The new vision on high redshift clusters with XMM: clusters scaling laws at Z ~ 0.5

Clusters:

Optical light	⇒ Stellar masses + metals		
	⇒ velocity dispersion	⇒	total mass
	⇒ lensing	⇒	total mass
X-ray light	⇒ imagery	⇒	gas mass
	⇒ spectroscopy	⇒	total mass+ metals
SZ	⇒ pressure	⇒	gas mass

.

2-10 keV ⇔ **M** $\sim 10^{-15} M_{\odot}$ ⇔ R ~ 5-20 h^{-1}Mpc

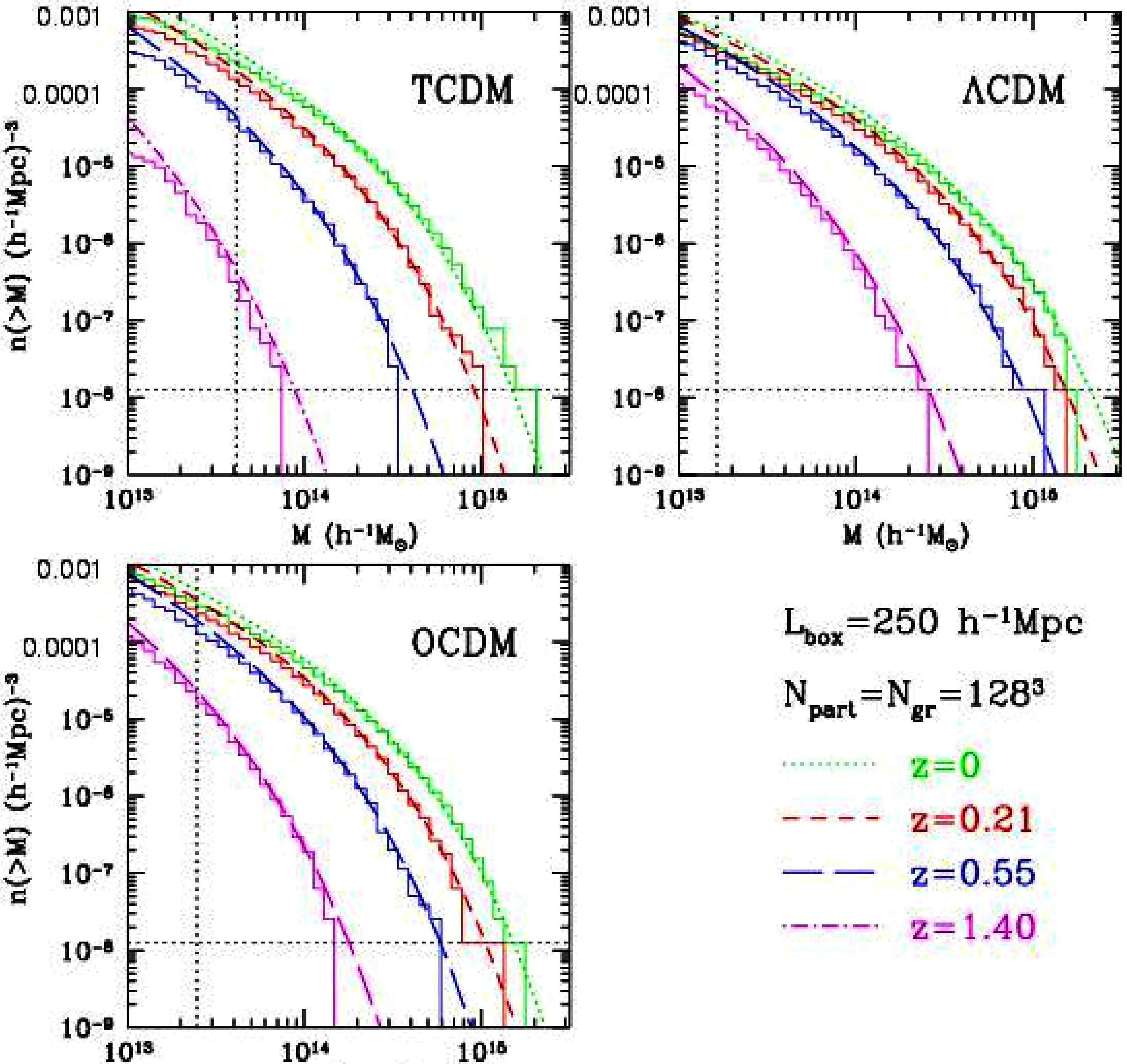
IC 2007.

You can (potentially) learn

a lot

in cosmology from Clusters

TESTING THE MASS FUNCTION



Borgani et al., 2000

Scaling argument for Clusters:

Clusters are geometrically identical

With virial radius-mass relation

$$M = \frac{4\pi}{3}\rho_0(1+z)^3(1+\Delta)R_{\rm v}^3$$

i.e.

$$R_{\rm v} = \sqrt[3]{\frac{3M}{4\pi\rho_0(1+\Delta)}}\frac{1}{1+z}$$

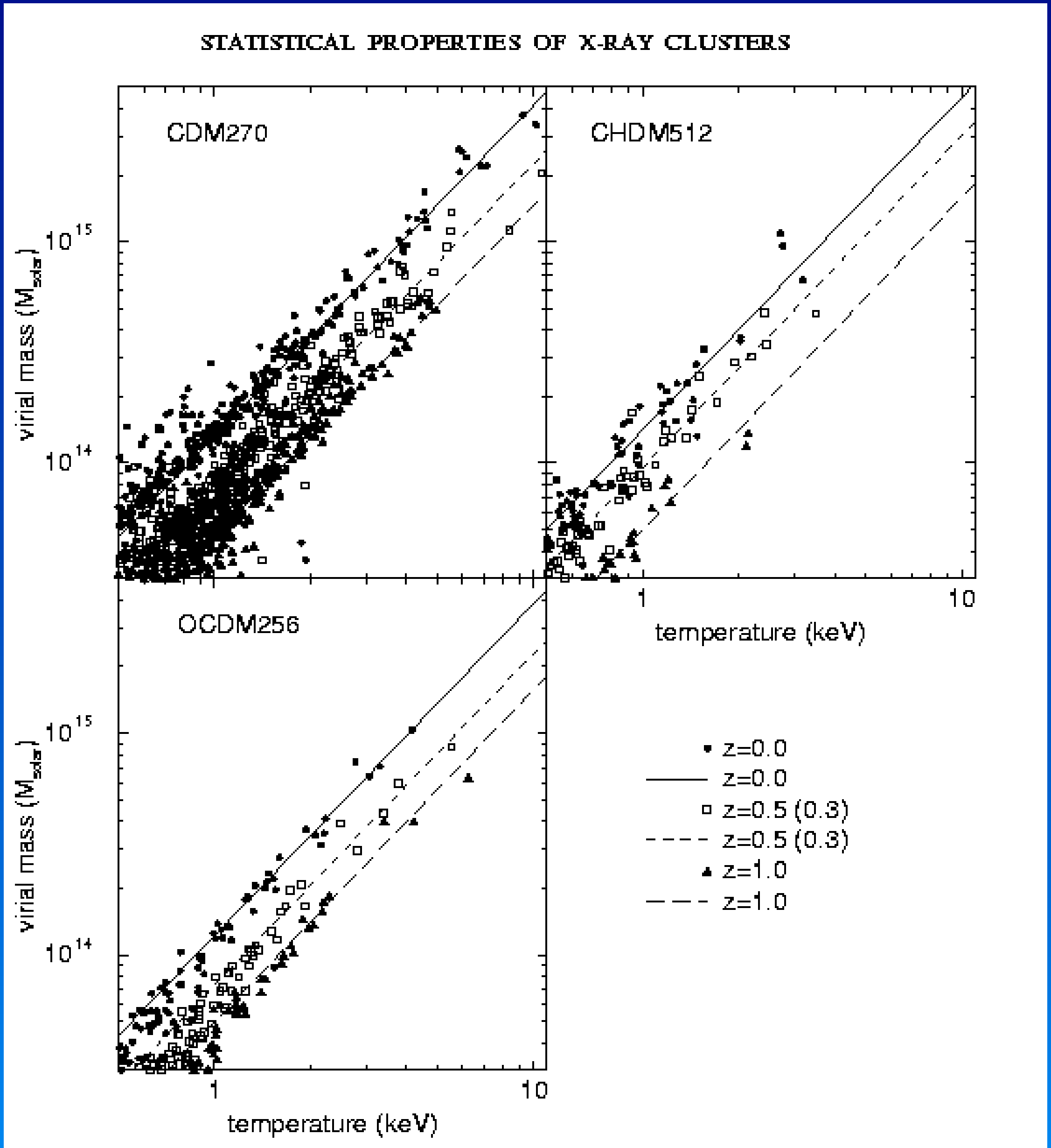
Mass-Temperature Relation :

$T \propto GM/r$

whatever you do with gravity...

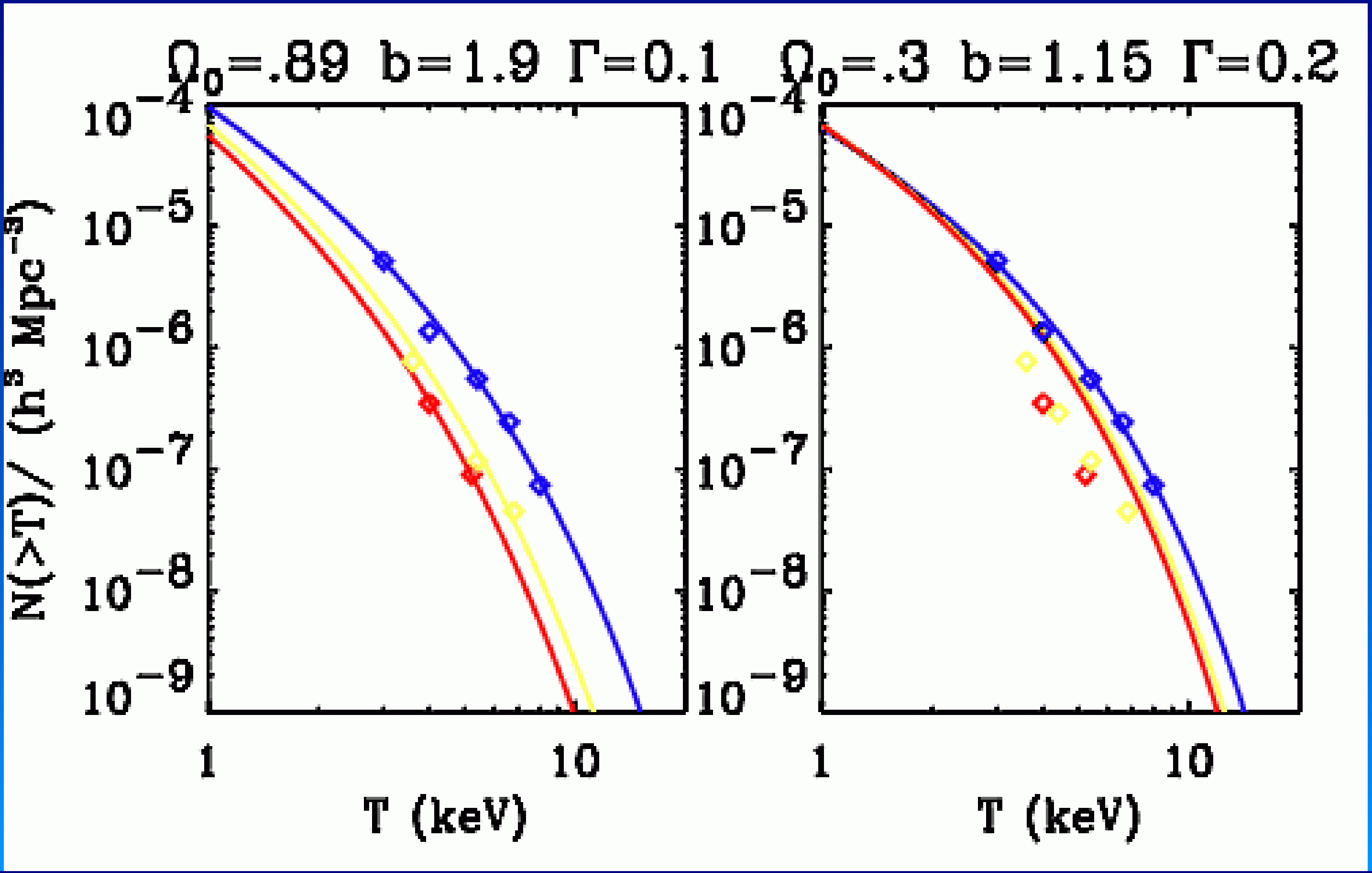
$$T_x \simeq A\, M^{2/3}\, (\Omega\Delta)^{1/3}(1+z)\ \mathrm{keV}$$

Numerical simulations, Bryan & Norman, 1998



Bryan & Norman (ApJ 495 80 1998)

Principle

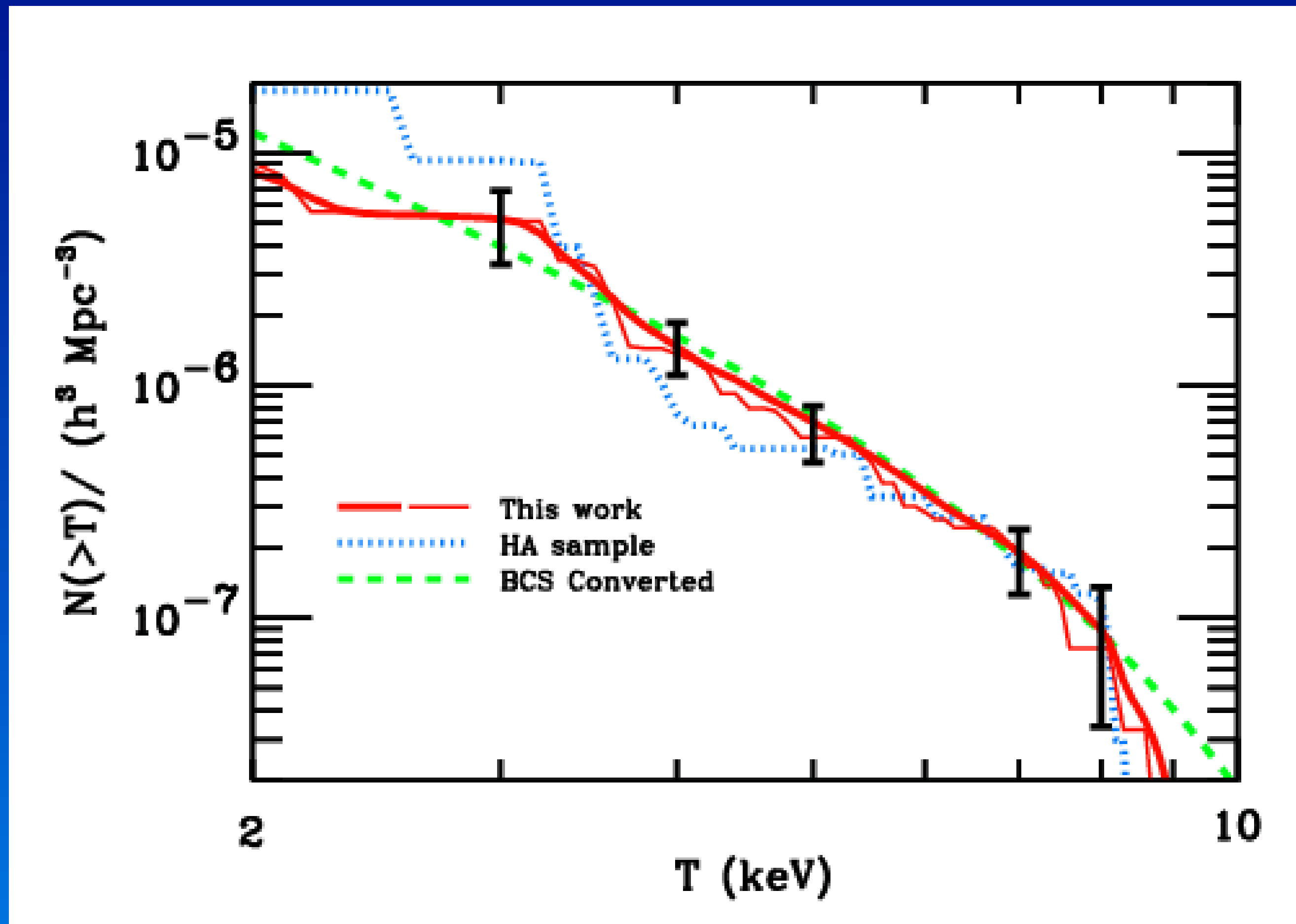


Oukbir, Blanchard, 1992, A&A, 262, L21

X-ray clusters allow precision cosmology...

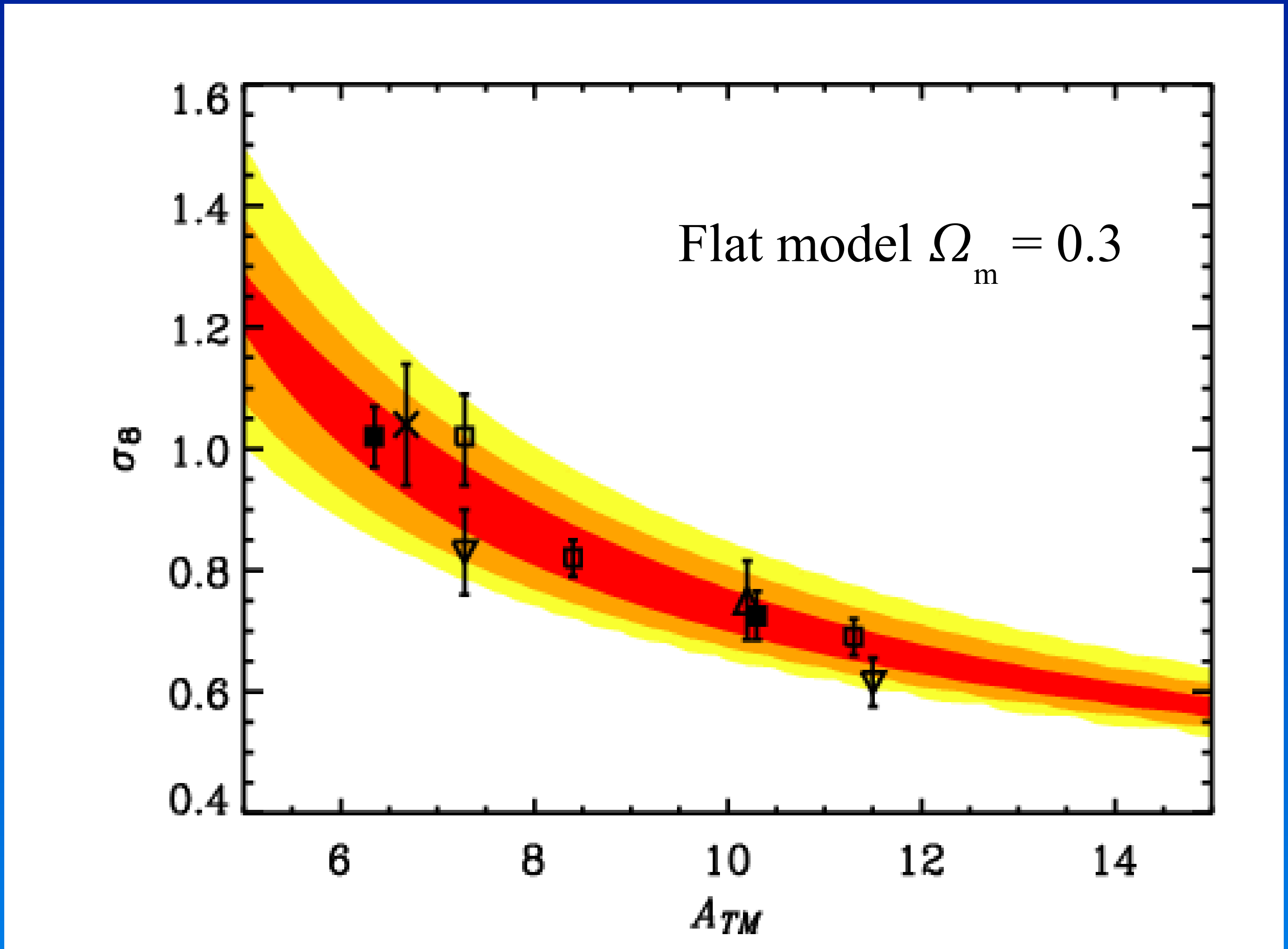
σ_8

Estimated N(T) at z 0.05



50-60 ROSAT clusters => “Convergence” : (Markevitch, 1998), Blanchard et al. (2000), Pierpaoli al (2001), Ikebe et al (2002), Pierpaoli et al (2002)

σ_8 from X-ray clusters:



Ω_m

From X-ray Clusters

Number evolution

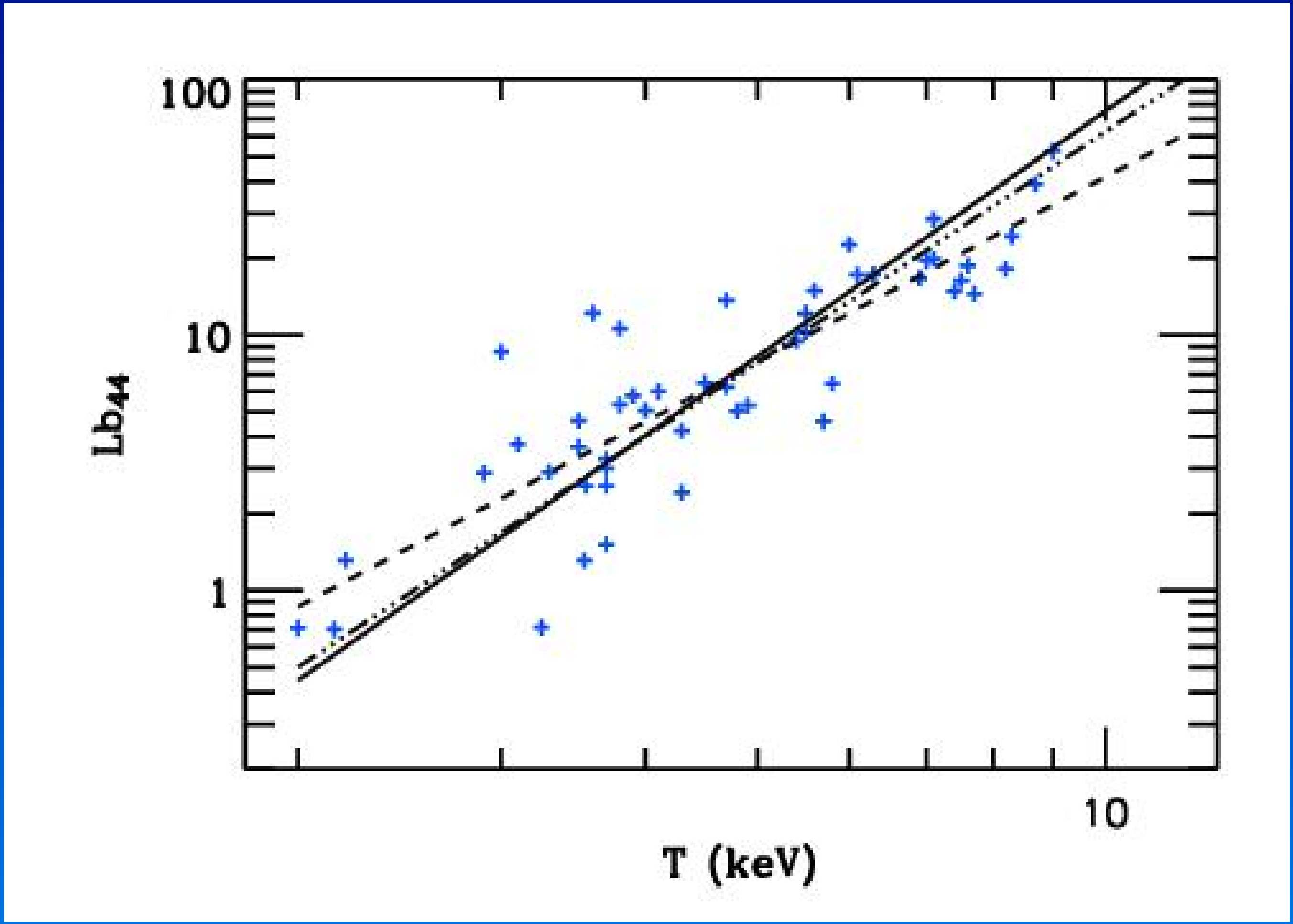
Mass-Luminosity Relation :

$$L_x \propto n^2 T^{1/2} V$$

$$L_x \simeq B\, M^{4/3}\, \Omega^{1/6} \Delta^{7/3} (1+z)^{3.5}$$

$$L_x \propto T^{2} \Delta^{1/2} (1+z)^{1.5}$$

Observed Temperature -Luminosity Relation



$$L_x \propto T_x^{\sim 3}$$

No standard scaling for L-T
and *its evolution...*

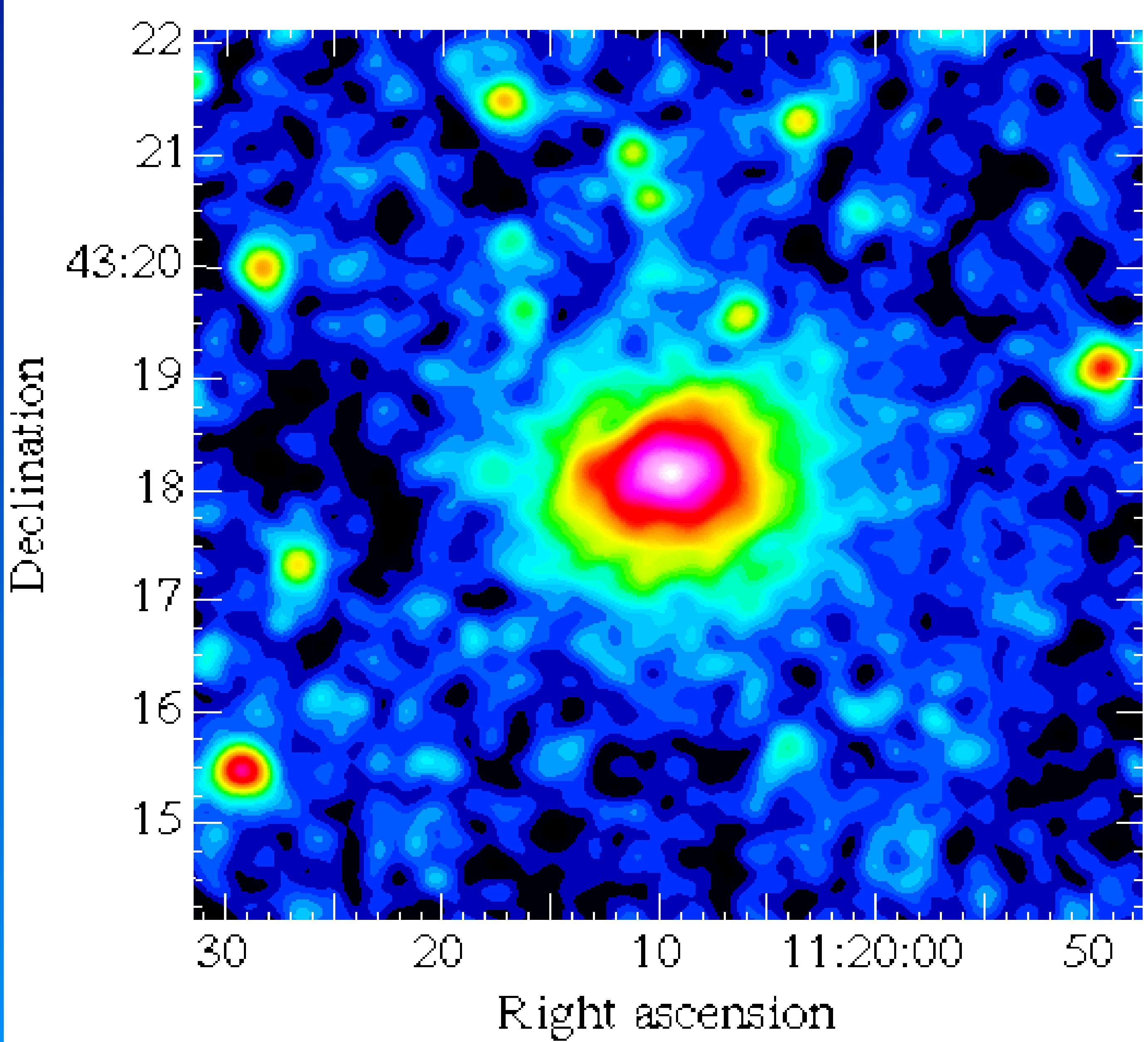
XMM
Ω-Project

X-ray properties of distant SHARC clusters for Cosmology with a complete flux limited survey.

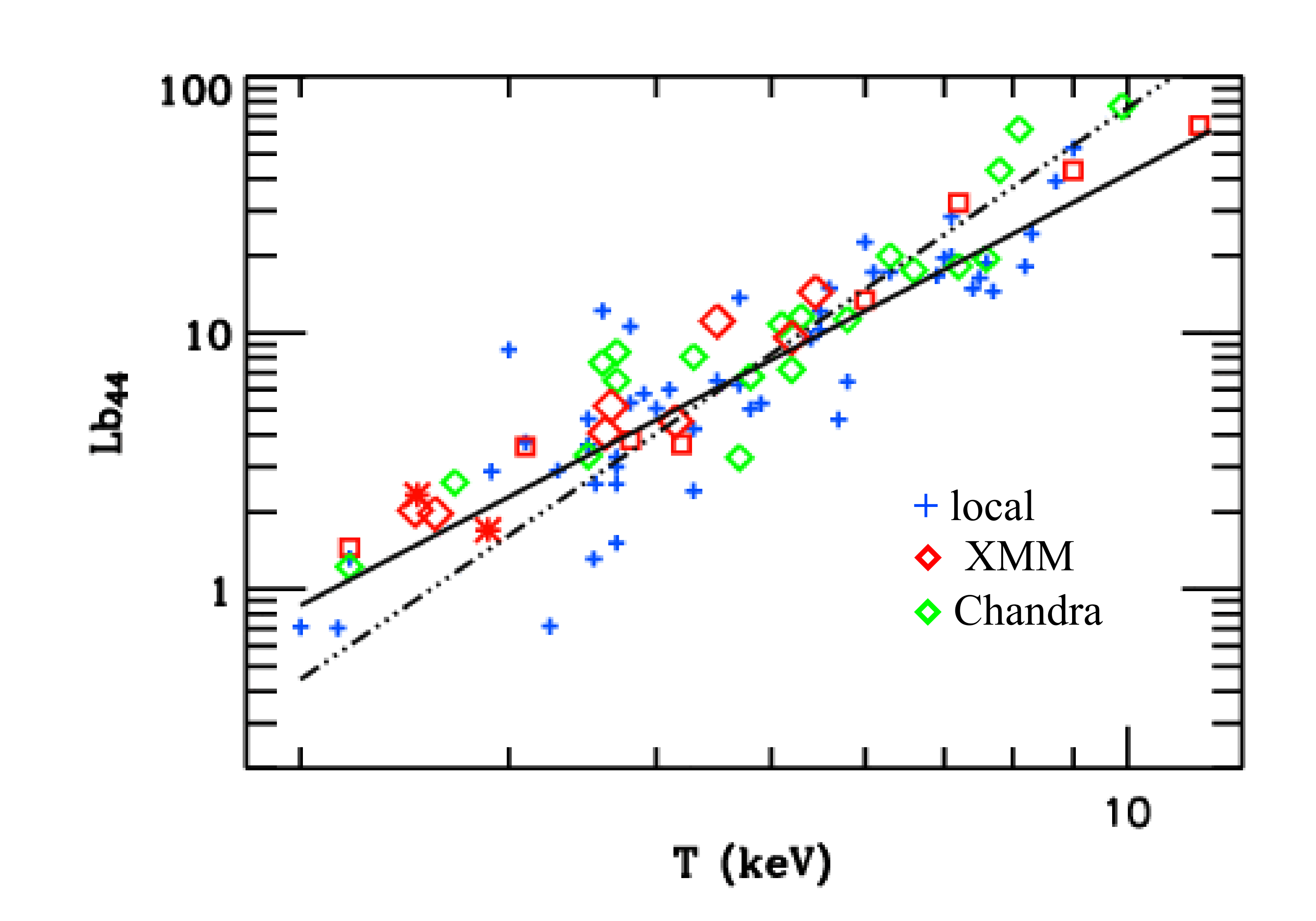
Z ≈ 0.6

XMM

RXJ1120



XMM Lx-Tx evolution



Conclusion on evolution:

- remarkable convergence

$$Lx/Tx)_z = Lx/Tx)_{z = 0}(1+z)^{\beta}$$

with = 1.52 0.28 D.Lumb et al., 2003

in full agreement with ASCA (Sadat et al., 1998; Novicki et al., 2003....), Chandra (Vikhlinin et al, 2002), and more recent XMM analyses (Kotov & Vikhlinin, 2006; Maughan et al. 2006)

Number counts:

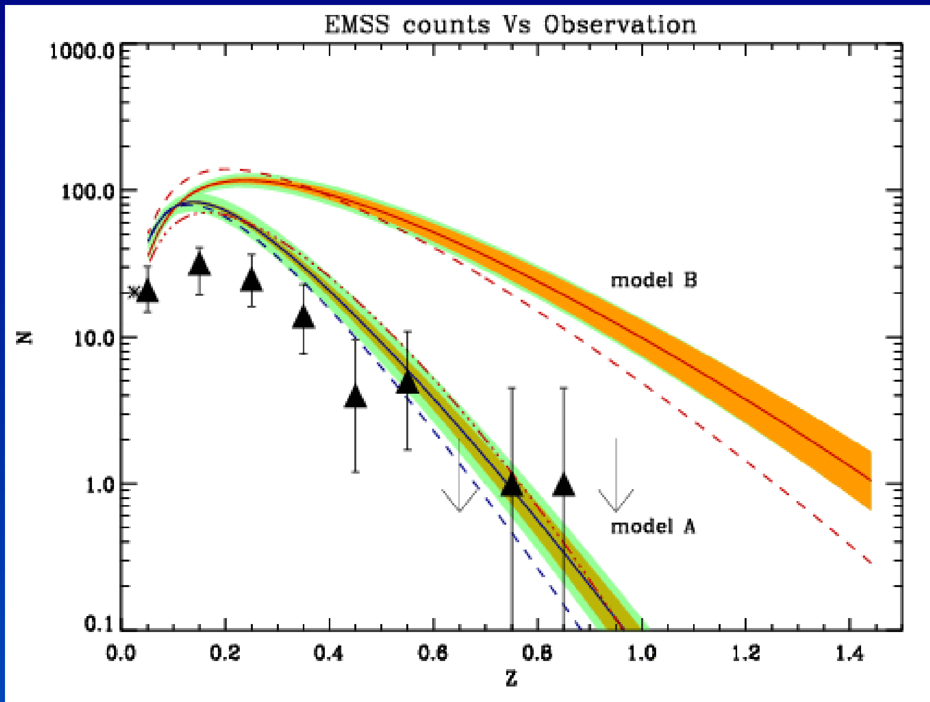
Vauclair et al, 2003
A&A 412, L37

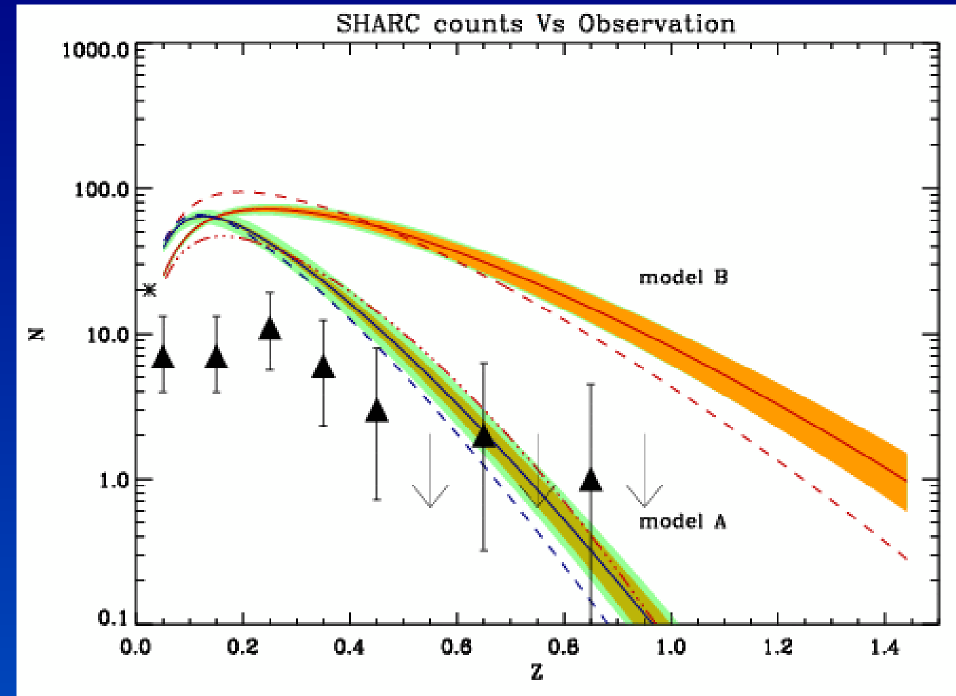
300 clusters
with $z > 0.3$

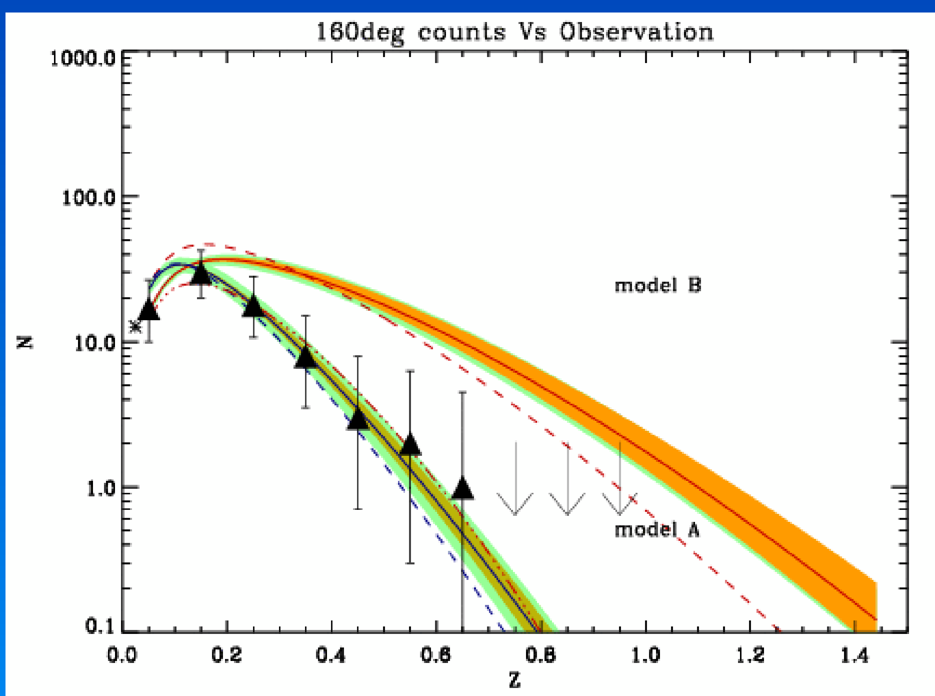
Method:

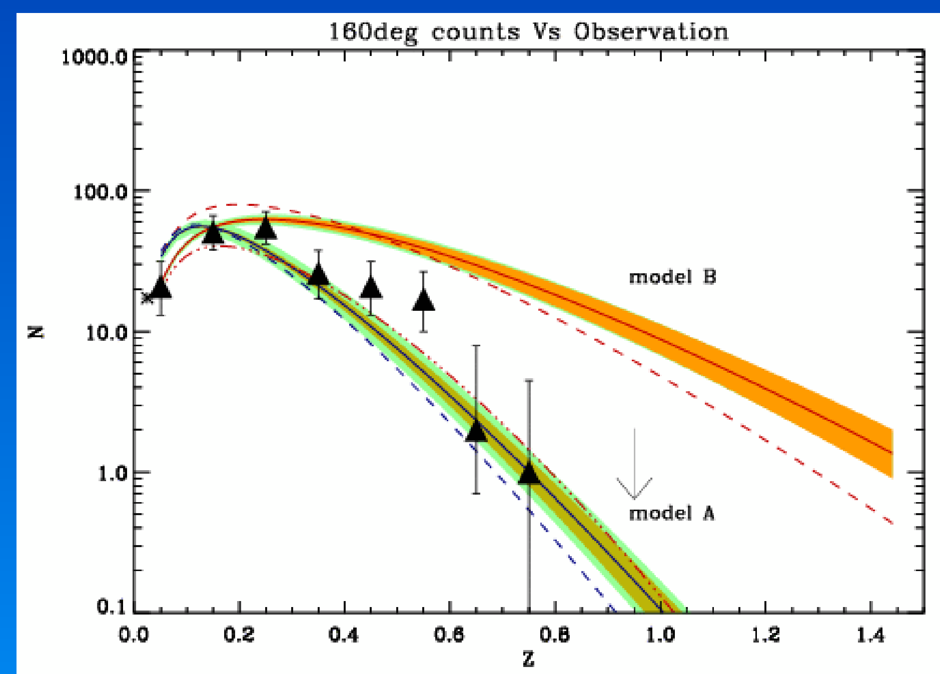
$$f_x \rightarrow L_x \rightarrow s, T_x$$

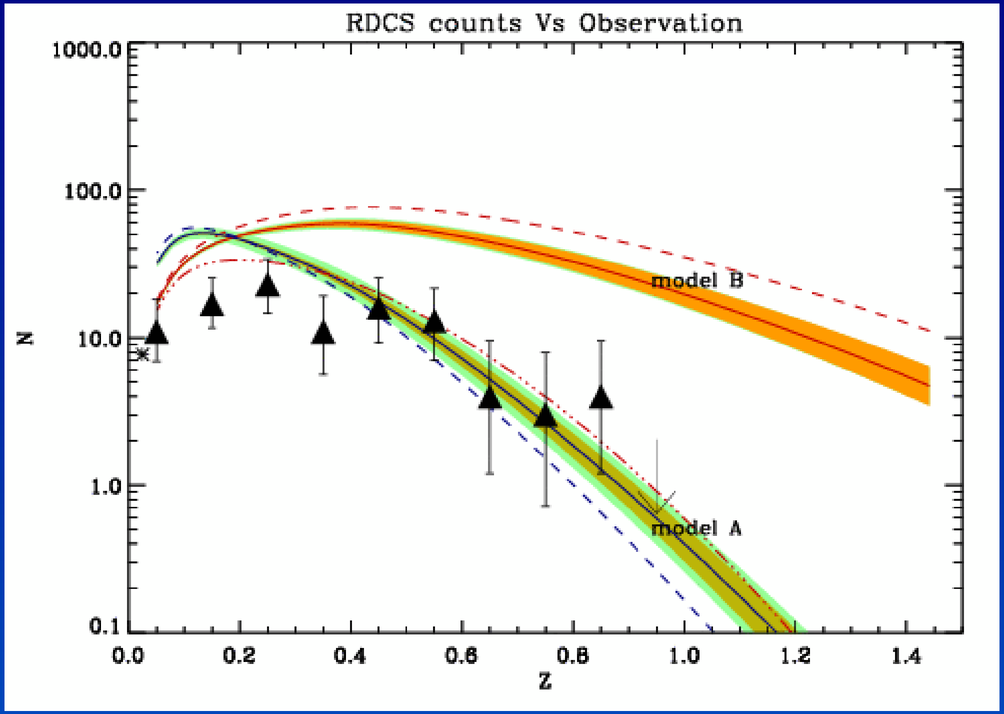
$$\begin{aligned} N(>f_x) &= \int_0^{+\infty}\int_0^{+\infty} s(T,z)N(T,z)dTdV(z) \\ &\gtrsim \int_0^{+\infty} N(>T(z))dV(z) \end{aligned}$$


EMSS counts Vs Observation
1000.0
100.0
10.0
1.0
0.1
N
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
Z
model B
model A


SHARC counts Vs Observation
1000.0
100.0
10.0
1.0
0.1
N
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
Z
model B
model A

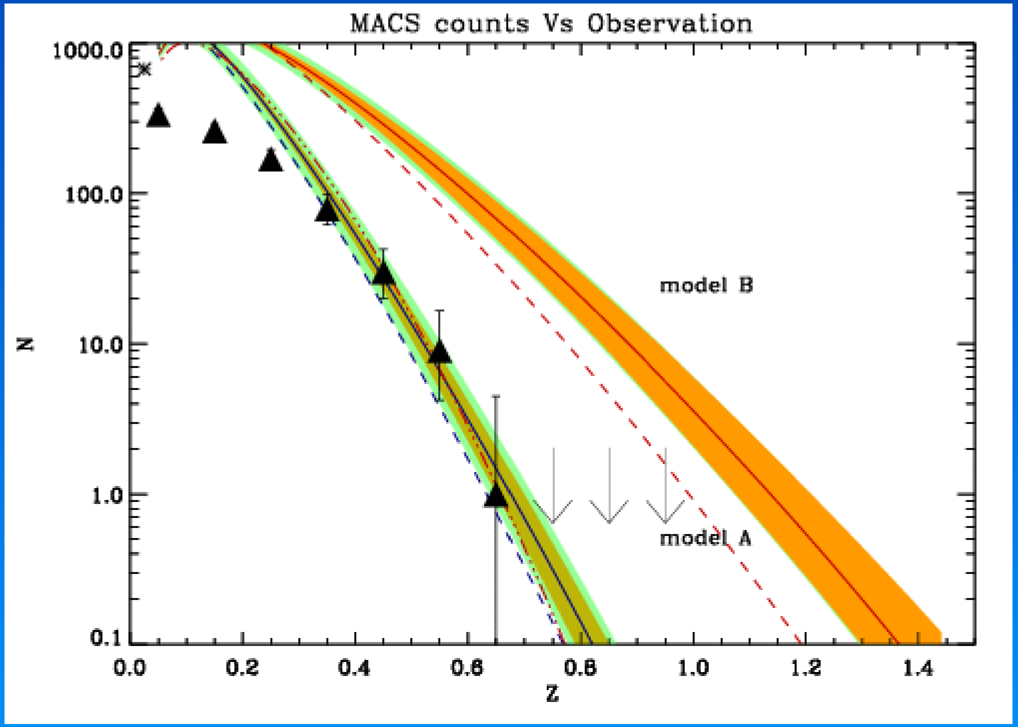

160deg counts Vs Observation
1000.0
100.0
10.0
1.0
0.1
N
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
Z
model B
model A


160deg counts Vs Observation
1000.0
100.0
10.0
1.0
0.1
N
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
Z
model B
model A

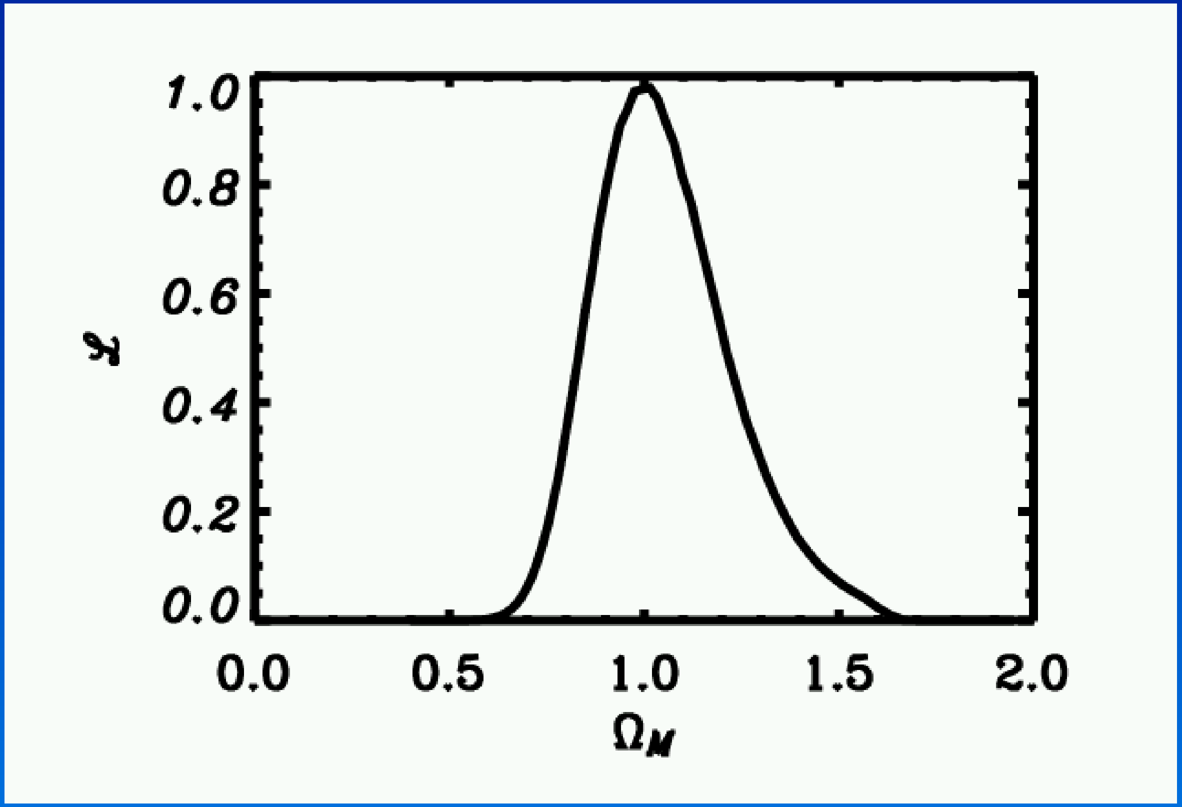


RDCS: 50 deg²
fx ≈3. 10^{-14} erg/s/cm²

MACS: 22 000 deg²
fx ≈ 10^{-12} erg/s/cm²



Likelihood analysis:



(Vauclair et al., 2004)

$\Omega_m = 0.99 \pm 0.15 \pm 0.15$

Conclusion at that point is :

Clusters observations are inconsistent with self similar models in concordance cosmology!

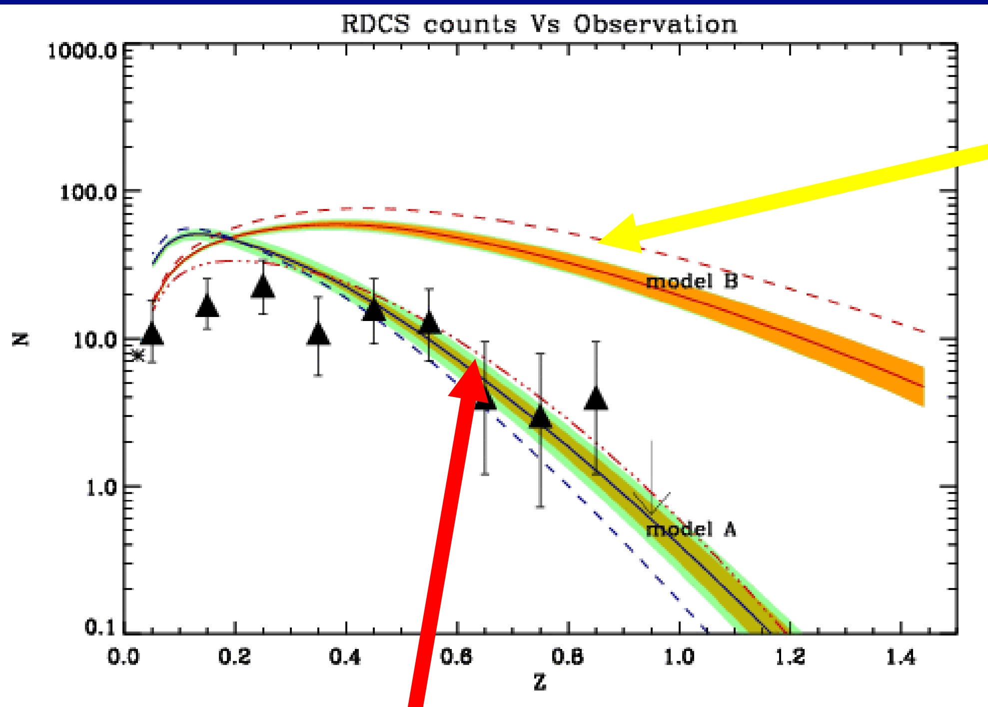
Kill the Mass-Temperature Relation :

$$T \propto GM/r + \ldots \propto GM/r\,/(1+z)$$

i.e. ~ forget gravity...

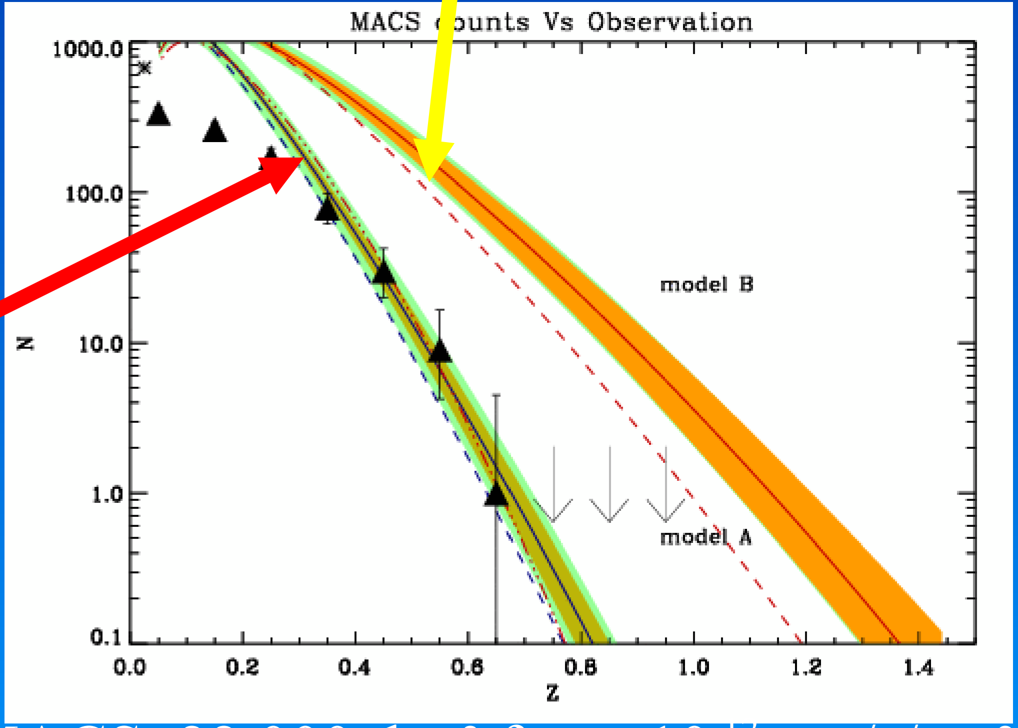
$$T_x \simeq A\, M^{2/3}\, (\Omega\Delta)^{1/3} (1+z)^0 \text{ keV}$$

RDCS: 50 deg^2, fx $\approx 3.\ 10^{-14}$ erg/s/cm^2



Concordance model
+
Standard M-T scaling law

Concordance model
+
Revised M-T scaling law



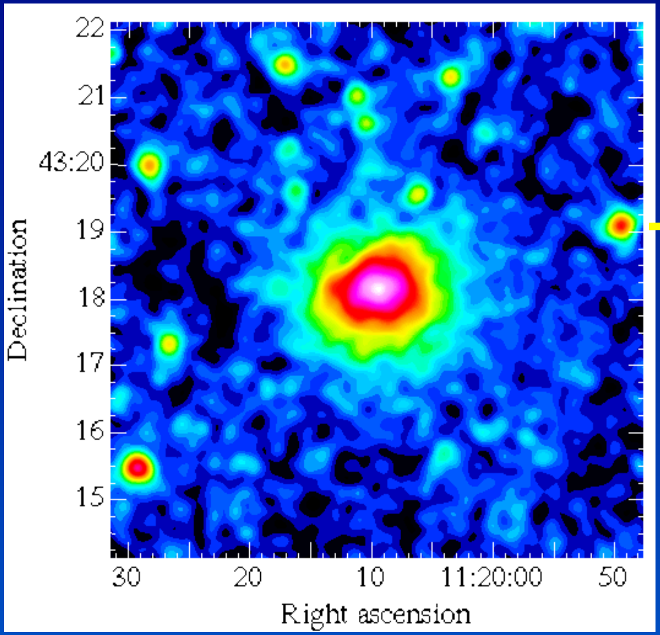
MACS: 22 000 deg^2 fx $\approx 10^{-12}$ erg/s/cm^2

II Ω_m From X-ray Clusters

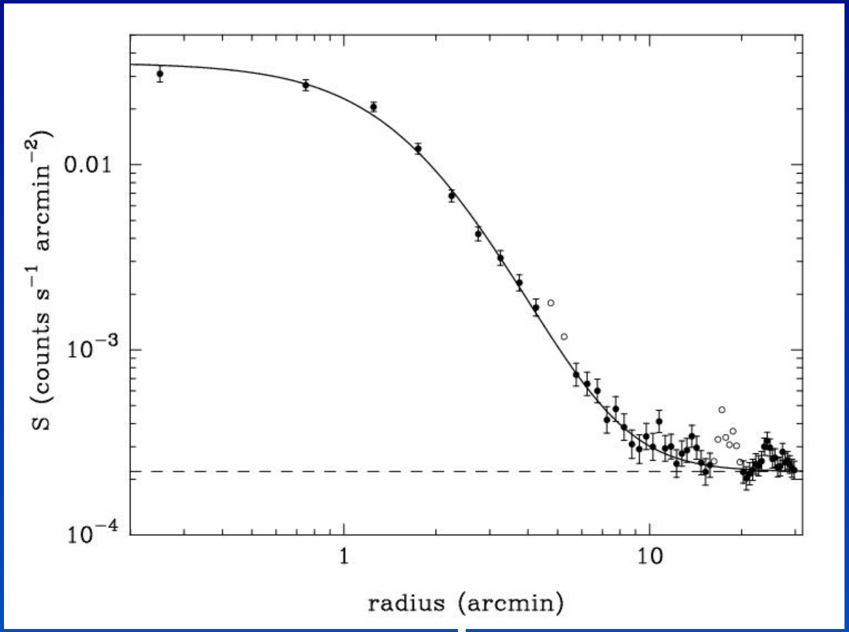
Baryon Fraction evolution in the XMM Ω-project

(Sadat et al., A&A 2005)

What do you do with a cluster?

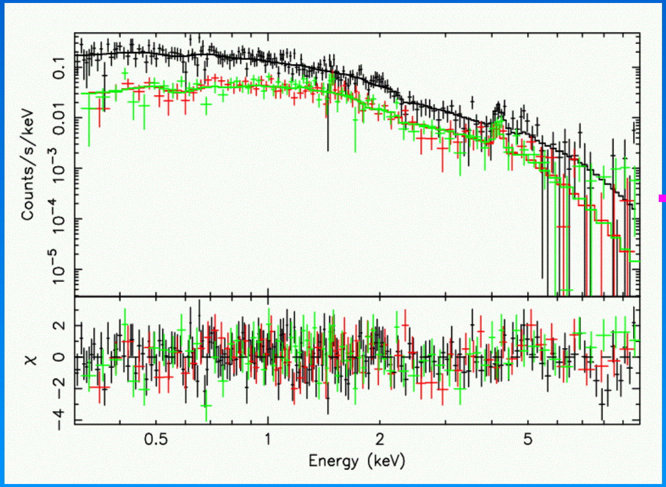


Fit

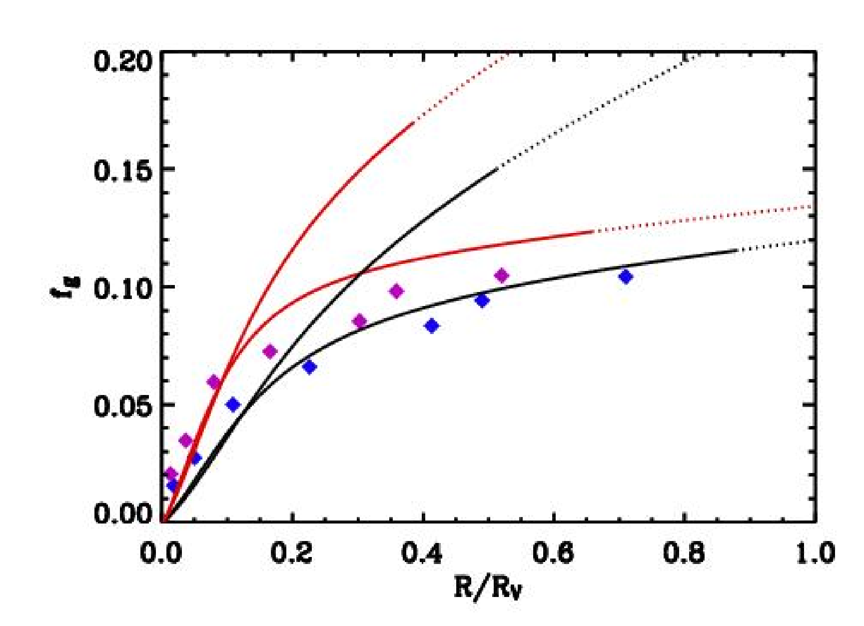


Gas mass $M_g(r)$

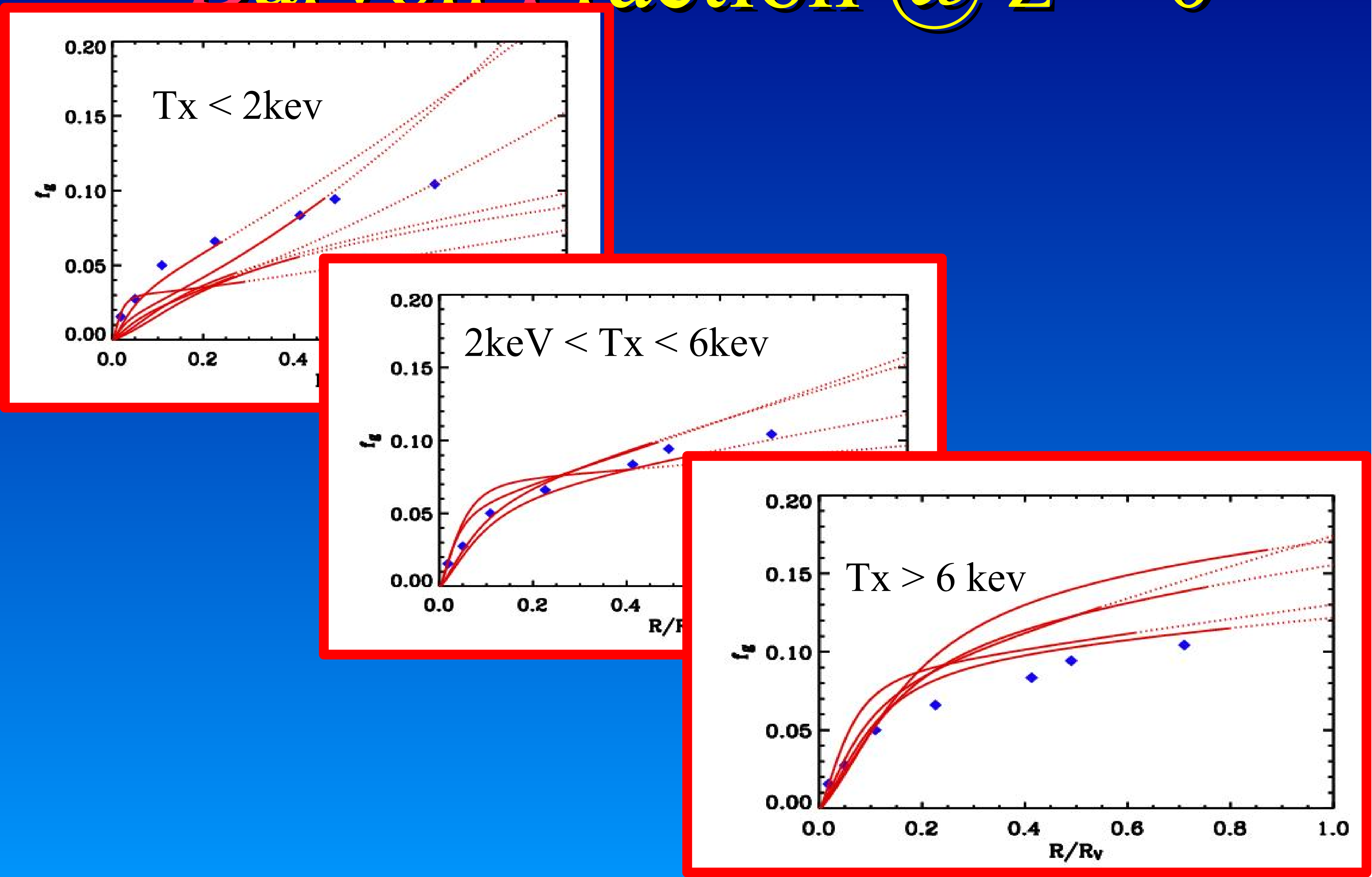
X-ray spectrum



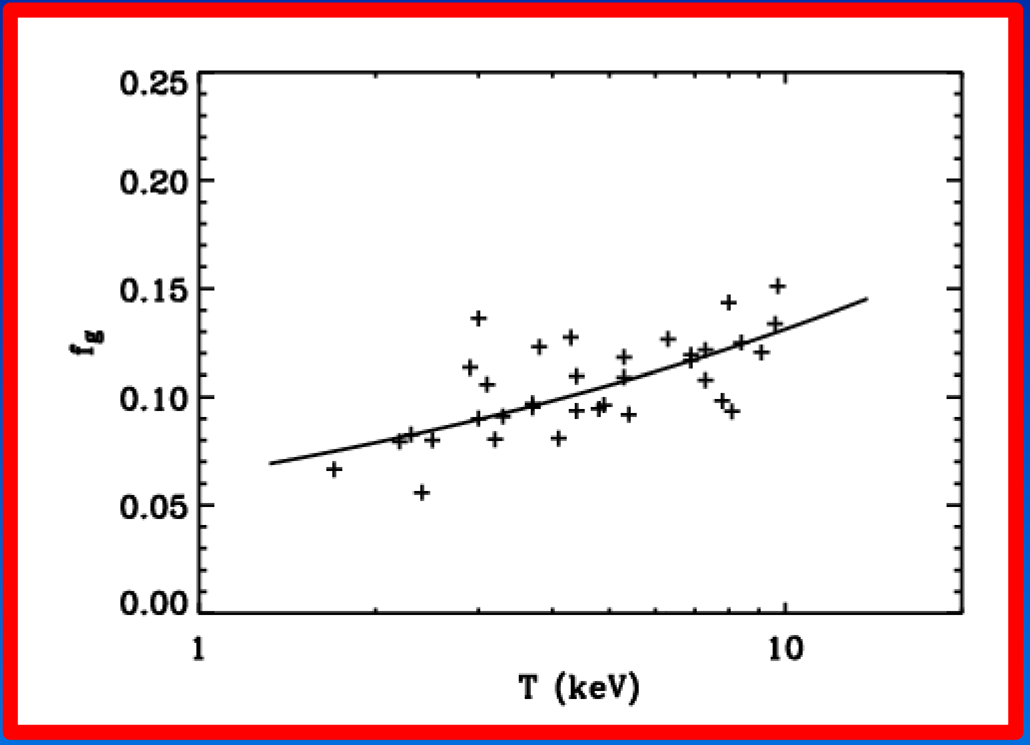
M(r)



Barvon Fraction @ z = 0

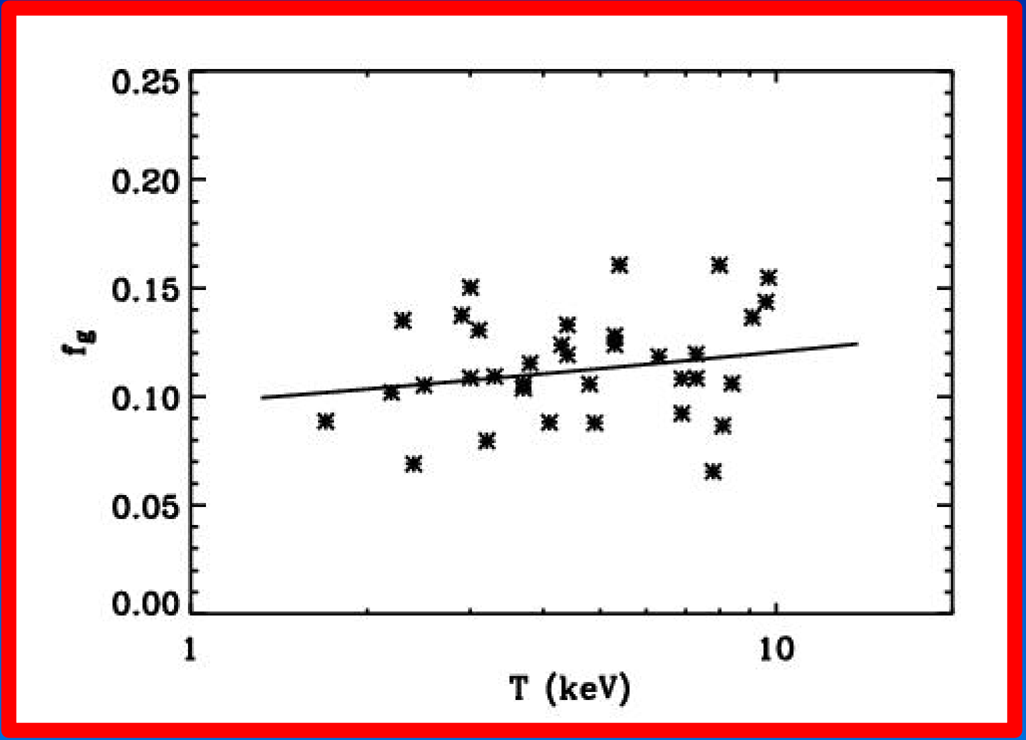


Baryon Fraction @ z = 0



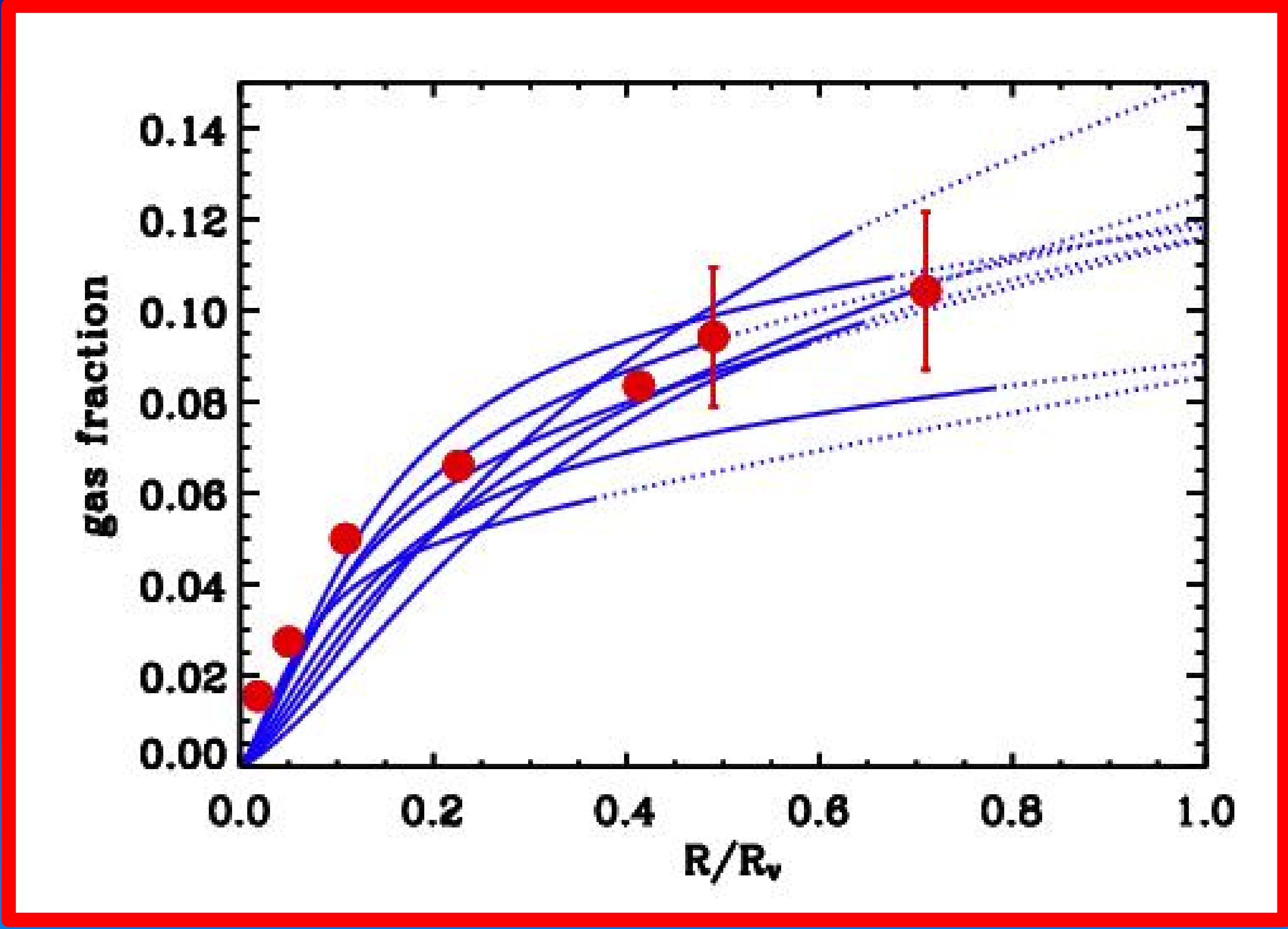
R_{2000} in Vikhlinin, Forman, Jones 1999 (~35-45% Rv)

Baryon Fraction @ z = 0

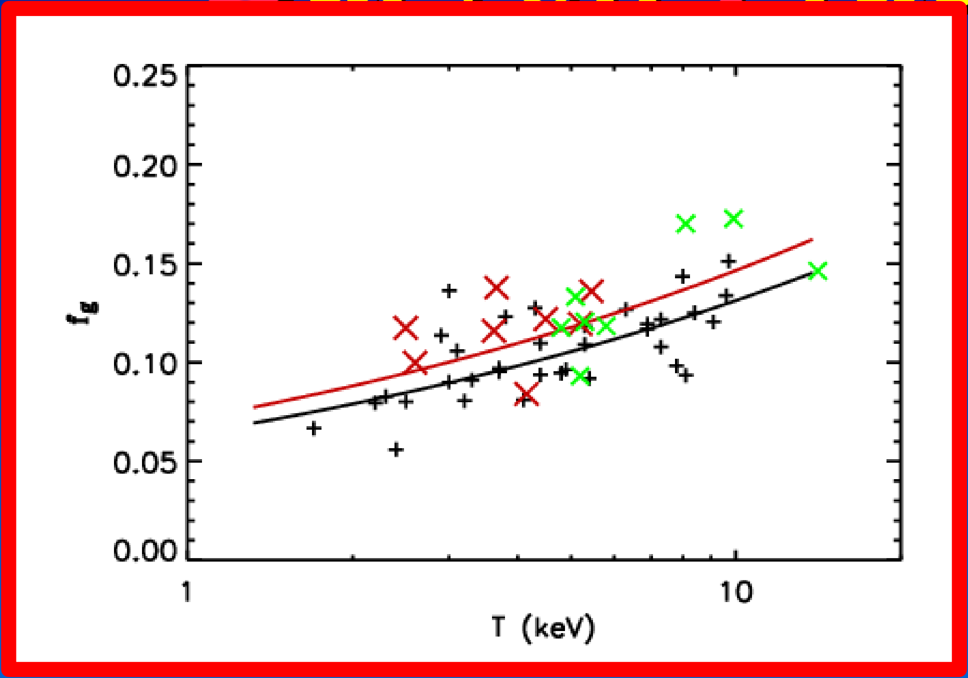


R_v in Vikhlinin, Forman, Jones 1999

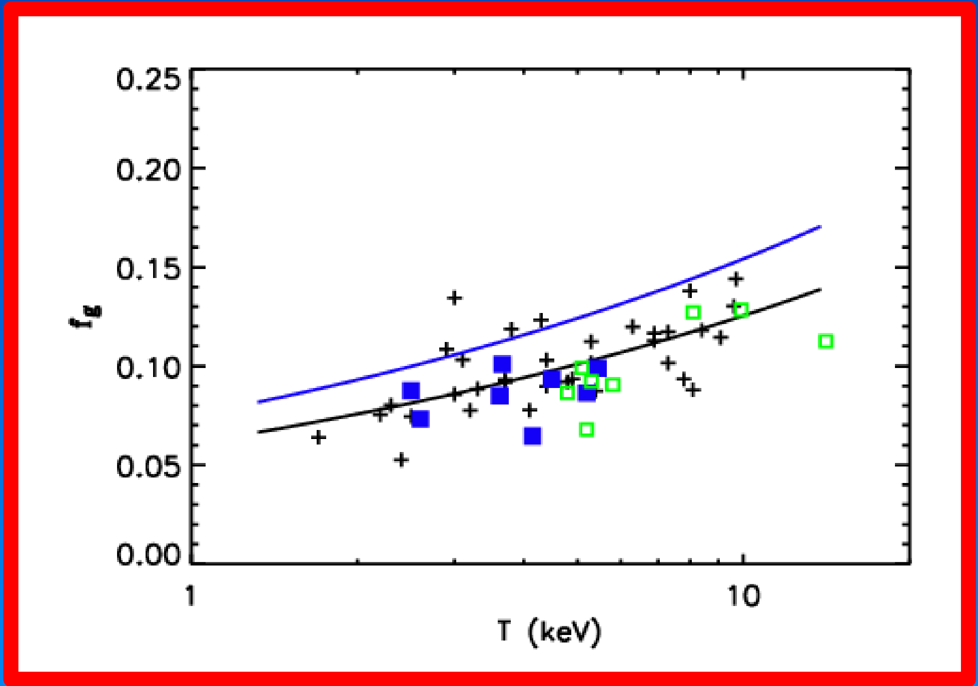
Baryon Fraction @ z = 0.6



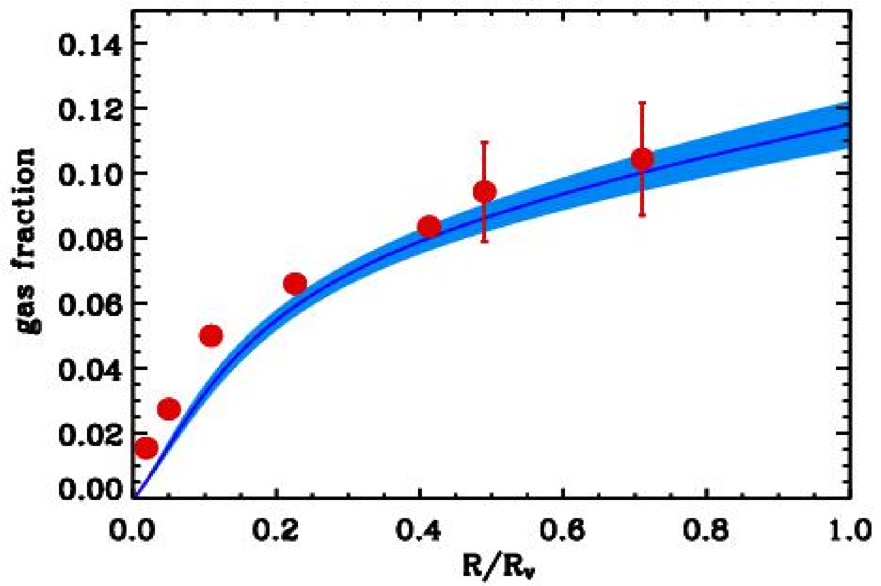
Barvon Fraction @ z = 0.6



$\Delta = 2000$

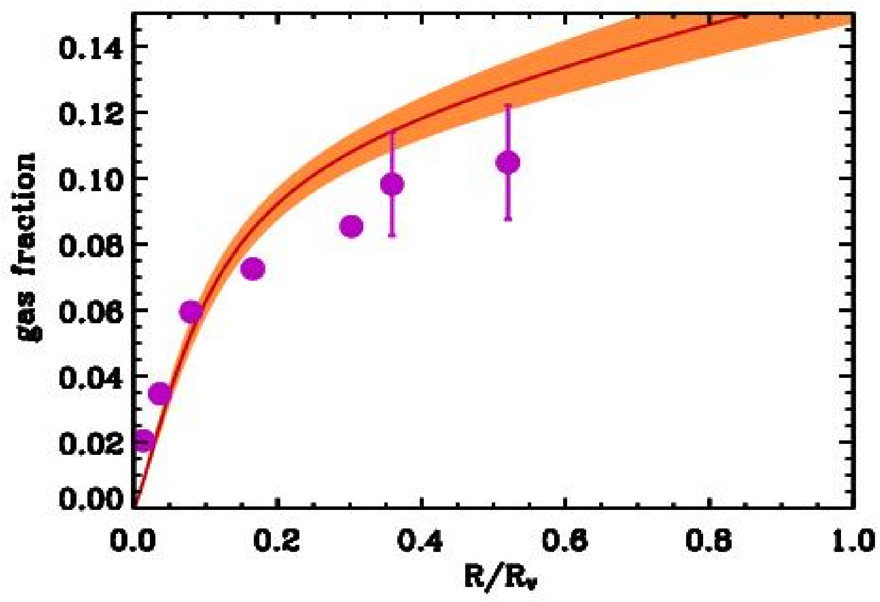


Barvon Fraction @ z = 0.6

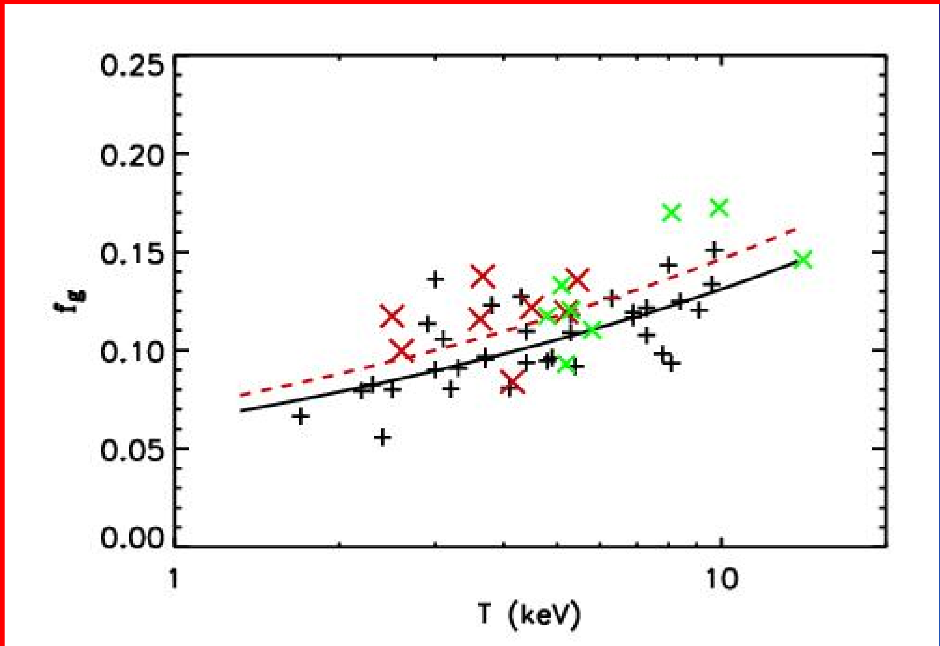


Internal structure

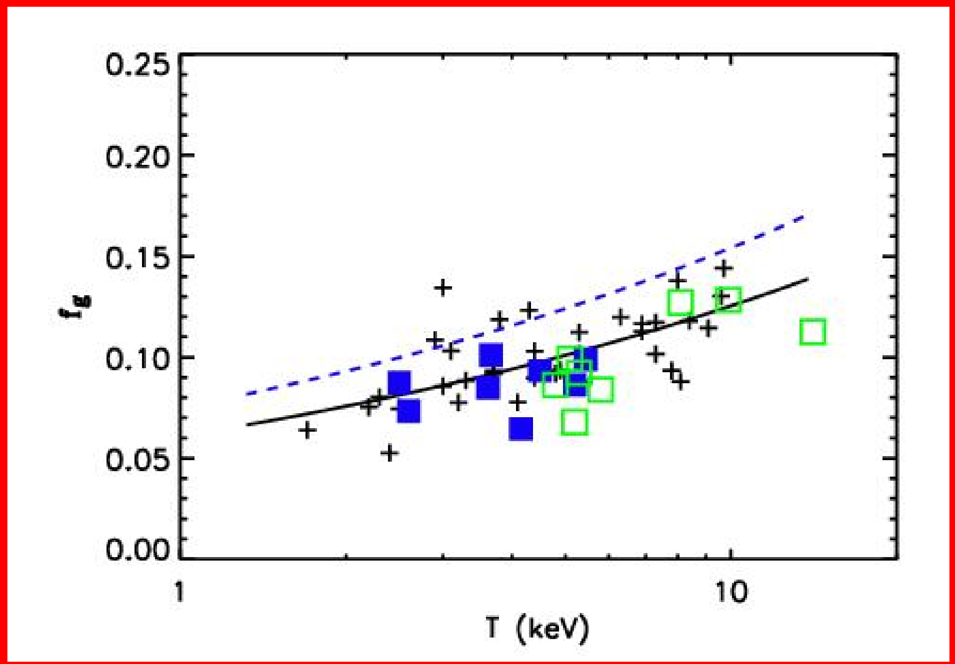
is complex...



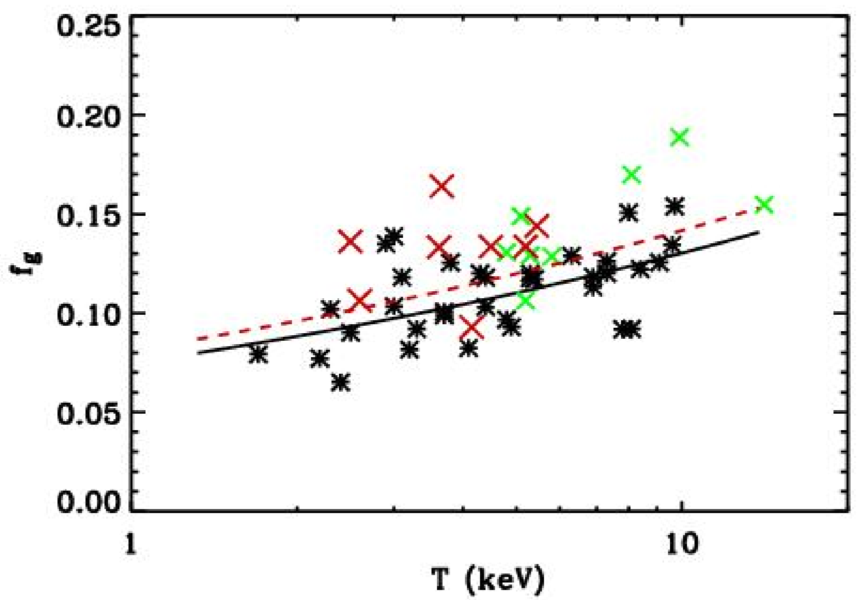
Barvon Fraction @ z = 0.6



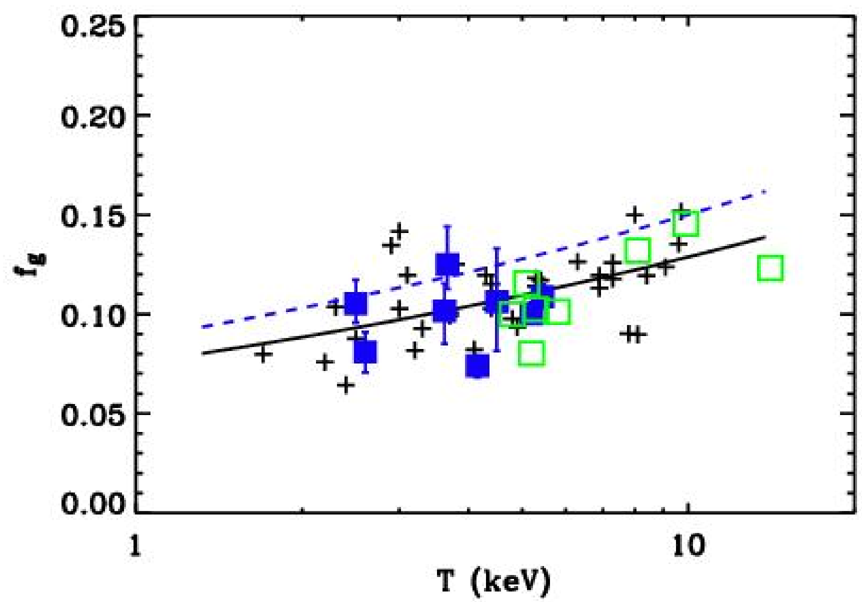
$\Delta = 2000$



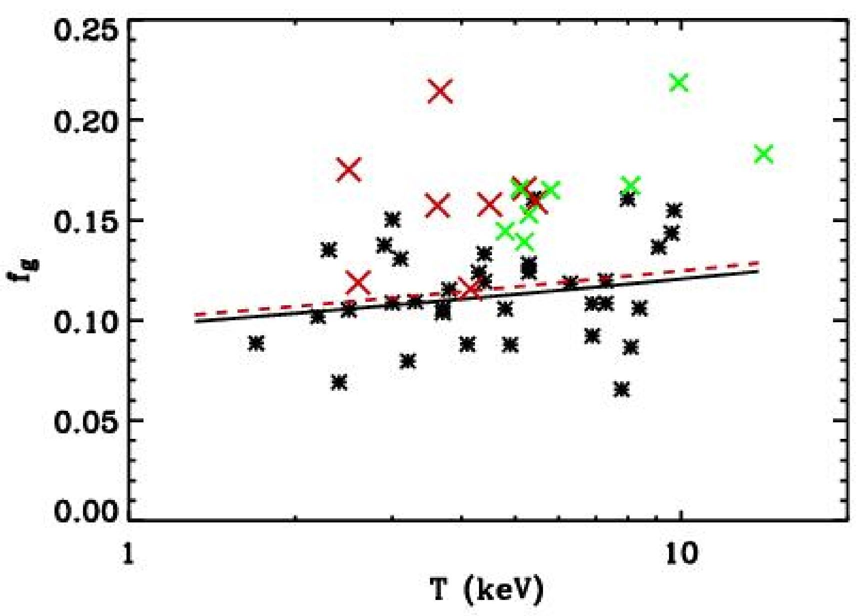
Baryon Fraction @ z = 0.6



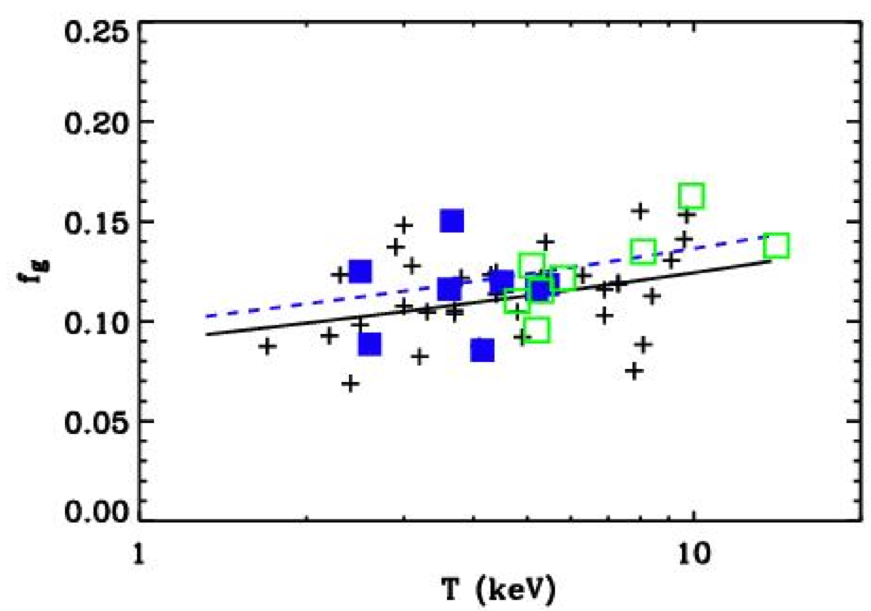
$\Delta = 1000$

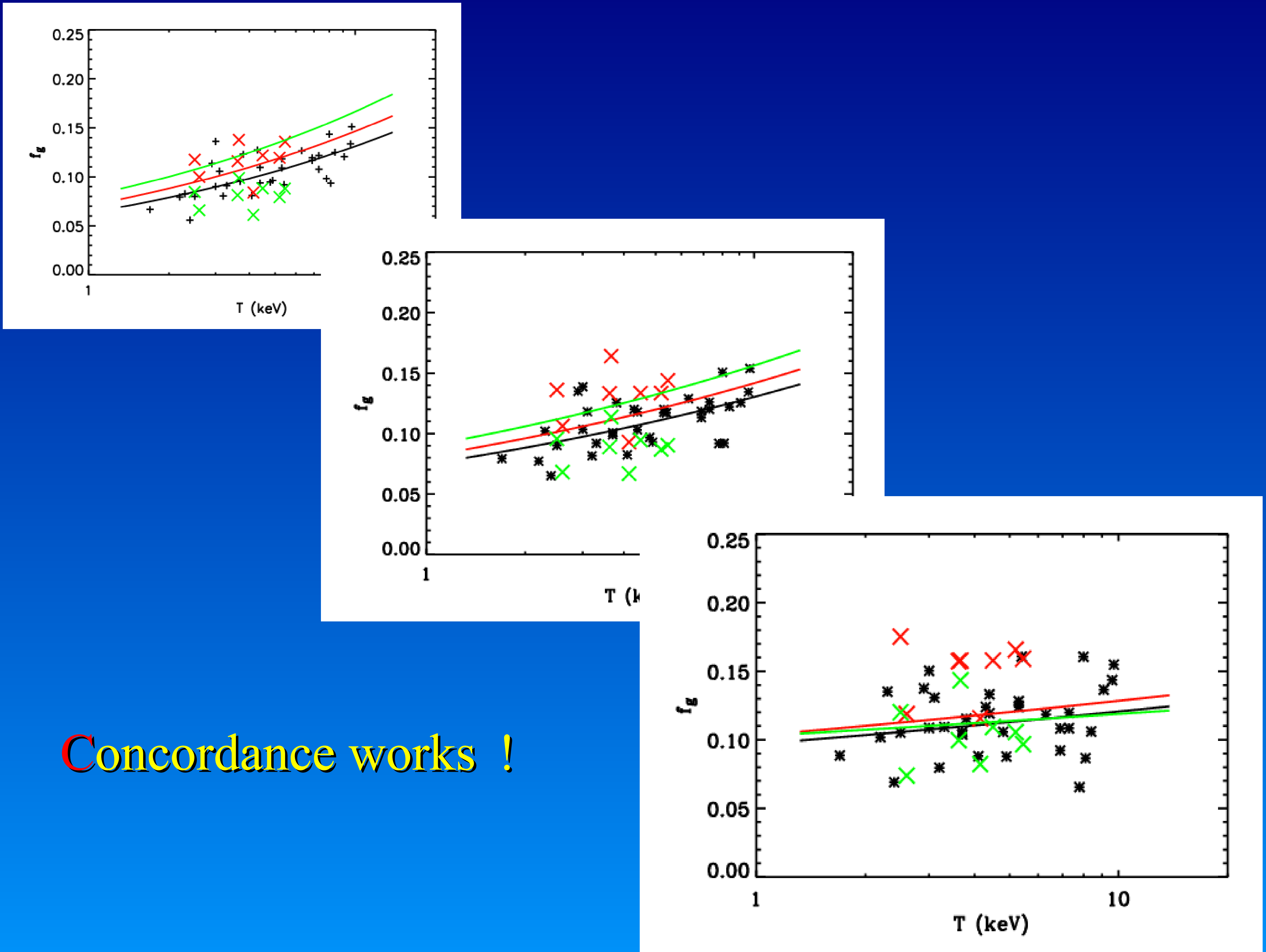


Baryon Fraction @ z = 0.6



Δ_v





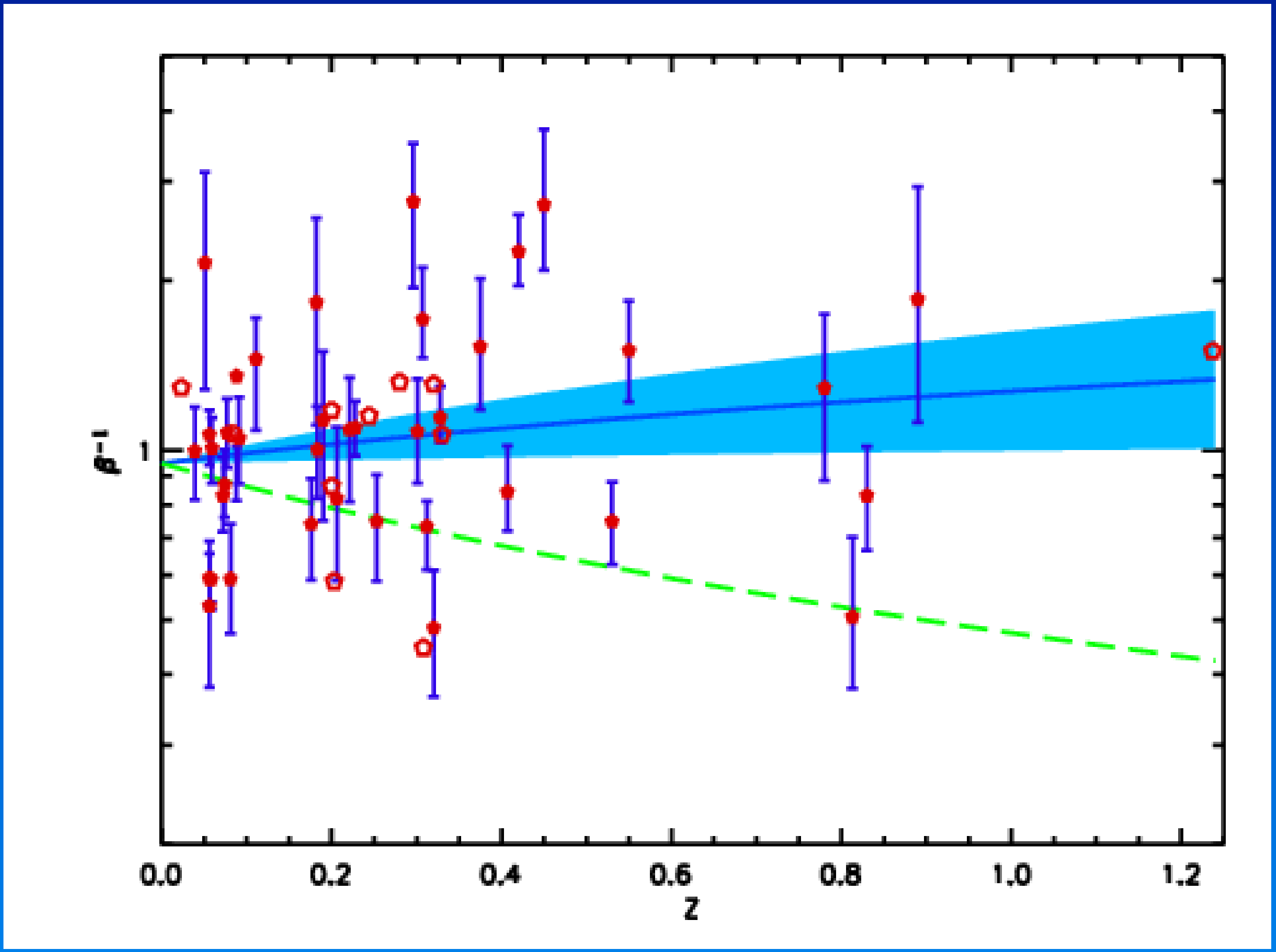
Concordance works !

Breaking the degenracy...

$$T \propto GM/r\,/(1+z) \propto \sigma^2/(1+z)$$

- **Testable... i.e.**

$$\boldsymbol{\beta}^{-1} \propto T/\sigma^2 \propto 1/(1+z)$$



1
β⁻¹
0.0
0.2
0.4
0.6
0.8
1.0
1.2
z

Conclusions I

- **Strong Evolution in the abundance of x-ray clusters appears from all existing surveys in a very consistent way.**
- **This is inconsistent with standard scaling laws in concordance model... ☺**
- **Consistent with f_b evolution ... ☺**
- **Consistent with f_b amplitude ... ☺**

Conclusions II

- This could require a major revision of standard scaling of M-T (z)
  i.e. $T_x \neq GM/r$
  New cluster (astro-)physics ?
- No sign of it in observed clusters...