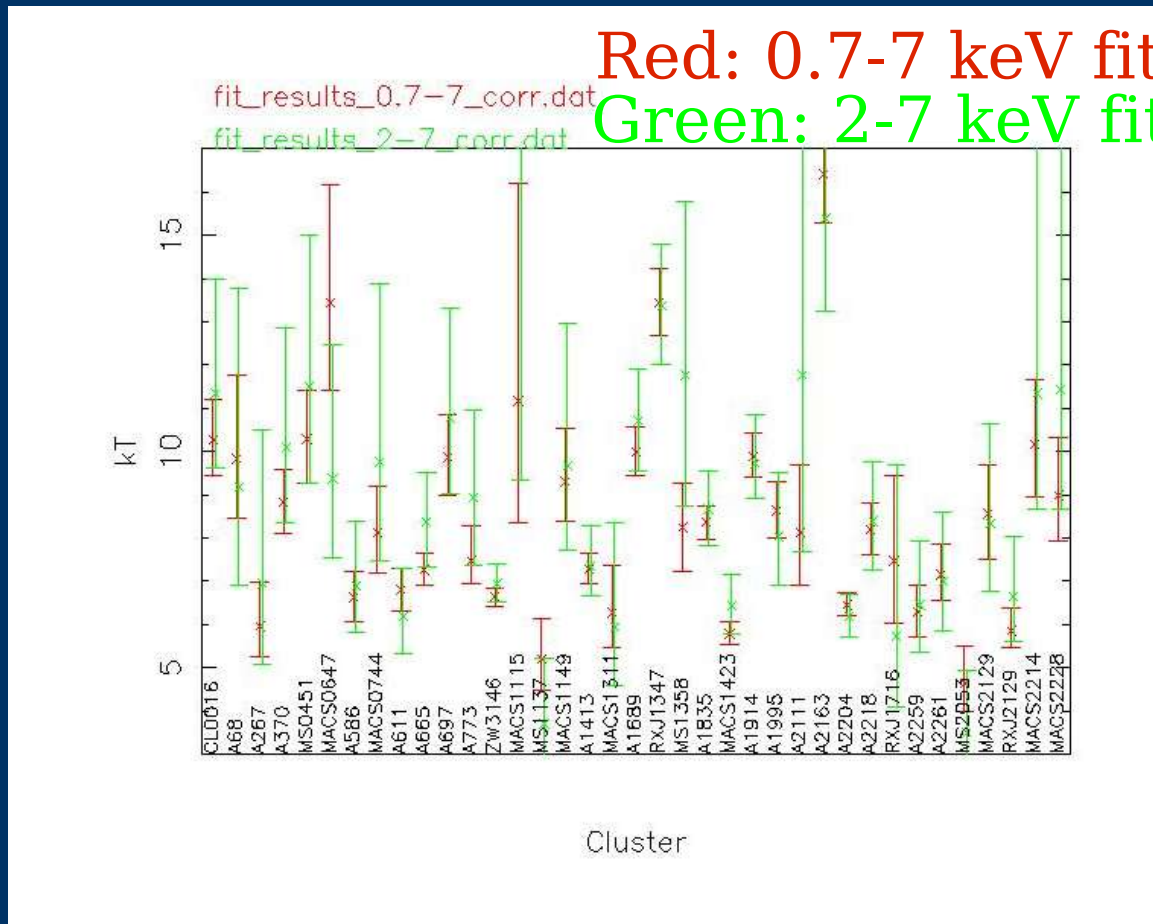
- \* Sample of 38 ACIS-S and ACIS-I clusters
- \* Fit 0.7-7 keV Chandra data
- \* Use CALDB 2.28
- \* Compare with spatial-dependent OBF correction (calcarf, by A. Vikhlinin)
- \* Compare with 2-7 keV fit
- \* Compare with 2-2.3 keV data removed (Ir edge)
- \* Compare with XMM/ASCA literature values

# COMPARISON: W/ AND W/O CALCARF CORRECTION

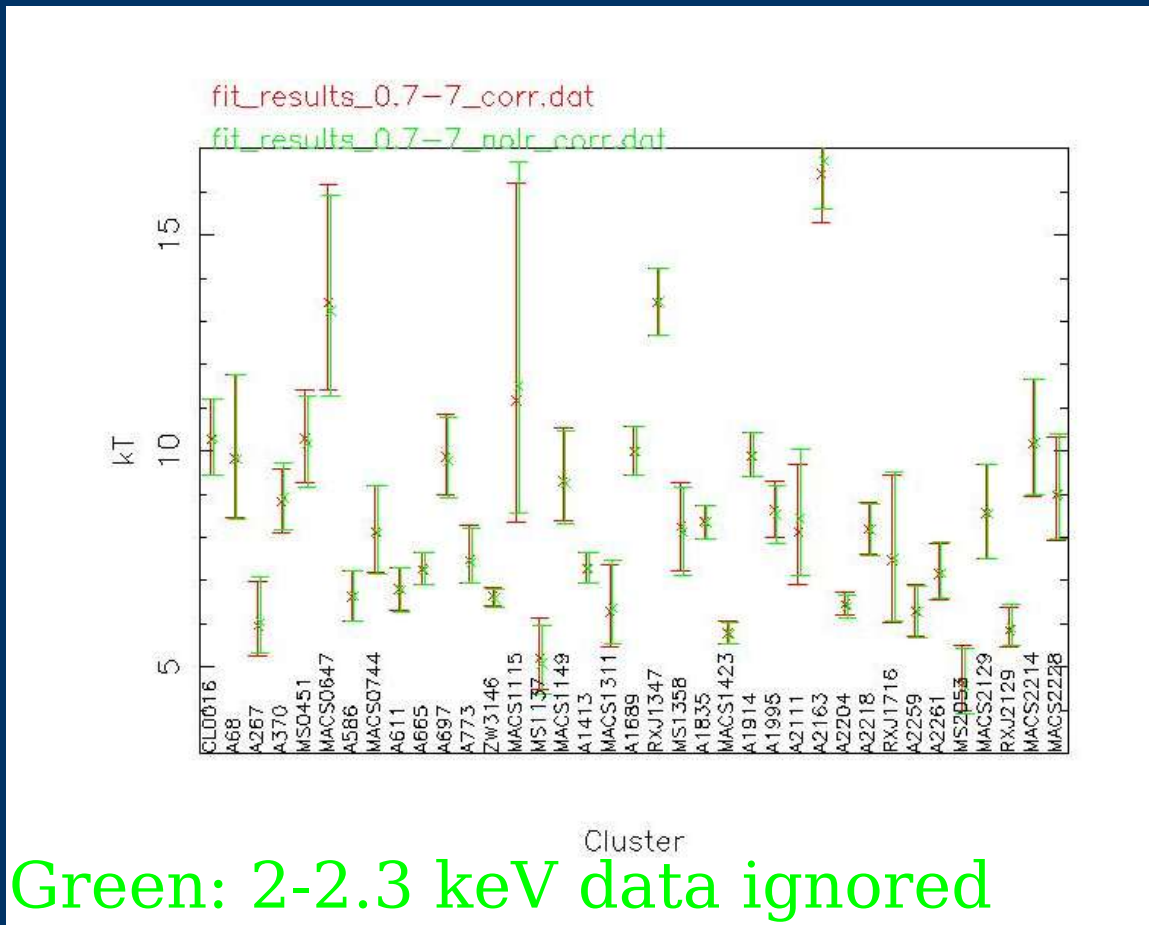


w/o correction  
calcarf correction applied

# COMPARISON: 0.7-7 AND 2-7 KEV FIT

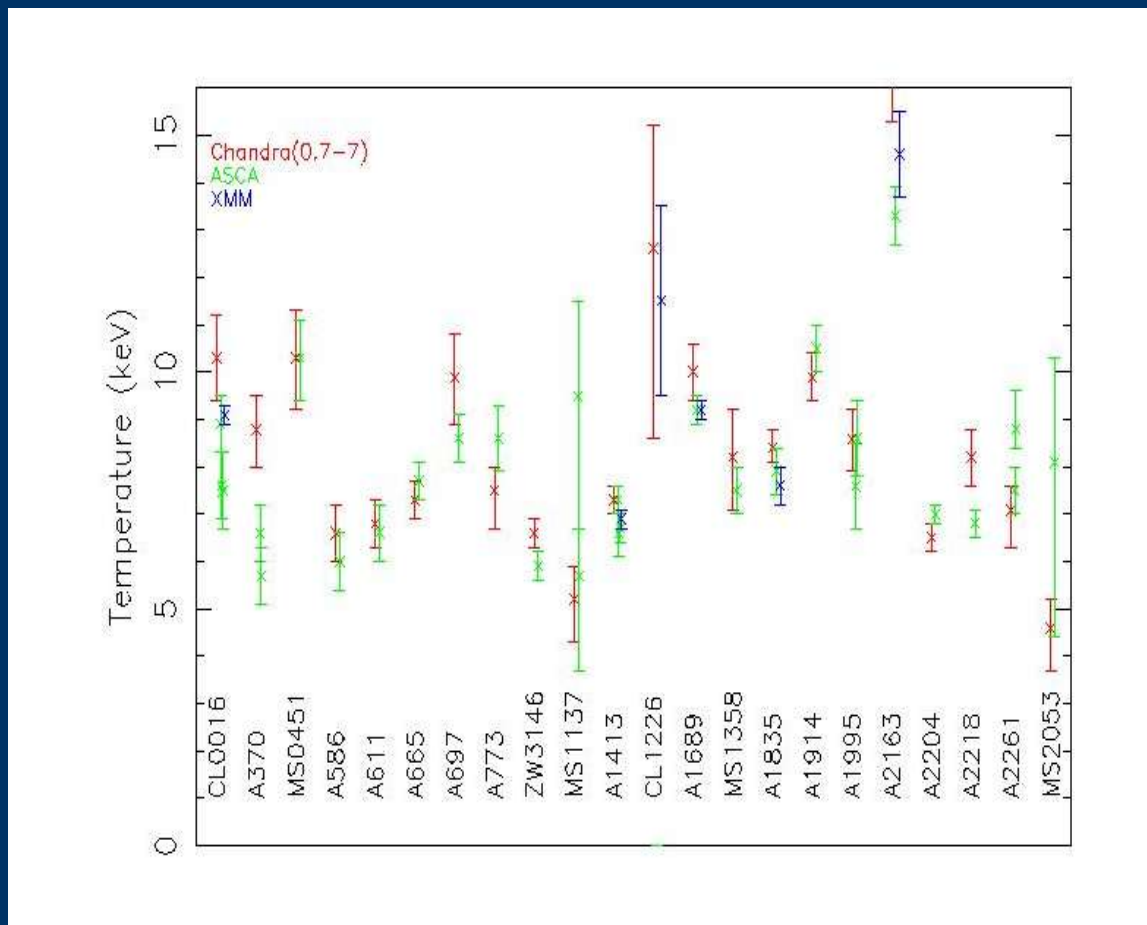


# COMPARISON: W/ AND W/O IR EDGE DATA





## COMPARISON: ASCA AND XMM RESULTS



## SUMMARY: 4 SOFT-EXCESS CLUSTERS

1. **QE calibration** differences (CALDB 2.26 vs. 2.28):
    - 1.1 strongly affect the soft X-ray fluxes;
    - 1.2 do NOT strongly affect temperatures.
  2. Presence of unphysical **deficit of soft X-ray** emission (0.3-2 keV) in some ACIS-S3 observations. Effects more severe with CALDB 2.28.
  3. Application of spatial-dependent OBF correction recovers **part** of the soft X-ray fluxes
  3. **Higher temperature** seen by Chandra w.r.t. XMM likely explained by the different 0.3-2 keV flux for these soft-excess clusters
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## SUMMARY: SAMPLE OF 38 CLUSTERS

1. ACIS OBF spatial-dependent correction (calcarf) **strongly affects** temperature measurements.
2. Agreement with other measurements (ASCA and XMM) when calcarf correction is applied
3. No systematic differences between 0.7-2 keV and 2-7 keV fit
4. Ir edge uncertainties do not affect temperatures

Contact:

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NASA/NSSTC, Huntsville, AL

See [accompanying draft](#) for further  
details, or contact me to obtain a copy