Cluster parameter estimation and mass-observable relation for the XXL

Florian Pacaud

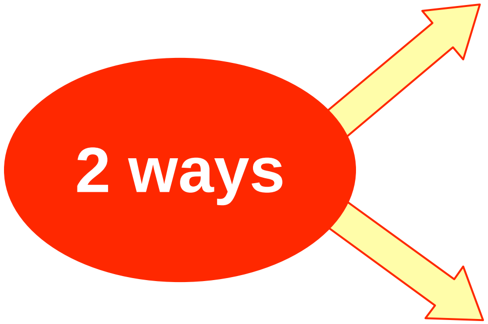
for the XMM-LSS collaboration

and *Greg Bryan*

How to handle the M-obs relation ?

Exploring the possibilities

[from J.-B. Melin's talk]

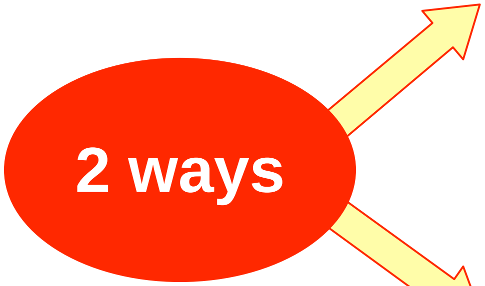


- Well controled mass-observable relations
  - External calibration, scaling relations
  - Self-calibration
  - Physical self-calibration
- Individual masses *to high precision*
  - From multi-wavelength data

How to handle the M-obs relation ?

Scaling relations ?

[from J.-B. Melin's talk]



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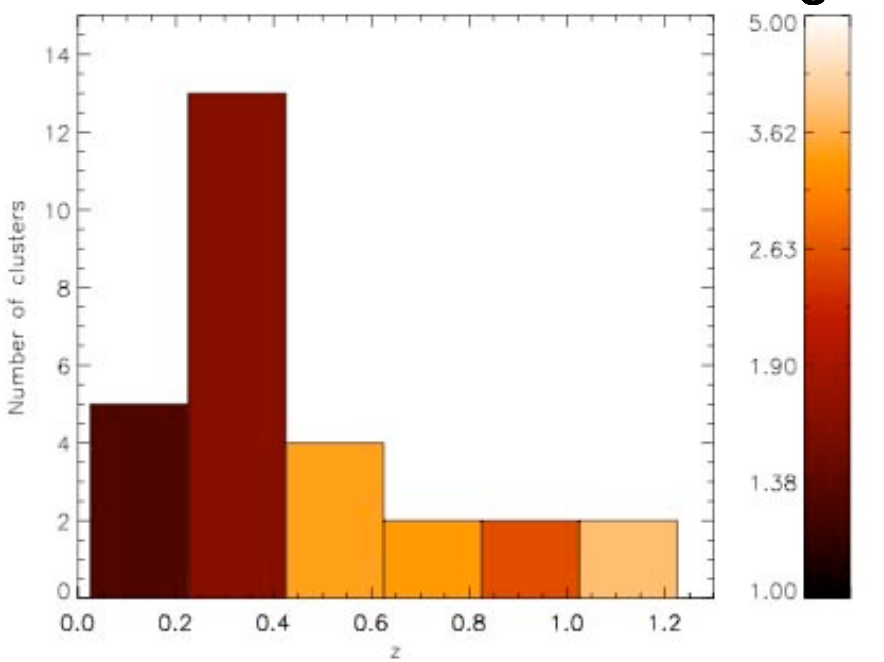
External scaling relations

We now have a good knowledge of X-ray scaling relations for T > 3 keV, z~0 galaxy clusters, e.g. :

- M-T : Arnaud et al 2005, Vikhlinin 2006
- M-L : Reiprich & Boehringer 2002
- L_X-T : Markevitch 1998, Arnaud & Evrard 1999
- M-Y_X: Arnaud, Pointecouteau & Pratt 2007

XMM-LSS distribution over 5deg²



BUT ...

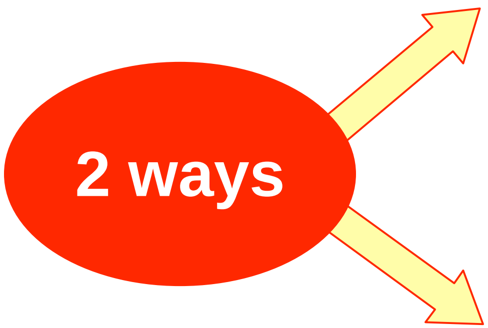
An XXL survey population would be dominated by T < 3keV, z > 0.2 clusters !

⇒ External relations are helpful but not sufficient

How to handle the M-obs relation ?

Self calibration ?

[from J.-B. Melin's talk]



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‘Physical’ self-calibration ?

G. Bryan’s contribution (Younger et al 2006)

Relies on a 2 step cluster model motivated by observations

Step 1 : Gas distribution in the absence of non-gravitational processes:

- NFW dark matter haloPerfect gas
- Hydrostatic equilibrium
- Gas mass conservation
- Outer boundary P_{vir} in the infall region

=> Baseline entropy profile from structure formation K(r)

Voit, Bryan, Balogh & Bower (2002),
Validated over simulations in Voit, Kay & Bryan (2005)

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Step 2 : Modified entropy distribution:

- Account for pre-heating of the ICM:

$$\mathbb{K}(r) = K(r) + K_0$$

- Cast the density as a function entropy:

$$\rho_g(r) = f(P,K) \Rightarrow f(P,\mathbb{K})$$

- Re-integrate the HE equation with same P_{vir}

=> Prediction for cluster the bulk properties of the ICM

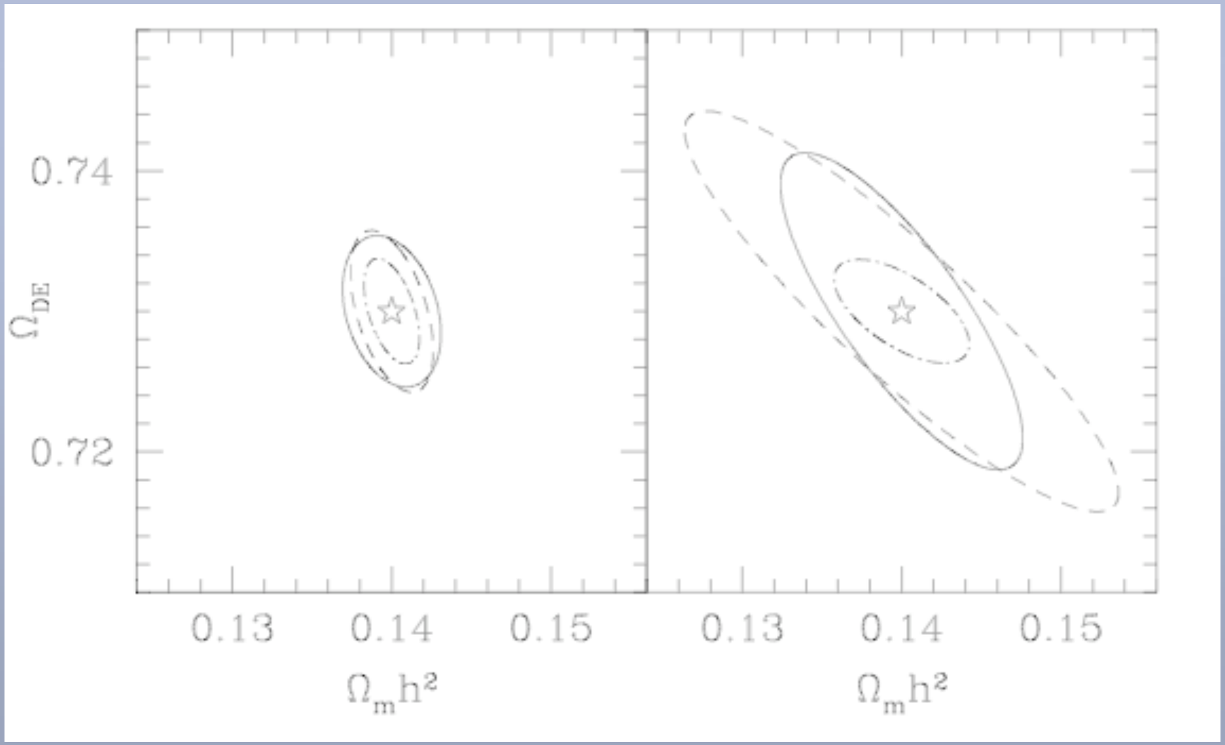
How to use it for self-calibration ?

Instead of assuming and self-calibrating power-law scaling relations:

- Describe all clusters with the above model
- Use $K_0(z)$ as free self-calibrated parameter
  (here in 40 bins of Δz=0.05)

4000 deg^2

SPT-like
SZ survey
+
S_{lim}=3.10^{14} cgs
X-ray survey



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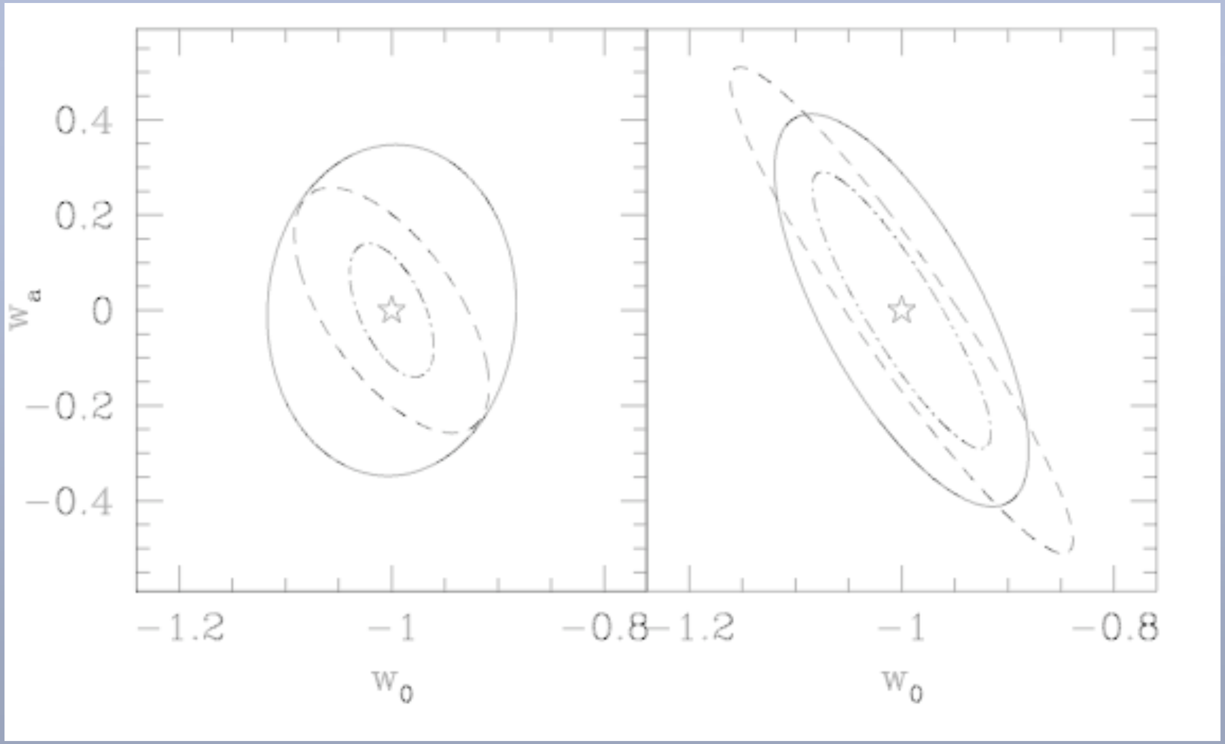


Physical self-calibration summary

- Factor 2-3 improvement on the constraints from dn/dz/dF as compared to standard self-calibration method using scaling relations

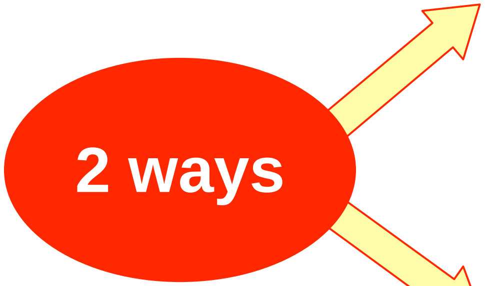
=> **preferable** **provided that the model is correct**

- Most of the improvement comes from tying together X-ray/SZ expectations: this effect doesn't hold on the precise physical model in use

- Still requires a **very large number of sources** so probably **not usable as such for the XXL**

How to handle the M-obs relation ?

[from J.-B. Melin's talk]



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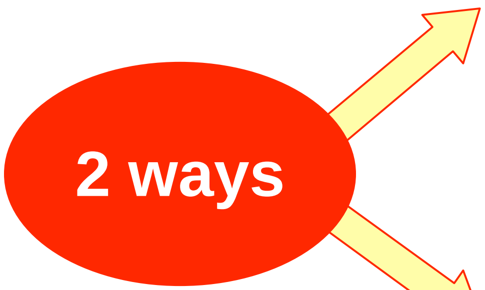

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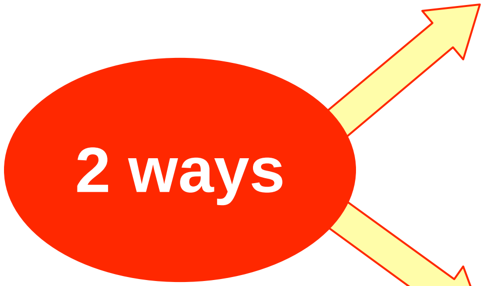

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  - First, what about X-ray alone ?

Using the X-ray data from the XXL

- In general using hydrostatic equilibrium

$$M = -\frac{rkT(r)}{G\mu m_p}\left(\frac{d\ln(T)}{d\ln(r)} + \frac{d\ln(n_e)}{d\ln(r)}\right)$$

- If clusters were exactly self-similar

  => unique T profile (all masses, all z)

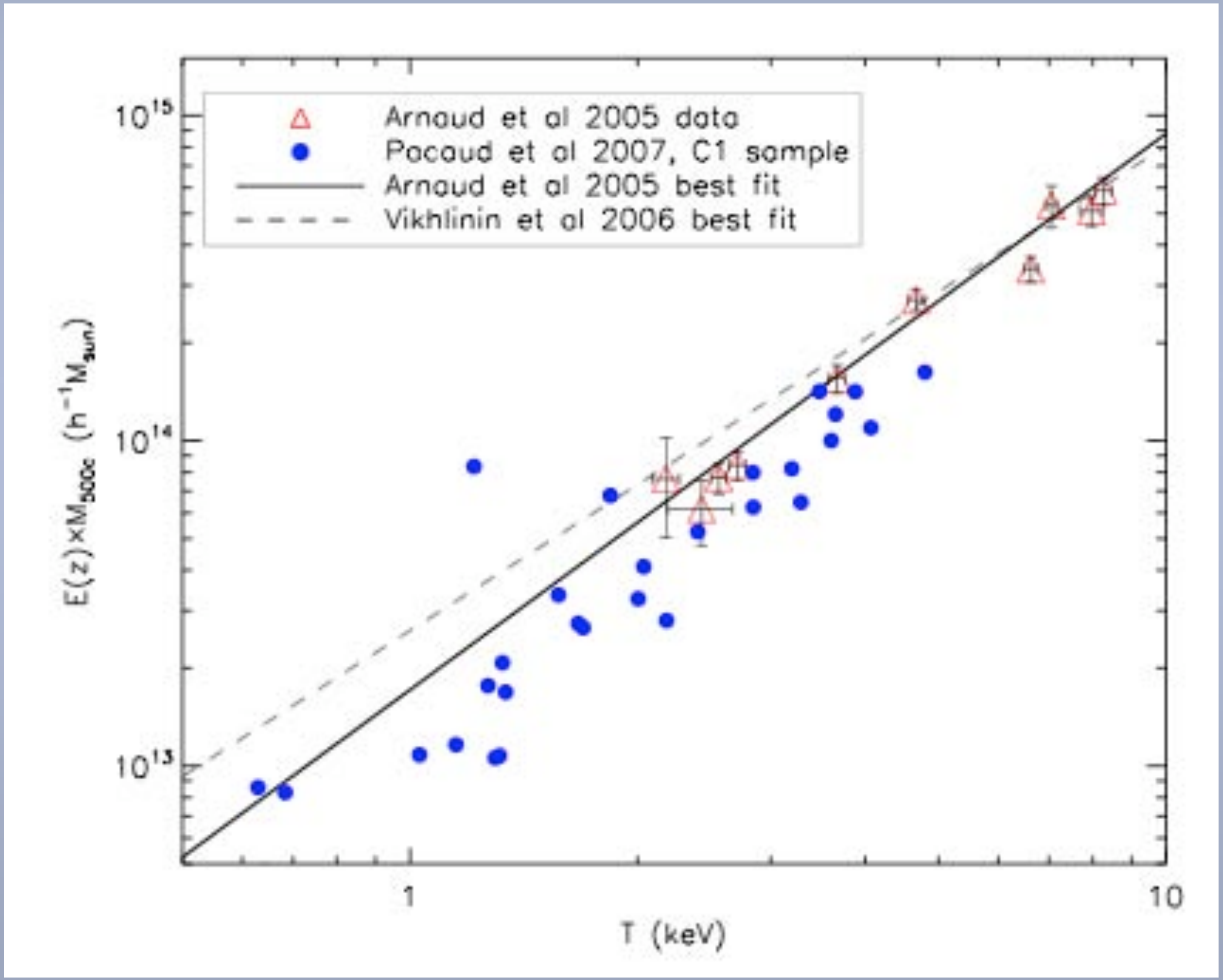
  => unique n_e profile

overall temperature would fully caracterise a system

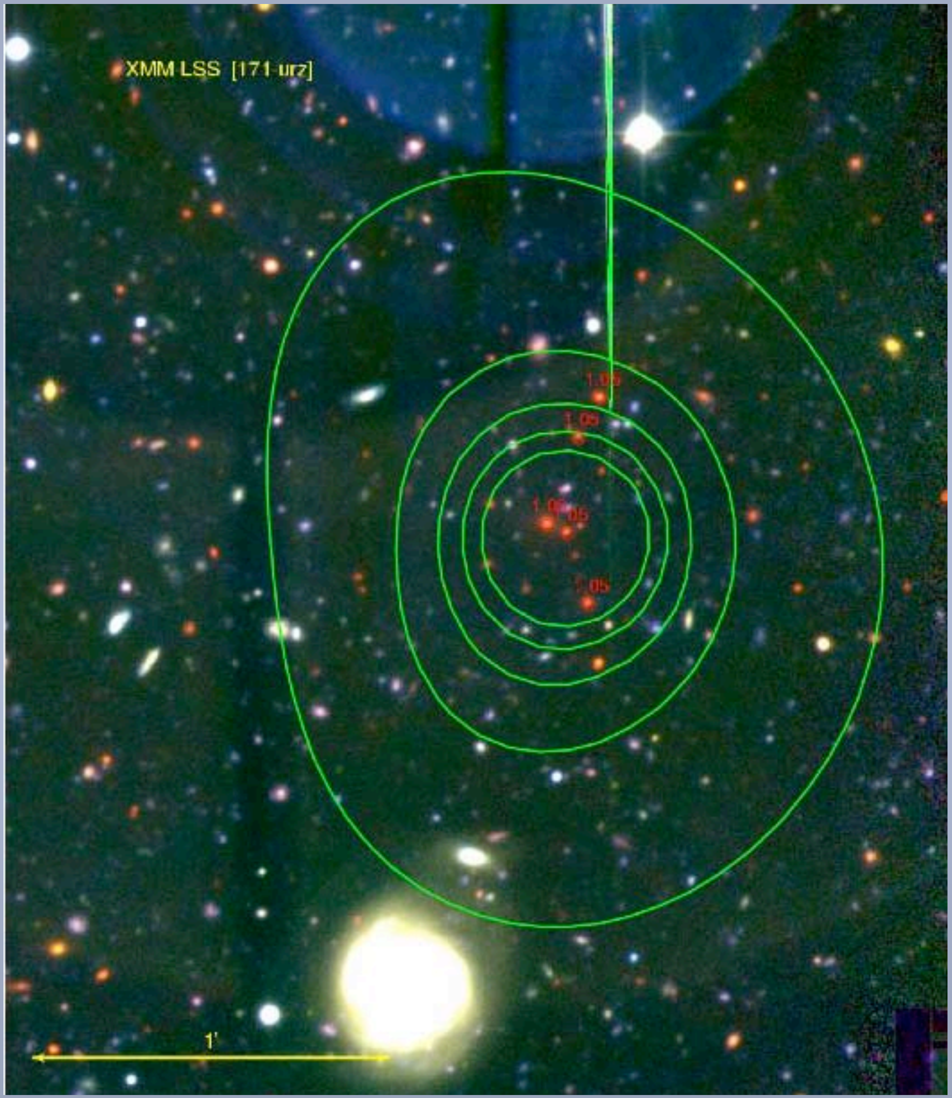
- The ability to measure <T> for a significant subsample (as shown for the XMM-LSS C1) is therefore most informative

X-ray masses of the XMM-LSS C1 clusters

From isothermal
β-model
with ~ 10 ks
exposures



Check with deep exposures



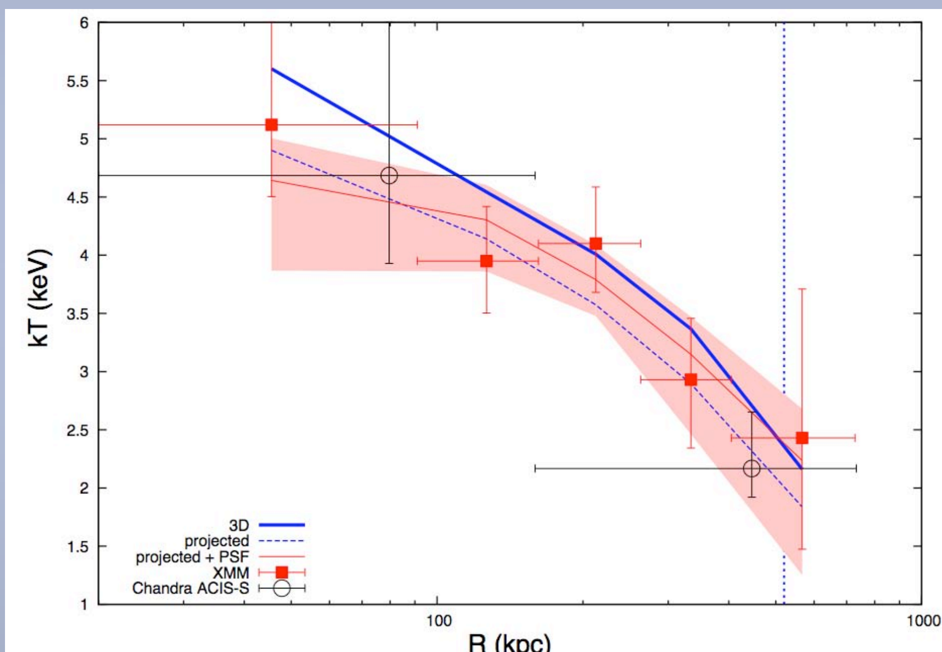
XLSSC-029 at z=1.05

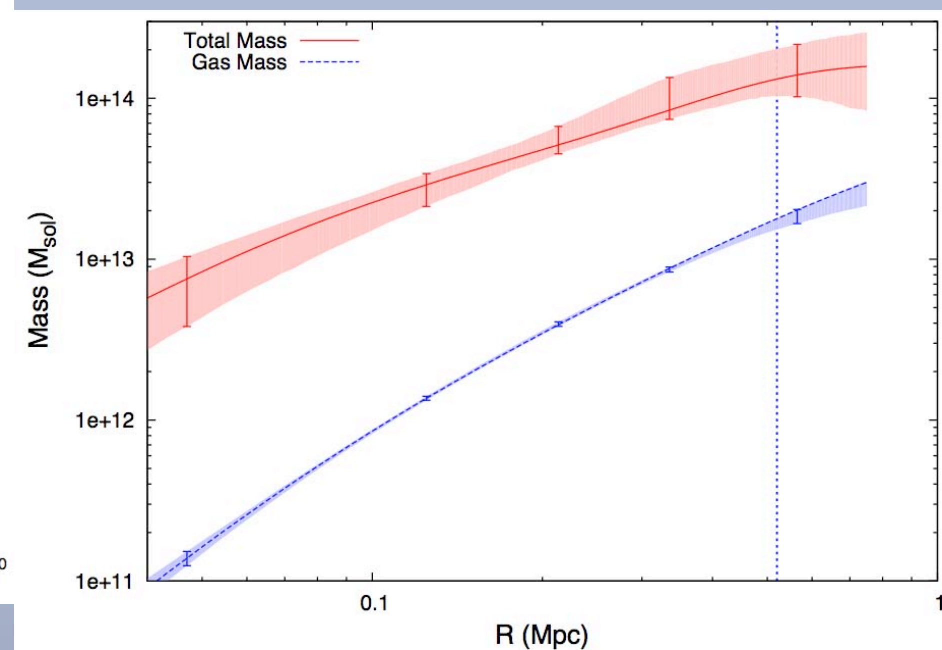
From the survey data:
300 source counts
T=4.1+/-0.8 keV
M ~ $8.6 \times 10^{13}\ h^{-1}\ M_{sol}$

Check with deep exposures (2)

Re-observed by XMM (80ks, 3400 cts)
and Chandra (130ks, 1300 cts)

$$M = 9.1^{+6.3}_{-2.1} \times 10^{13} h^{-1} M_{sol}$$



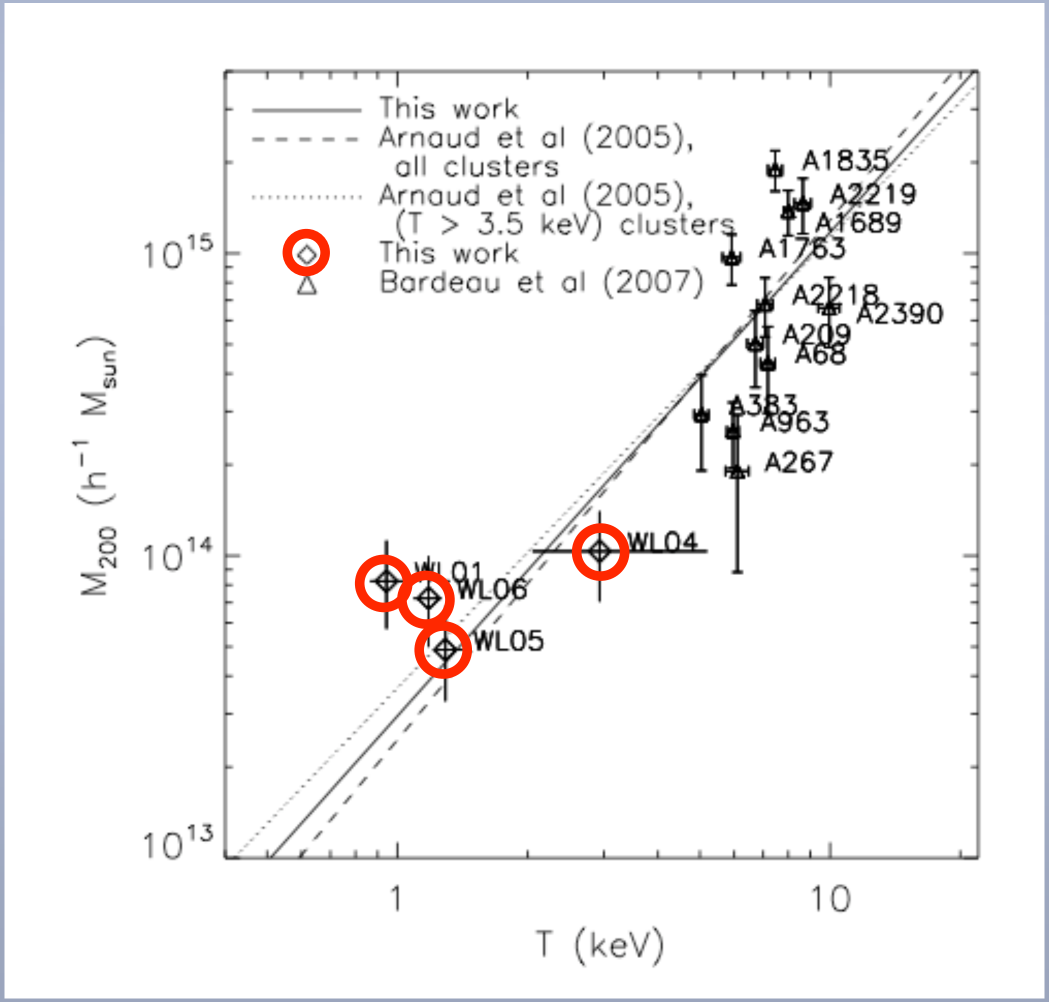


First T profile at z>1

Maughan et al (2008)

Lensing mases

Weak lensing masses for 4 out of 8 C1 clusters in the D1 CFHTLS deep field



2x more massive than from X-rays !!

Probably comes from the oversimple assumption of isothermal β-model in X-rays

Berge et al 2008

X-ray alone summary

With the XMM-LSS, and thus with any of the proposed XXL layouts, we have some information at hand on the X-ray masses of a controlled subsample

BUT ...

We have to understand better and pin down the systematics

How to handle the M-obs relation ?

[from J.-B. Melin's talk]

2 ways

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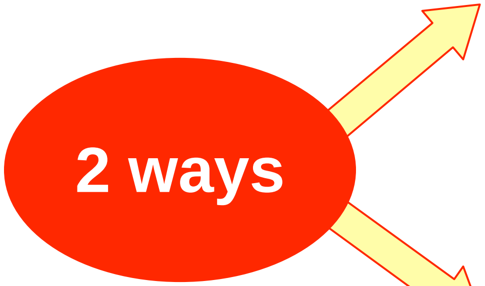

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Conclusion
and possible work-around

None of the proposed methods seems sufficient on its own

Multi-wavelength combination is the only way to go !!!

e.g. Mahdavi et al. (2007)

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Unless …

We find a way to combine the advantages from all of these methods

Suggestion for discussions: a full physical calibration

In his contribution G. Bryan only considered dn/dz/dF.

In an XXL survey, we would also have T for a subsample, surface brightness profiles and (hopefully) redshifts for all the clusters

=> more constraints available on cluster physical models

=> comming from a controlled sample

Detailled X-ray parameters contain information on both cosmology (via cluster mass) and cluster physics

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2 ways

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1 way ?

- Individual masses
  - multi-wavelength data
  - What about X-ray alone

Provided that we have a reasonable model framework to use …

1) Compute for each value of the model parameters (e.g. K_0) the likelihood that each source follow this model and has a given mass
2) Plug this directly into the physical self-calibrated cosmological likelihood
3) Sample the large resulting parameter space using e.g. MCMC

Optimally uses the whole information at hand

If the model gives a fair representation of the ICM, i.e. accurately describe the density/temperature distribution

=> no more biases as compared to e.g. isothermal β-model.

Using the whole available data

1) Such a method would also provide a straightforward framework for combining X/SZ/Lensing(/optical?) constraints on a source by source basis !

2) Local scaling relations, density/temperature profiles have a key role to play in determining what is the best suitable model to use

3) They can be used as prior to better isolate the set of physically plausible model parameters

How to handle the M-obs relation ?

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