Ringberg Workshop on Distant Clusters of Galaxies, October 2005

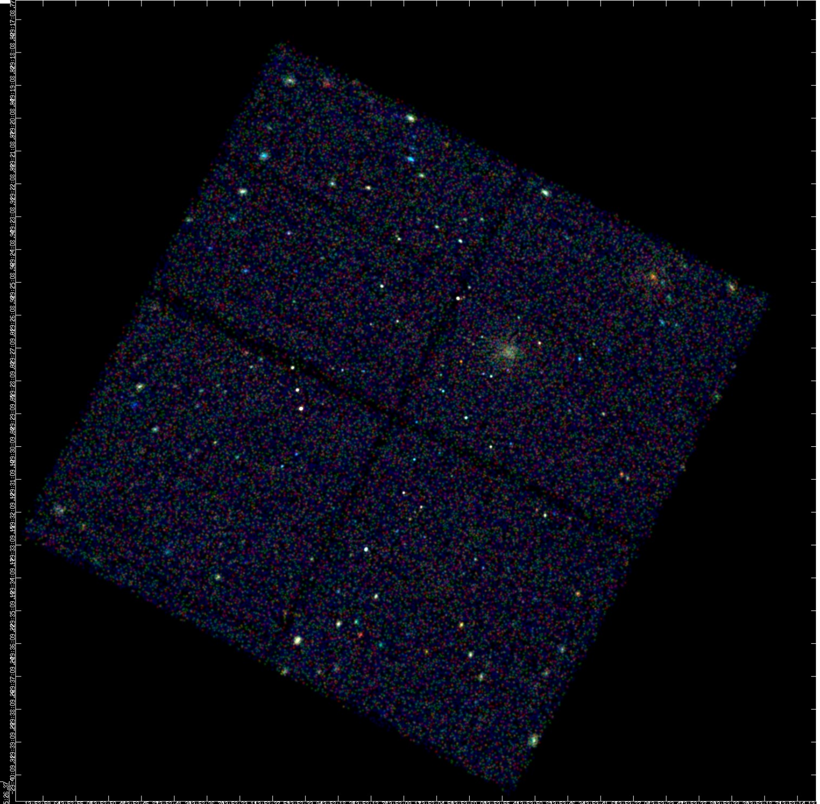
# The chemical enrichment of the IntraCluster Medium at high redshifts

Paolo Tozzi

with I. Balestra, S. Ettori, P. Rosati,
S. Borgani, V. Mainieri, M. Viola, C. Norman

INAF

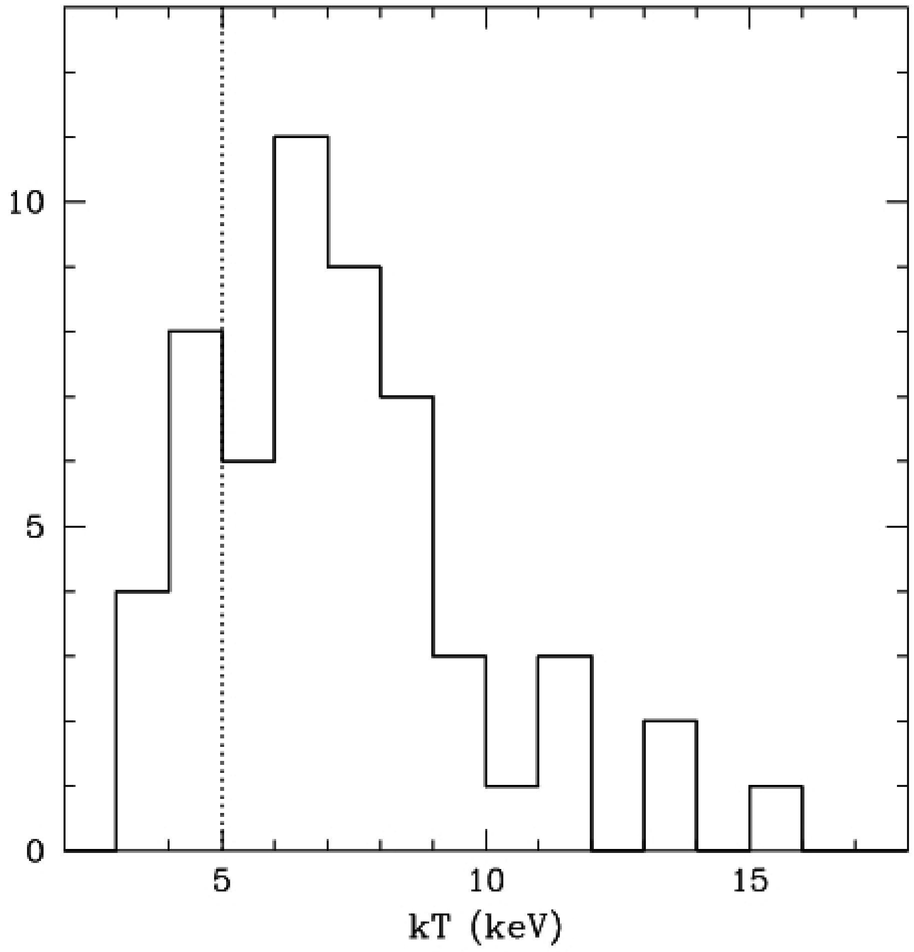
# High redshift (z>0.3) clusters in medium-deep Chandra exposures (ACIS-I and ACIS-S)

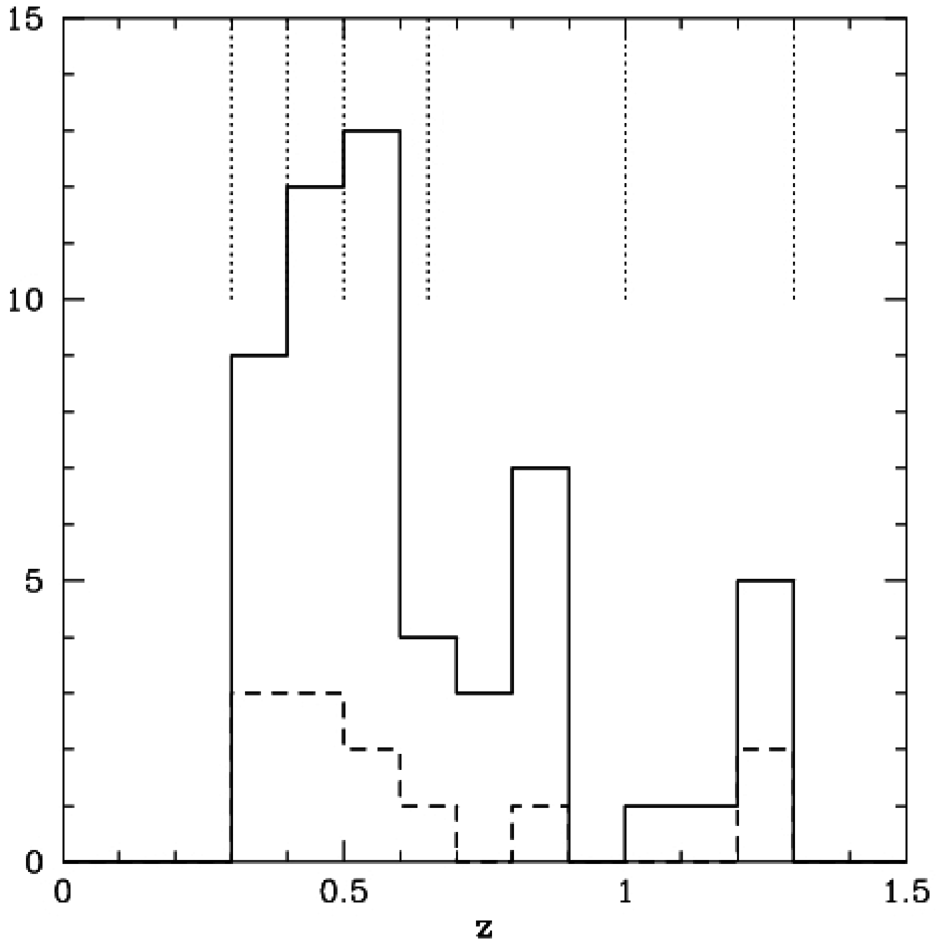


## Science:

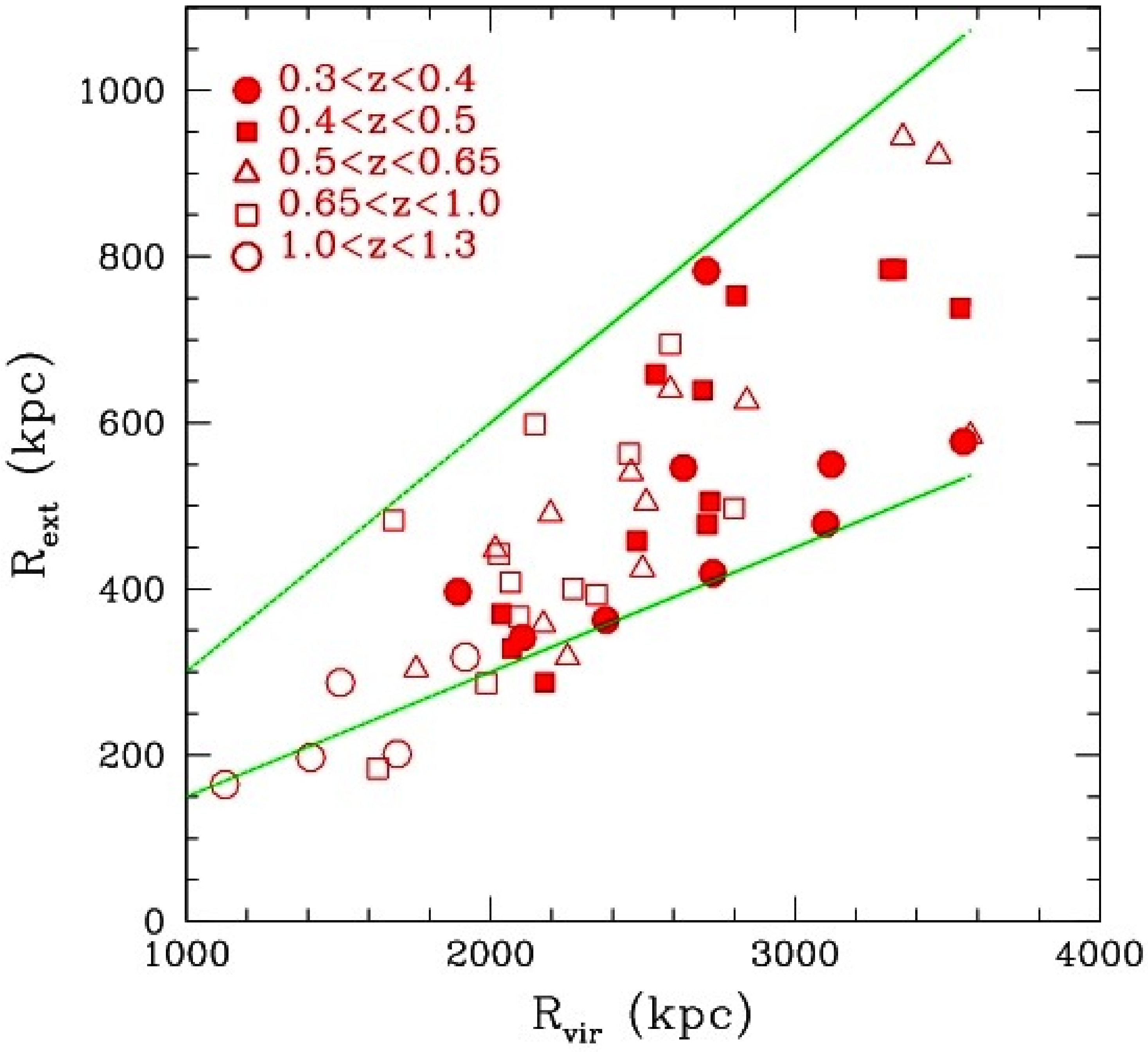
Scaling relations (temperature, luminosity, mass entropy)
Chemical enrichment
AGN around clusters
Baryon fraction
and cosmological test

# Distribution with temperature and redshift of the sample



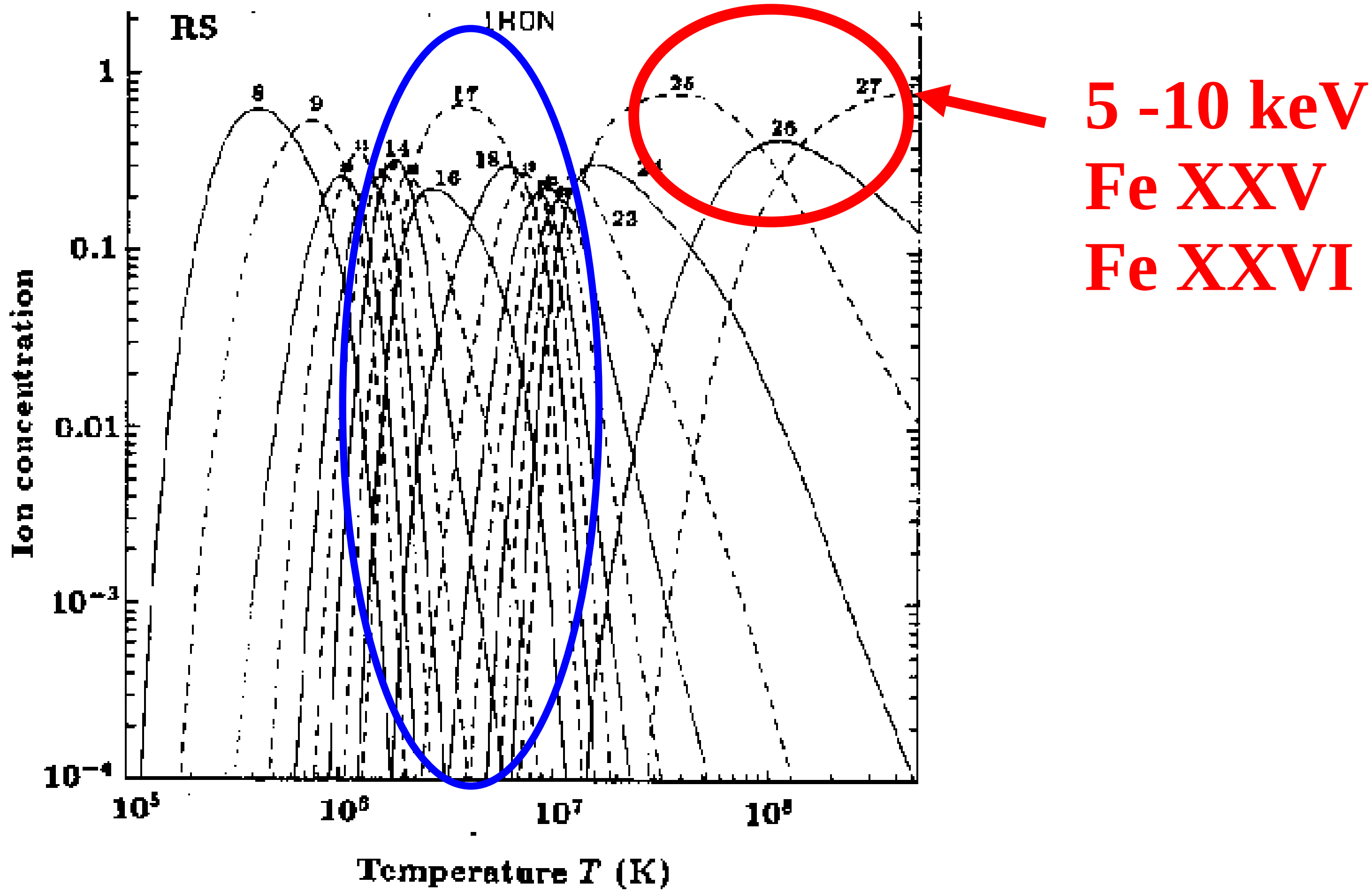




**We select from the Chandra archive**
**55 clusters at z>0.3**
**(among them 7 clusters at z>1)**




**We sample central regions between 0.15 and 0.3 $R_{vir}$ depending on the redshift of the cluster**

# Fe Ions concentration as a function of the ICM temperature



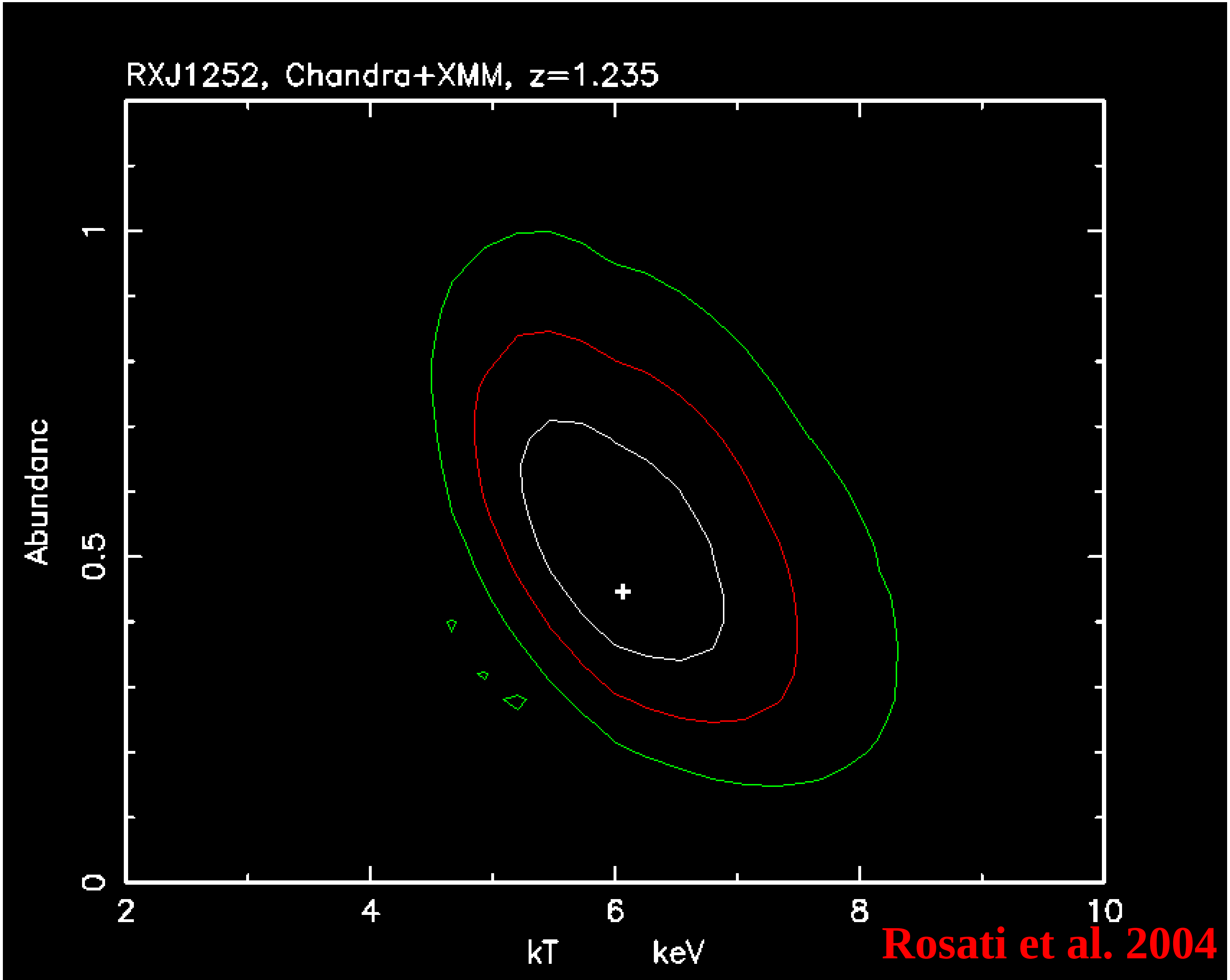

Collisionally dominated optically thin coronal plasma as a function of electron temperature (Mewe 1991)

**The Iron abundance is determined almost uniquely by the K-shell complex at 6.7-6.9 keV rest-frame**


Detection of the Fe line of the most distant X-ray clusters
Z=0.35
Z=1.235
RXJ1252
~1000 net counts
180 ks with ACIS-I
Rosati et al. 2004

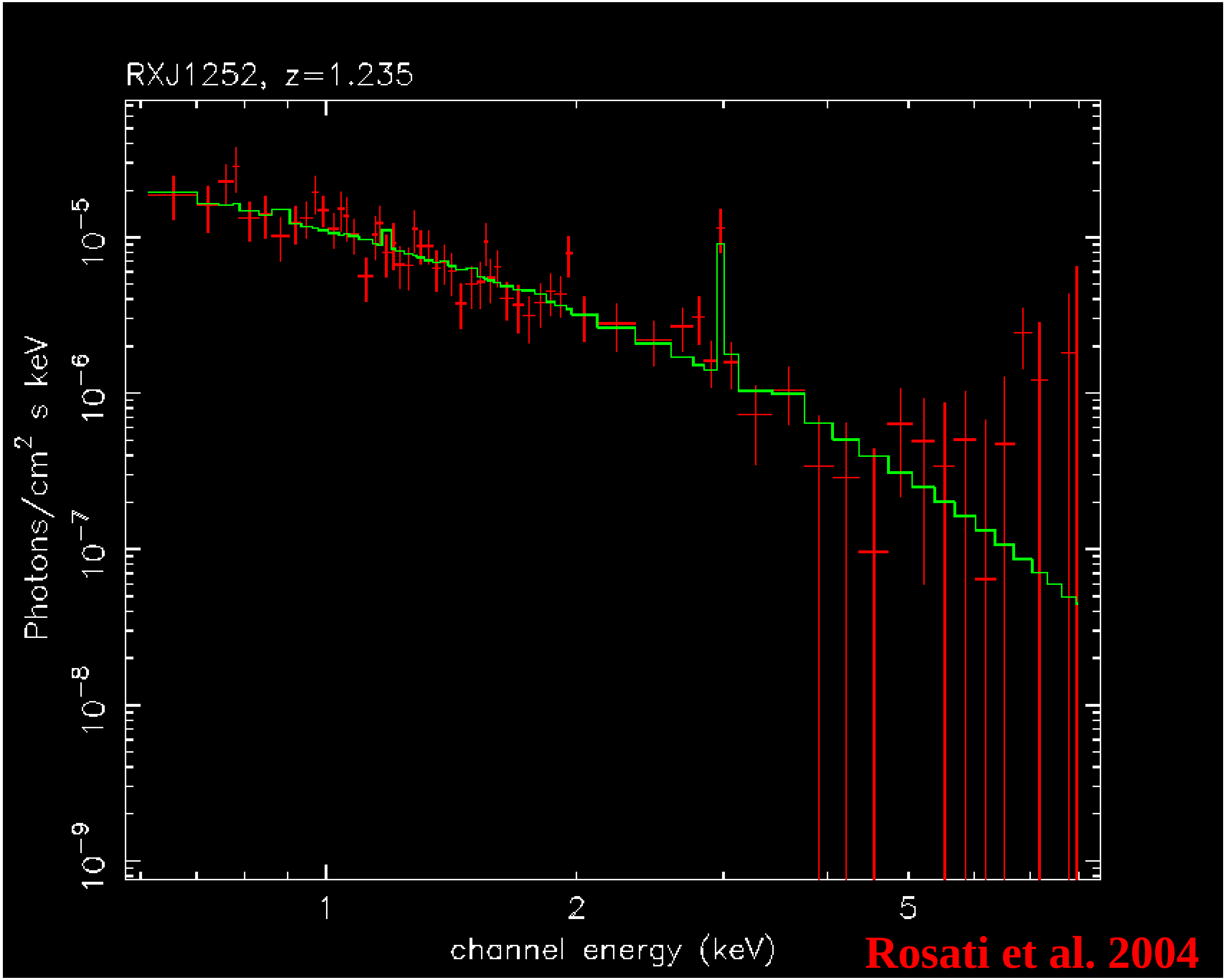

Detection of the Fe line of the most distant X-ray clusters
Chandra+XMM observation of RXJ1252
Rosati et al. 2003

# Temperature and Fe abundance from Chandra+XMM (MOS) combined fit



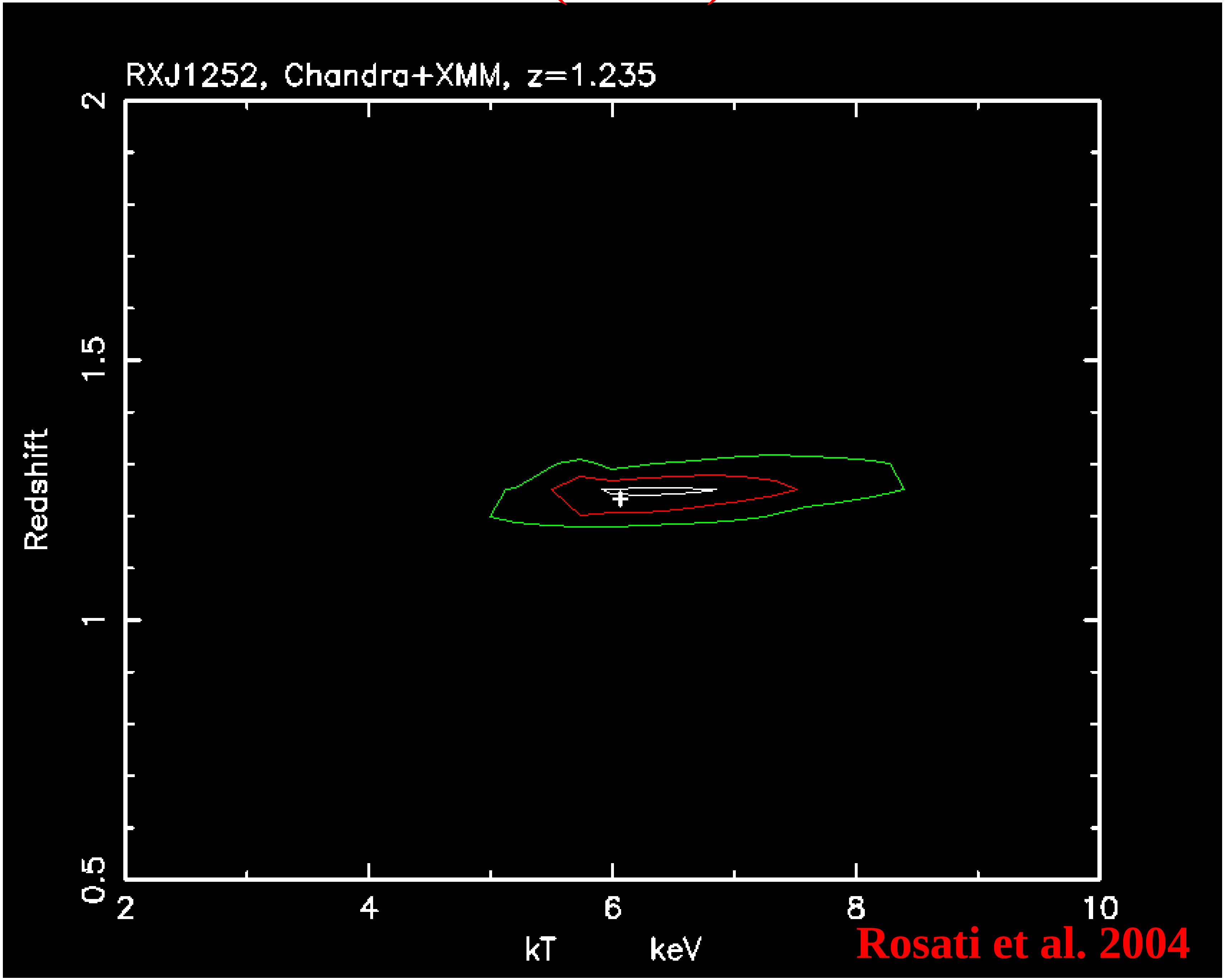

Rosati et al. 2004

# RXJ1252: first detection of the Fe line at z=1.23



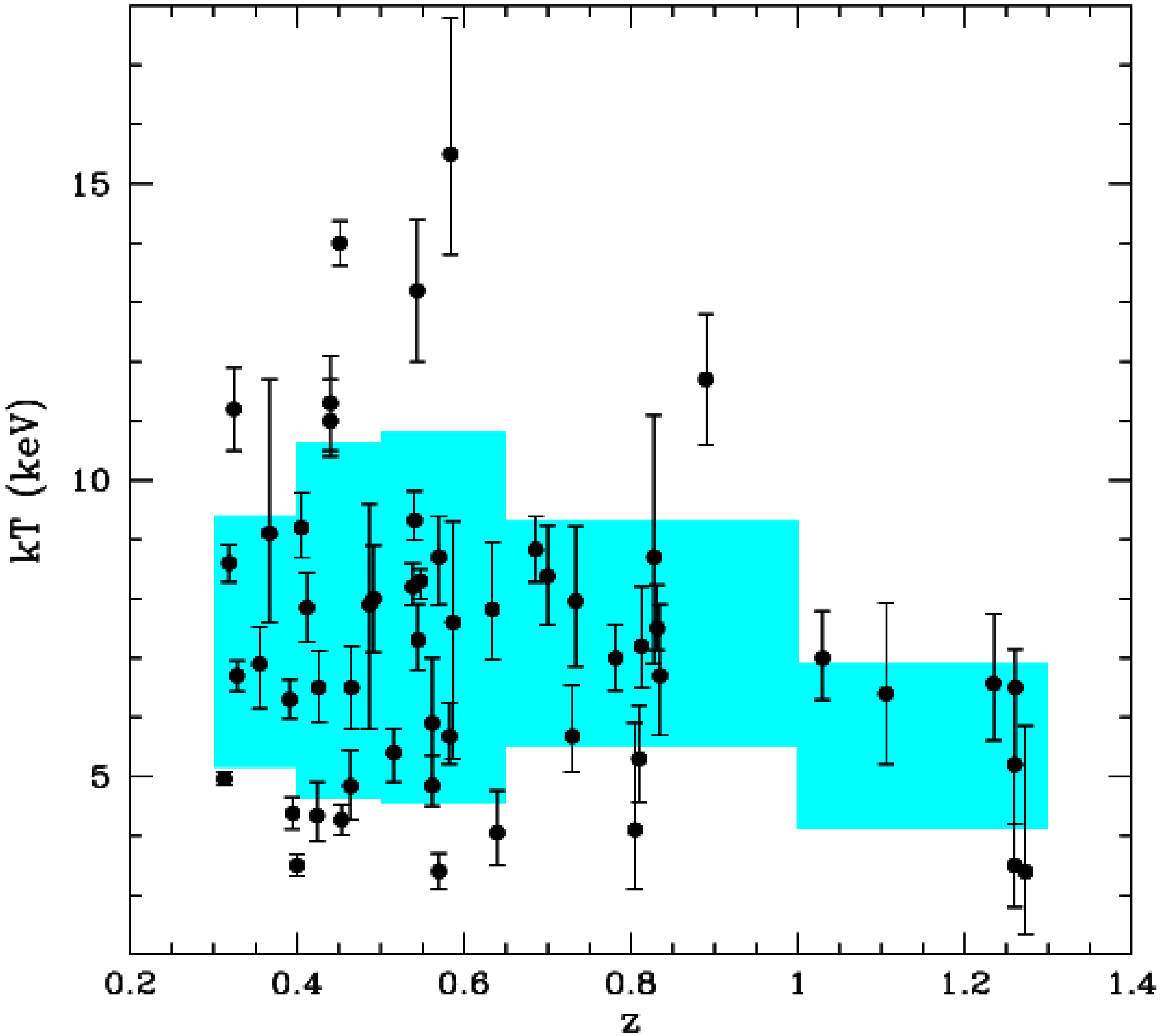

Rosati et al. 2004

# Redshift measure from Chandra+XMM (MOS) combined fit




Rosati et al. 2004

# Temperature vs redshift (55 clusters @ z> 0.3)
## 3 times more objects than in Tozzi et al. 2003




**Caveat: two different values of solar Fe abund in the literature:**

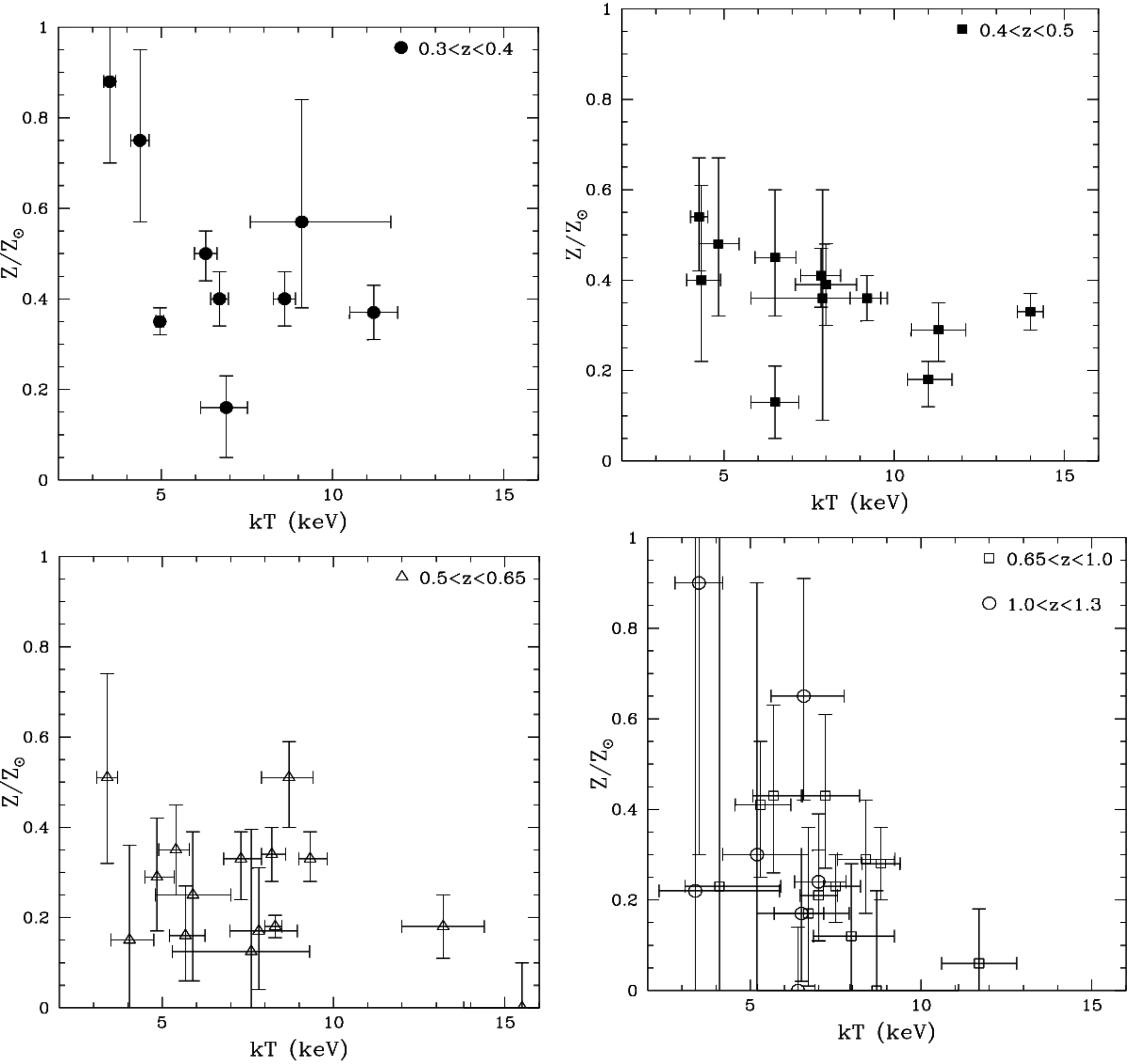
**Anders & Grevesse 1989**
**$Fe/H = 4.68 \times 10^{-5}$**

**Grevesse & Sauval 1998**
**$Fe/H = 3.16 \times 10^{-5}$**

**$Z_{FeGS} = 1.48\ Z_{FeAG}$**

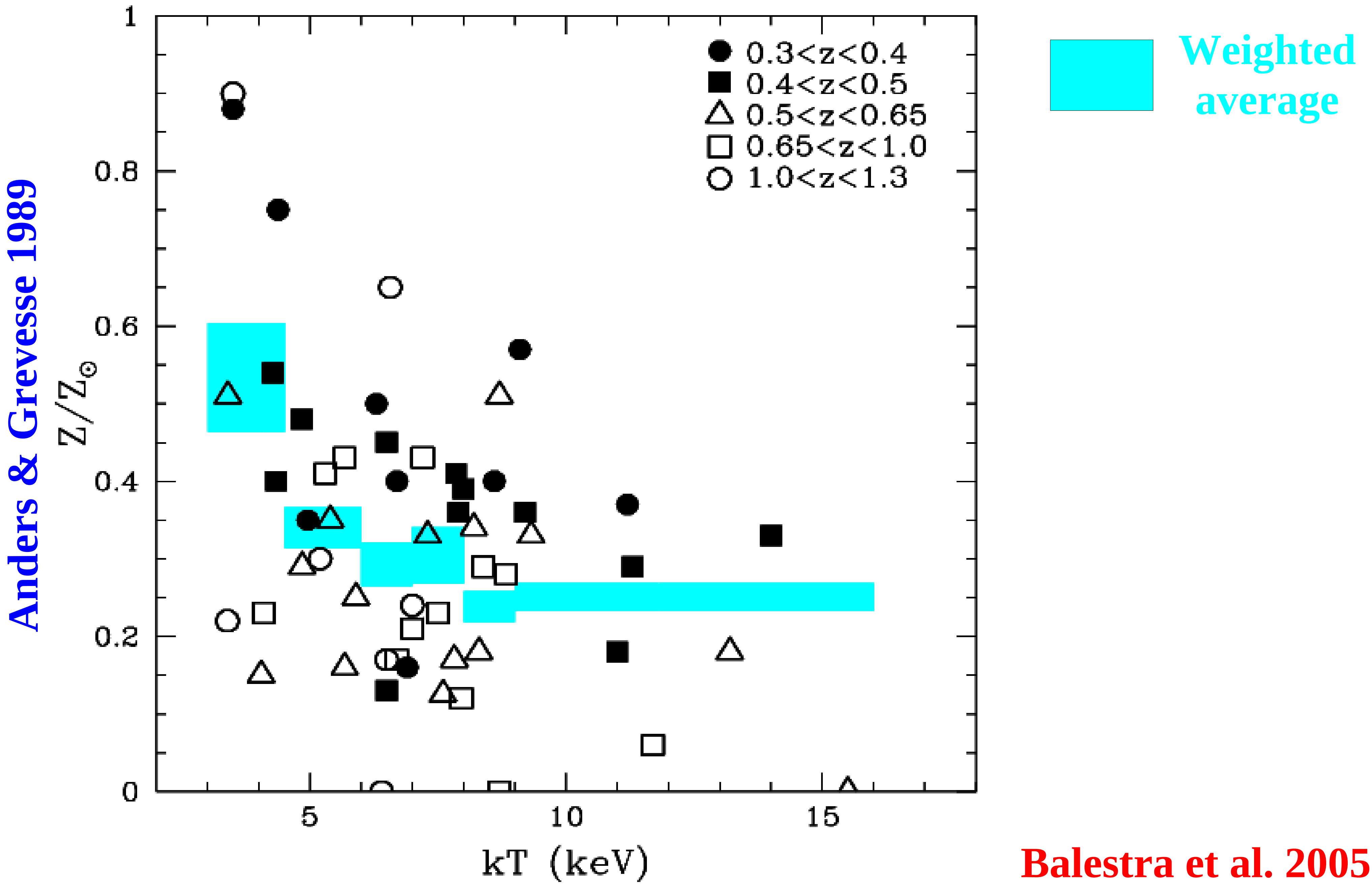
**Balestra et al. 2005**

# Fe abundance-Temperature in different redshift bins




**Scatter comparable with statistical errors hint of higher Fe abundance at low kT<5 keV**

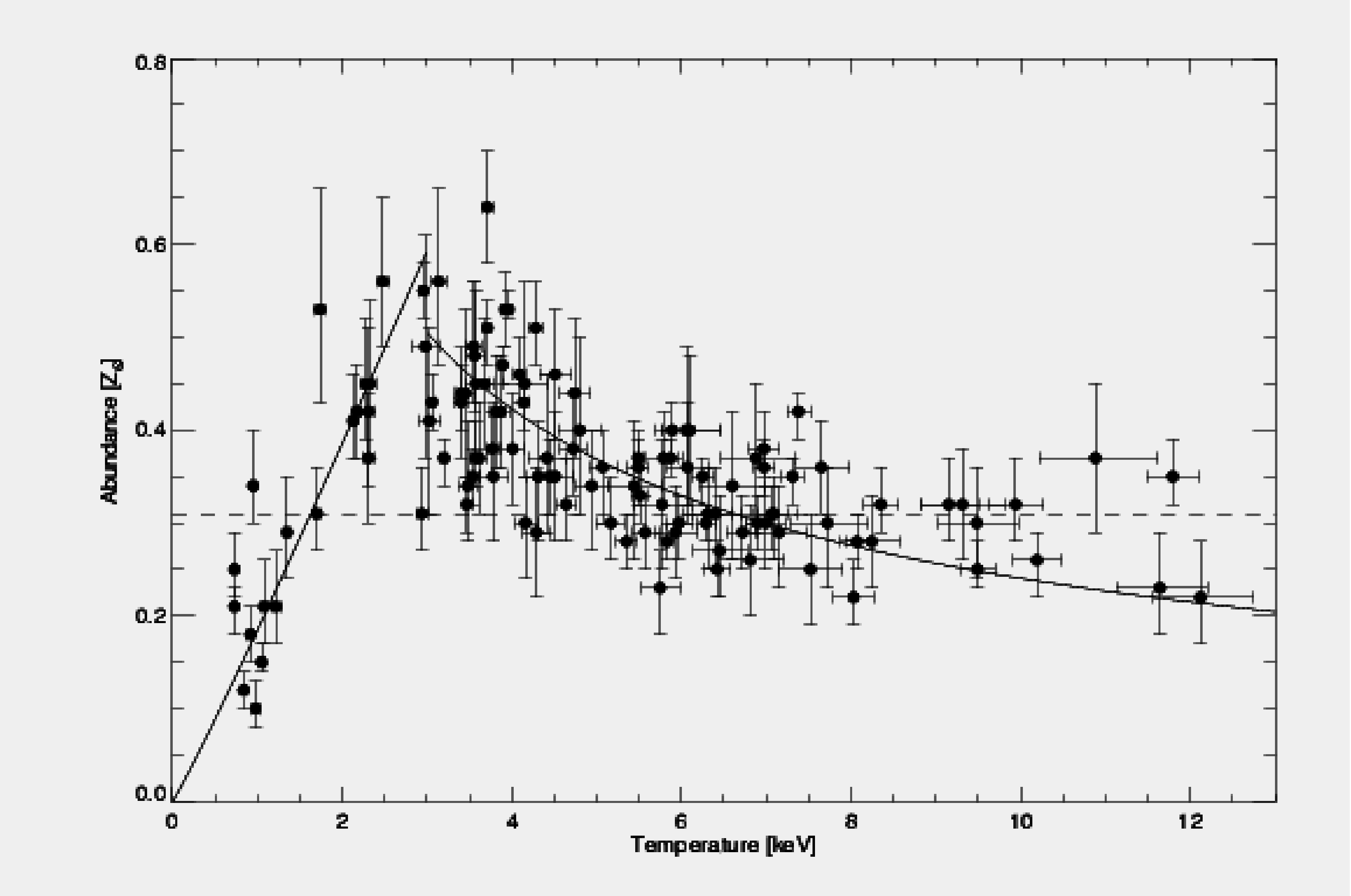
# Iron abundance -Temperature




Balestra et al. 2005

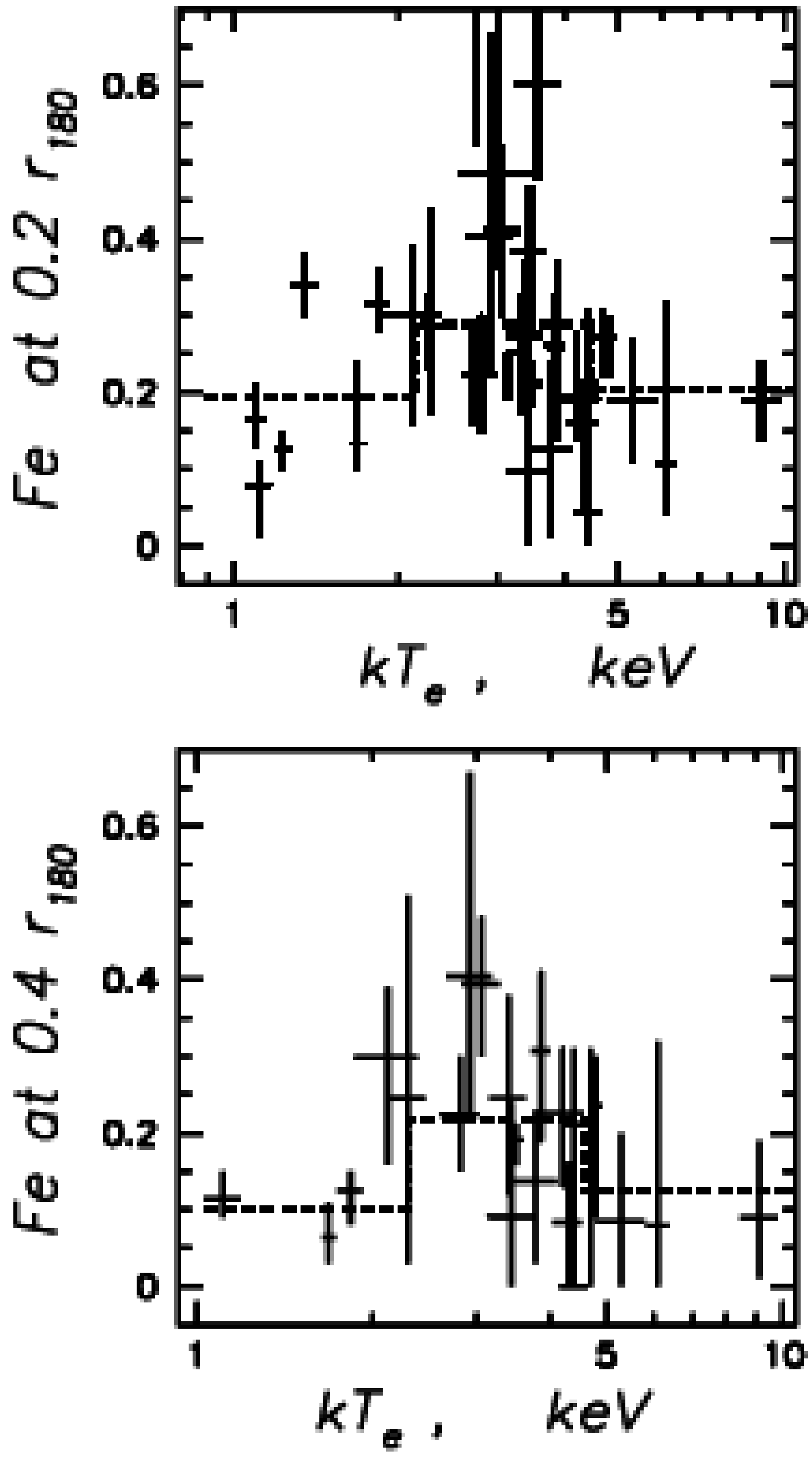
# Local sample 273 clusters observed with ASCA

Grevesse & Sauval 1998




Horner 2001 PhD
Baumgartner et al. 2005

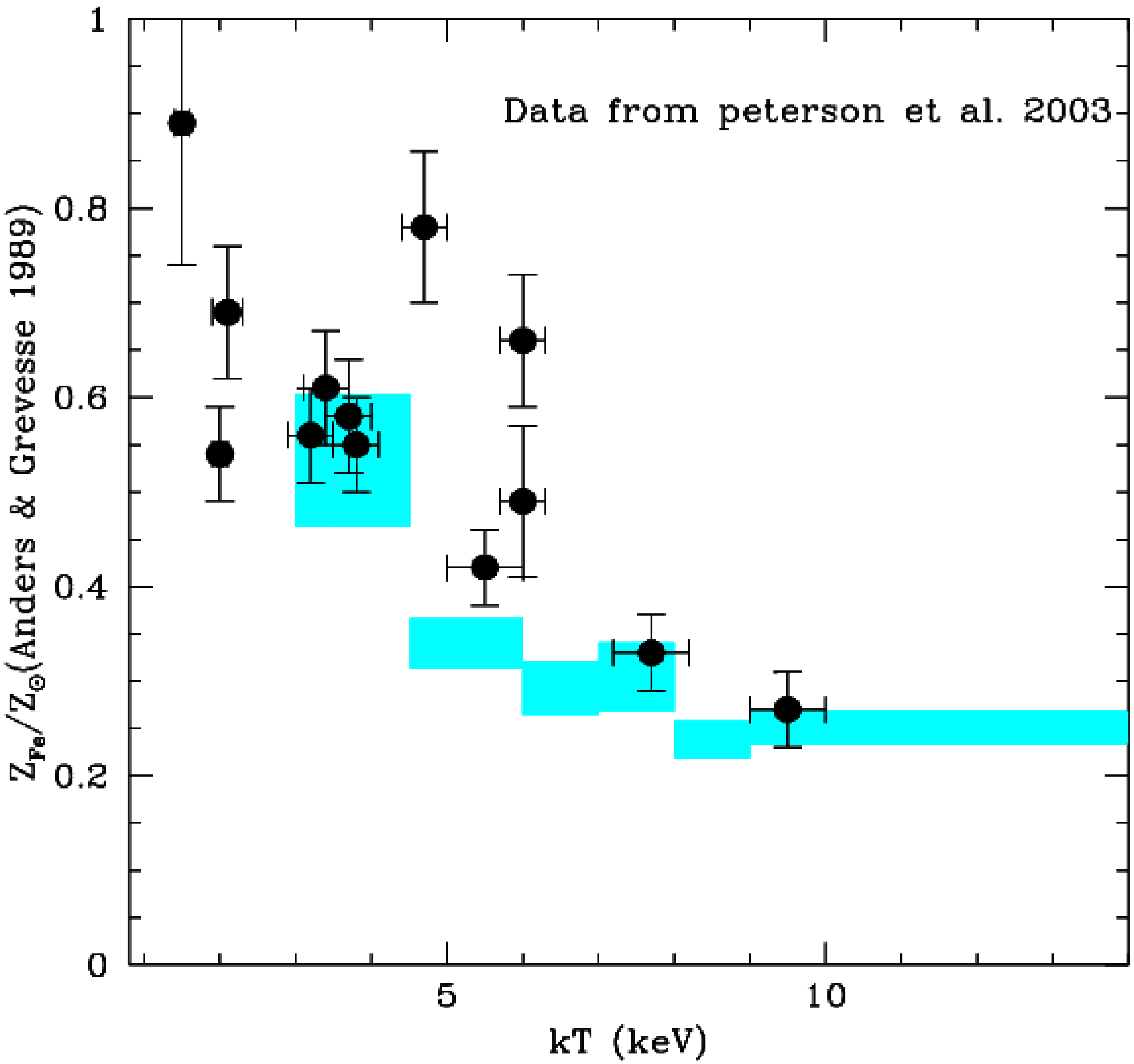
Anders & Grevesse 1989




**18 local clusters observed with ASCA**

**Finoguenov, Arnaud & David 2001**

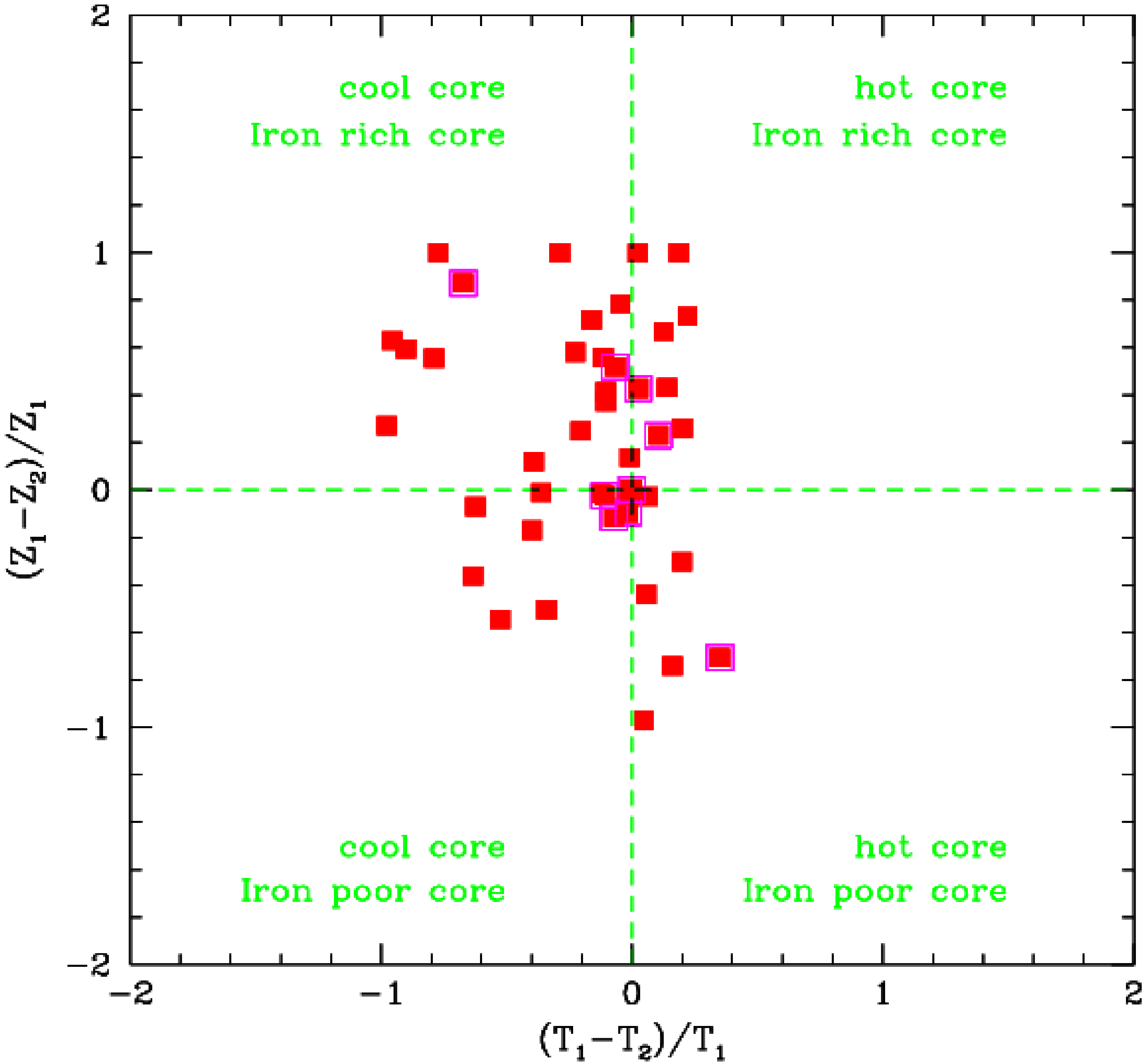
# XMM-Grating data from cool core cluster




**Iron abundances tend to increase for lower mass systems; no trends in other elements**

**Peterson et al. 2003**

# Is it due to cool core with Iron excess?

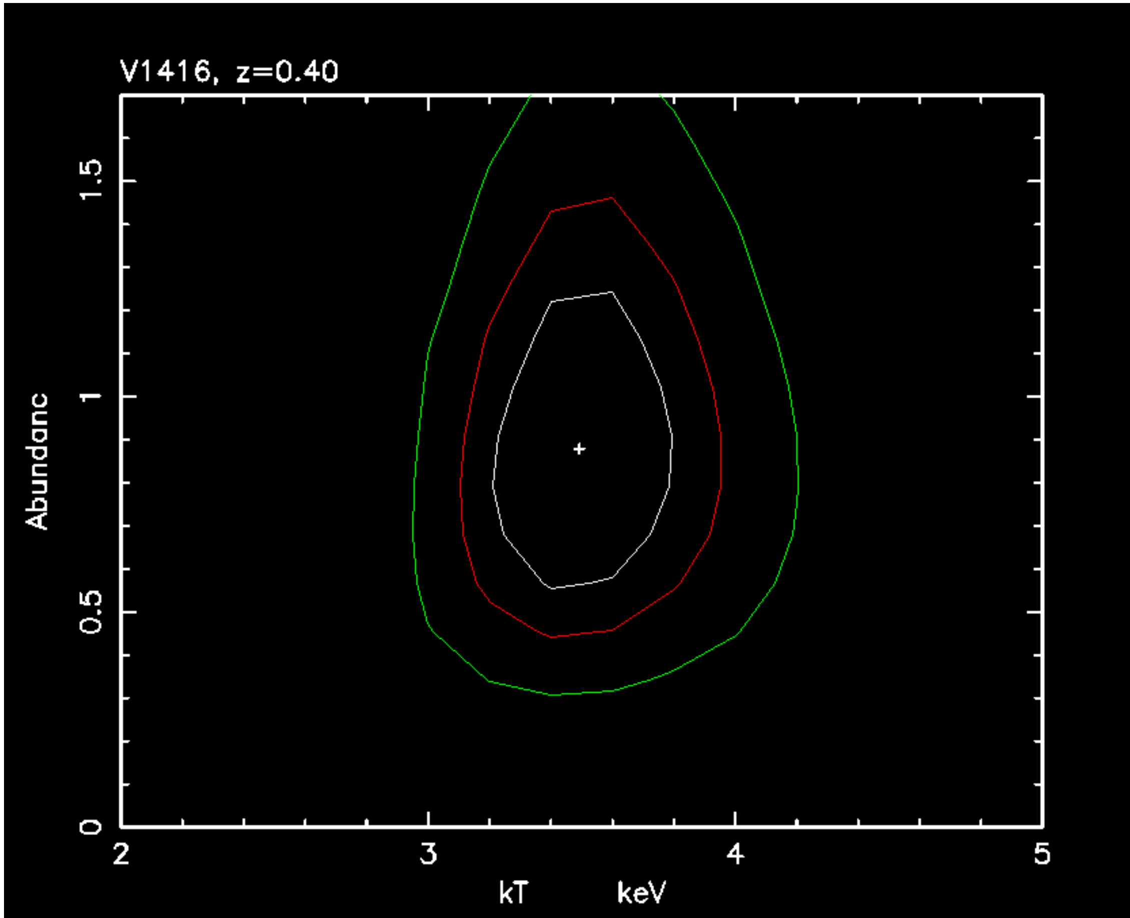



Simplistic spatial spectroscopy (first 2 rings with reasonable S/N)

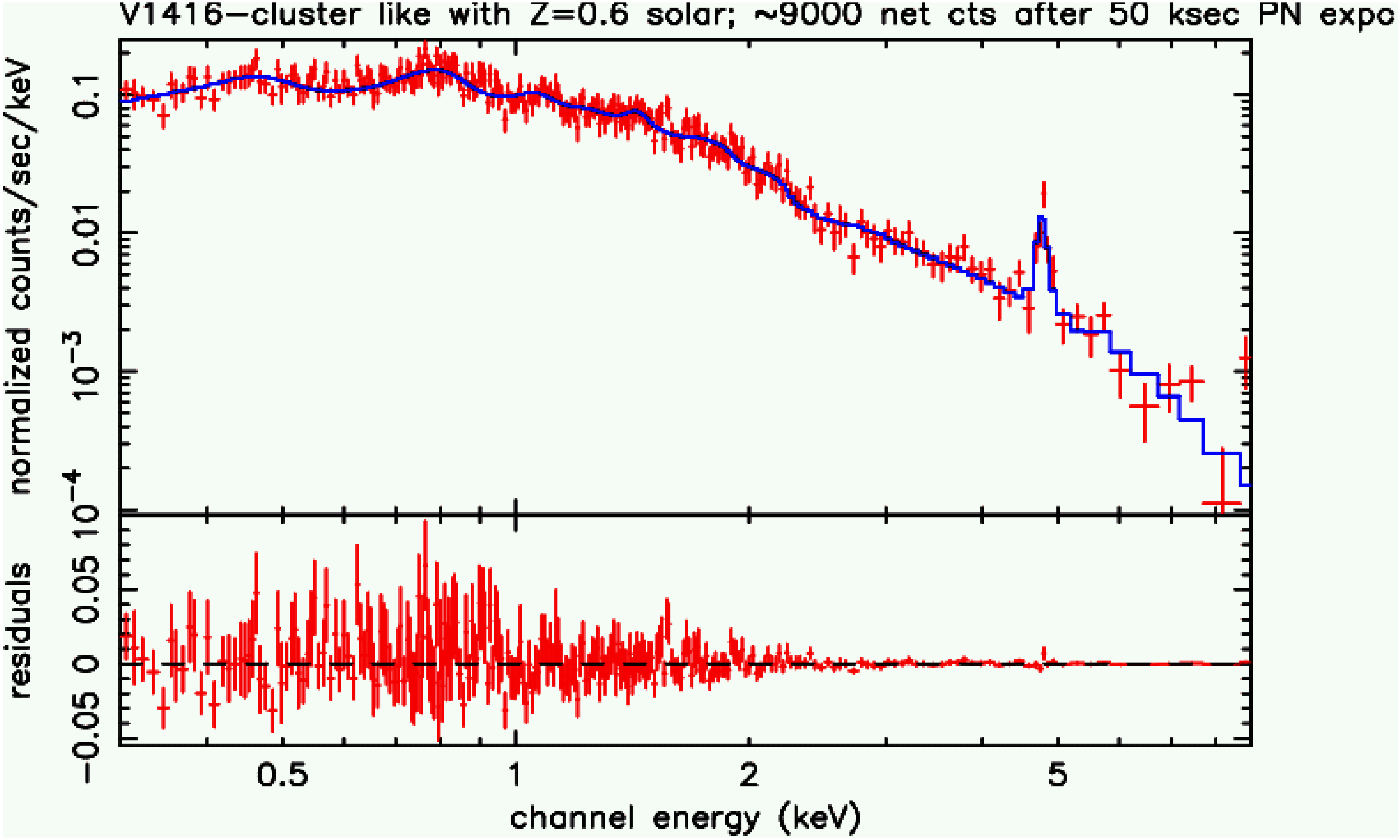
kT < 5 keV

Iron-rich clusters do not necessarily show Iron-rich cores

# What is the nature of low temperature, Iron rich clusters?
# A typical example: V14156, z=0.4



# Investigating the nature of Fe-rich clusters: Simulated XMM spectrum of V1416 - 50 ksec

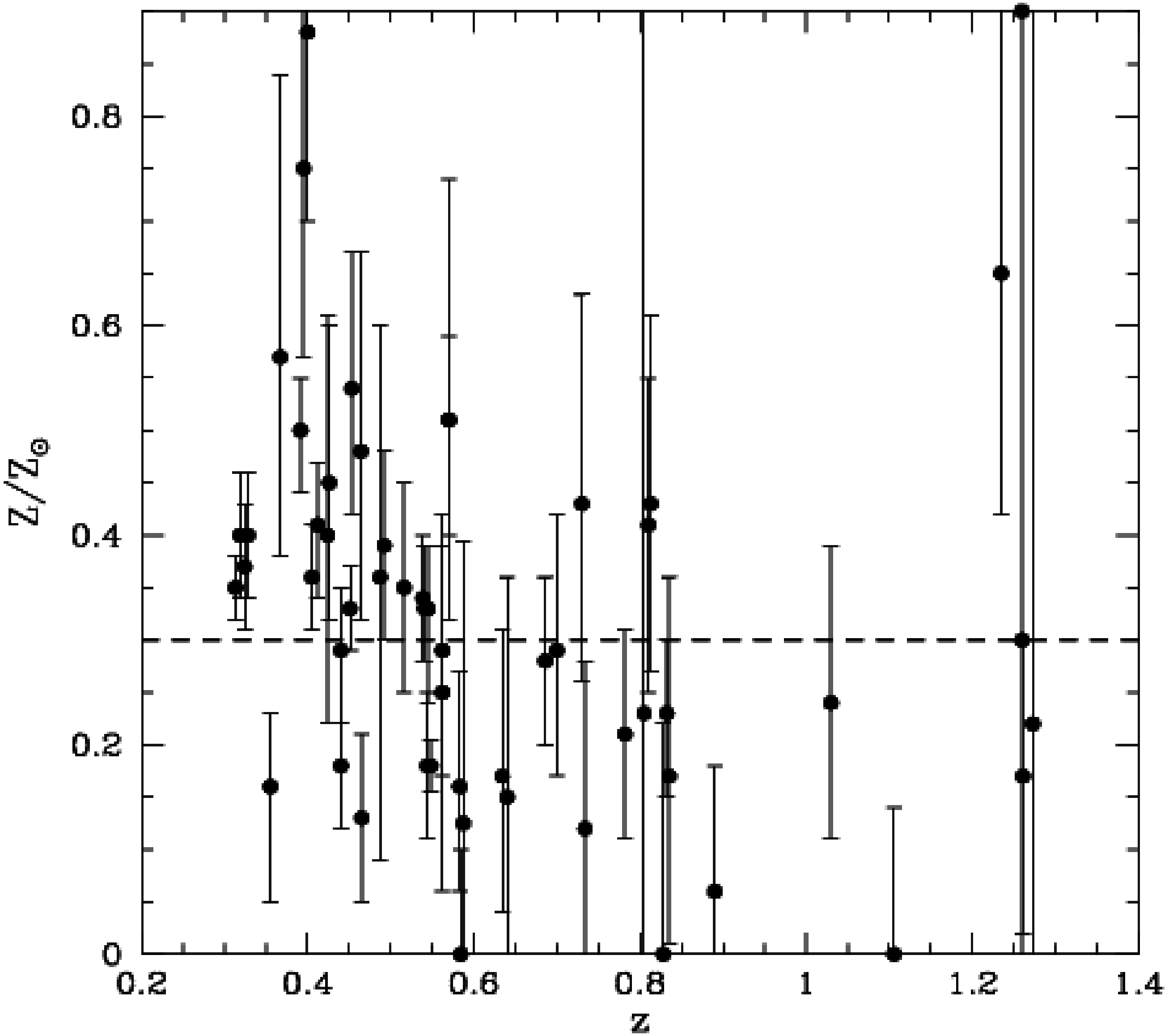



**XMM proposal:**

**Why low-temperature clusters have high Iron abundance?**

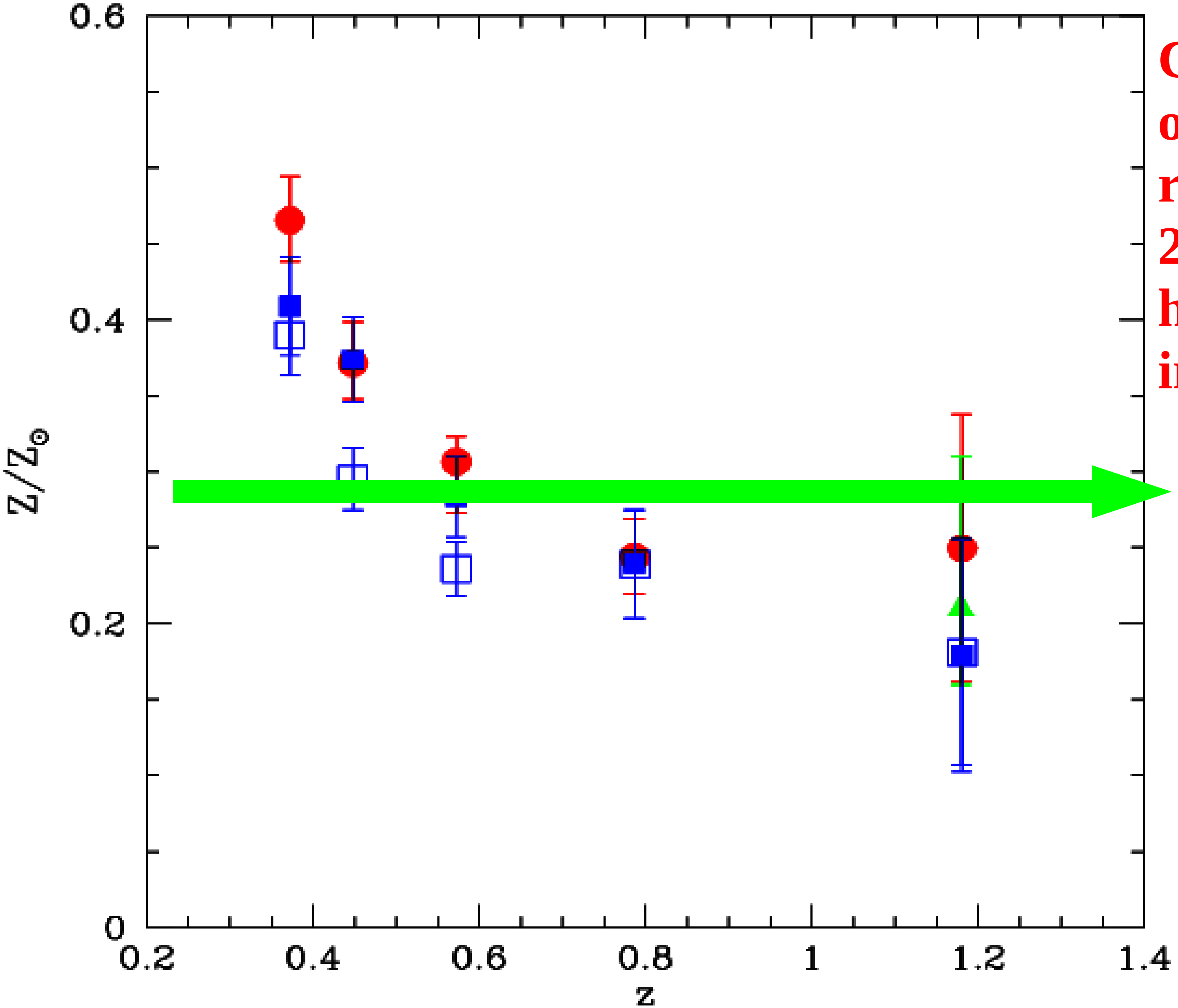
**The case at 0.2 < z < 0.5**

# Iron abundance versus redshift




Balestra et al. 2005

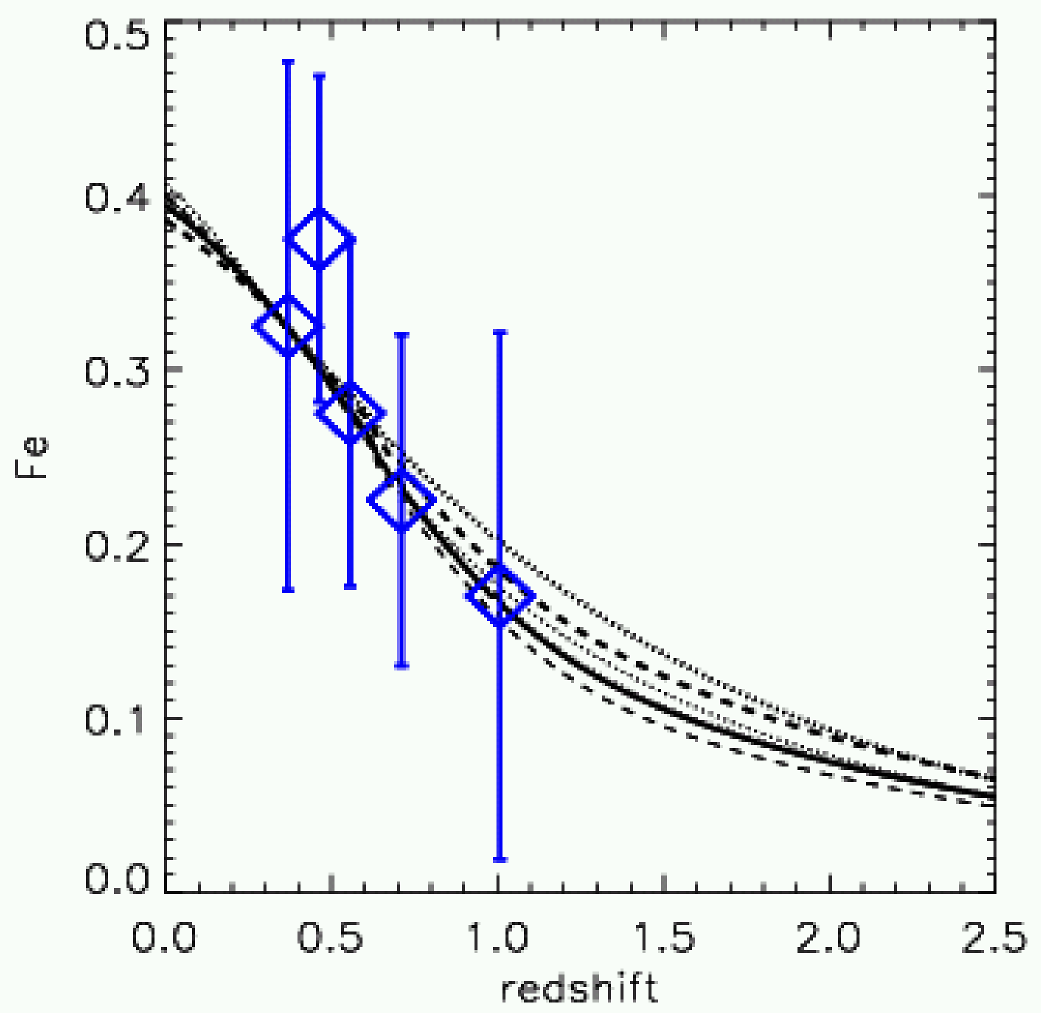
# Average Iron abundance versus redshift

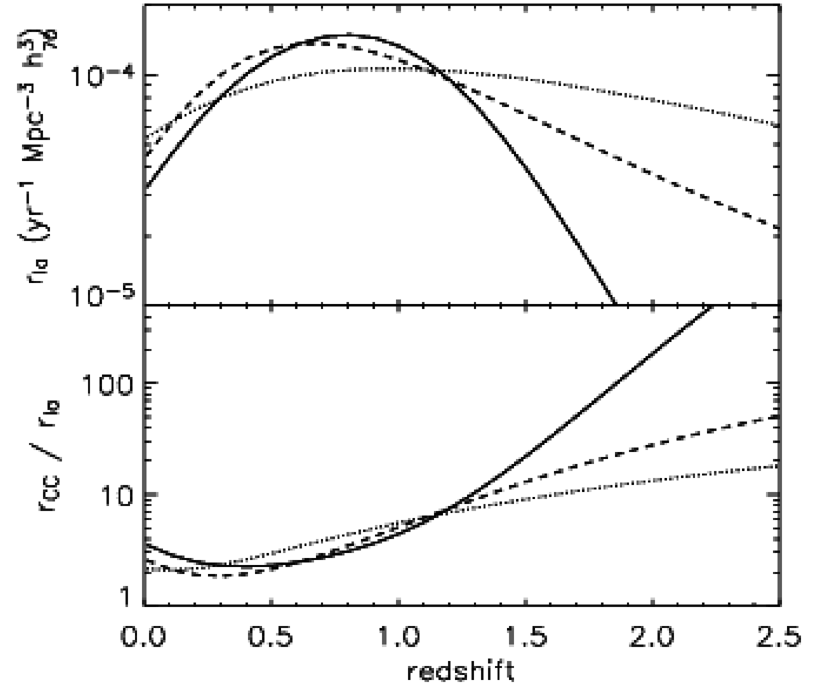



**Confirm no strong hints of evolution at high redshifts (see Tozzi et al. 2003), but unexpected higher Fe abundance in the 0.4-0.5 redshift bins**

**Balestra et al. 2005**

# Is the Iron abundance evolution expected?

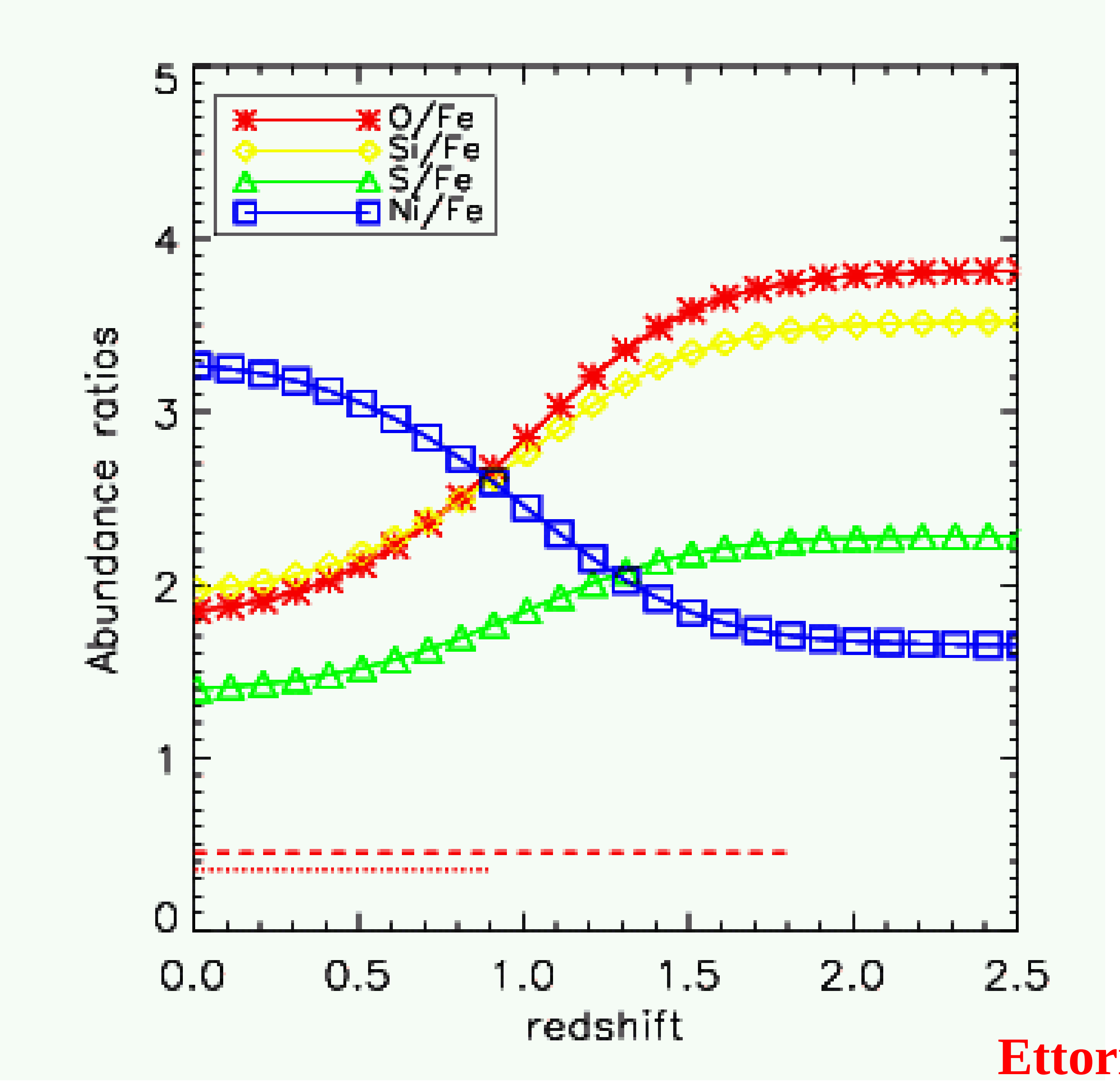



**Fe abundance in the ICM from the observed cosmic Star Formation Rate with different delay times for TyIa Sne**

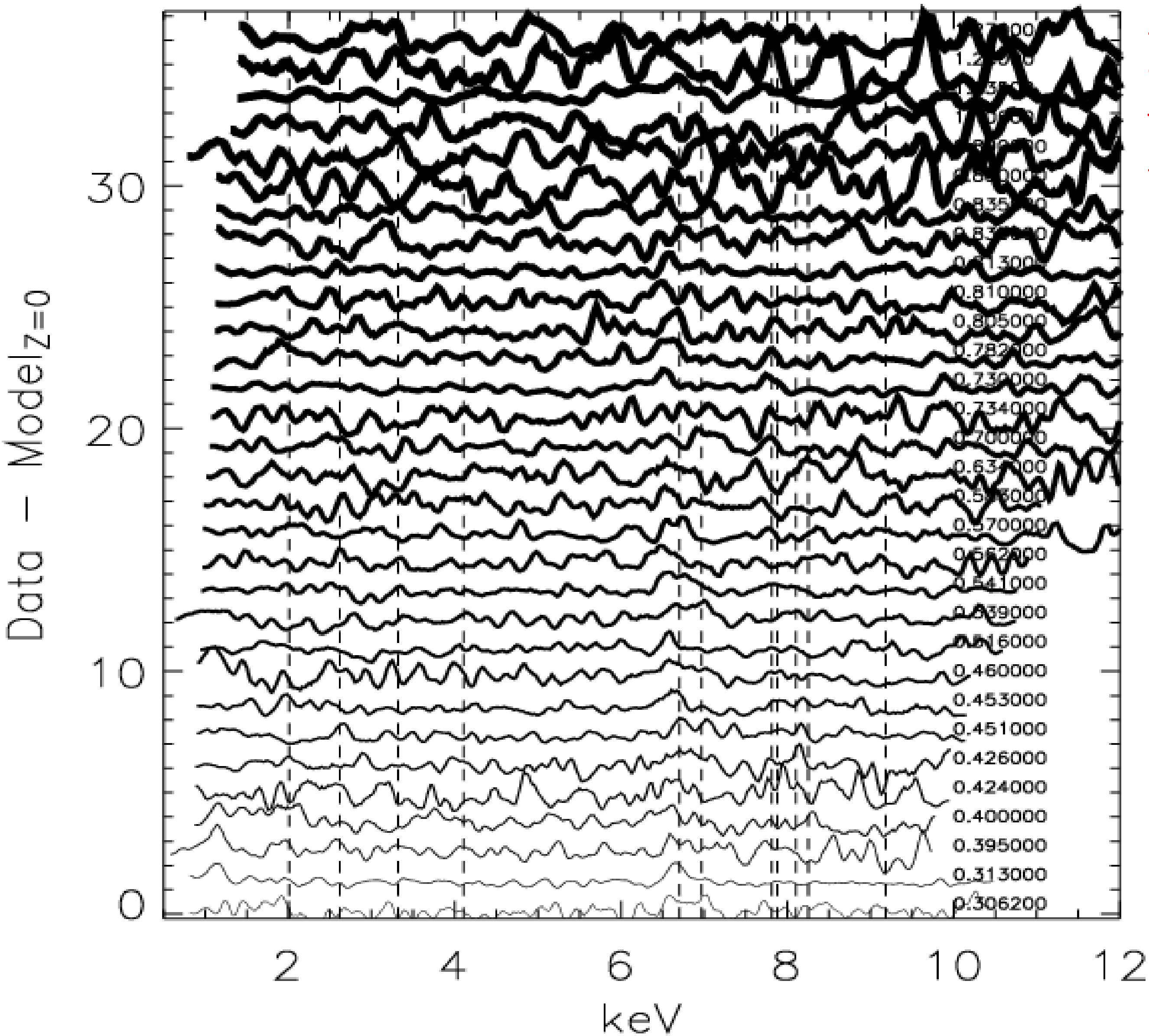
**Ettori et al. 2005**

# Abundance ratios at z~1 as diagnostic tool



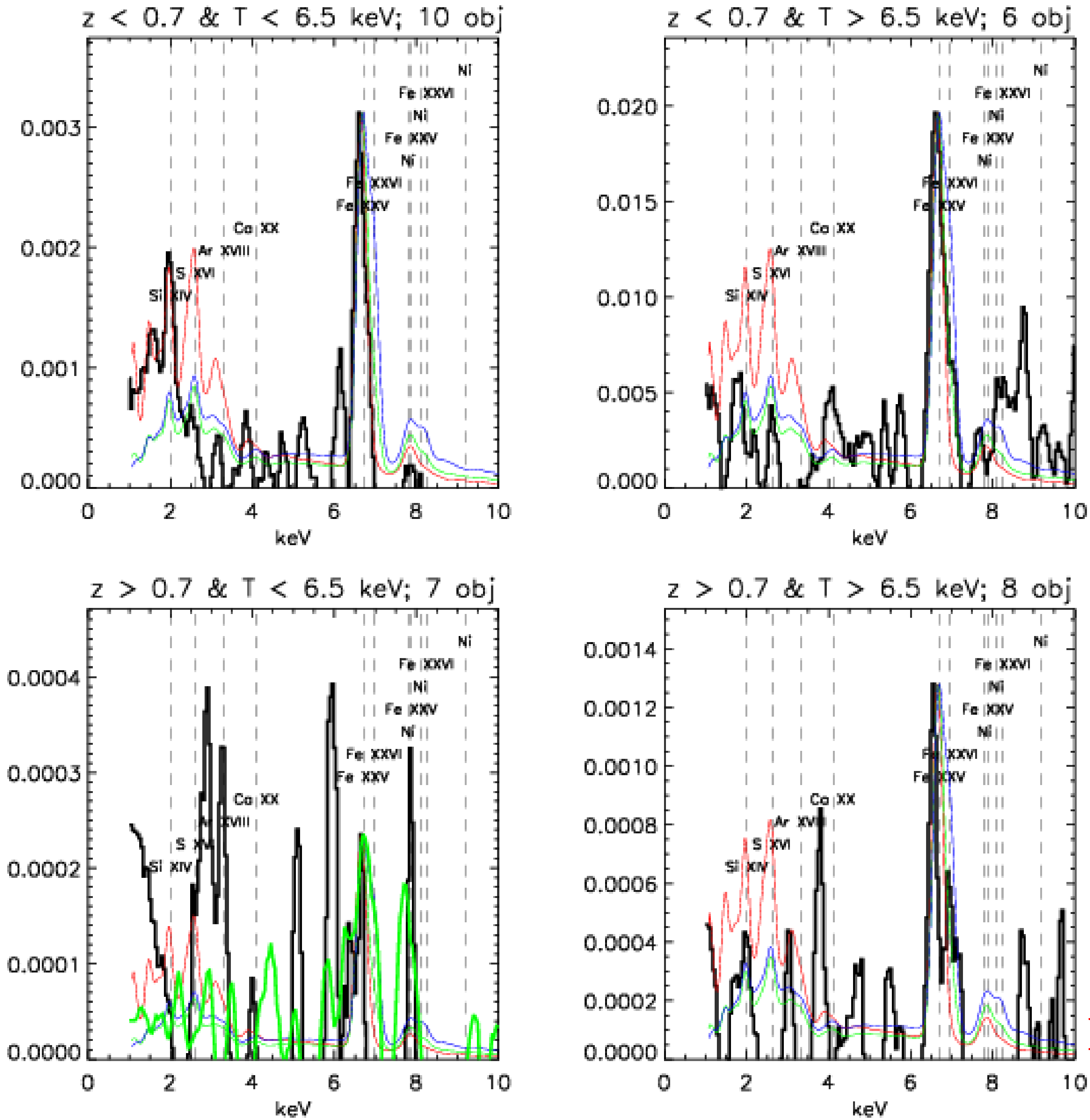

Ettori et al. 2005

# Can we measure the $\alpha$ elements at high redshifts through the stacking technique?




**Residual of the spectra with respect to the bremmstrahlung only model**

**Ettori et al in progress**




**The residuals match with expected lines from Si, Ca, and S!**

**Ettori et al in progress**

# CONCLUSIONS

## A sample of ~55 clusters @ z>0.3 observed with Chandra

**Clear detection of the Iron line in the large majority of high-z clusters, up to z~1.3**

***Correlation in the Iron abundance – Temperature: Iron abundance is larger below 5 keV (and possibly drops again below 2 keV)***

**Fe abundance ~ 0.25 $Z_\odot$ constant for z>0.5**

***Higher average Fe abundance in the z~0.4 redshift bin***

**If decrease of the average Iron abundance from $Z_{Fe}$=0.4 $Z_\odot$(@ z~0.3) to $Z_{Fe}$=0.2 $Z_\odot$ (z~1.3), consistent with cosmic star formation rate (see also talk by Luca Tornatore)**