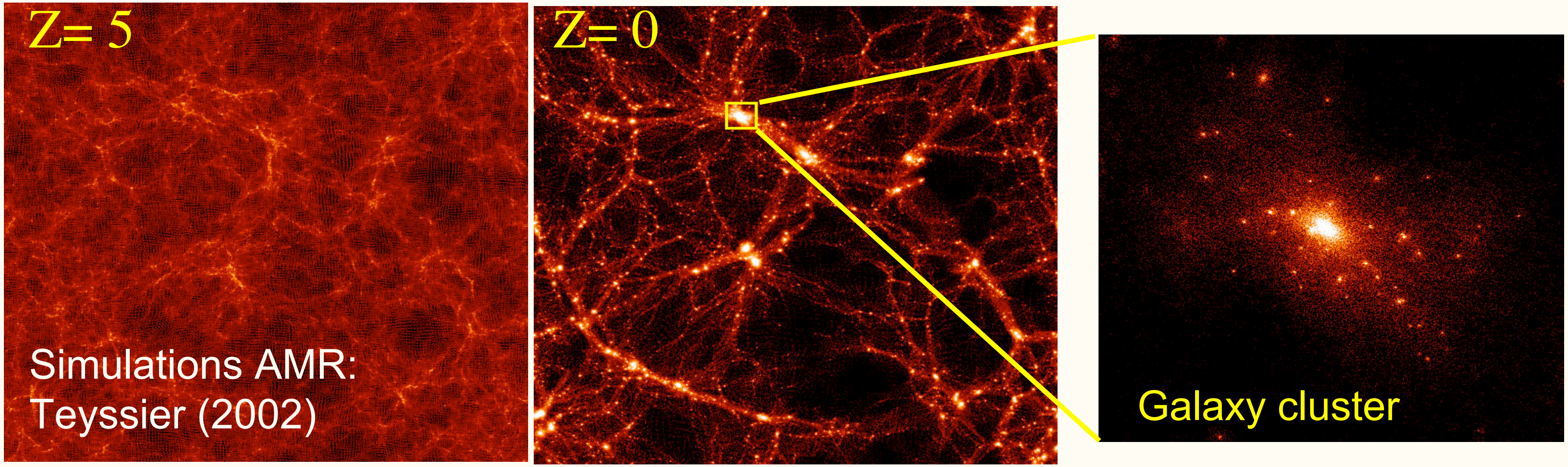
High redshift clusters and their evolution

M.Arnaud (CEA-Sap Saclay France)

Clusters and structure formation



- Primordial fluctuations (DM) that growth under the influence of gravity

  ⇒ the cosmic ‘ web ’: Voids, Filaments, Blobs : The clusters of galaxies

- Hierarchical clustering:

  clusters: forming/growing since z~2 *till now* by merger/accretion along LS filaments

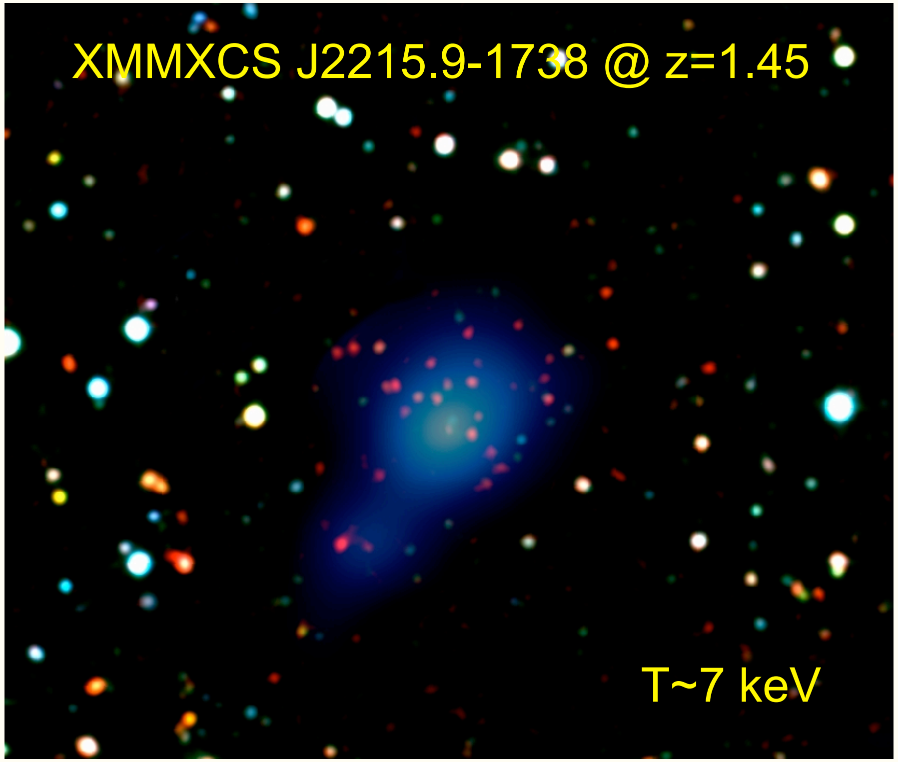
- The cluster population is an evolving population

  ⇒ test of structure formation scenario *(Dark Matter and Gas)*

  ⇒ constrain the cosmological parameters

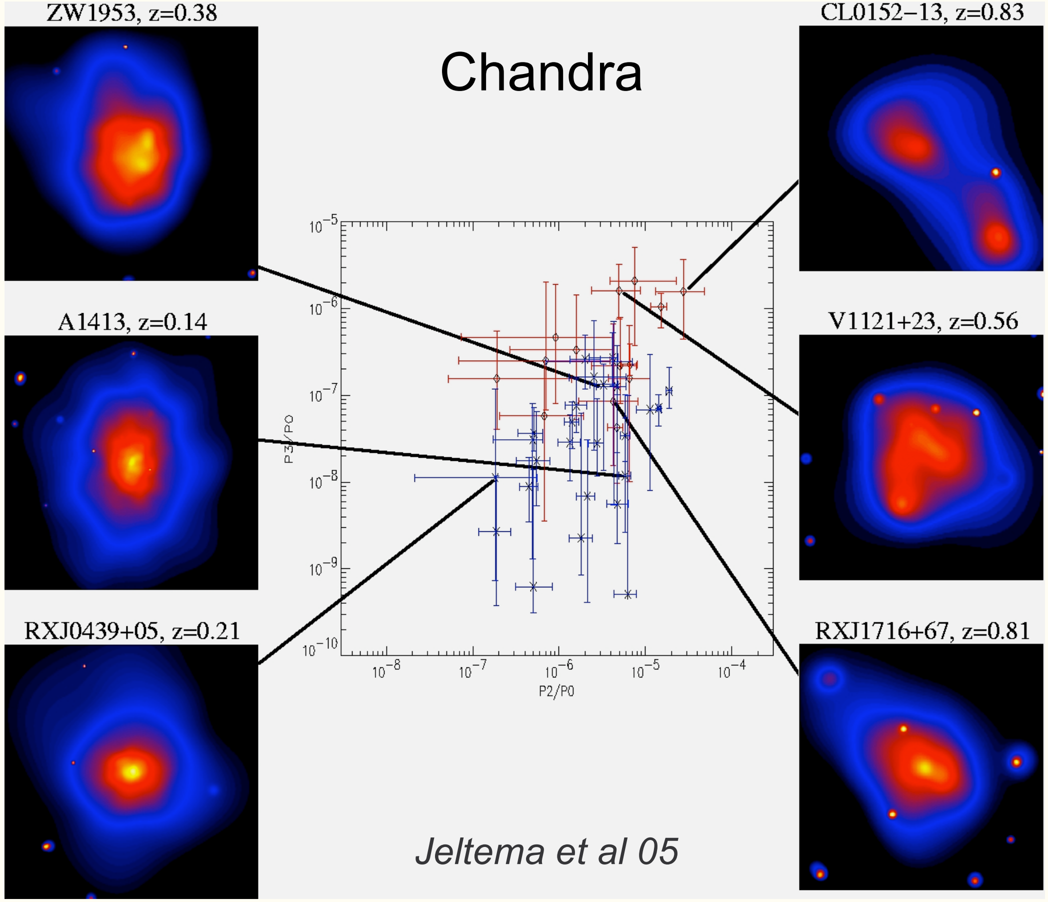
Clusters do exist up to high z

Stanford et al, 06



The most distant (confirmed) cluster

Evolution of dynamical state



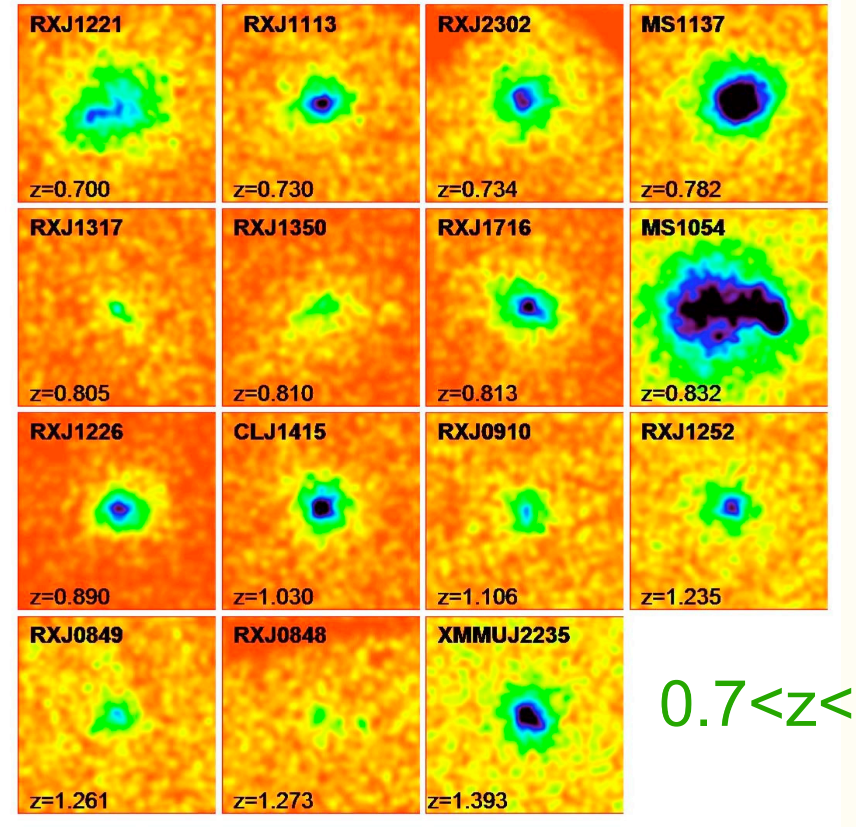
See also Hashimoto et al, 07; Maughan et al,08

High z (> 0.5) clusters:

more substructures
dynamically younger

as expected in
hierarchical scenario

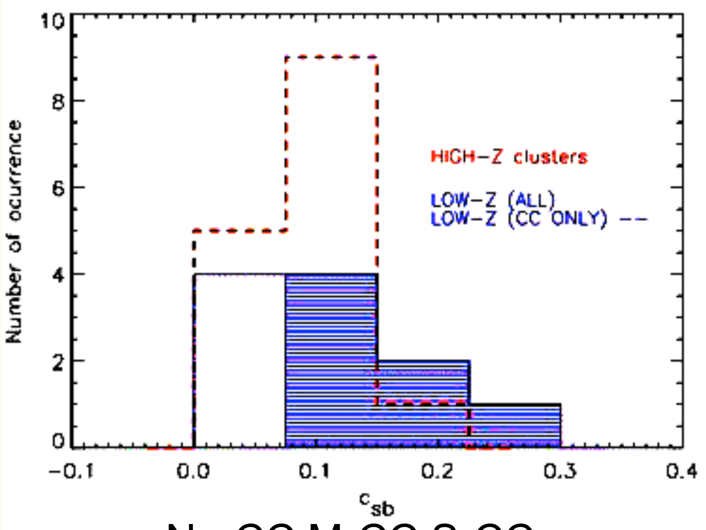
Evolution of (cooling) core



0.7<z<1.4

Santos et al,08

See also Vikhlinin et al, 06



No-CC M-CC S-CC

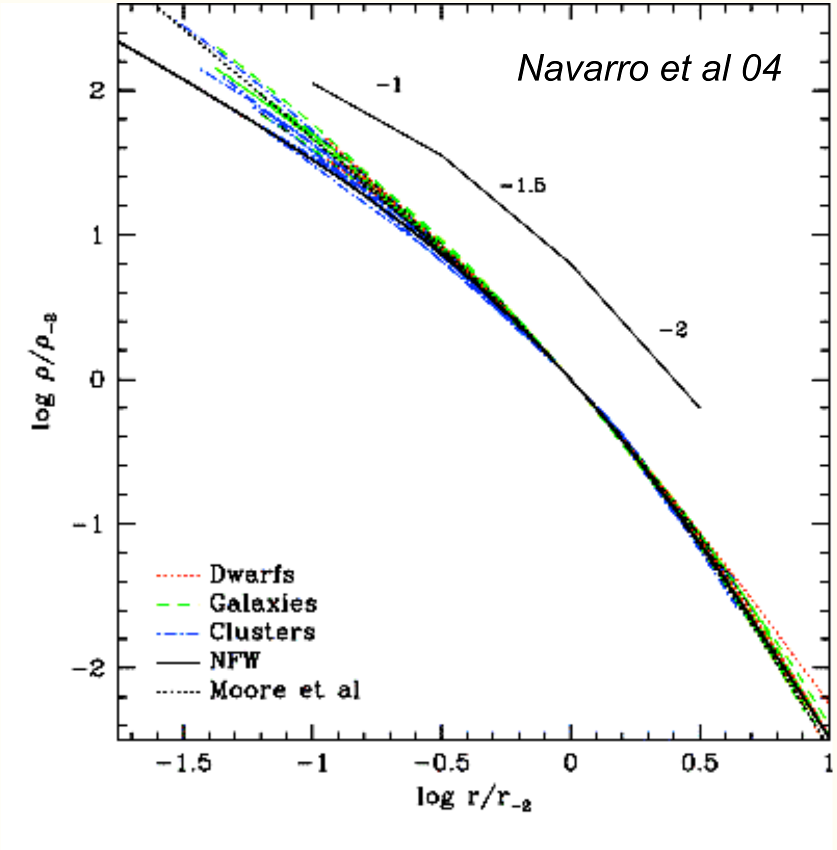
No strong CC

Likely related to higher merger rate & lower t_H vs t_{cool}

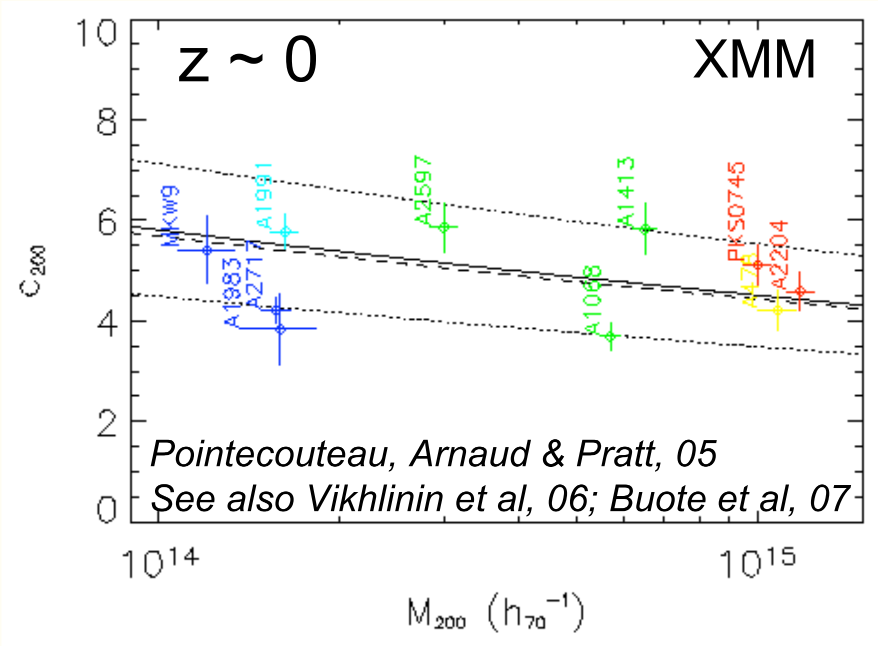
The evolution of scaling properties

as compared to the self-similar model

The dark matter



ΛCDM simulations of structure formation:
Universal $\rho/\rho_c(z)$ cuspy profiles

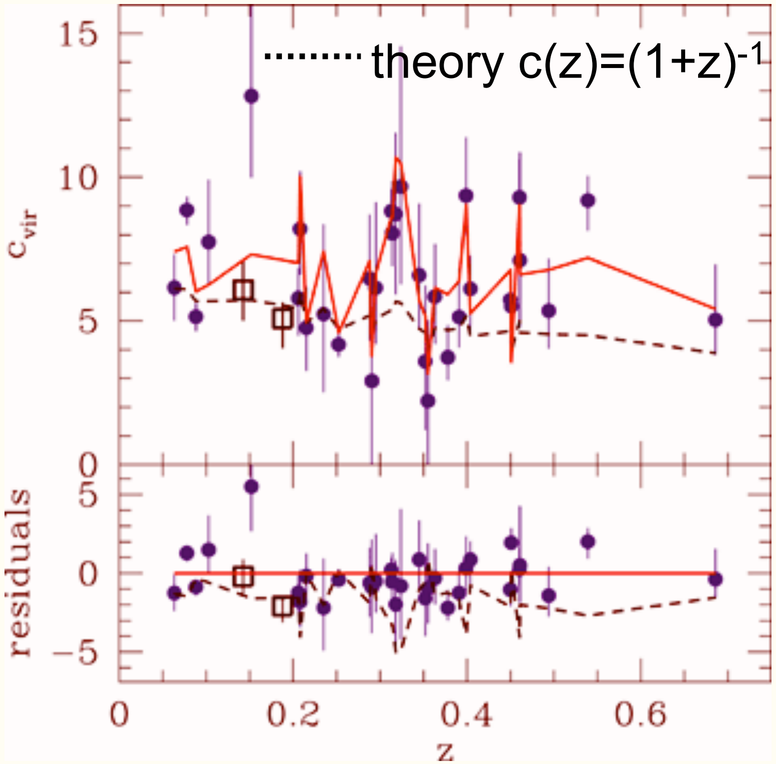


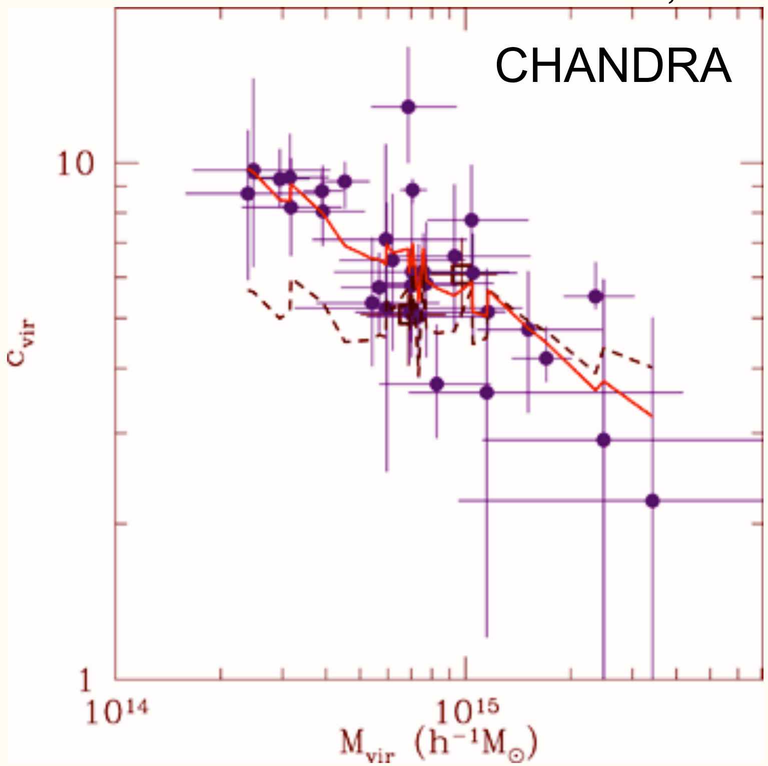
XMM/Chandra: precise mass profiles from kT(r) - n(r) and HE (relaxed clusters)

Universal profile
shape as expected from simulations

The dark matter profile evolution

Schmidt & Allen, 07





Smaller evolution?

or an artefact of steeper c-M ?

Still large uncertainties (e.g from T(r) mapped up to $0.3R_{200}$ only)

Evolution study just starting …

Gas scaling properties

- Standard self similar model

  ICM evolving in the gravitational potential of the DM

  - universal gas profiles as for the DM
  - scaling laws from

    1) $GM/R^3 = \langle\rho\rangle = \delta\ \rho_c(z) = \delta\ h^2(z)$; δ~500-200

    2) The virial theorem: $kT\ \alpha\ GM/R$

    e.g: $M\ \alpha\ h^{-1}(z)\ T^{3/2}$; $L_x\ \alpha\ h(z)\ T^2$

- Observation local clusters: 'modified' self-similarity

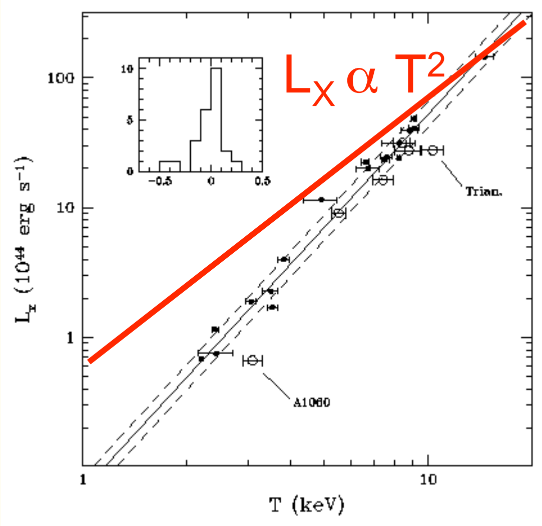
  effect of non gravitat. processes:

  cooling and/or AGN/SN heating

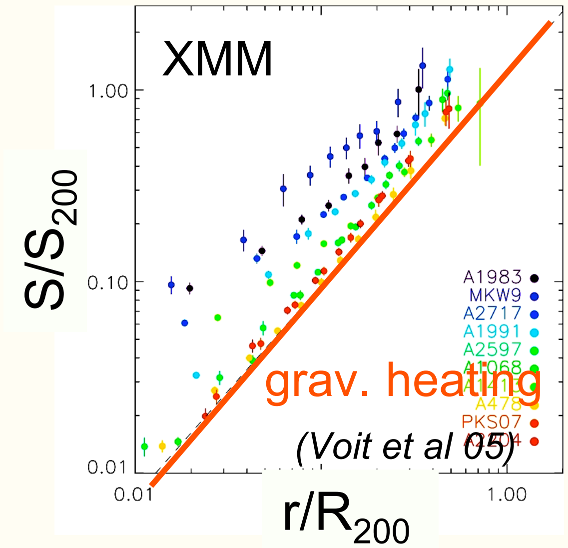
- Interest of evolution study:

  understand physics of structure formation

  empirical X-M laws when using clusters for cosmology



Arnaud & Evrard, 99



Pratt, Arnaud & Pointecouteau, 06

The challenge of evolution studies (1)

An illustration: the *most studied* L_X-T

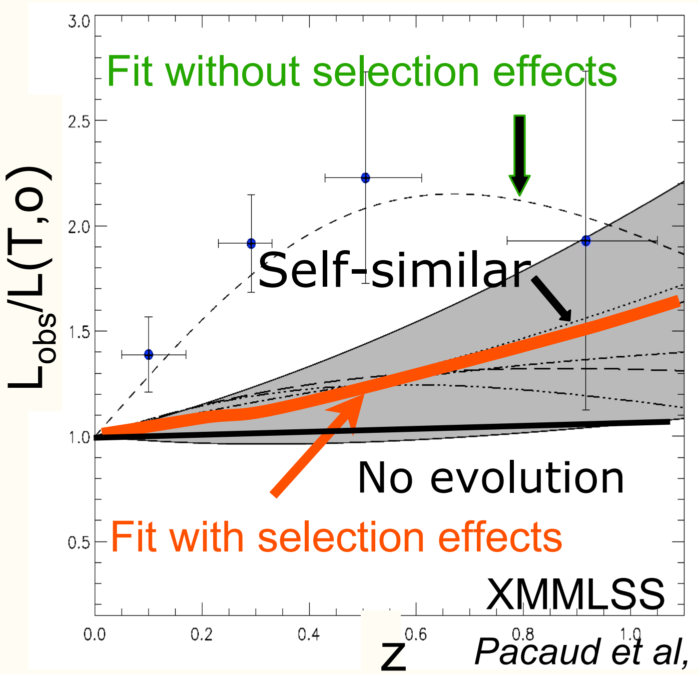
expected: L(T,z) = L(T,0) [h(z)~$(1+z)^{0.6\text{-}0.9}$]

observed: no consensus

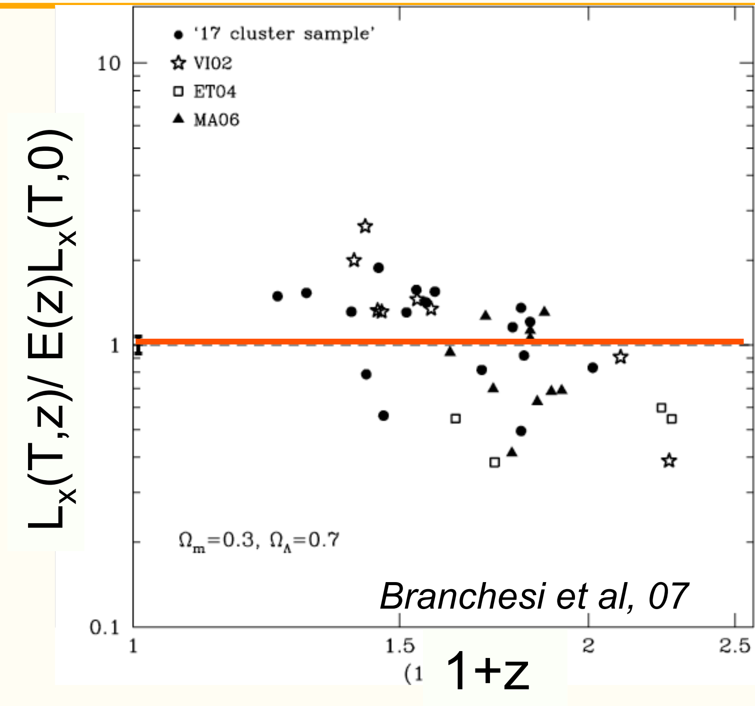
larger: $(1+z)^{1.8\pm0.3}$ *[Kotov & Vikhlinin, 05]*

smaller: h(z) $(1+z)^{-1.04\pm0.3}$ *[Ettori et al 04]*

larger or smaller depending on z ?



Pacaud et al, 07



Branchesi et al, 07

and must take into account Malmquist bias:

⇒ evolution as expected ?

The challenge of evolution studies (2)

- Expected 'standard' evolution is not large: $h(z) \nearrow 30\%$ @ $z=0.5$ for ΛCDM

  ⇒High precision required to measure deviations from standard model

- Decreasing systematics is the main issue
- Recent progresses from :
  - archival Chandra/XMM studies

    ⇒ (now) large samples covering $0.2 < z < 1$

    ⇒ quantities derived from same instrument and with same method/definition

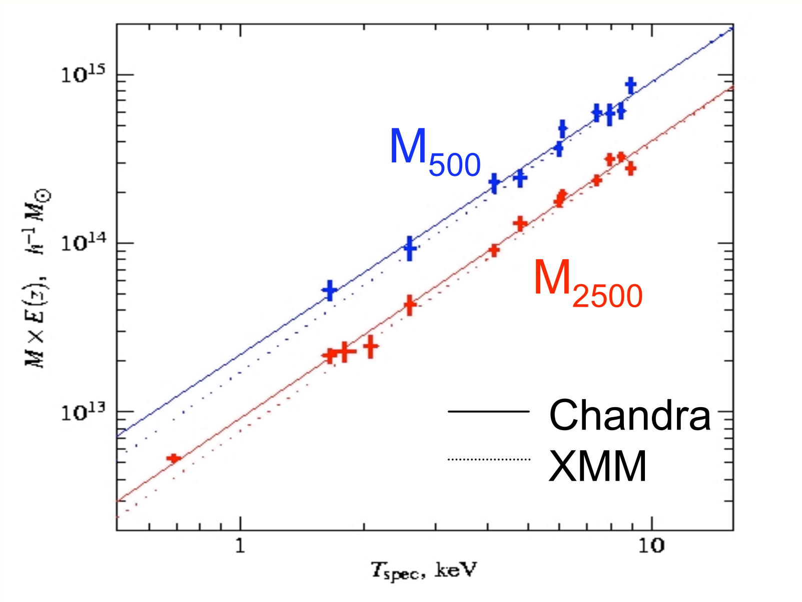
    10% syst on T_X due to cross-calibration ≡ 30% syst on L_X ≡ standard evolution

  - better estimate of 'virial' radius R_{500}
    - need to compare quantities @ various z within given fraction of R_{500}
    - use (now better understood/calibrated) mass-proxy relations rather than HE eq. specially for unrelaxed clusters and too poor stat. data

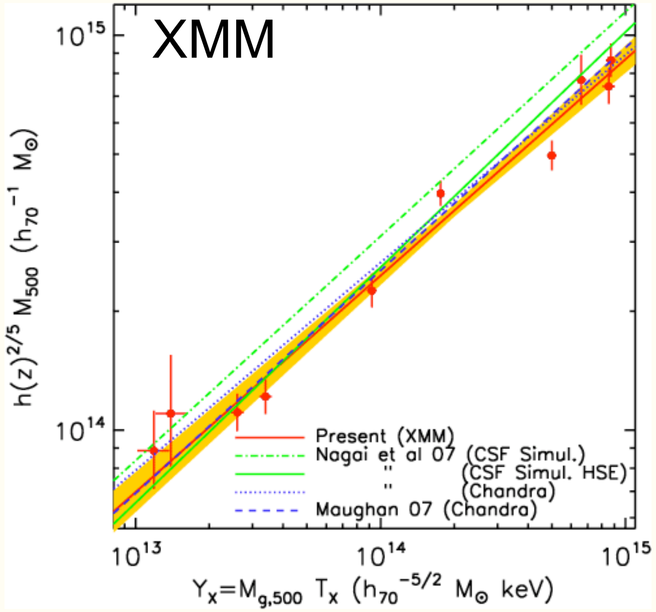
- More (on going) progresses from dedicated LP on 'unbiaised' cluster samples including at $z \sim 0$

The (fundamental) mass - proxy relations

not only for R_v but also to compare observ. with theory (N(M,z); gas prop versus M)



Vikhlinin et al, 05;
comp: Arnaud, Pointecouteau & Pratt, 05



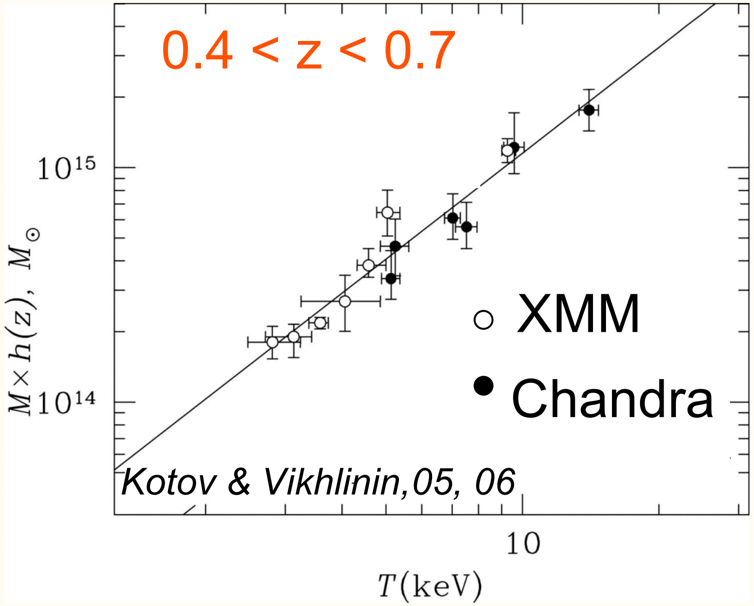
Arnaud, Pointecouteau & Pratt, 07
comp: Nagai et al, 07; Maughan 07

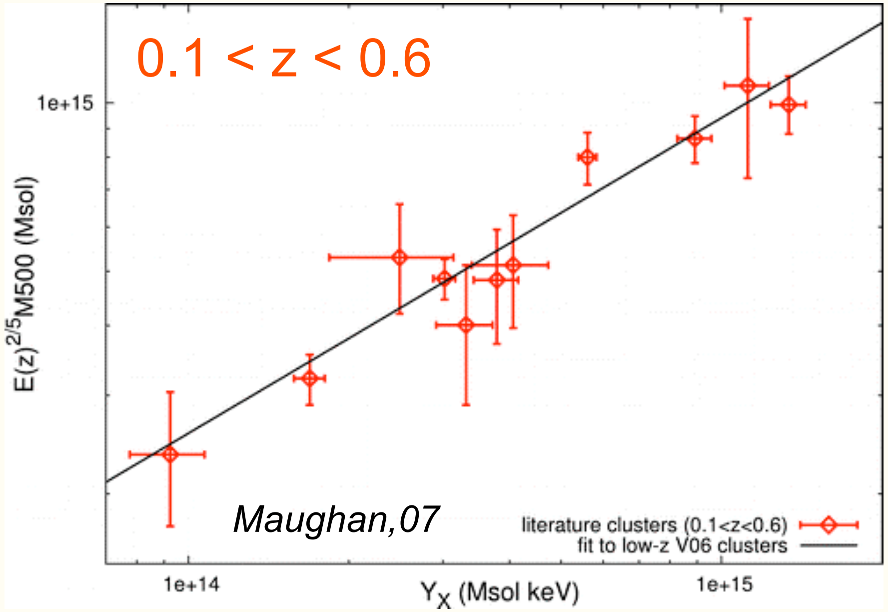
Y_X: expected robust *new* proxy *(Kravtsov et al, 06)*

Precise converging calibration of the *local* M-T and M-Y_X relations
(normalisations differ from pure grav. models)

The mass - proxy relations : evolution

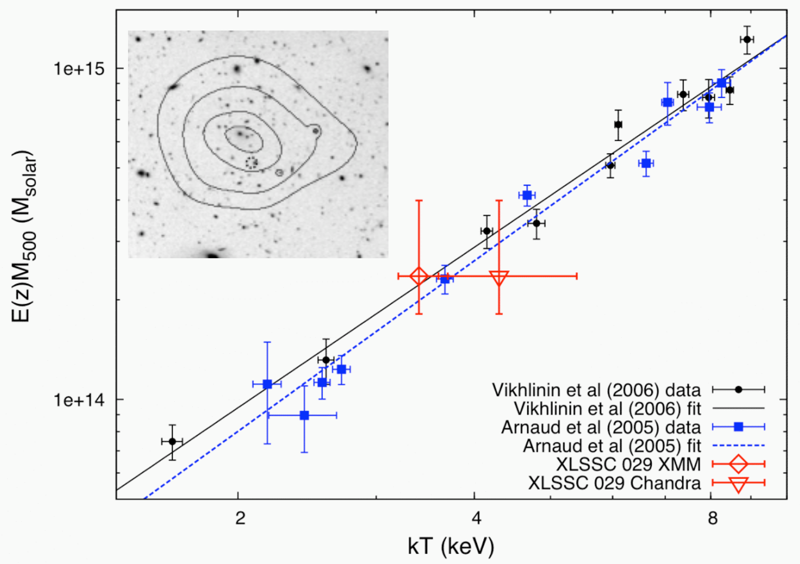
Mass at high z from HE and spatially resolved kT profiles

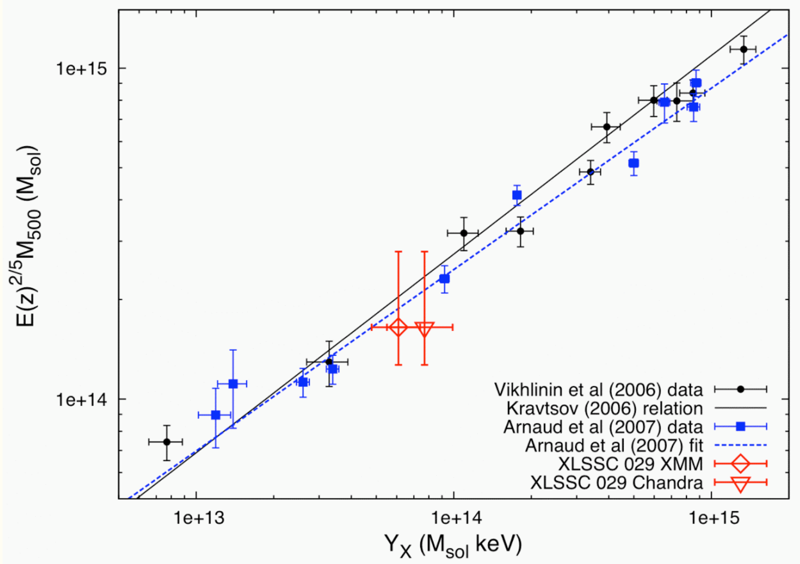




$M_{500} = h(z)^{1.02\pm0.20}\ T^{3/2}$

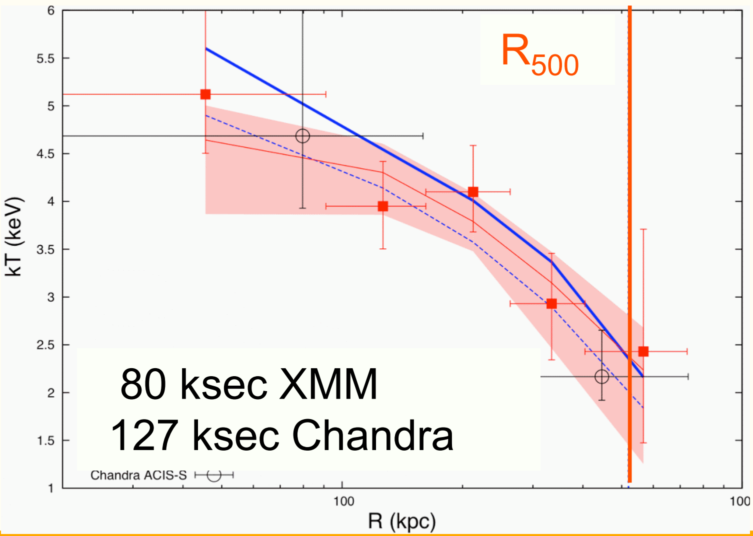
Standard evolution





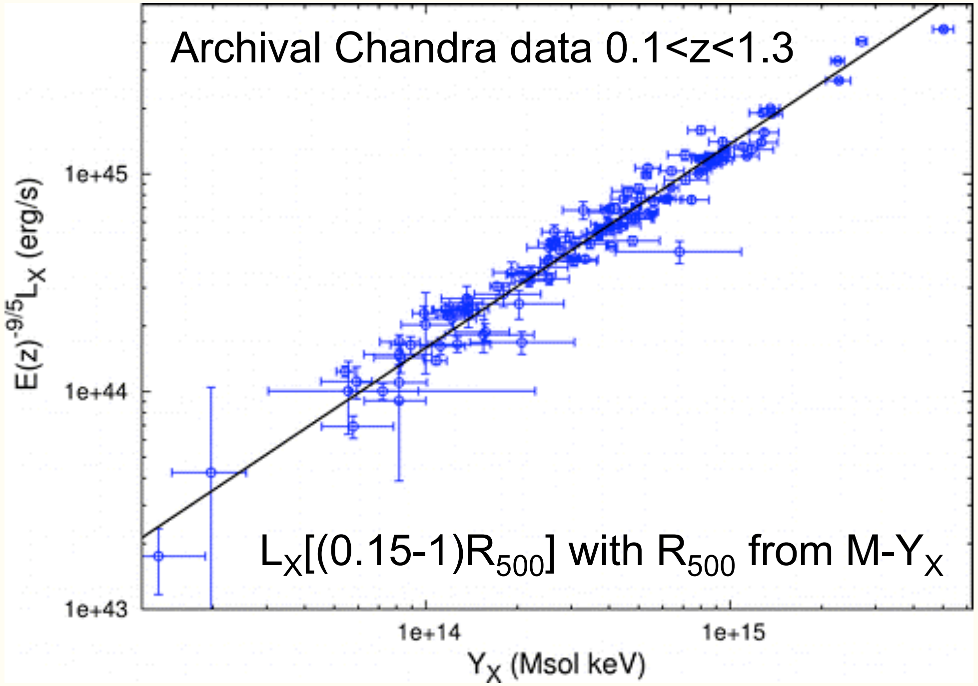
Maughan et al, 08

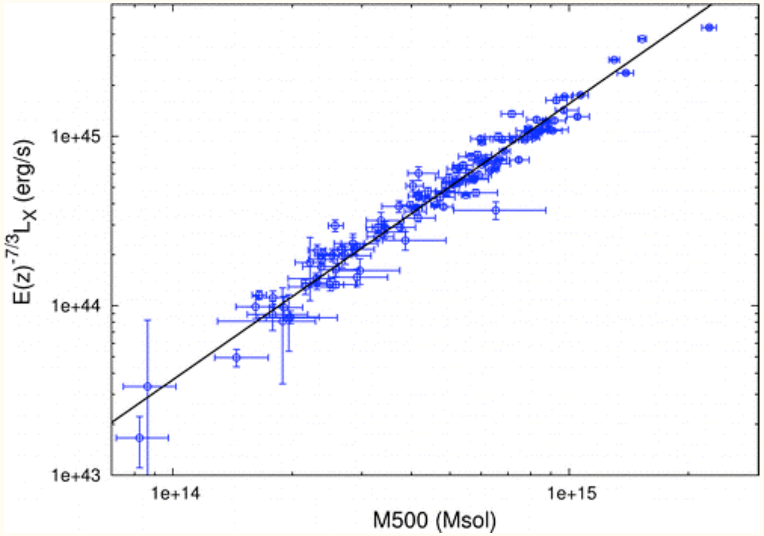
XLSSJ022403.9 z=1.05



(likely) up to z ~ 1

The gas properties - Y_X relations





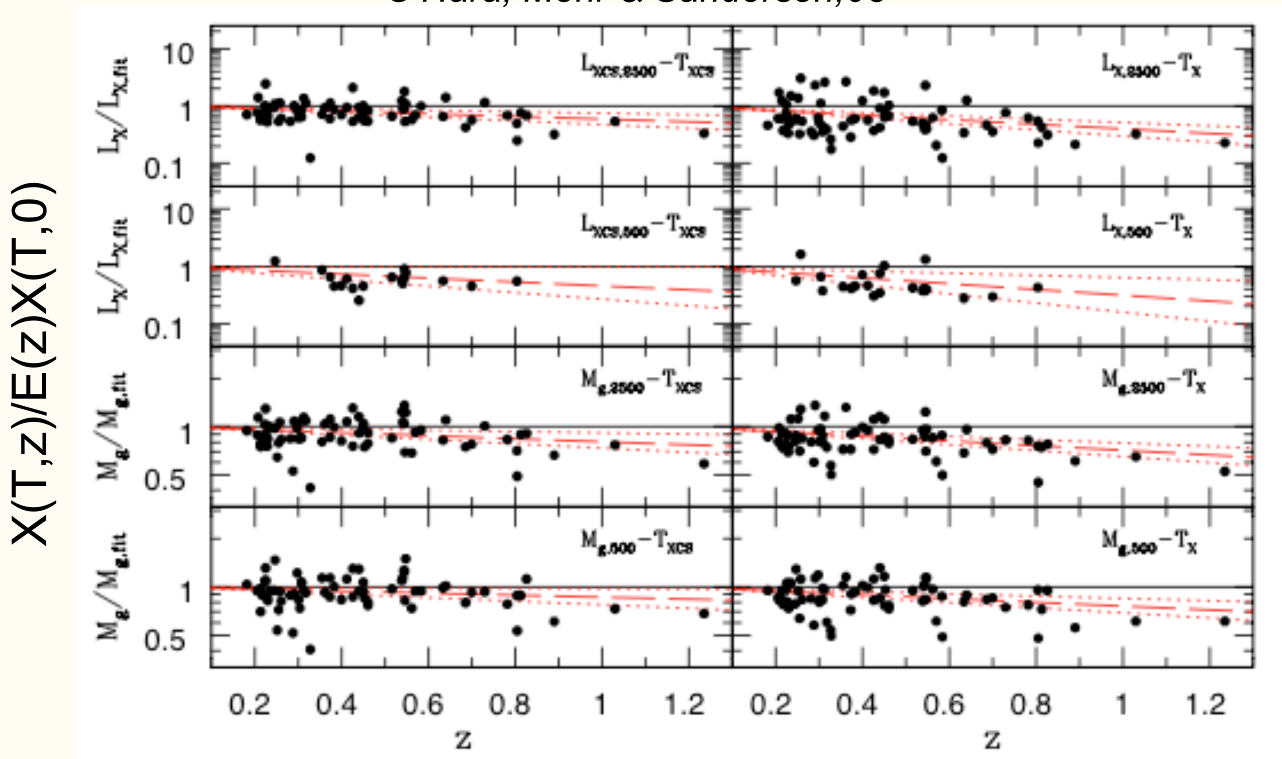
Maughan, 07

Scatter 3 lower for L_x with core excluded ⇒ L_x also a ‘good’ mass proxy

Standard evolution

The gas properties - T_X relations

O'Hara, Mohr & Sanderson,08



Chandra
archival data

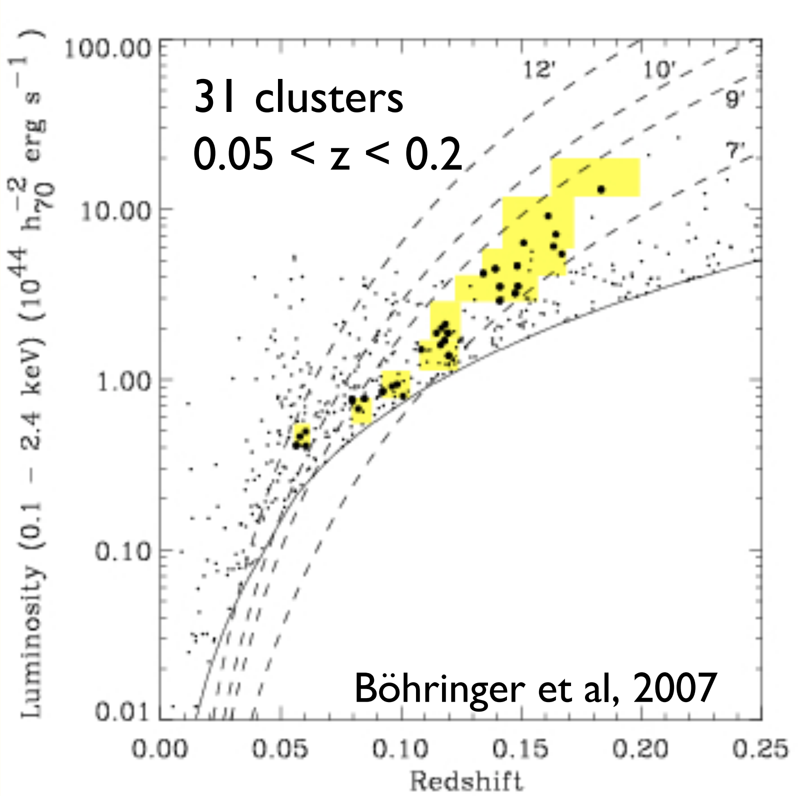
$R_{500\text{-}2500}$ from h(z)R-T calibrated at z=0; assume slope indpt z

Less evolution than in standard model

consistent with $f_{gas} \equiv (1+z)^{-0.39\pm0.13}$
more consistent with SSM when core excluded (CC evolution)

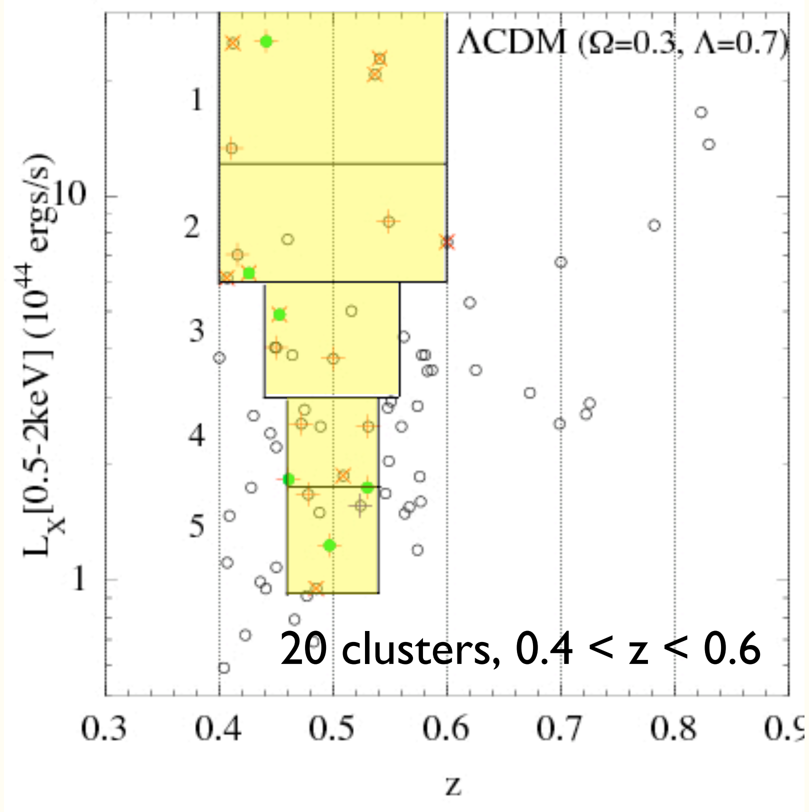
Evolution from representative cluster samples

REXCESS XMM-LP



Pratt et al, 07; Croston et al, 08

distant cluster XMM-LP (PI: MA)

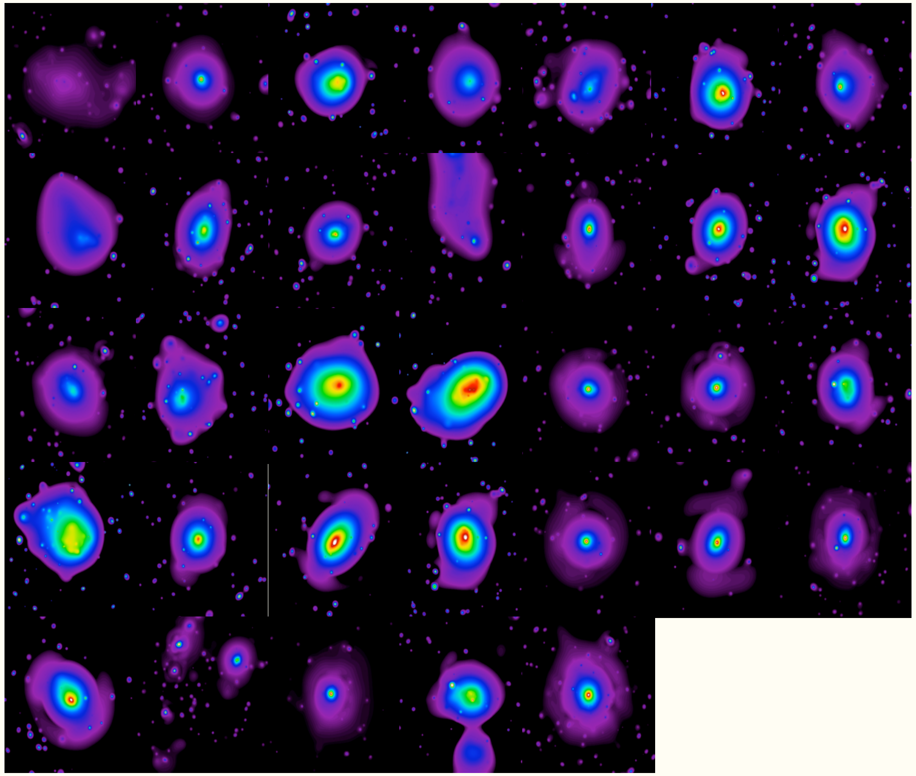


Selected in log(Lx) bin

⇒ 'unbaised'

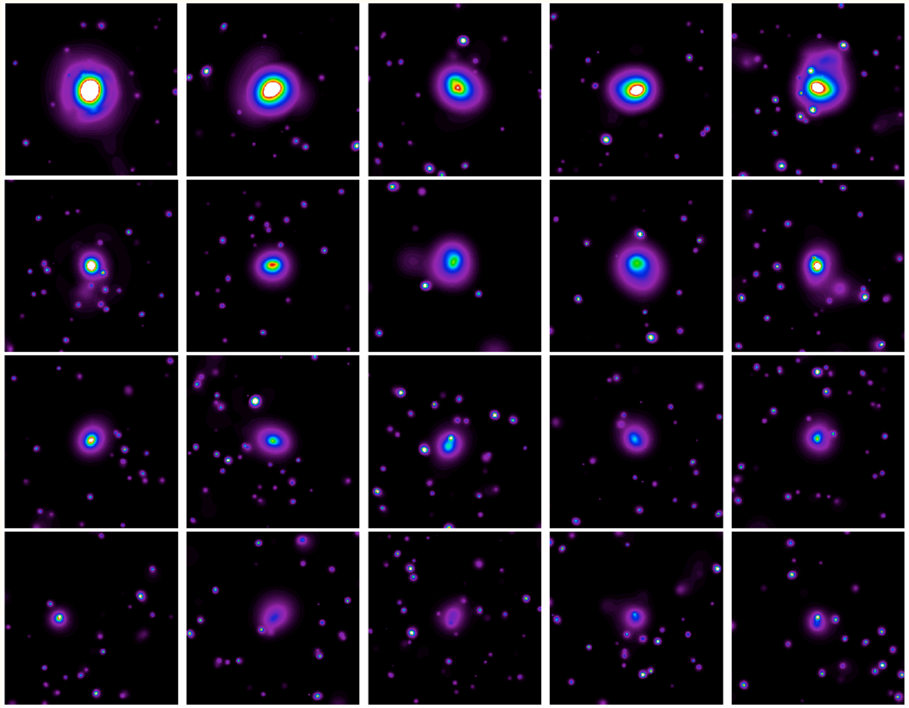
⇒ good coverage of 2-10 keV range ⇒ slope evolution

Evolution from representative cluster samples (cont)



Böhringer et al, 2007

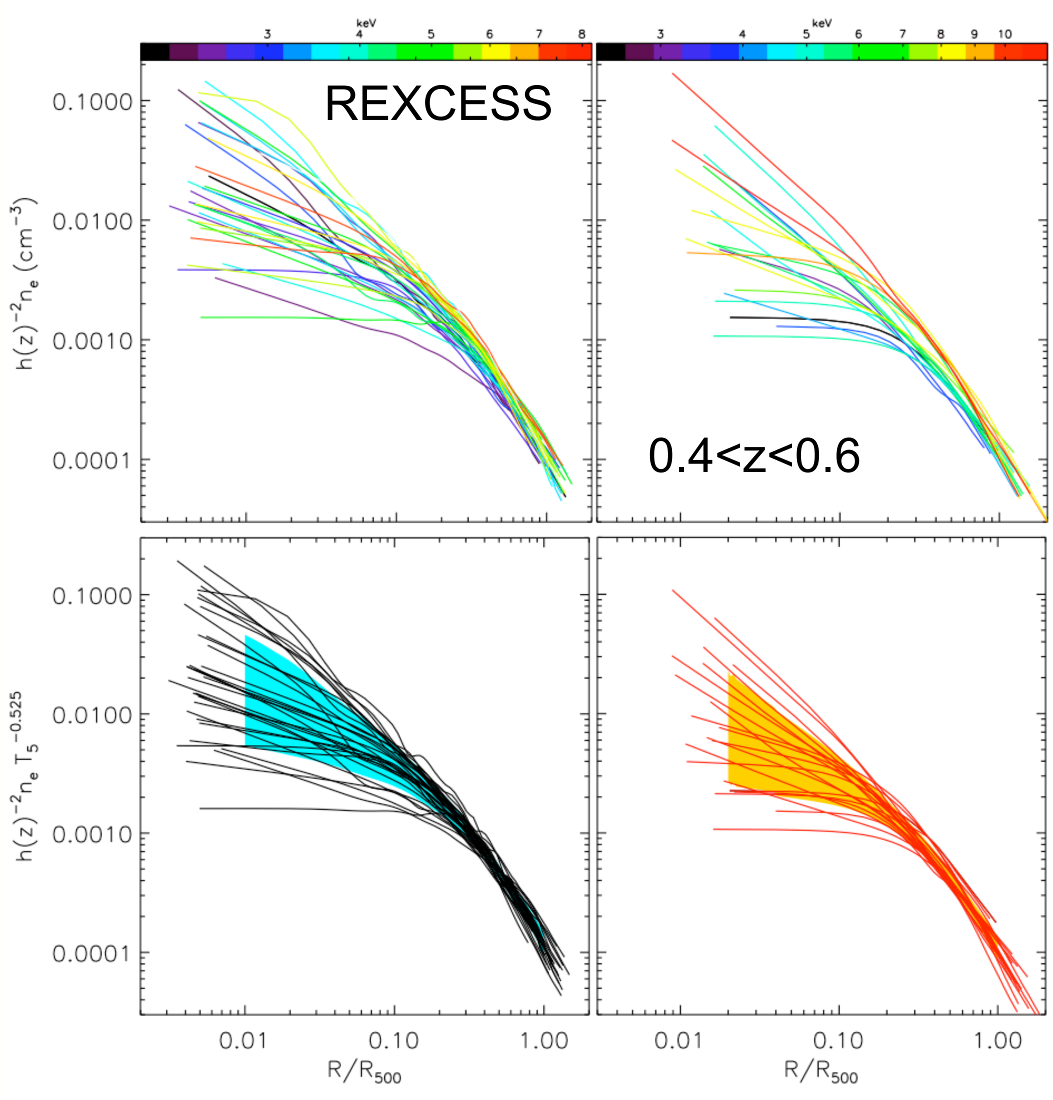
REXCESS



Arnaud, Jetha, Pointecouteau, Pratt, Bohringer et.al

0.4 < z < 0.6 sample

Evolution from representative cluster samples (cont)

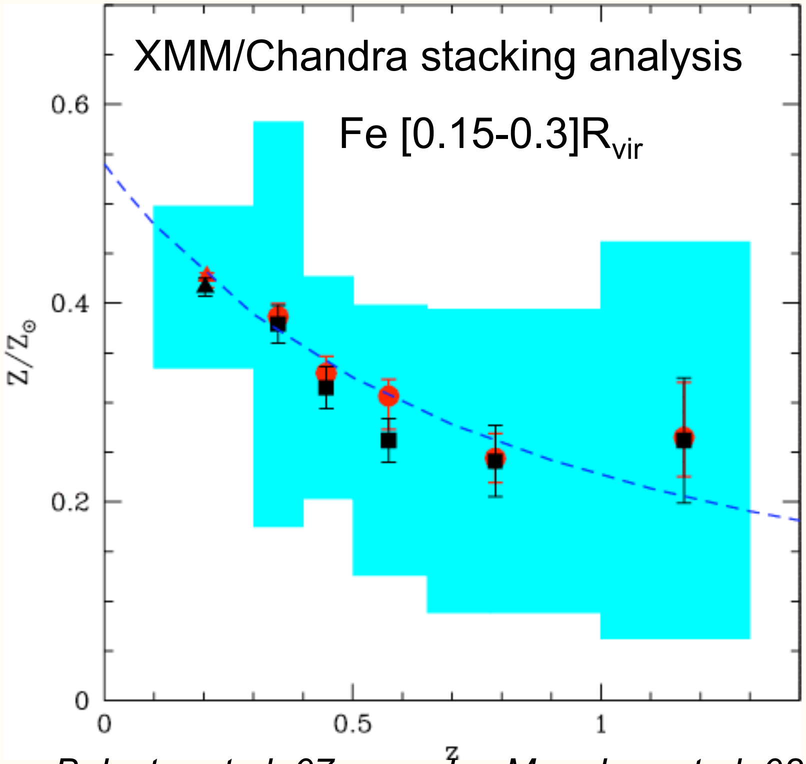


R_{500} from $h(z)^{2/5}$ M_{500} - Y_X

REXCESS: adapted from Croston et al, 08
Distant sample: Pointecouteau et al in prep

(Slight) departure from Standard evolution

More on baryon physics



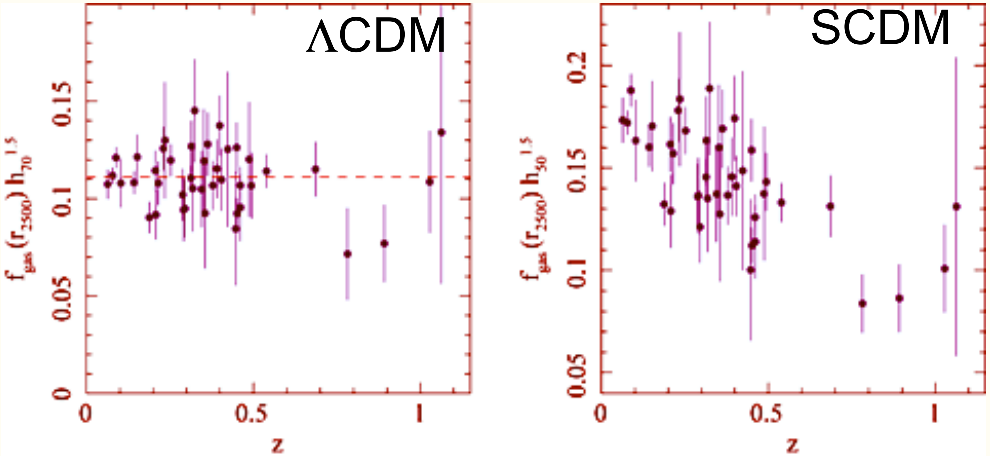
Balestra et al, 07; see also Maughan et al, 08

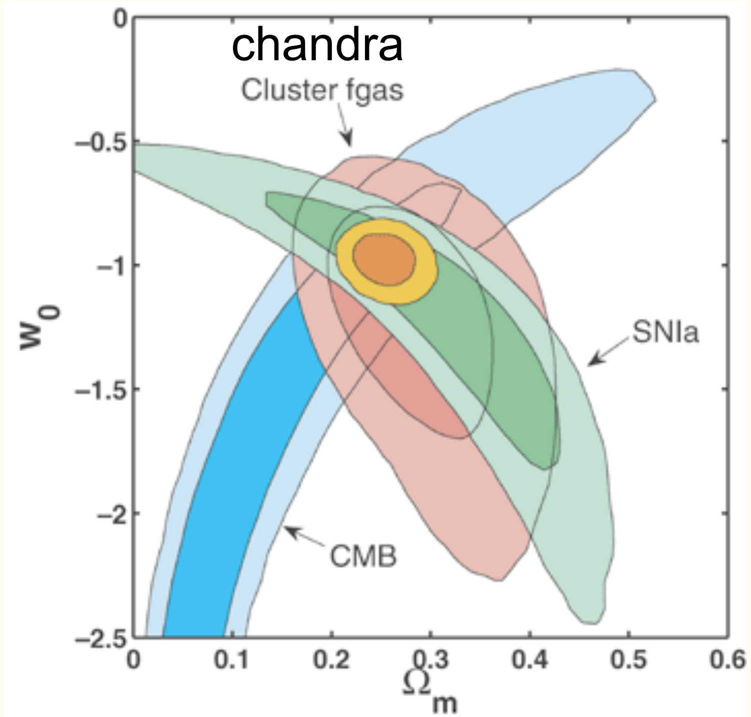
First evidence of significant decrease of Fe abundance with z

Might be due to progressive sinking of low entropy gas enriched at high z *(Cora et al, 06)*

Cosmology with clusters
and
cluster surveys

Cosmology from gas mass fraction





Allen et al, 08

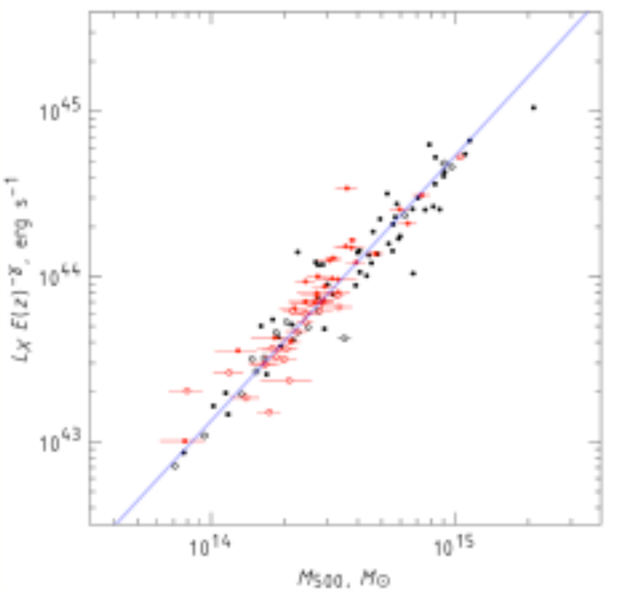
Principle:

$$f_{gas}\,(1 + f_{gal}/f_{gas}) = \Omega_b/\,\Omega_m$$

Normalisation ⇒ Ω_m

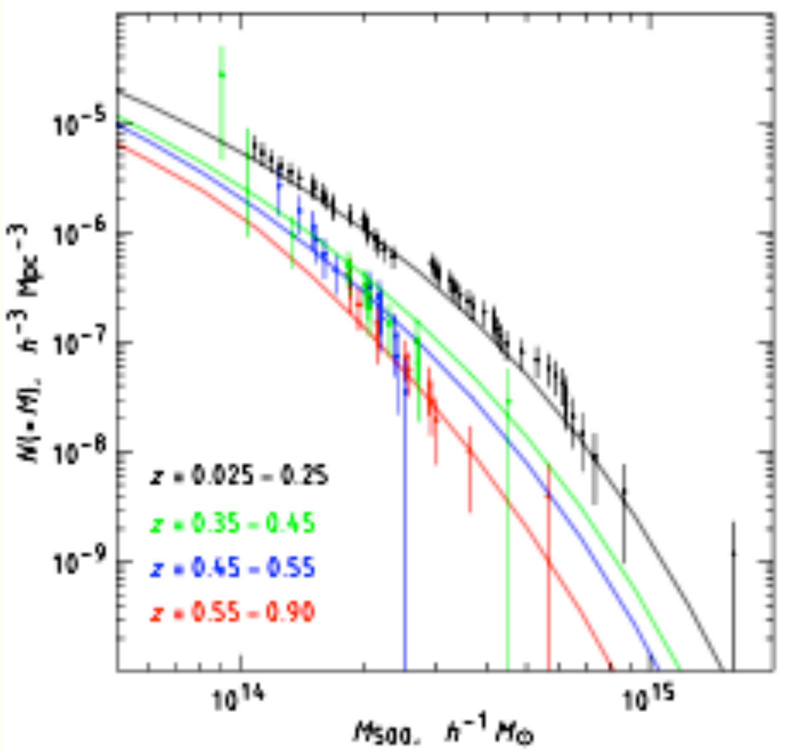
Distance indicator (as SNI) ⇒ $\Omega_m\ \Omega_\Lambda\quad w$

Evolution of the mass function



Chandra follow-up of flux limited RASS and 400SD (sub)samples

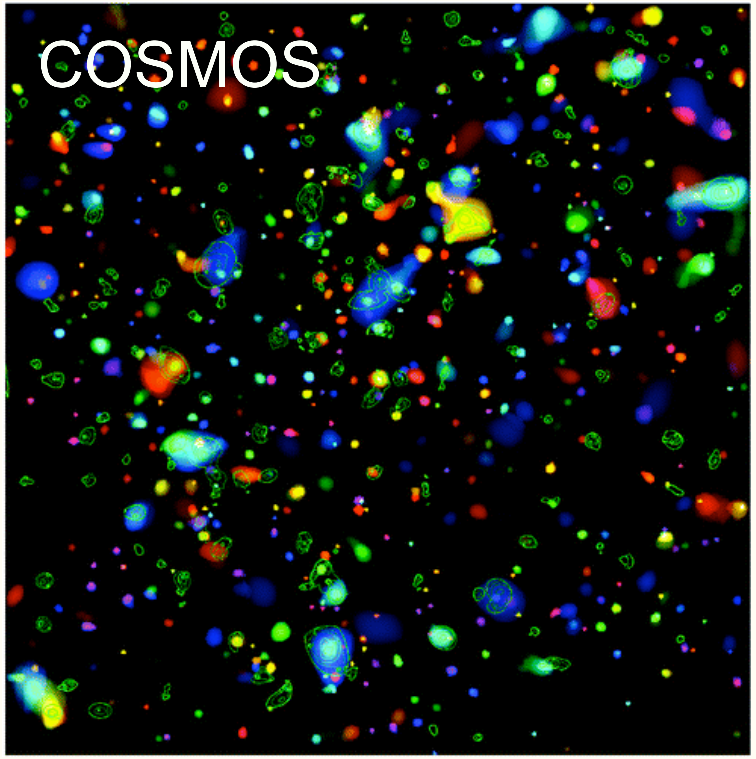
M and L_x - M (selection function) from precise mass-proxy relations with correction of Malquist bias



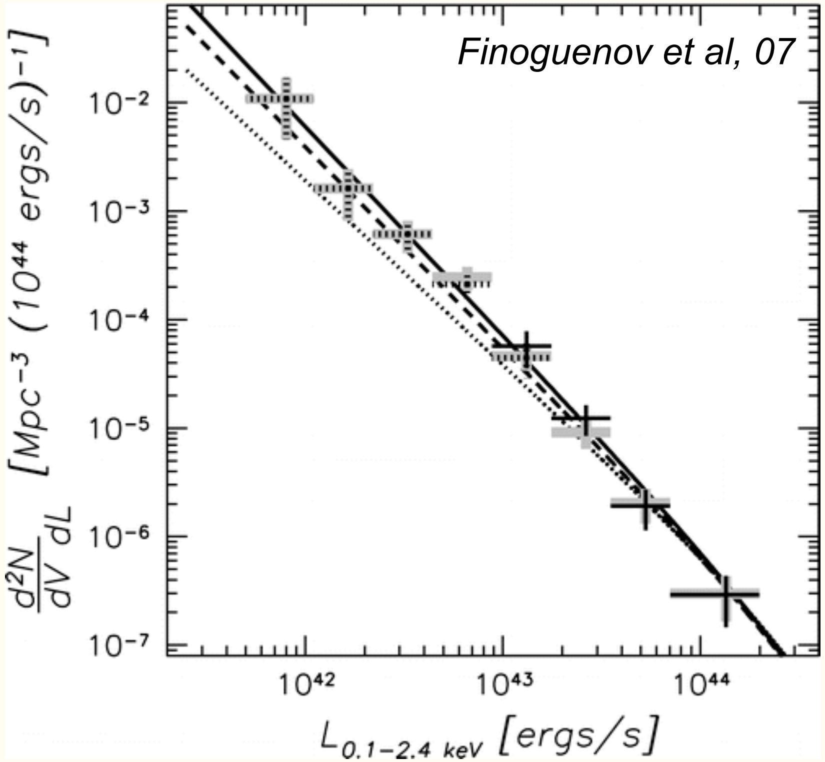
Vikhlinin et al, 08

Evolution
as expected in concordance cosmology

New (XMM) cluster surveys (1)



XMM-LP:
72 cluster/groups up to z=1.25

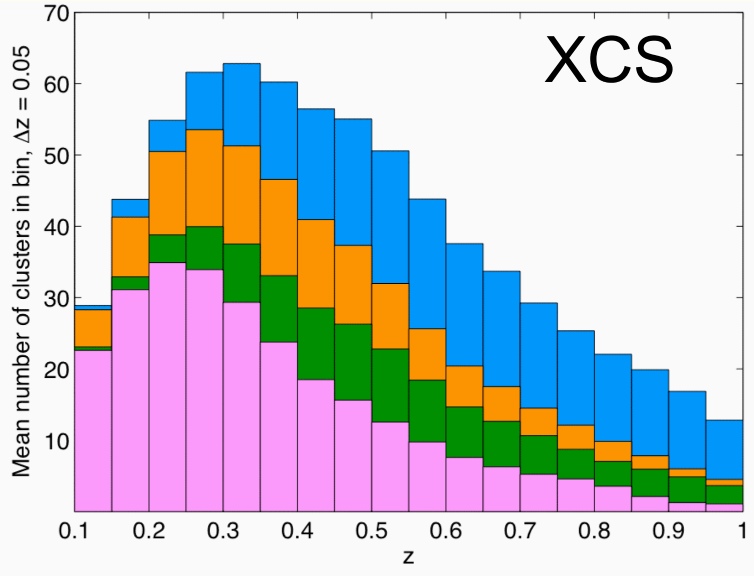


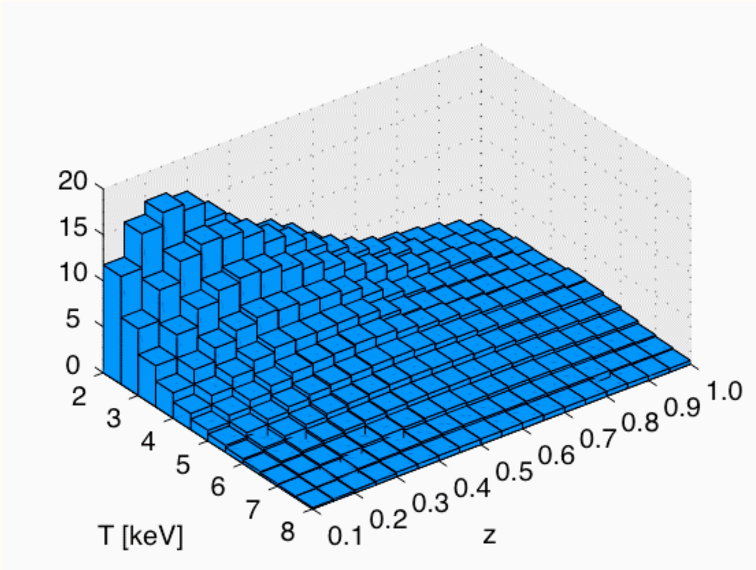
Probe evolution of the faint end of XLF

No significant evolution up to z=1.3

Consistent COSMOS and XMMLSS (Pacaud etal, 07) results

New (XMM) cluster surveys (2)





Sahlen et al, 08

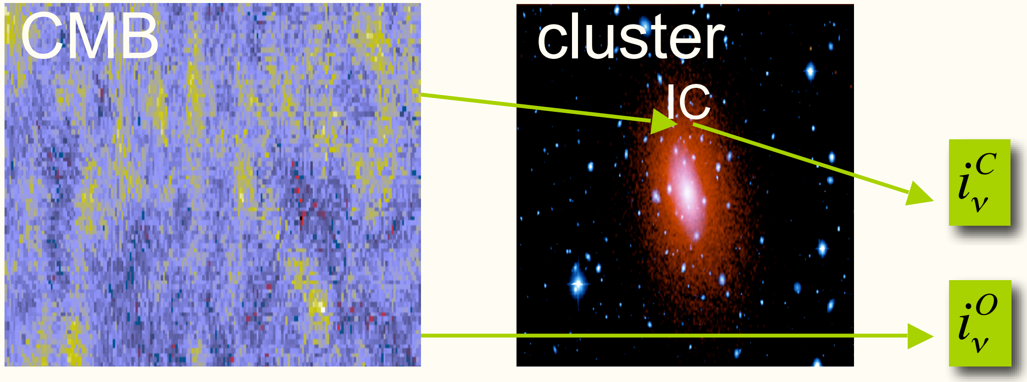
XCS: serendipitous survey from XMM archive

- Area 500 deg^2
- Clusters (> 500 cts ⇒ kT): 250-700 (124 with z so far))
- Mesure Ω_m and σ_8 to ~5% accuracy
- Evolution of scaling relations: first results see Llyod -Davies talk

Prospects with SZ (Planck) surveys

combined with XMM follow-up

Gain from SZ surveying

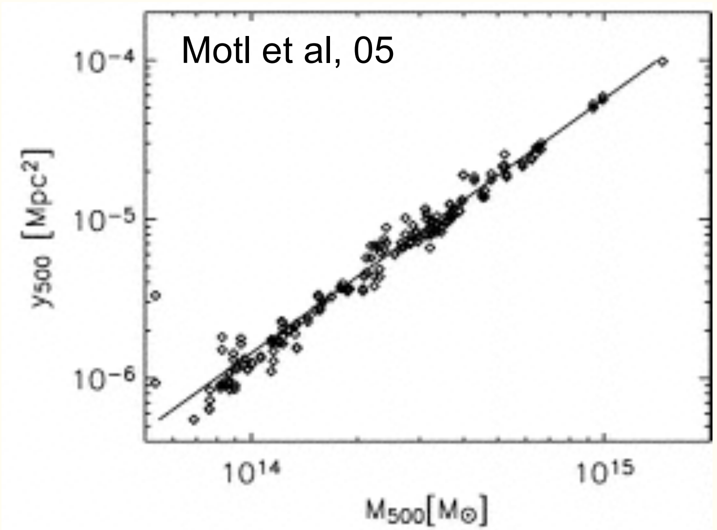


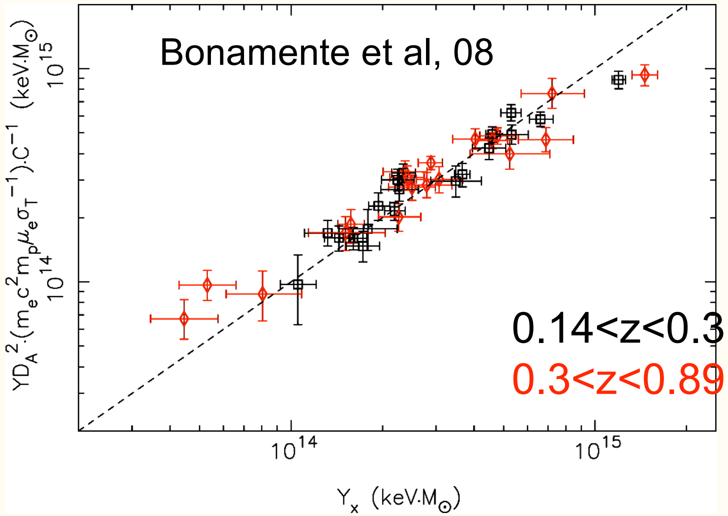
$$\Delta i_\nu \; \alpha \; y \; \alpha \int_{los} n_e T dl$$

no $(1+z)^4$ dimming

$$Y = \int_{amas} y \, d\Omega \; \alpha \; \frac{M_{gaz} T}{D_A^2(z)}$$

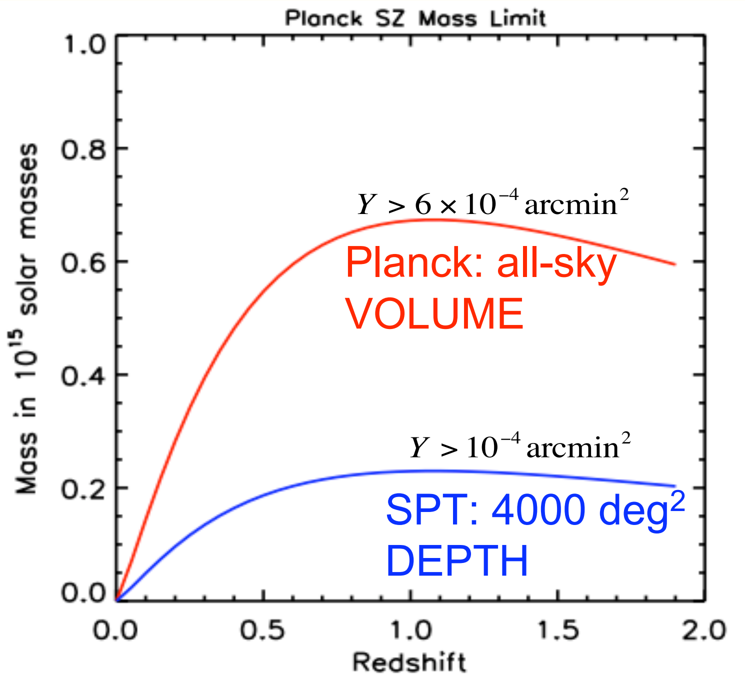
gas thermal energy

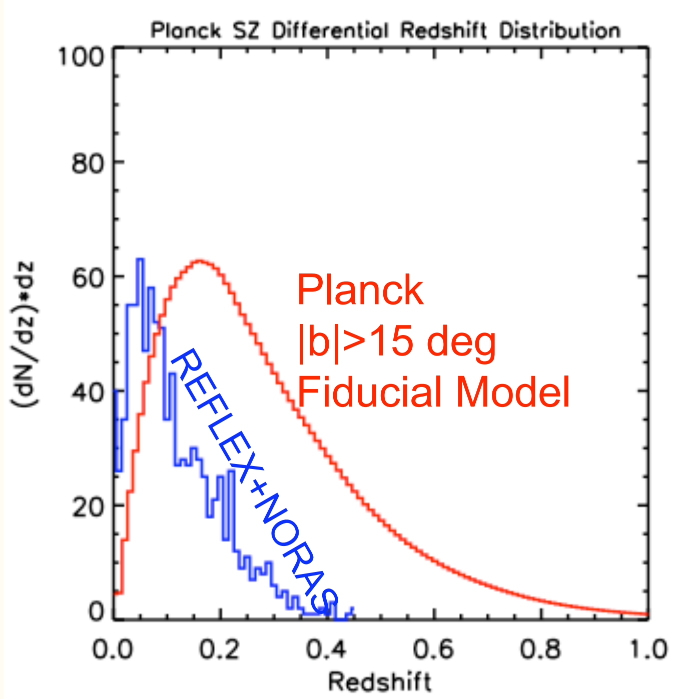




Closely related to the mass

Planck SZ survey

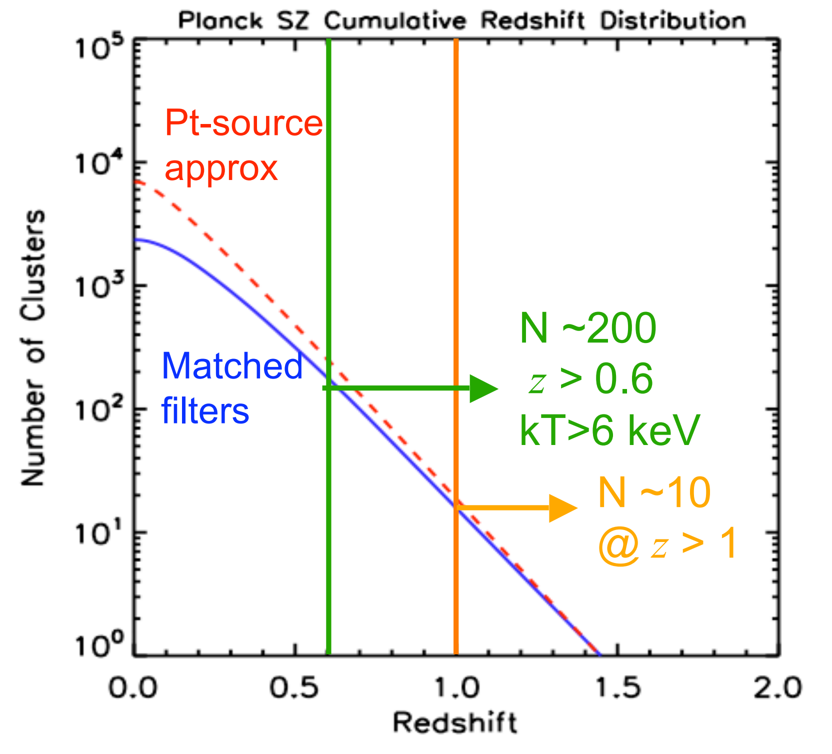




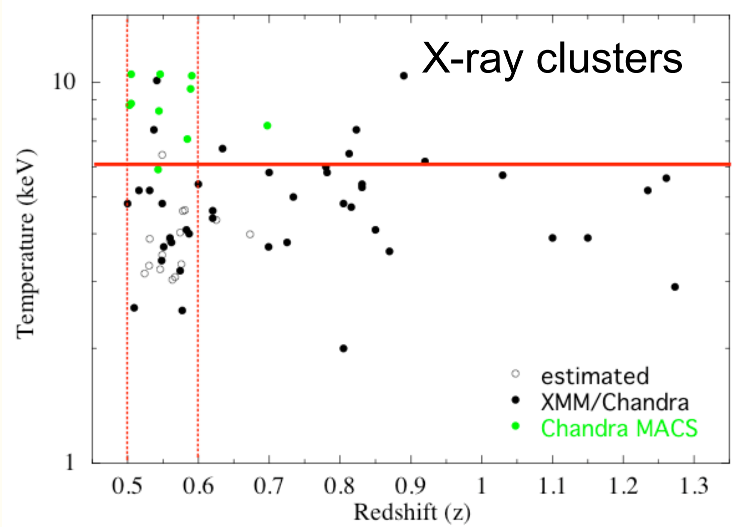
Courtesy of A. Chamballu & J.Barlett; See also Bartlett et al, AN, 08

Close to mass selected survey
Efficient at high z

Planck SZ survey (cont)



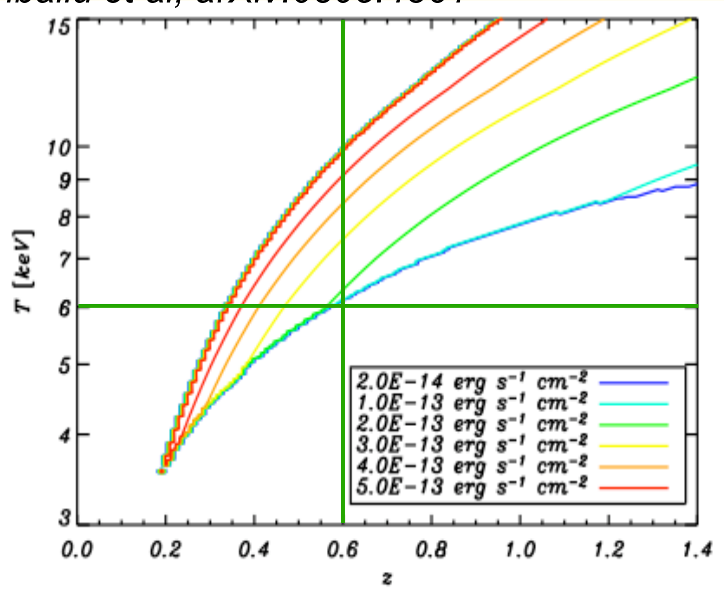
Courtesy of A. Chamballu, J.Barlett & J.B Melin



~50-fold increase in sample size of massive clusters

combined with XMM follow-up (example)

Chamballu et al, arXiv:0805.4361



X-ray bright clusters: S_x[0.5-2]keV >10^{-13} cgs

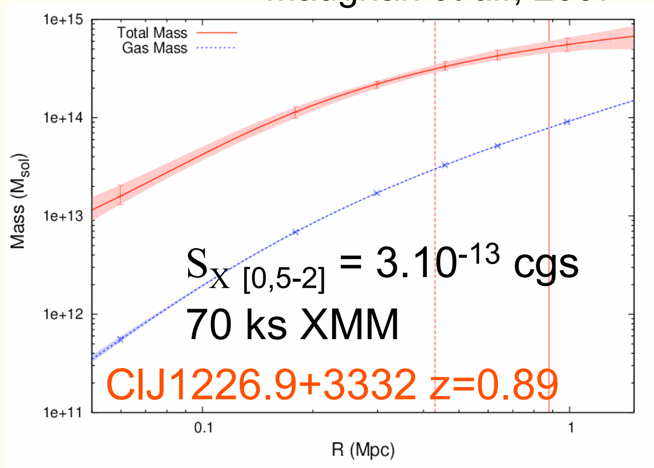
kT with 10% errors and kT profiles with

25-70 ks XMM per cluster

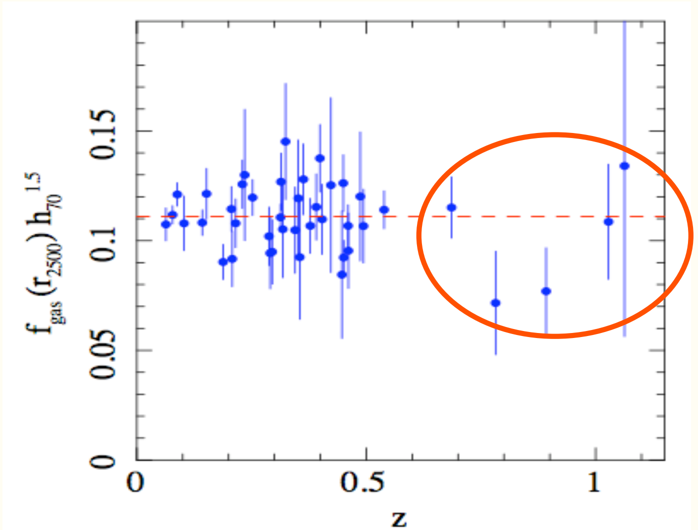
⇒ Cosmology from f_{gas} and
N(Y_{SZ},z) with well calibrated M- Y_{SZ}

⇒ Full test of DM collapse models

Maughan *et al.*, 2007



Precise mass profiles



and f_{gas} on much larger sample

CONCLUSION

Significant progress in the determination of the evolution of cluster properties (decrease of systematical errors).

Mass - (new) proxy relations evolve as in standard model
=> good new for cosmology using clusters
=> Still need to improve constrains on DM properties

Slight but significant deviations observed in gas scaling (Mg-T, Lx-T) relations.
=> new constrains on non grav effects models
=> Need to study the entropy evolution

Evolution of N(M,z) now established and extension of N(Lx,z) to low mass
=> more expected from XCS survey

Major step forward expected by combining XMM with forthcoming Planck data