FFP 14
On scaling relations and the baryon fraction in clusters

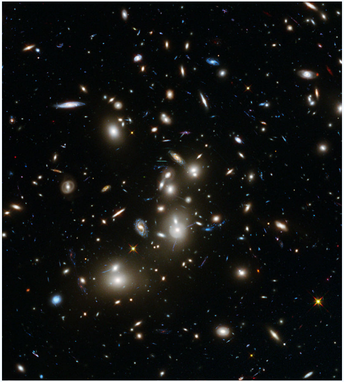
Stéphane ILIĆ

with
A. Blanchard & C. Marinoni

15th July 2014

A sensitive indicator of cosmology

Clusters of galaxies

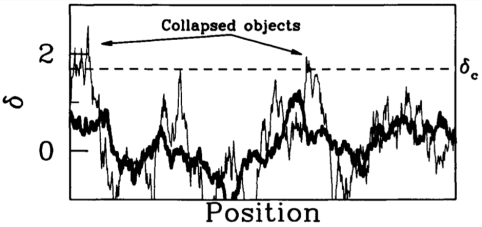


- (Statistical) Properties depend on cosmology
- In particular : depend on **growth rate** of structures and its history

Clusters as cosmological probes

How to extract information from clusters ? **Count them !**

- Press–Schechter (1974) formalism



(Dodelson, 2003)

- Predicts N_{clusters} for any M & $z \rightarrow$ **mass function**
- Fits simulations very well
- Modern variants (S&T, Tinker, ...)

Application to data

Then : **compare observed and predicted** $N_{\text{clusters}}(M, z)$

But in practice : **difficult !**

- Identifying clusters in the real data ?
- Precise definition of a cluster ?
- Total mass is not an observable !

Application to data

Several definition of cluster mass/radius :

- R/M_{virial}
- M_{500}
- $M_{500\mathrm{critical}}$,...

Several observables :

- X-Ray Temperature
- Sunyaev-Zel'dovich
- Weak Lensing

Masses and observables need to be calibrated

Often need additional assumptions/models

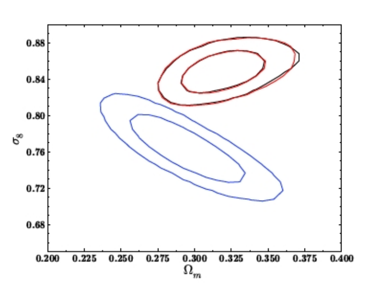
Current status

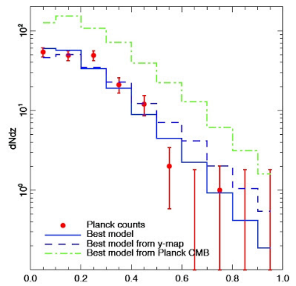
In the literature :

Tensions between observables, e.g. T_X vs. WL masses
Over/under/no bias ?

Also :

Tensions in derived **cosmological results**
E.g. SZ measurements with Planck





Our alternative approach

Instead of using clusters for cosmology...

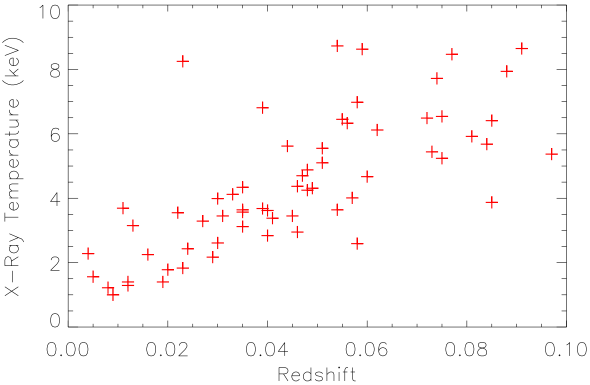
...use cosmology to constrain physical state of clusters

In practice :

- Start from observation : (robust) sample of X-ray clusters w/ T_X
- Formulate a T_X-M scaling law w/ free normalisation
- Enforce agreement with cosmology
- No other assumptions needed

Alternative approach

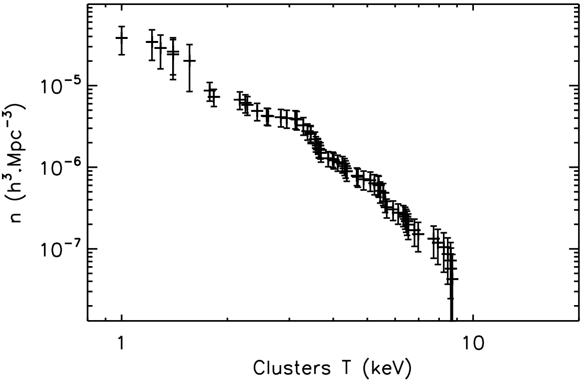
Starting point : flux limited sample of (64) local X-ray clusters



Alternative approach

From this : derive $n(> T)$ using unbiased estimator

$$n(> T) = \sum_{T_i > T} \frac{1}{V_i}$$



T_X-M scaling

- **Virial theorem :** $T \propto GM/R$
- **Cluster definition :** $M_\Delta = \frac{4\pi}{3}\Delta\Omega_m\rho_c(1+z)^3R^3$

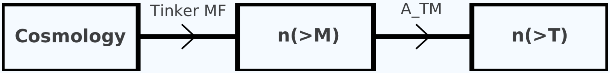
Scaling law :

$$T = A_{TM}(hM_\Delta)^{2/3}\left(\frac{\Omega_m\Delta}{178}\right)^{1/3}(1+z)^{1+\alpha_{TM}}$$

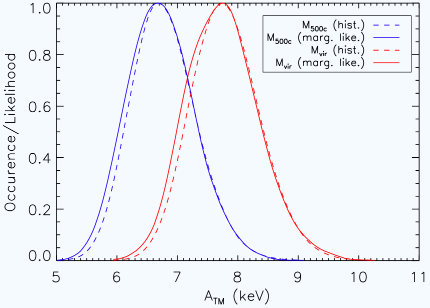
$\Rightarrow$ **Use cosmology to determine** A_{TM}

Calibrating T-M with cosmology

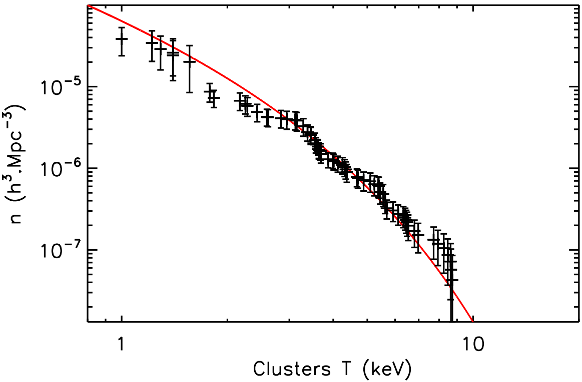
- Perform MCMC on { cosmological parameters + A_{TM} }
- Fit cosmological data (CMB) and $n(> T)$
- Each step :



Likelihoods for A_{TM} for any M definition



Calibrating T-M with cosmology



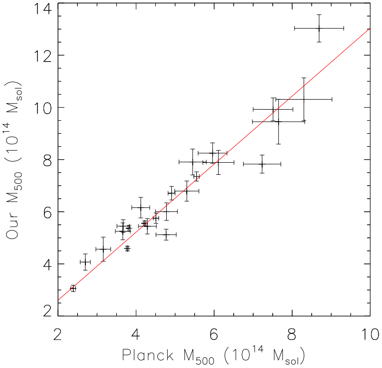
We can estimate M for any X-ray cluster

...but : calibration valid only if cosmology is valid...

Application of the calibration

First application

- **Comparison** of our derived M with other estimates
- Focus on local Planck SZ clusters

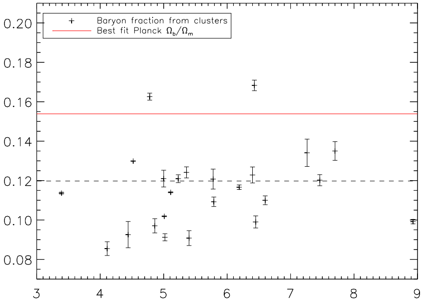


- ~30% bias in Planck masses
- Alternatively :
  fitting Y-M scaling
  → requires ~34% bias

Application of the calibration

With M_{gas} available ($+M_*$ assump.) $\rightarrow$ **baryon fraction** :

- Clusters : representative volumes of Universe
- $M_{\text{baryons}}/M_{\text{total}}$ should match universal ratio Ω_b/Ω_m
- Earliest evidences of $\Omega_m \neq 1$



$\Longrightarrow$ **Missing baryons**

Conclusions

- **Self consistent modelling of clusters**
- **Allows to check consistency of cosmological models**

Assuming Planck's ΛCDM :

- Lack of baryons in X-clusters
- Masses are higher than standard (hydrostatic) estimates

Thank you for your attention !