OCEVU WORKSHOP : BEYOND 6 PARAMETERS

Clusters abundance
& mass-temperature scaling

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with

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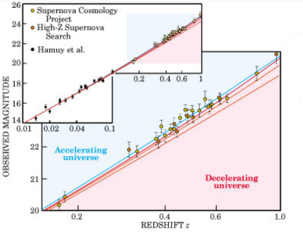
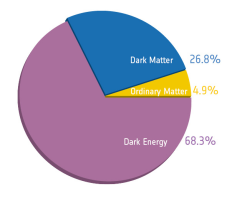
Plan

Context

Dark Energy (DE)



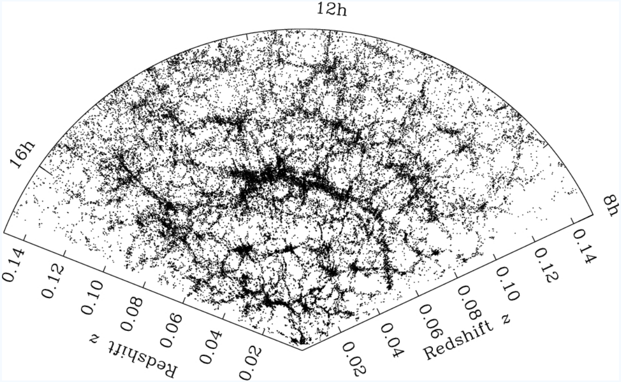
- Responsible for accelerated expansion of the Universe
- Evidenced in the late 1990s
- Crowned by the 2011 Nobel Prize in Physics



- In the standard model : $\Lambda \rightarrow$ most “economical”
- But many alternatives :
  - scalar fields
  - modified gravities
  - inhomogeneous models...

Sensitive indicator of cosmology

Galaxies surveys

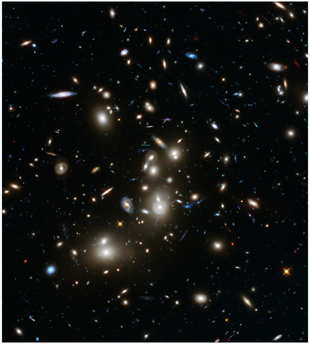


- (Statistical) Properties depend on cosmology
- In particular : **Two-point correlation function**
- **How about “one-point” (⇔ abundance) ?**

Sensitive indicator of cosmology

Galaxies are **non-linear**, abundance hard to predict ; **however....**

Clusters of galaxies



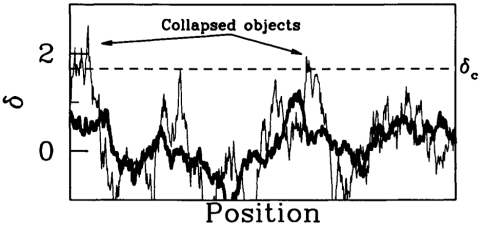
- Scales closer to the **linear regime**
- Strong dependence on **growth rate** of structures

Clusters as cosmological probes

How to extract information from clusters ?

- Count them
- Compare to **predictions**

Press–Schechter (1974) formalism

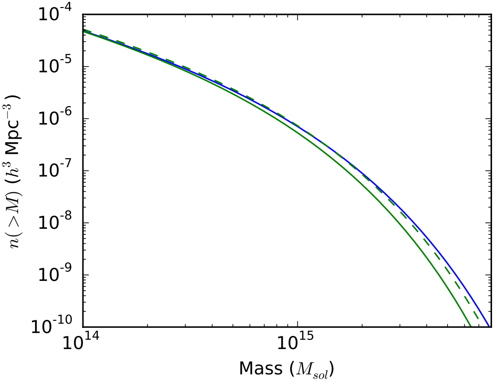


(Dodelson, 2003)

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

Theoretical mass function

$$n(>M) = \int_M^\infty \frac{dn}{dM} dM$$



(blue=S&T, green=Tinker, dashed green=Tinker w/ σ_8 shift)

Application to data

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

Difficult in practice :

- 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}
- $M_{500\text{critical}}$,...

Several observables :

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

- **Masses and observables need to be calibrated**
  - **Often need additional assumptions/models**

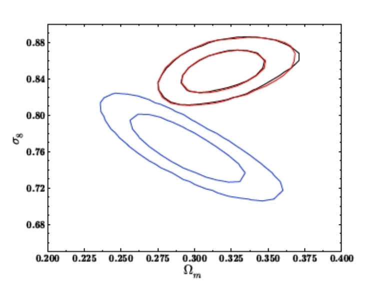
Current status

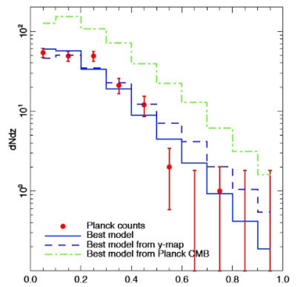
In the literature :

- Tensions between observables, e.g. T_X vs. WL masses
- Over/under/no bias ? **Not clear**

Also :

- Tensions in derived **cosmological results** $\Rightarrow$ Planck SZ
- Pb with clusters **mass** (bias ~ 0.6) ? Selection function ?
  Or **cosmology** (ΛCDM extensions) ?





Plan

Our alternative approach

Instead of using clusters for cosmology...

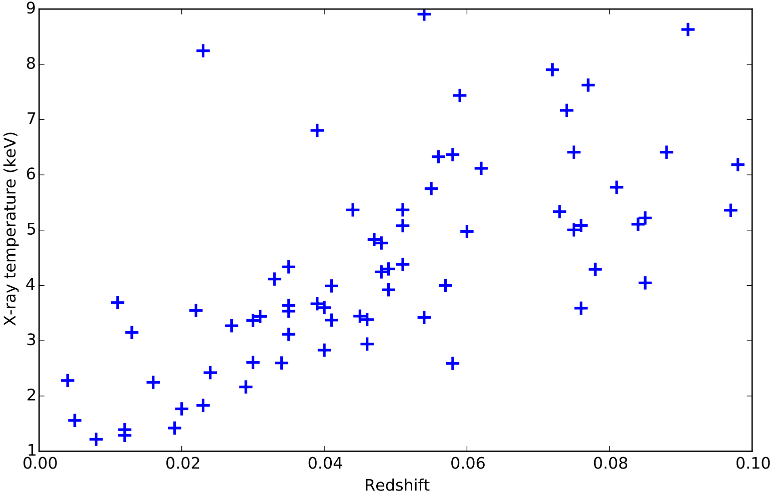
...use cosmology to constrain physical state of clusters

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

1st ingredient : clusters data

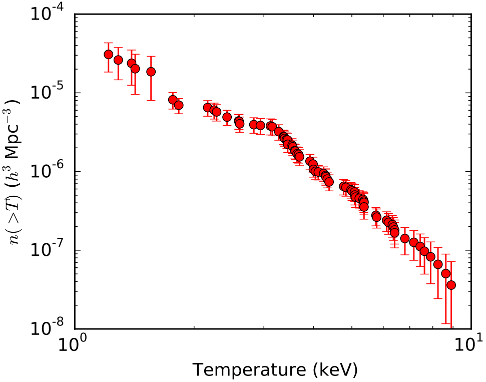
Starting point : flux limited sample of (70) local X-ray clusters
each with detection volume



1st ingredient : clusters data

From this : unbiased estimator of $n(>T)$

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



2nd ingredient : 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 :

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

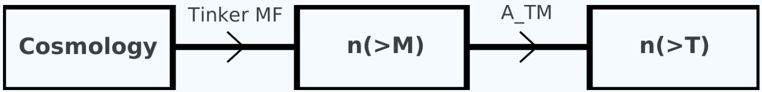
$\Rightarrow$ **Use cosmology to determine** A_{TM}

Plan

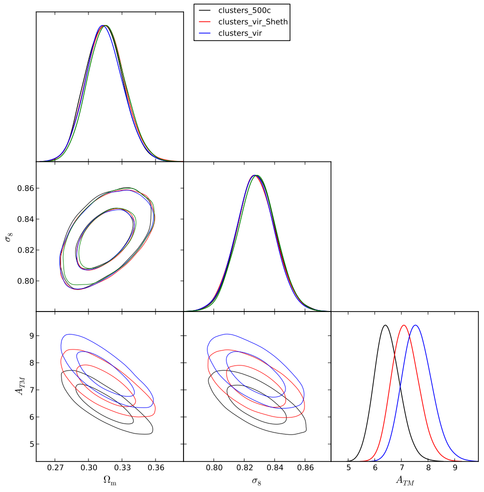
Calibrating T-M with cosmology

Using the CosmoMC engine :

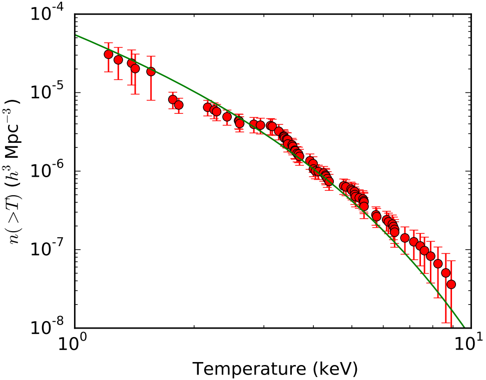
- Perform MCMC on $\{$ cosmological parameters $+ A_{TM}$ $\}$
- Fits cosmological data (CMB)...
- ... and fits $n(> T)$ thanks to a new module
- At each step :



Likelihoods for A_{TM} for any M definition and MF model



Calibrating T-M with cosmology



We can estimate M for any X-ray cluster

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

Plan

Application of the calibration

Planck masses

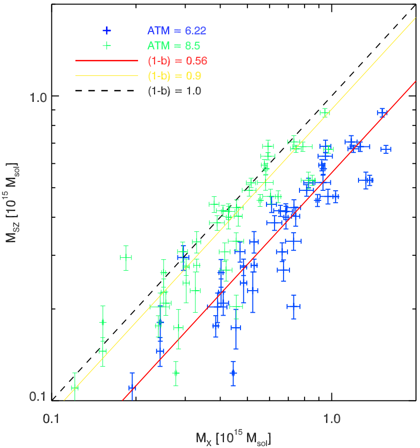
- Measure of SZ observables (Y_{500}, θ_{500})
- (External) SZ-M scaling relation (w/ hydrostatic equilibrium)
- Resulting masses known to be biased : $M_{estimated} = (1-b)M_{true}$
- Fiducial $(1-b) = 0.8$ (motivated by num. simulations)

Our masses

- Measure of X-ray temperatures
- T_X-M scaling law with free parameter A_{TM}
- A_{TM} determined by cosmological data

Application of the calibration

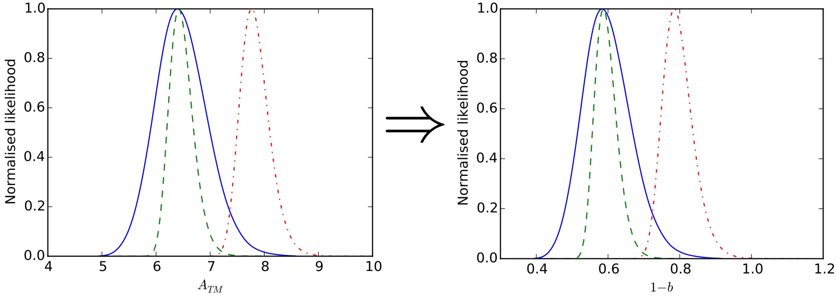
Comparing our mass estimates with Planck SZ masses



- Planck masses < ours
- We can play on Planck bias $(1-b)$ to match both
- **One** $A_{TM} \rightarrow$ **one** $(1-b)$

Application of the calibration

Translate A_{TM} likelihood into (1-b) likelihood



- CMB cosmology favours $(1-b) \sim 0.6 \Rightarrow$ Same as determined by Planck
- "SZ cosmology" favours $(1-b) \sim 0.8 \Rightarrow$ Same as "fiducial" SZ Planck

Everything appears coherent

Conclusions & Prospects

Conclusions

- Local temperature distribution well reproduced
- M/T calibration determined with a $\sim 10\%$ accuracy
- Self-consistency with ΛCDM

Prospects

- Move to higher redshift
- Include possible evolution effects
- Strong constraints on growth rate
- Discriminate Dark Energy/MG