Structure formation
&
Clusters for Cosmology

Alain Blanchard

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3D surveys

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Velocity dispersion in galaxy clusters.

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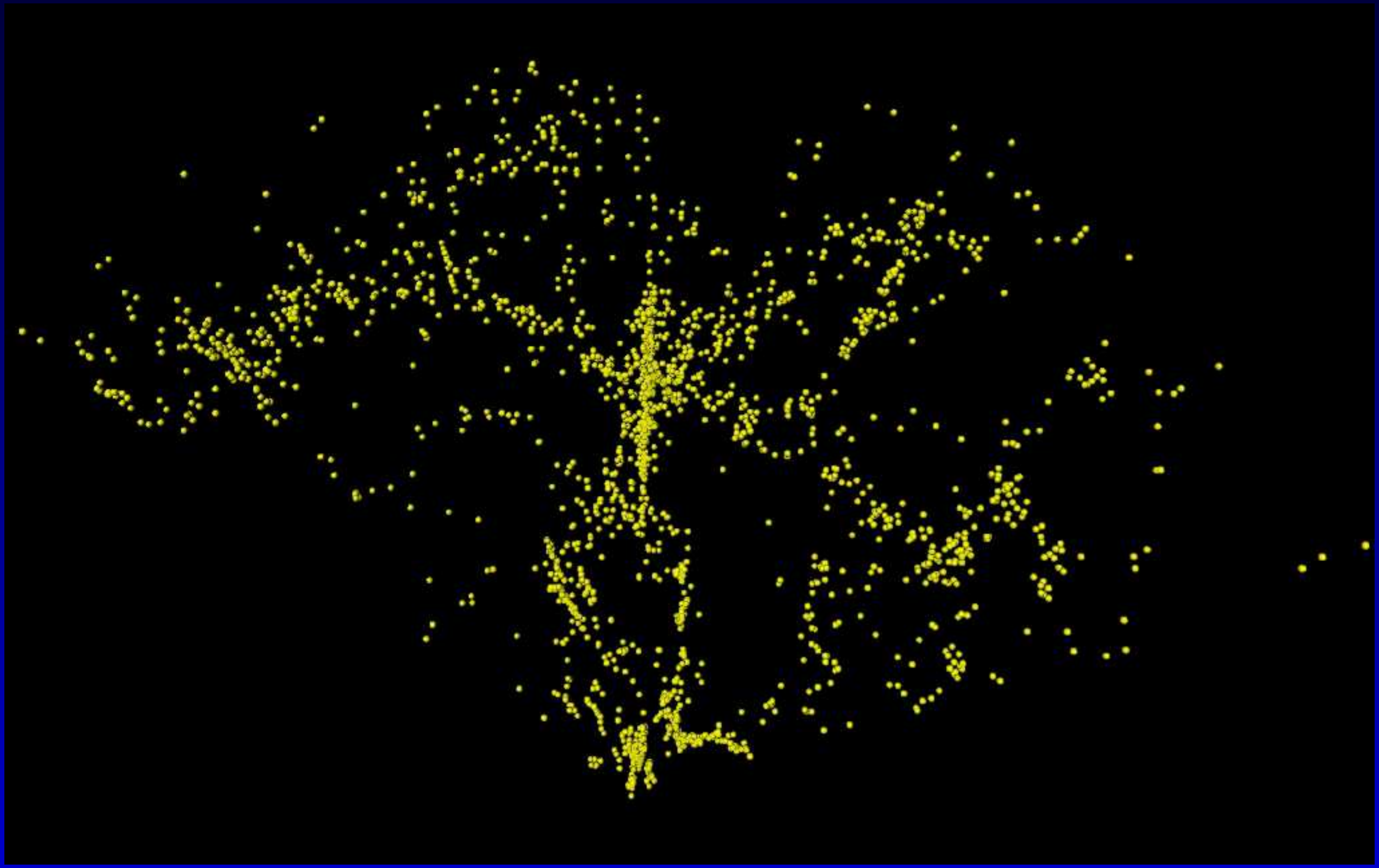

$$v = H_0 D + v_{pec} \cos(\theta)$$

Clusters: a tool for cosmologists

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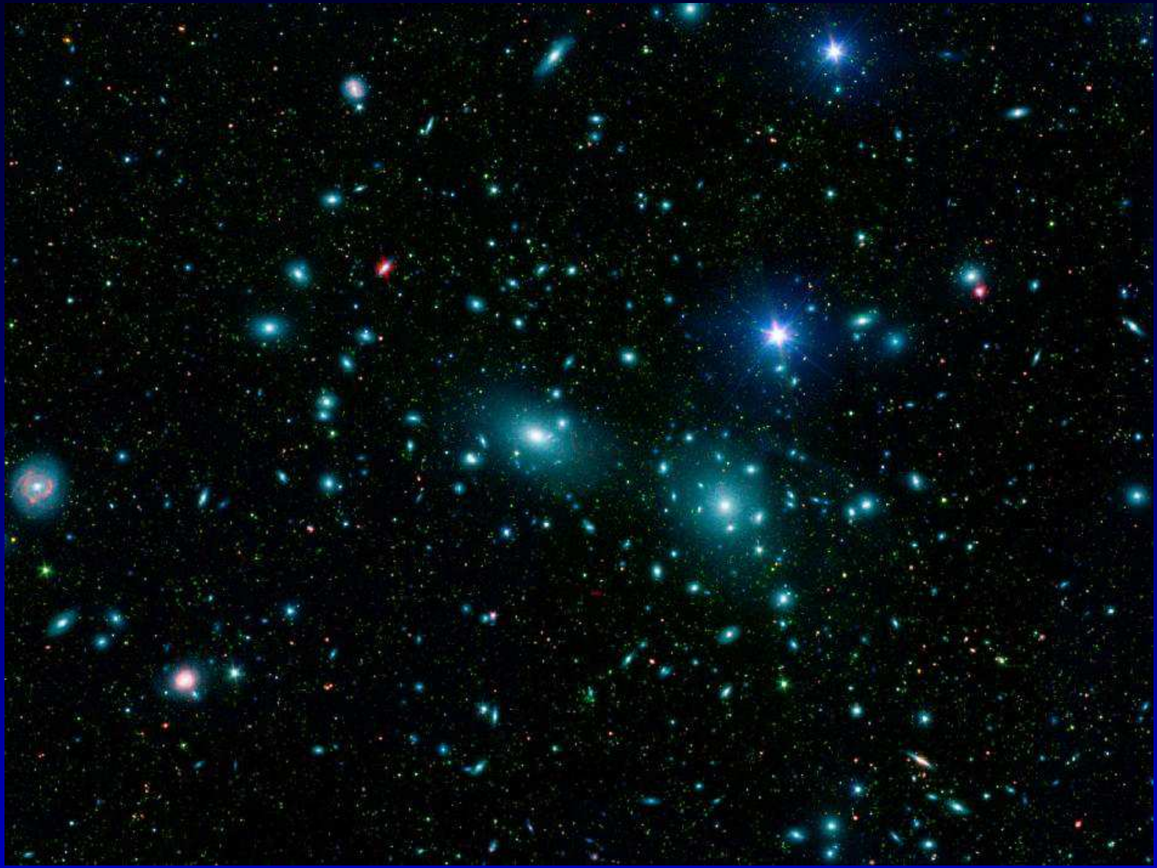

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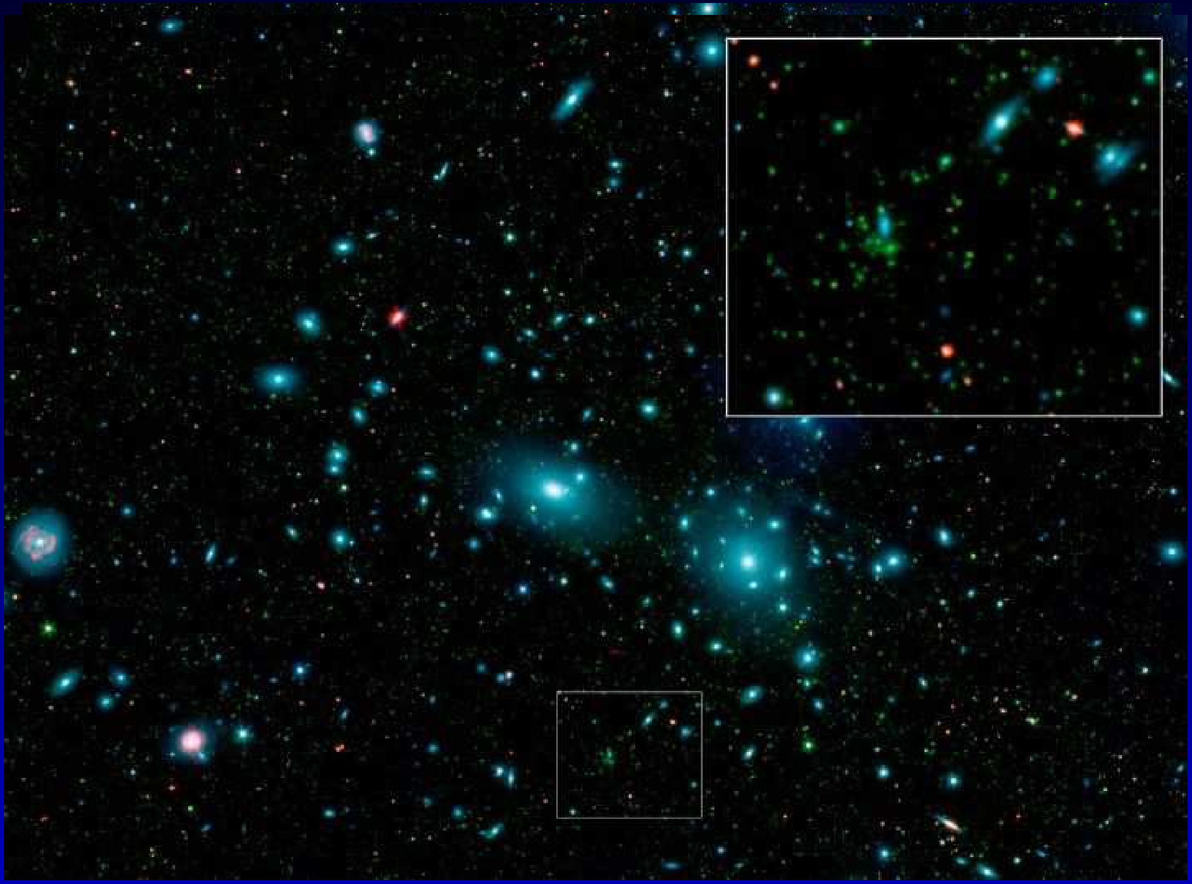

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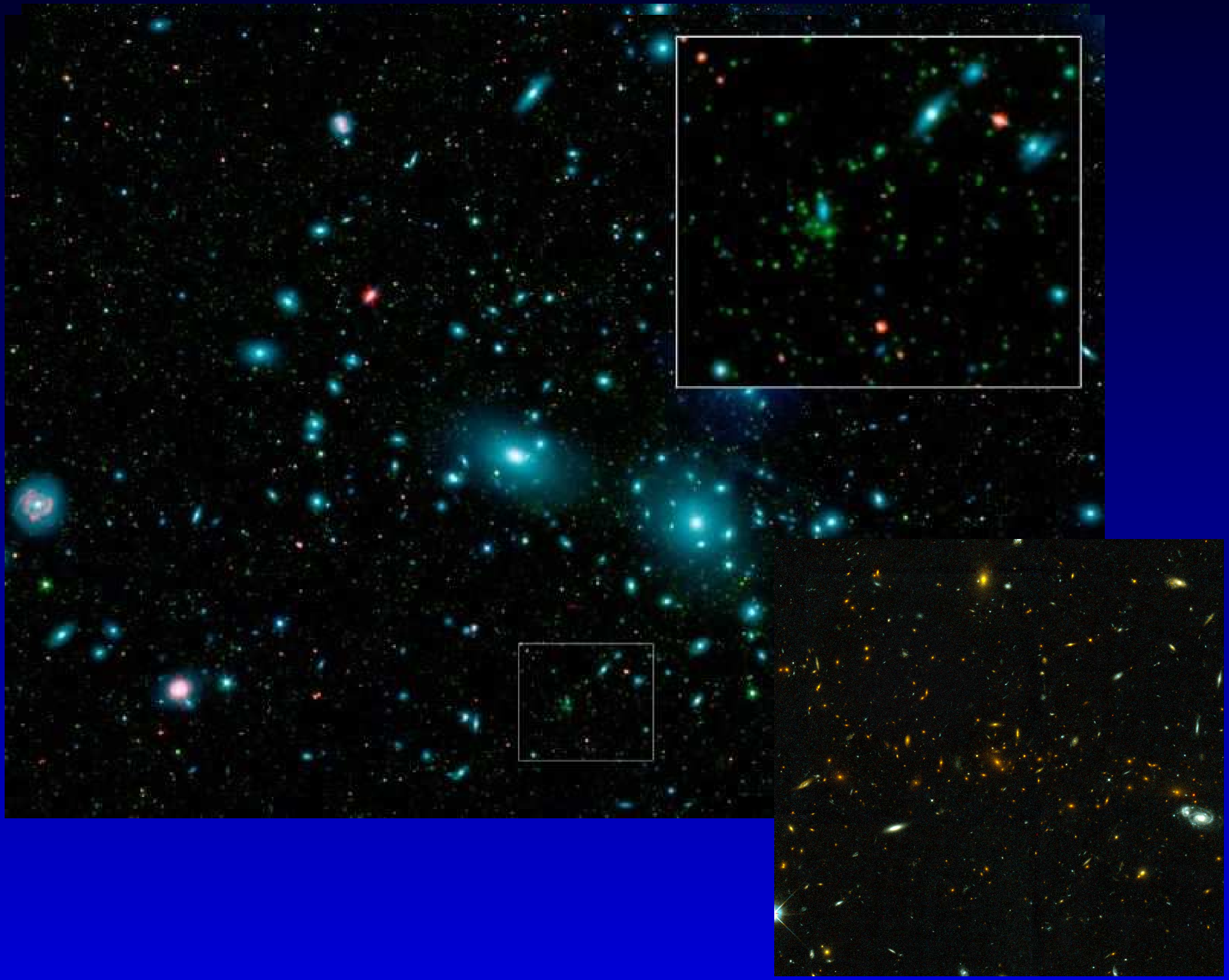

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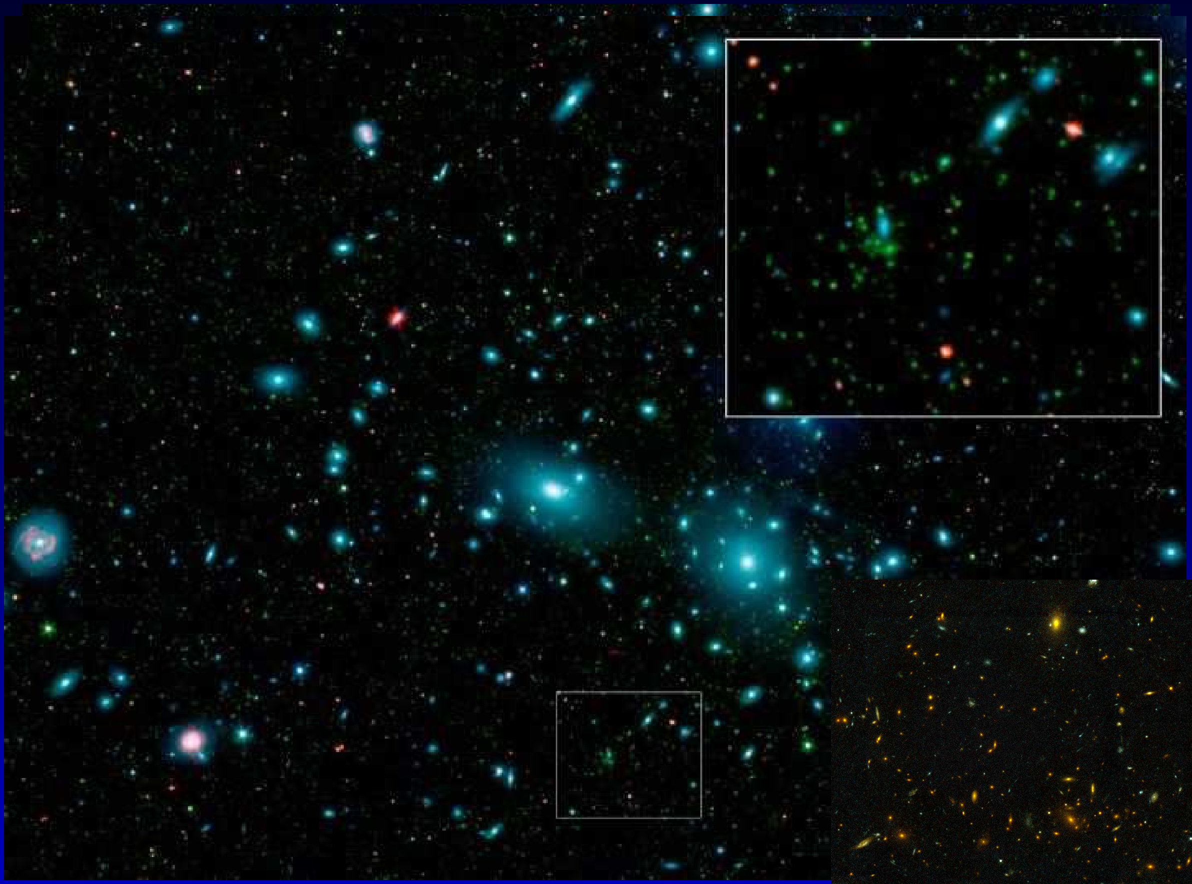

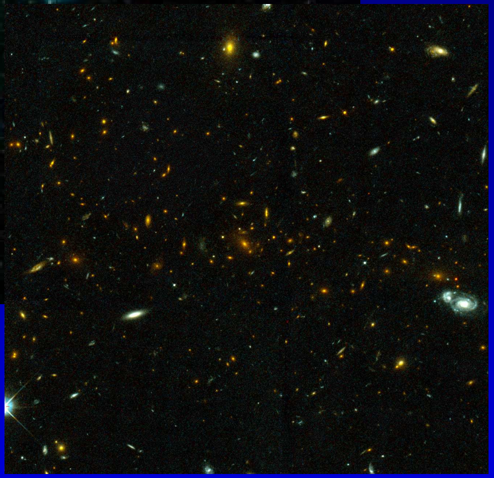

Optical data : Stars, metals, velocity dispersion $\rightarrow$ Mass...

Visions on clusters

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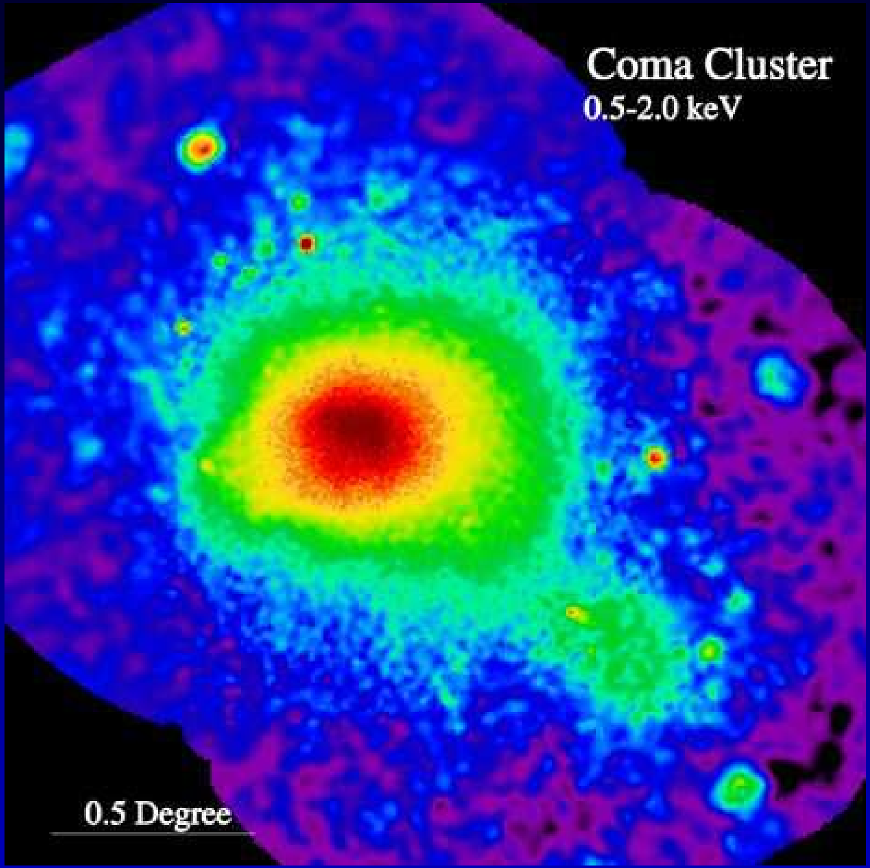

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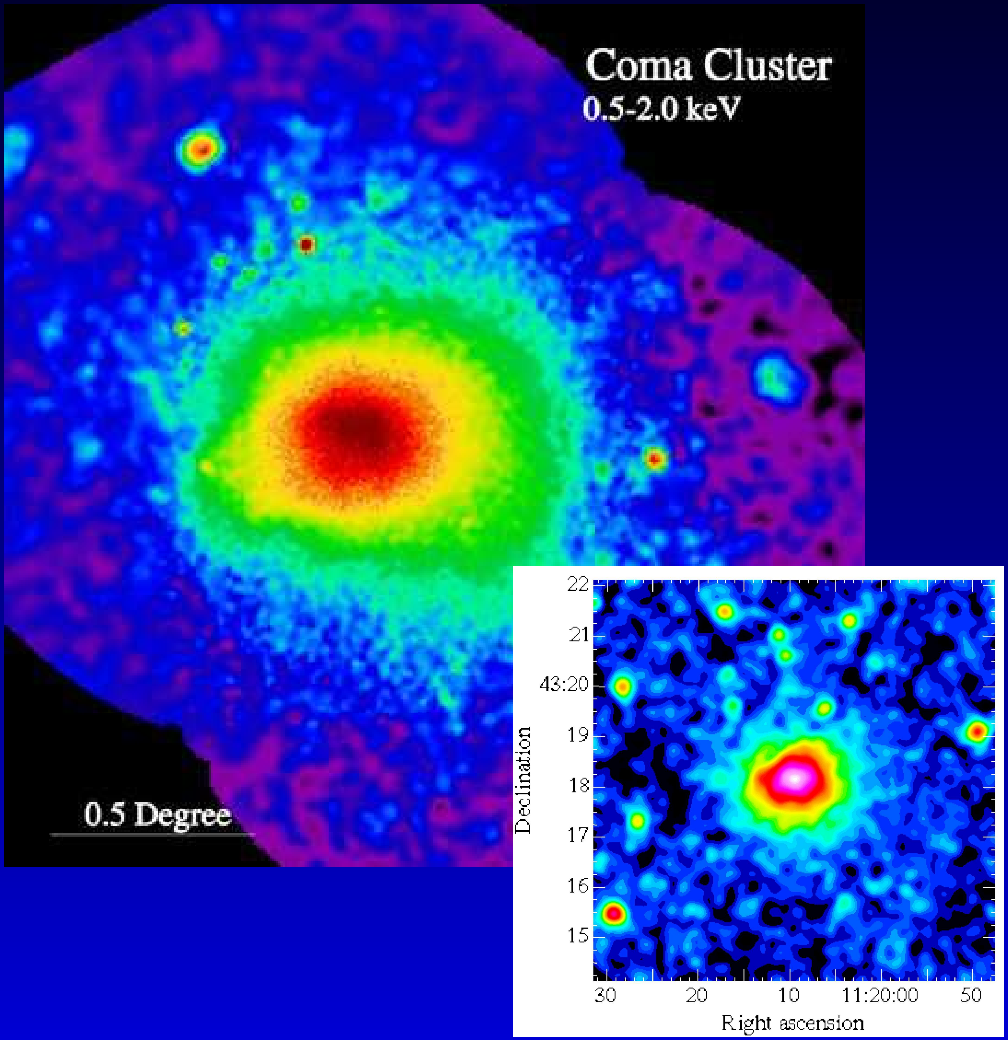

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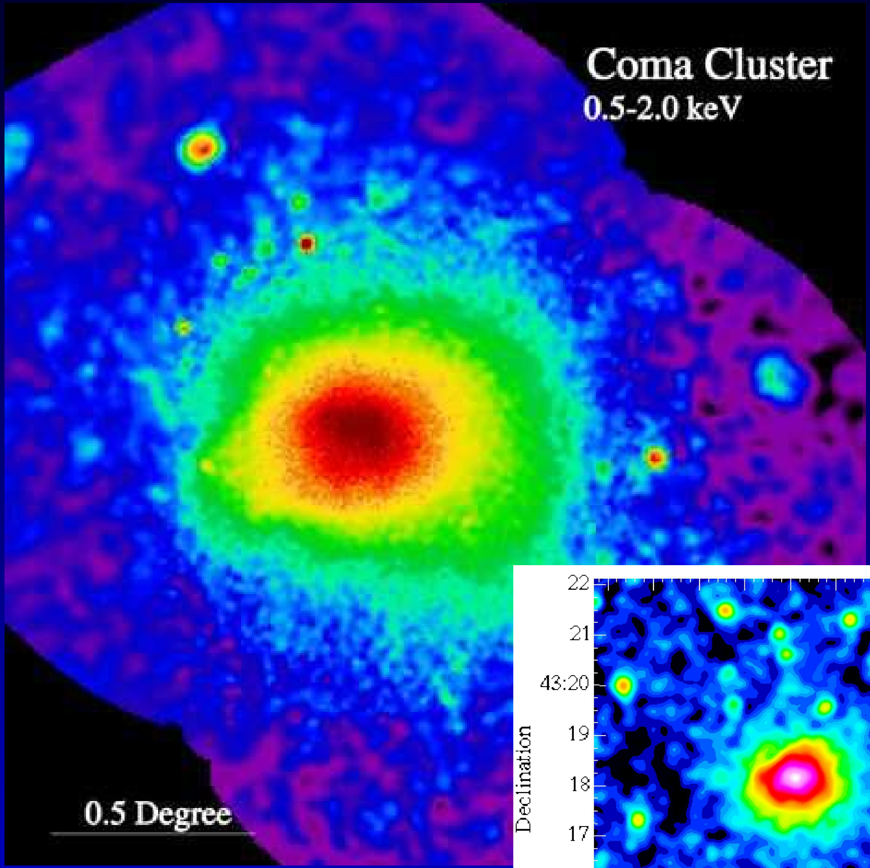

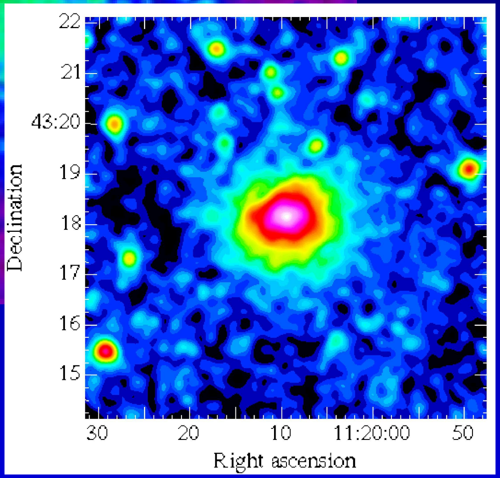

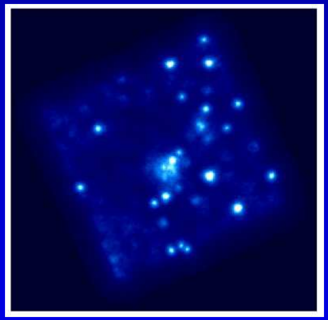

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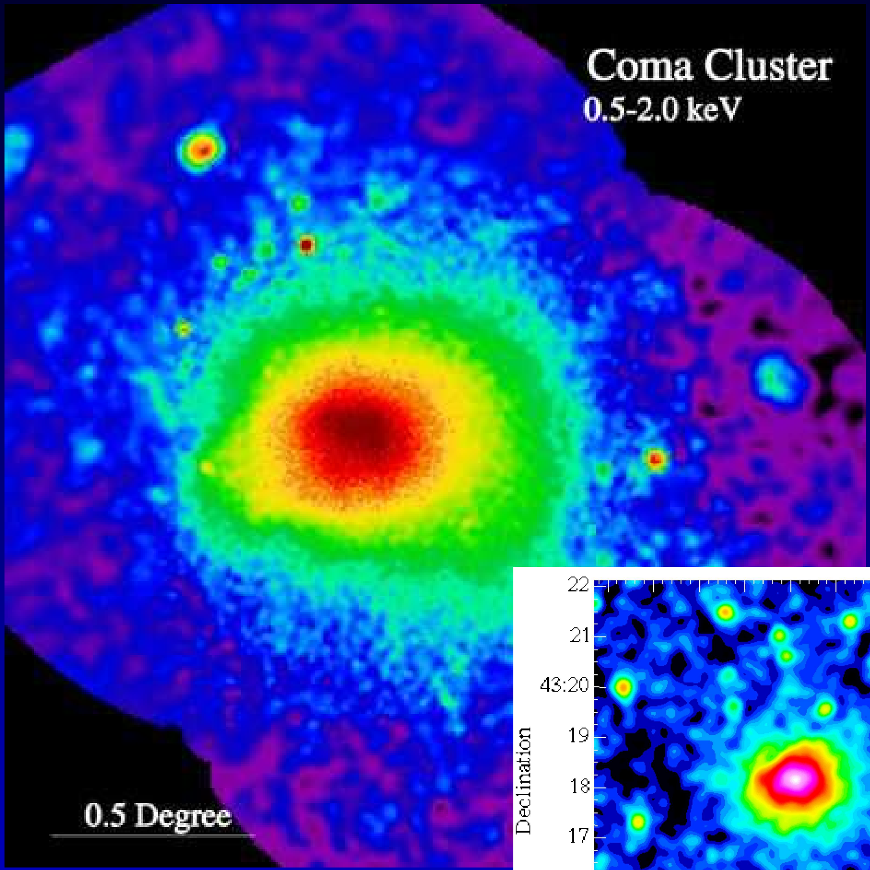

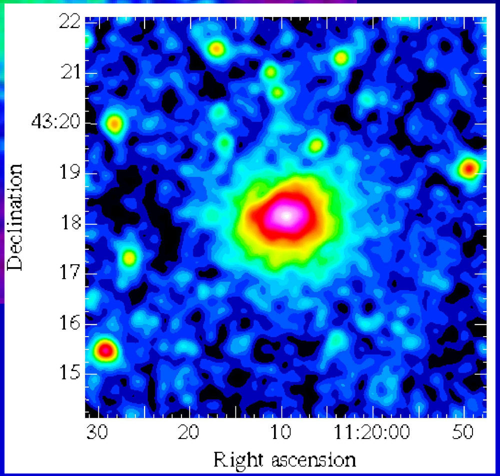

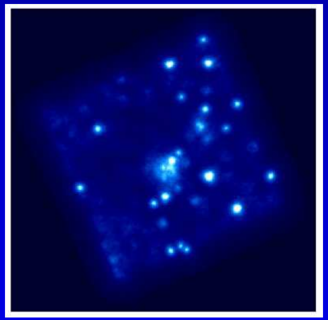

X-ray data : Gas, metals, temperature $\rightarrow$ Mass...

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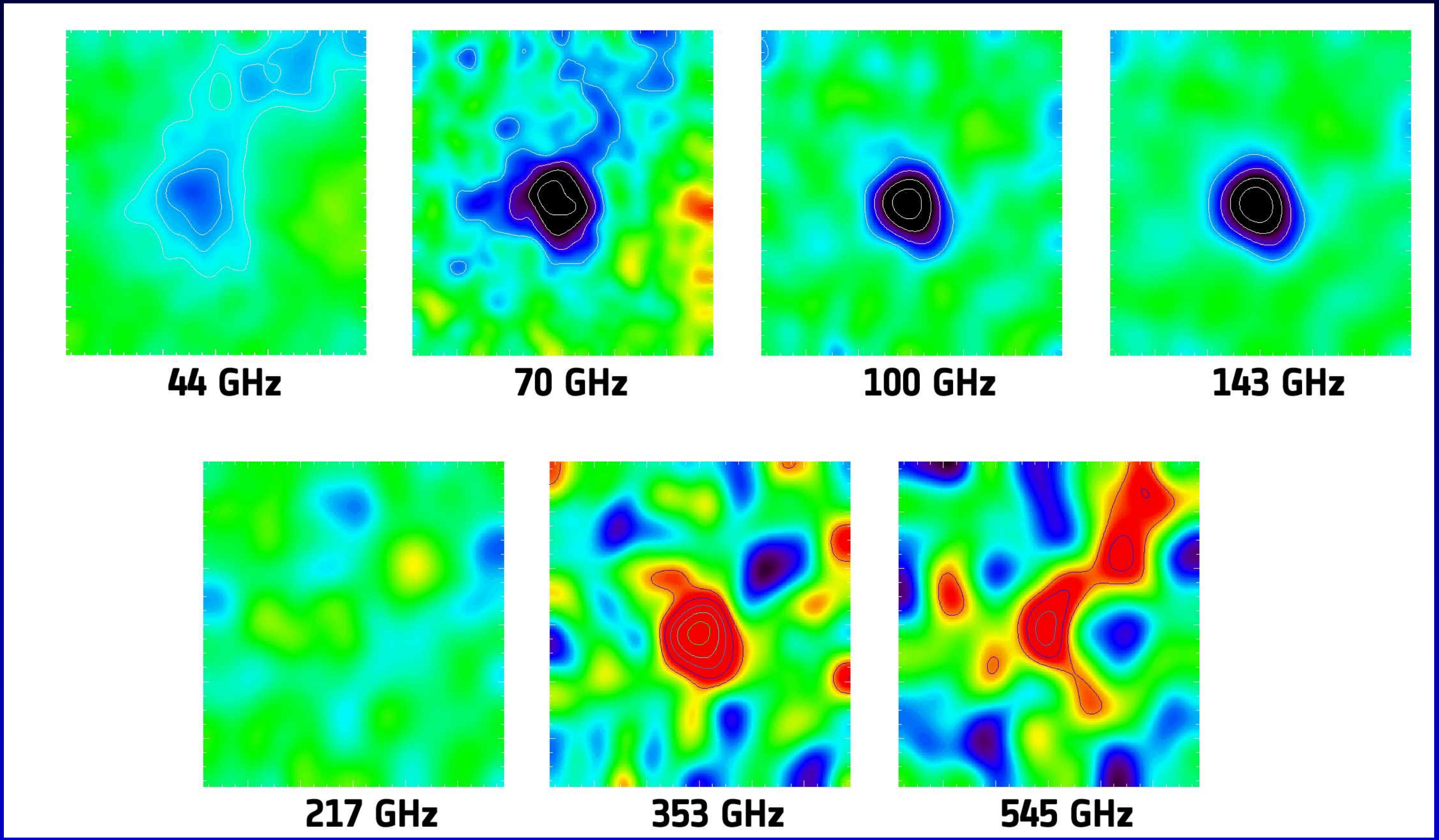
A2319 by Planck



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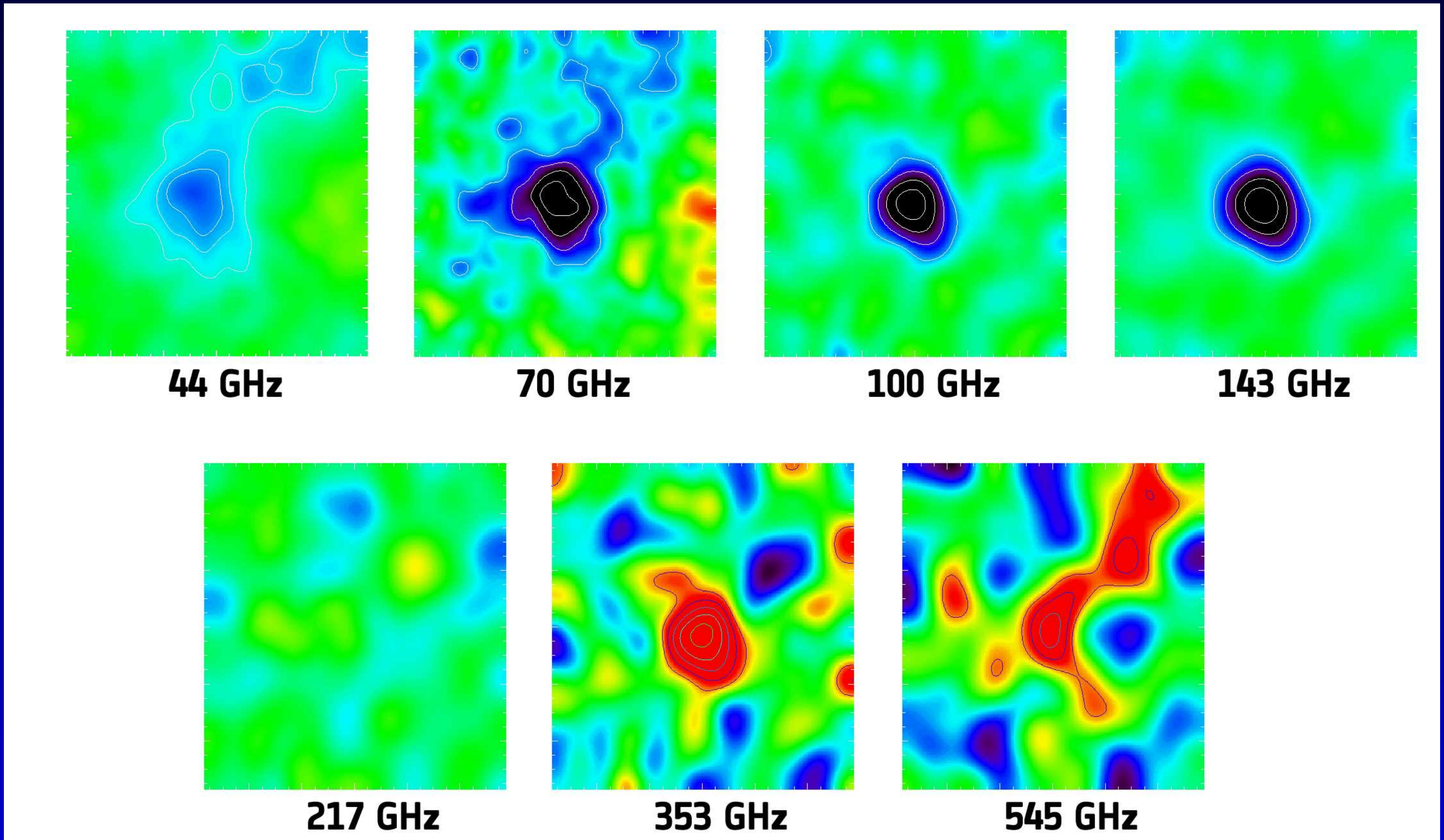

SZ Signal : Gas mass $\times$ temperature $\rightarrow$ Mass...

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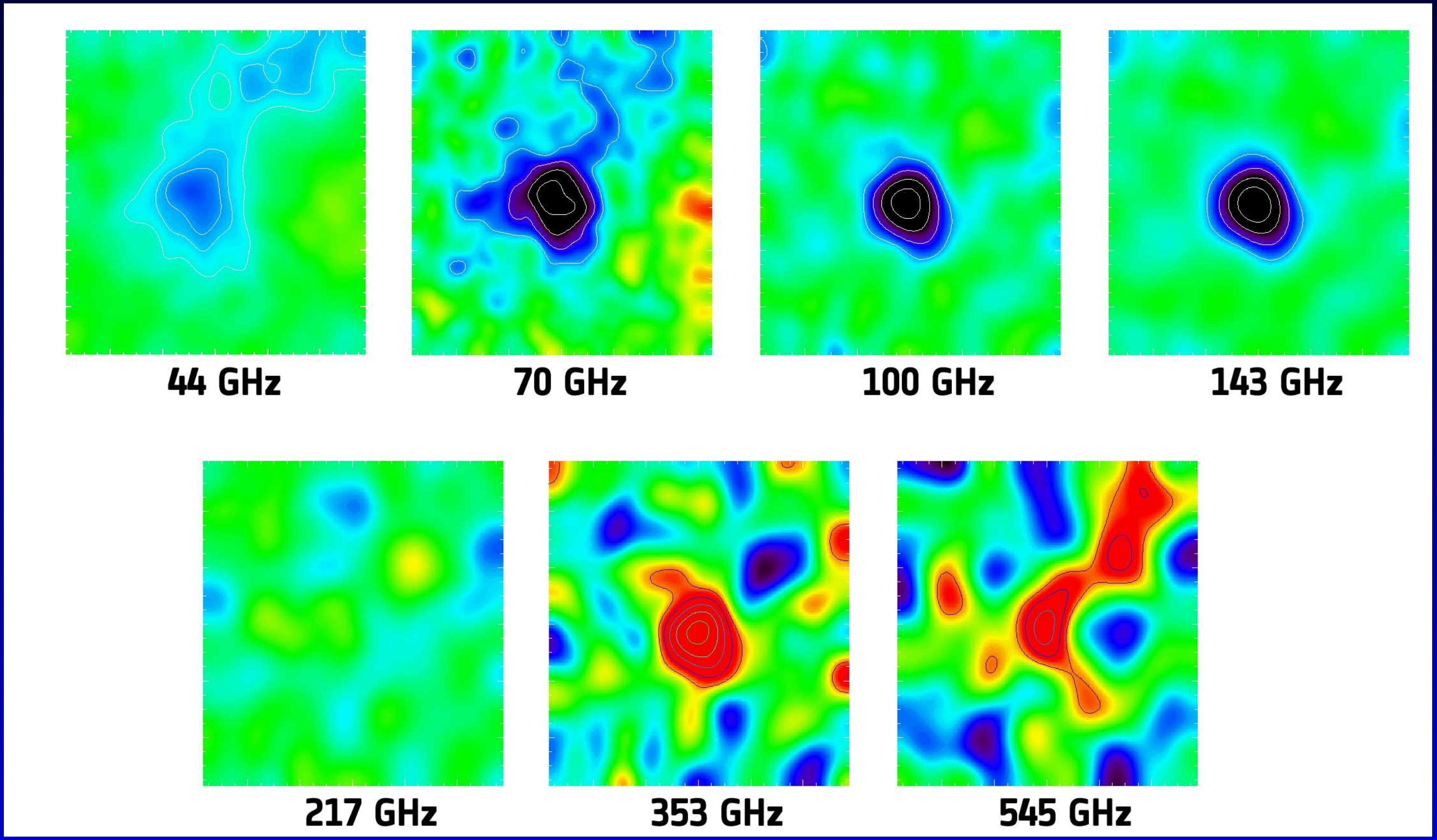

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No dimming with redshift

Final words

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Clusters are unique objects in astrophysics:

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- $\rightarrow$ fundamental probes for cosmology

Cluster as cosmological tools

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Important progresses are due to numerical simulations:

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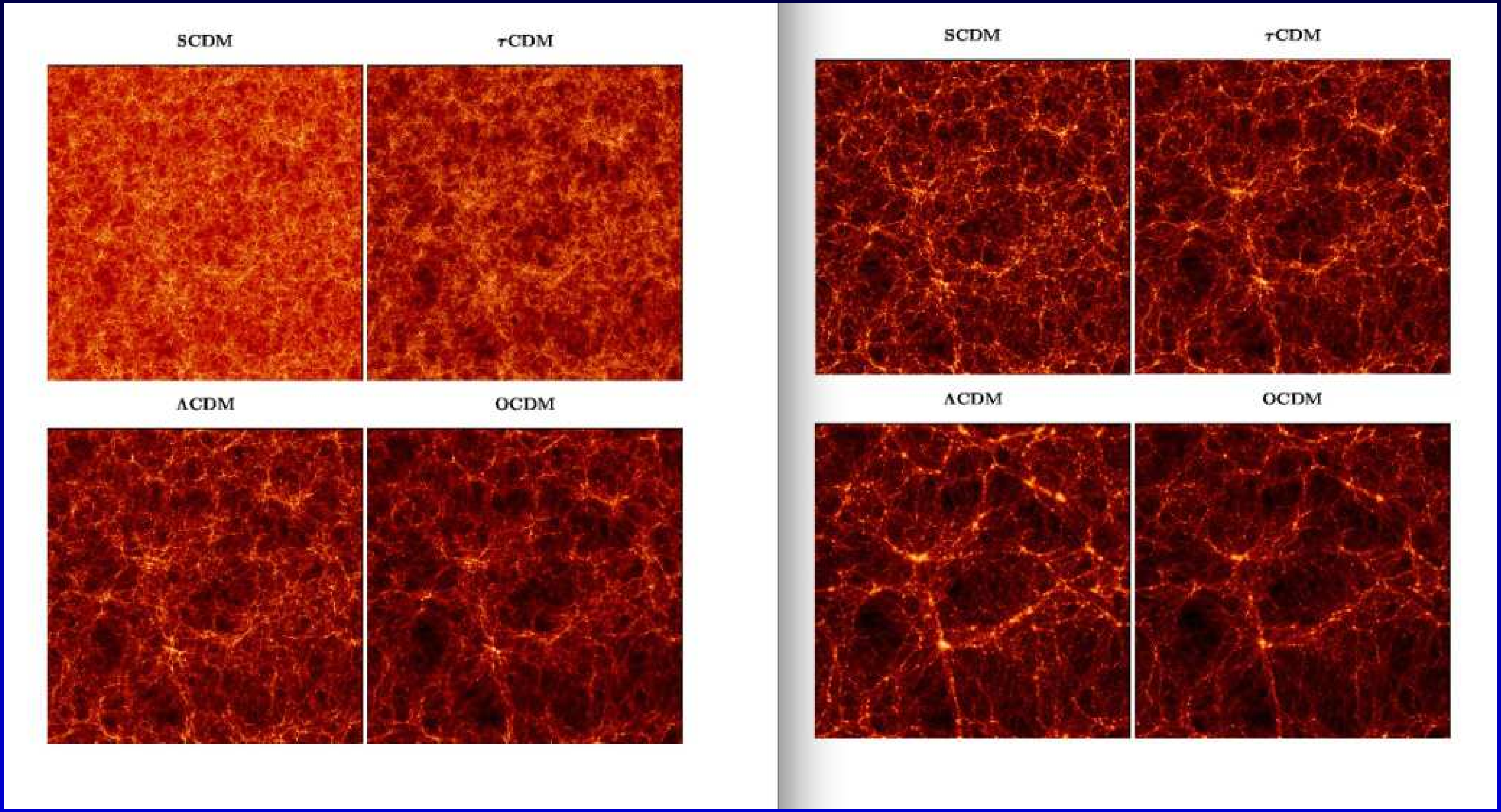

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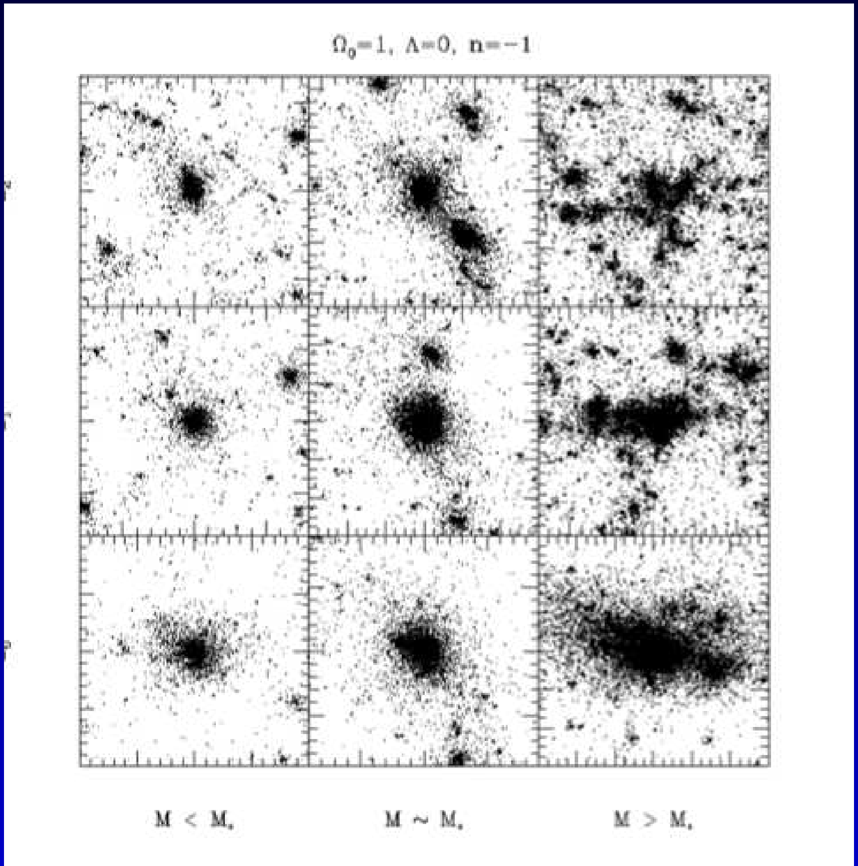

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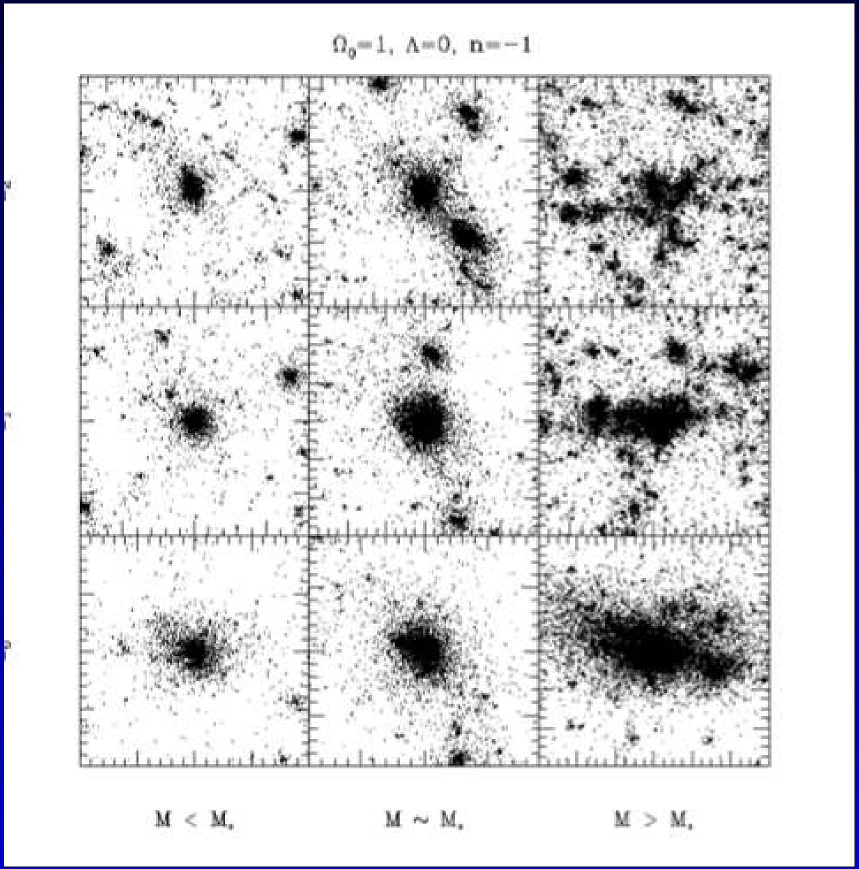

$$\sigma(M_*) \sim 1$$

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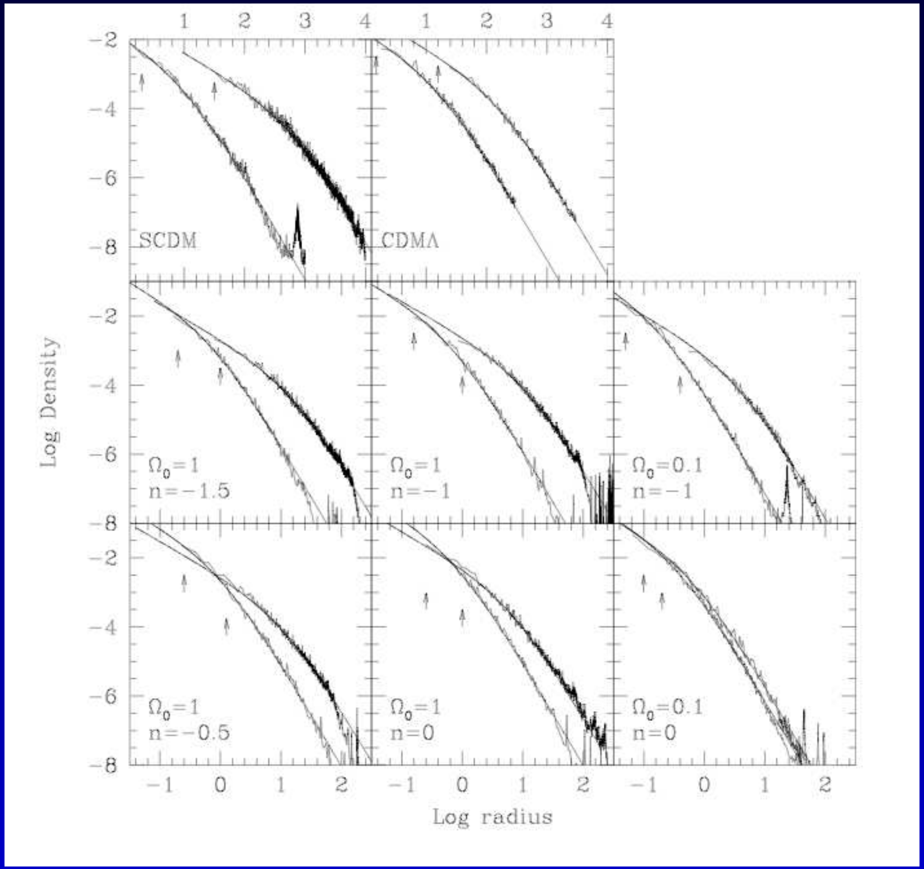

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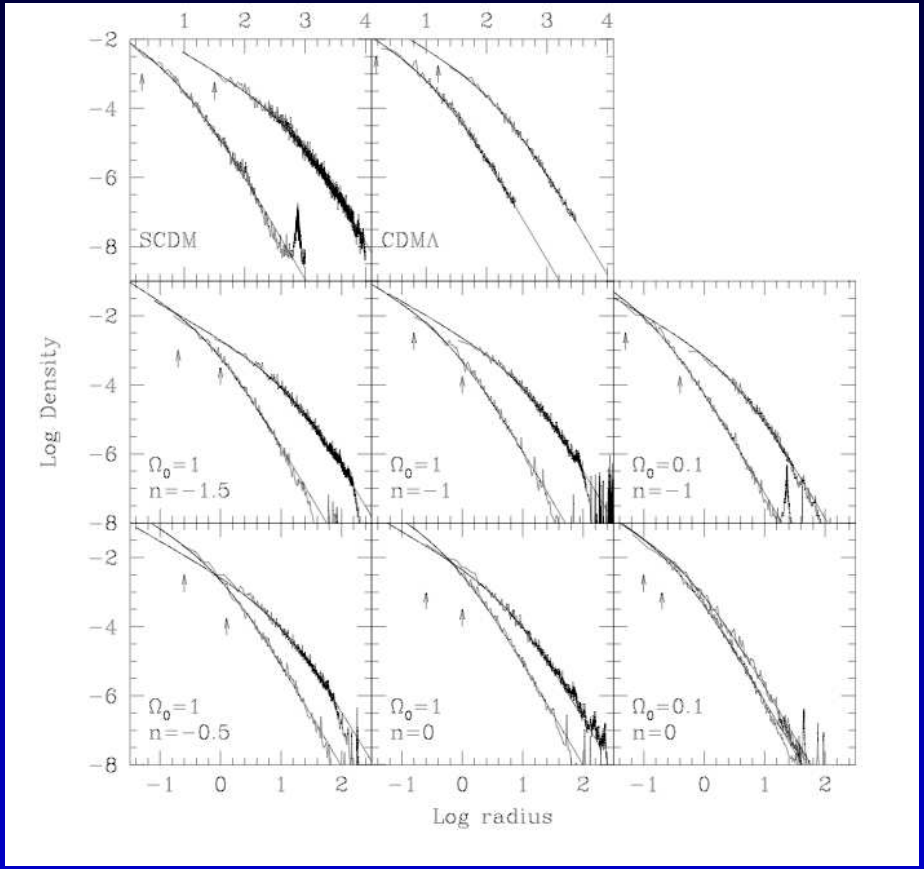

NFW profiles

From numerical simulations DM halo appear to be well fitted by the so-called NFW profile:

$$\frac{\rho(r)}{\rho_c} = \frac{\delta_c}{(r/r_c)(1. + r/r_c)^2}$$

Two parameters: mass in some radius (for instance $\Delta = 200$) and one parameter: the concentration c : $r_c = r_{200}/c$

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allows analytical $M(r)$

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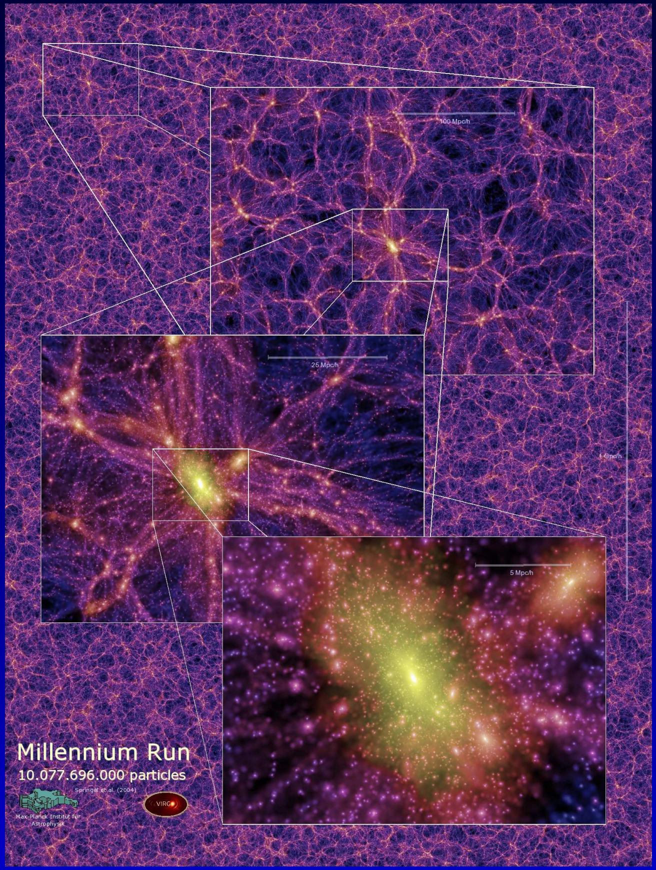

Millenium simulation: much more detailled pictures...

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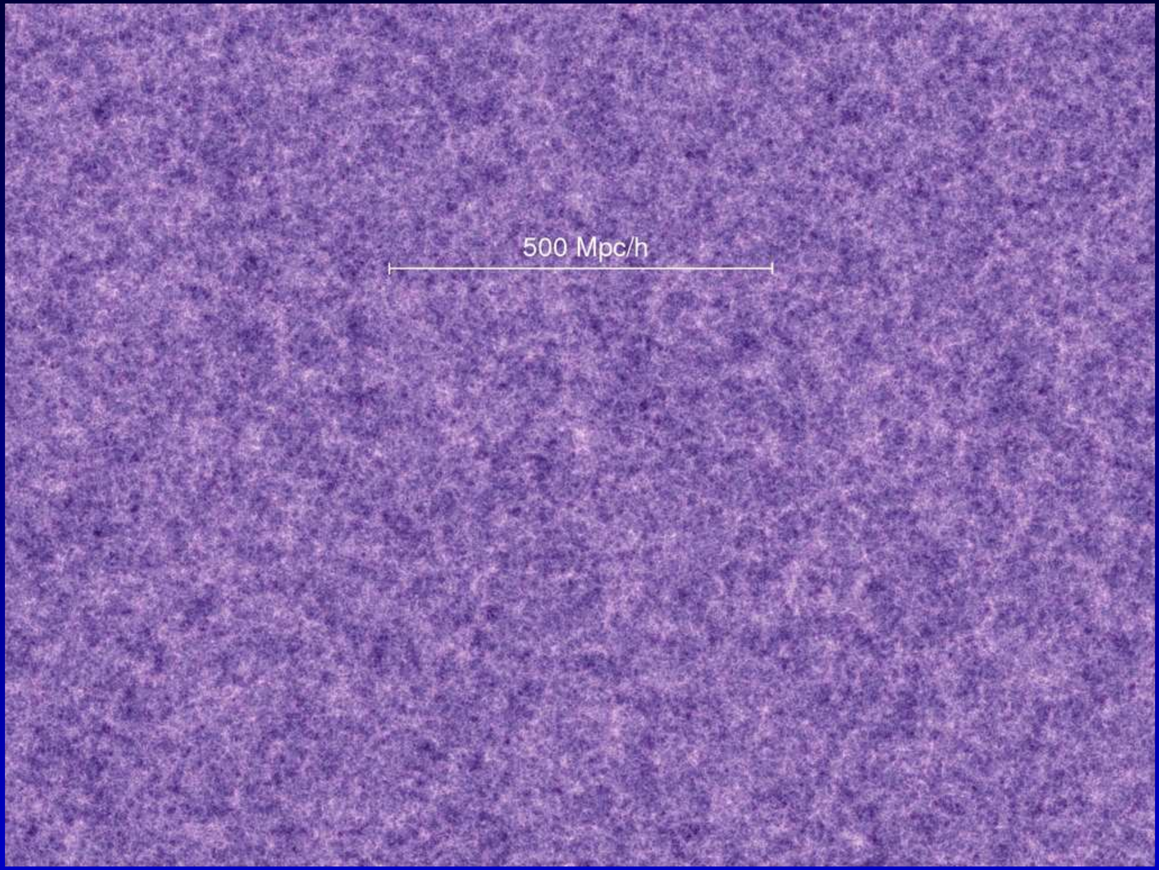

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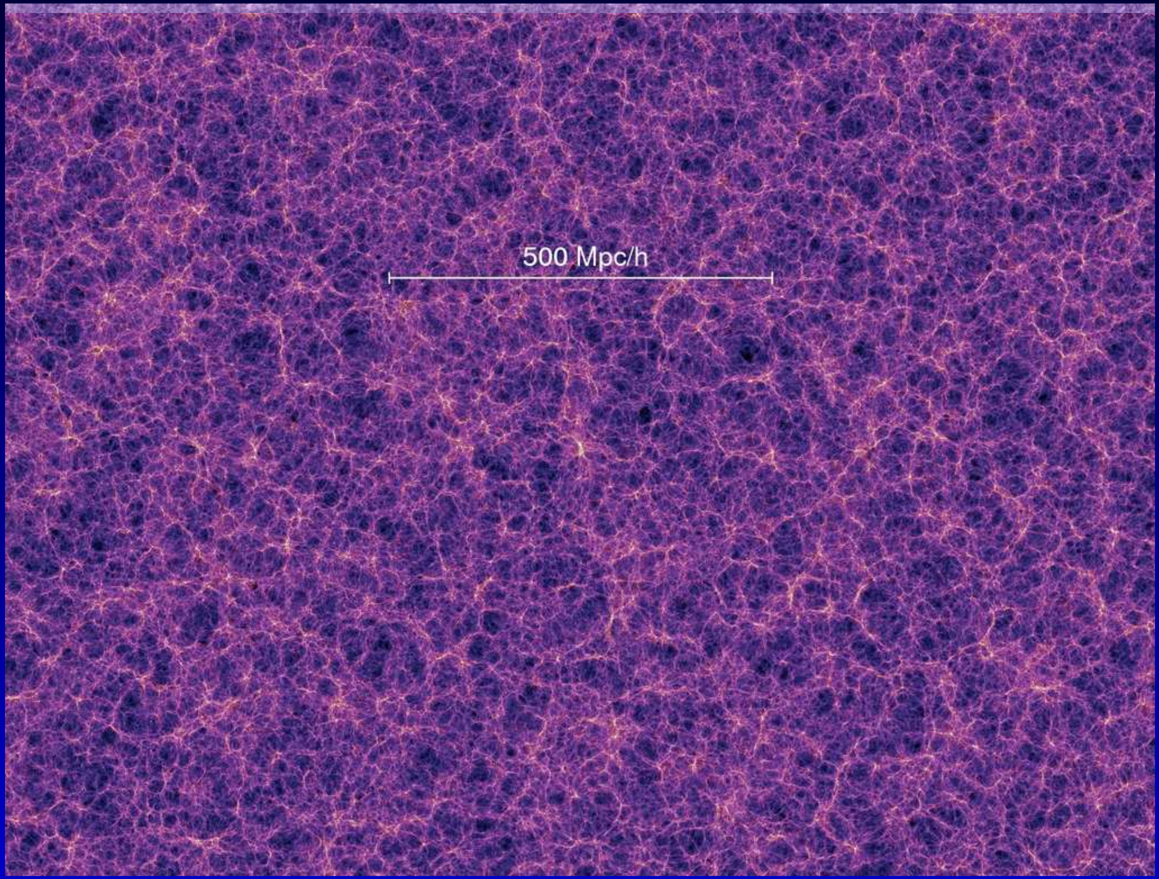

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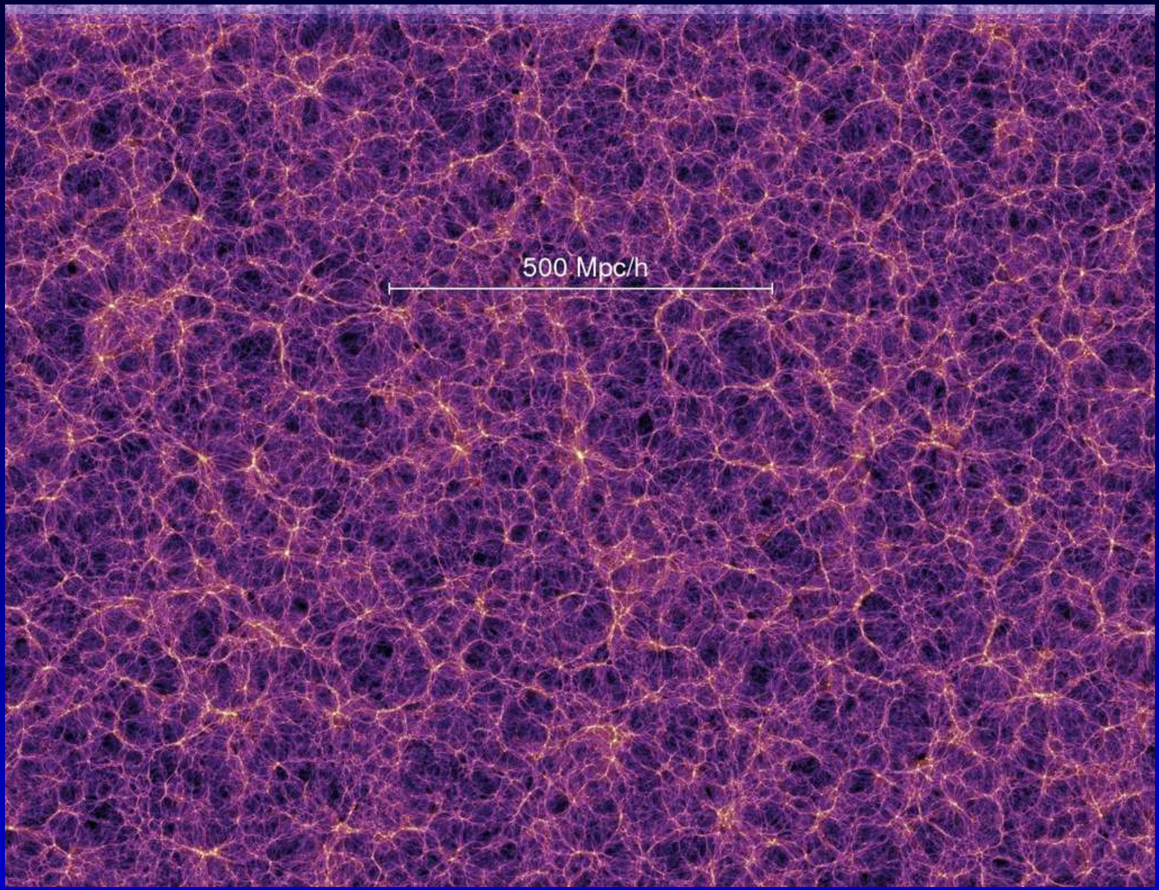

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Which reference contrast (Δ_{th})? Δ_v, 178, 200, 500, 2000...

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Can be generalized to other models

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Test beyond geometrical characterisation of the universe. (Oukbir and A.B, 1992)

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so that M and z are the only two numbers to characterize a cluster. (you can add further ingredients like c NFW concentration parameter, ν...)

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so that:

$$T_x = A_{TM} M^{2/3} (1+z)(\Omega_m \Delta/178)^{1/3}$$

(this depends on the choice of ρ_r).

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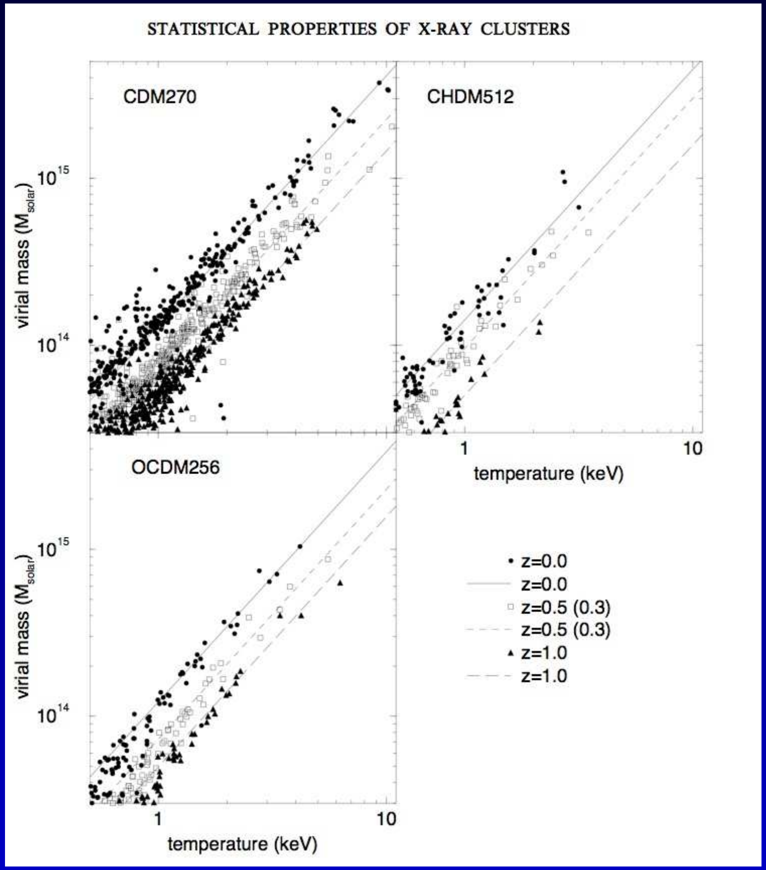

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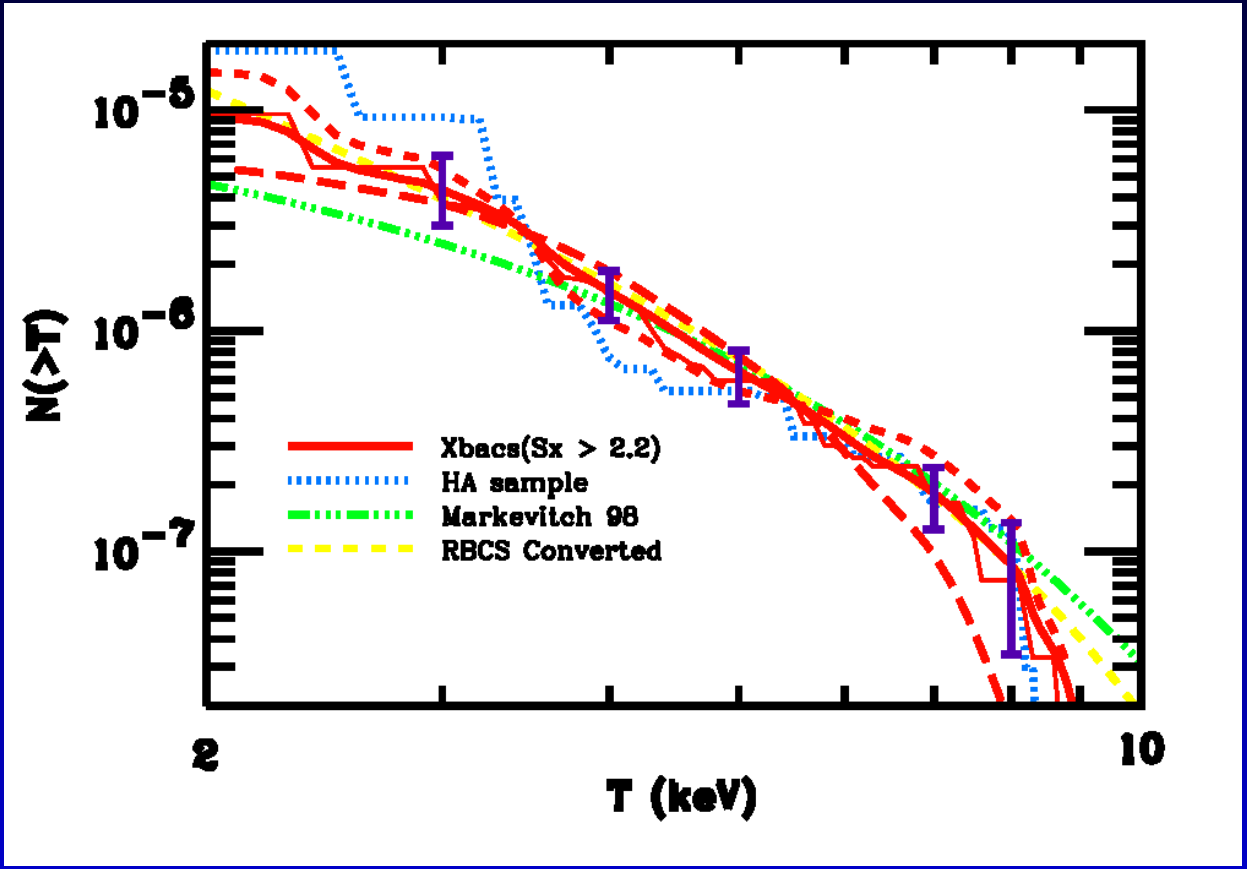

From mass to observables: applications

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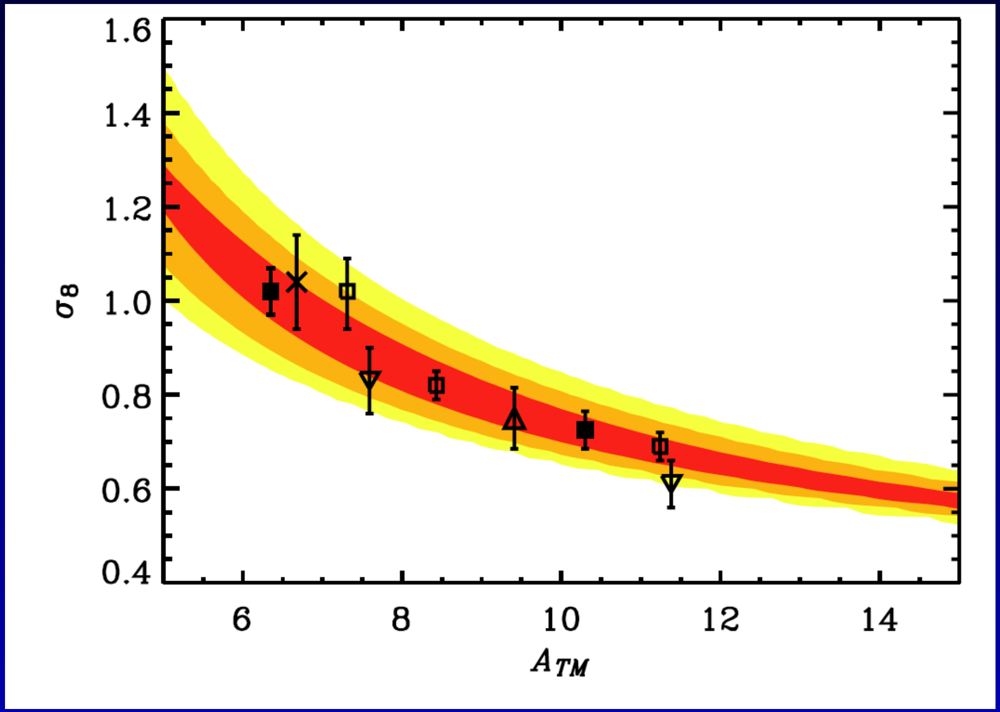

Evard et al (2002), Pierpaoli et al. (2003), Seljak (2002), Vauclair et al. (2003), Viana et al. (2003)

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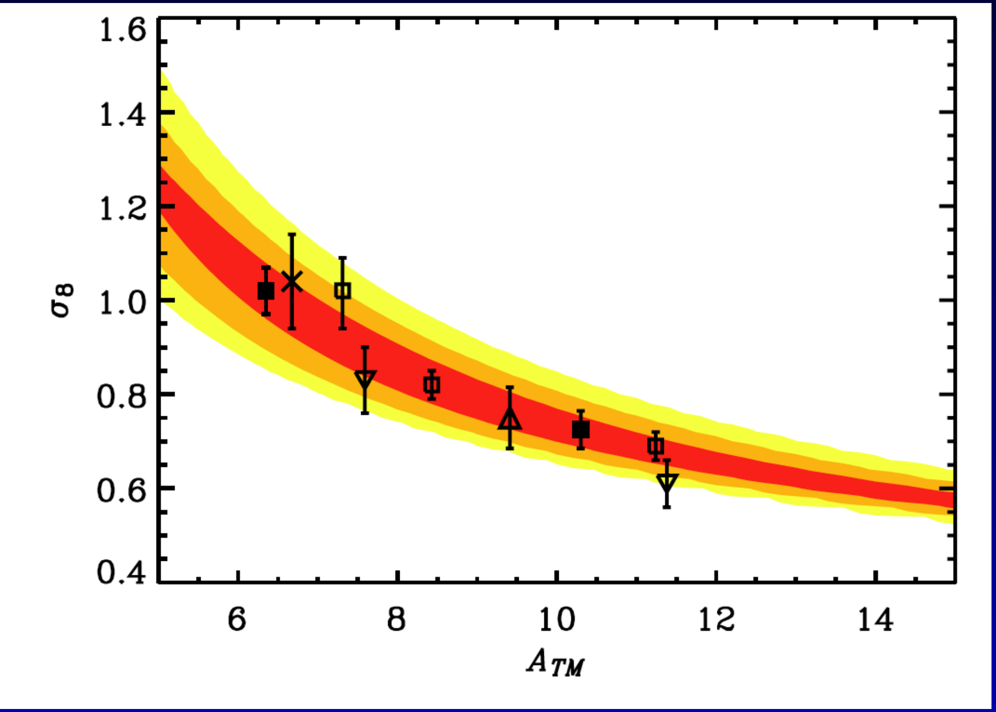

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Consistency and degeneracy...

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Gas in clusters needs extra heating.

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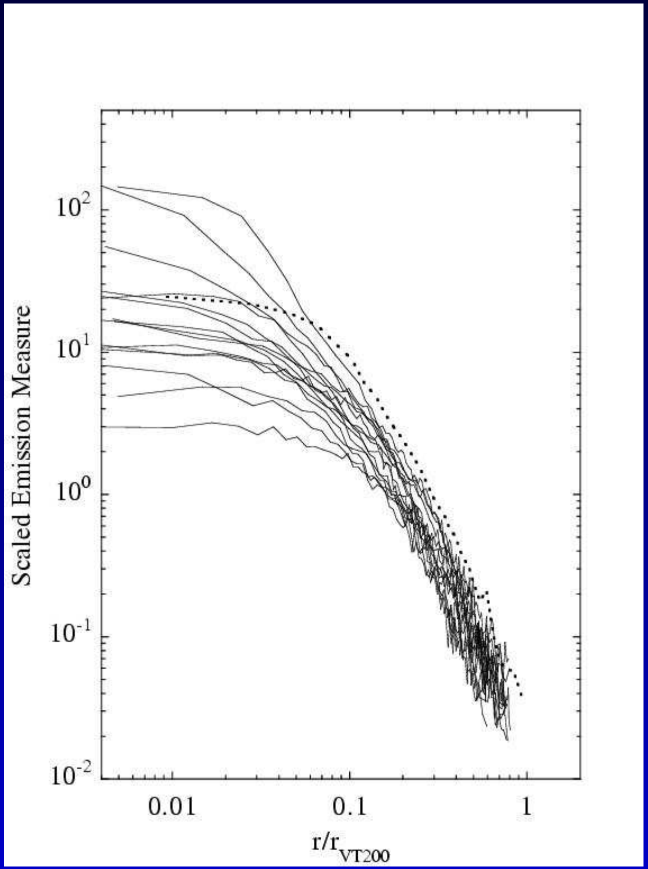

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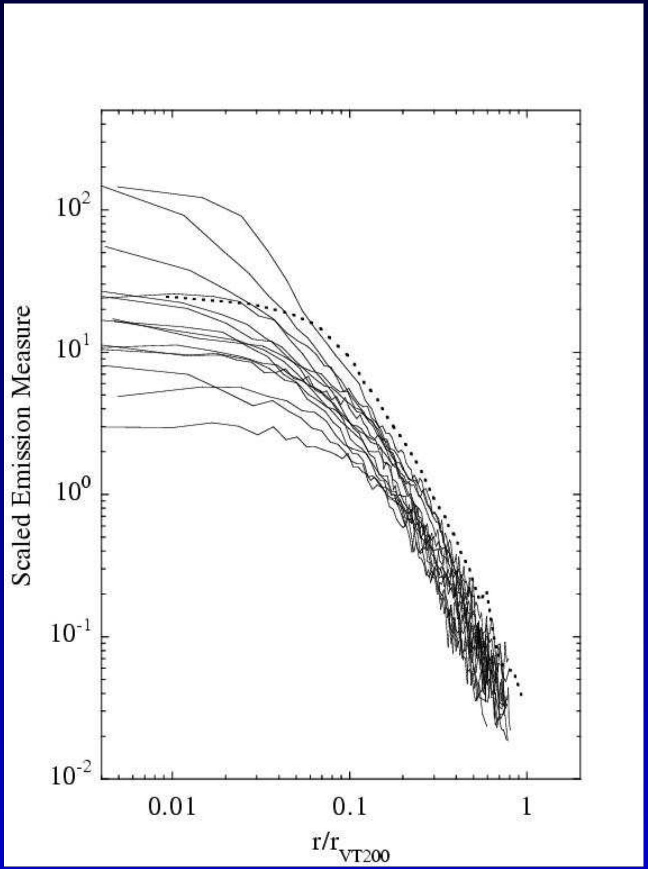

So clusters may be self-similar after all...

Sunyaev Zeldovich

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$$Y = K M_g T_g D_a^{-2} \tag{1}$$

Sunyaev Zeldovich

(1) $$Y = K M_g T_g D_a^{-2}$$

Leading to the scaling law

$$Y = \kappa \xi A_{TM} f_B M^{5/3} h^{8/3} \left(\Omega_M \frac{\Delta(z, \Omega_M)}{178} \right)^{1/3} (1+z) D^{-2}$$

where $\kappa = 1.816.10^{-4}$ and ξ accounts for the difference between T_x and T_g.

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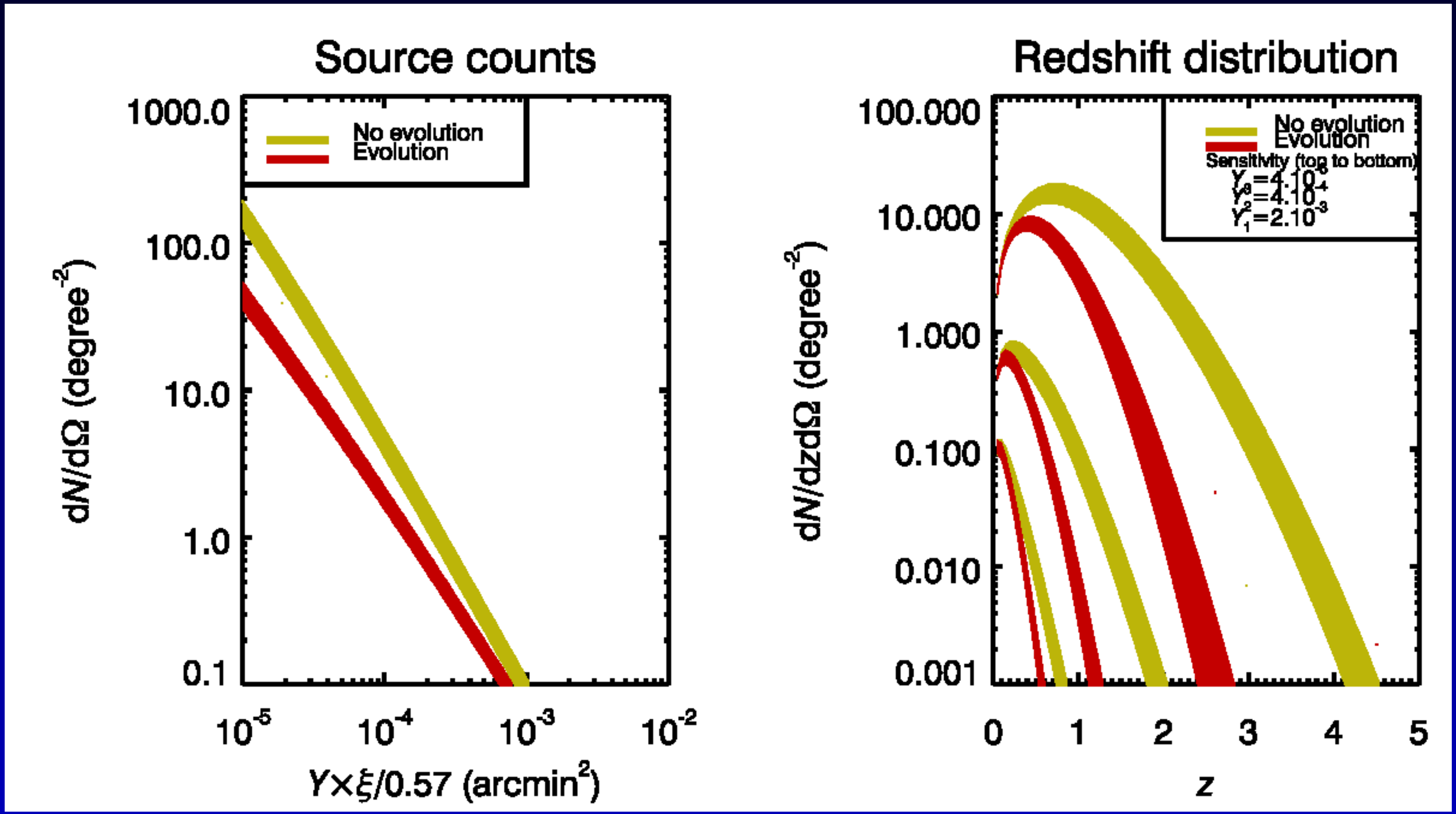

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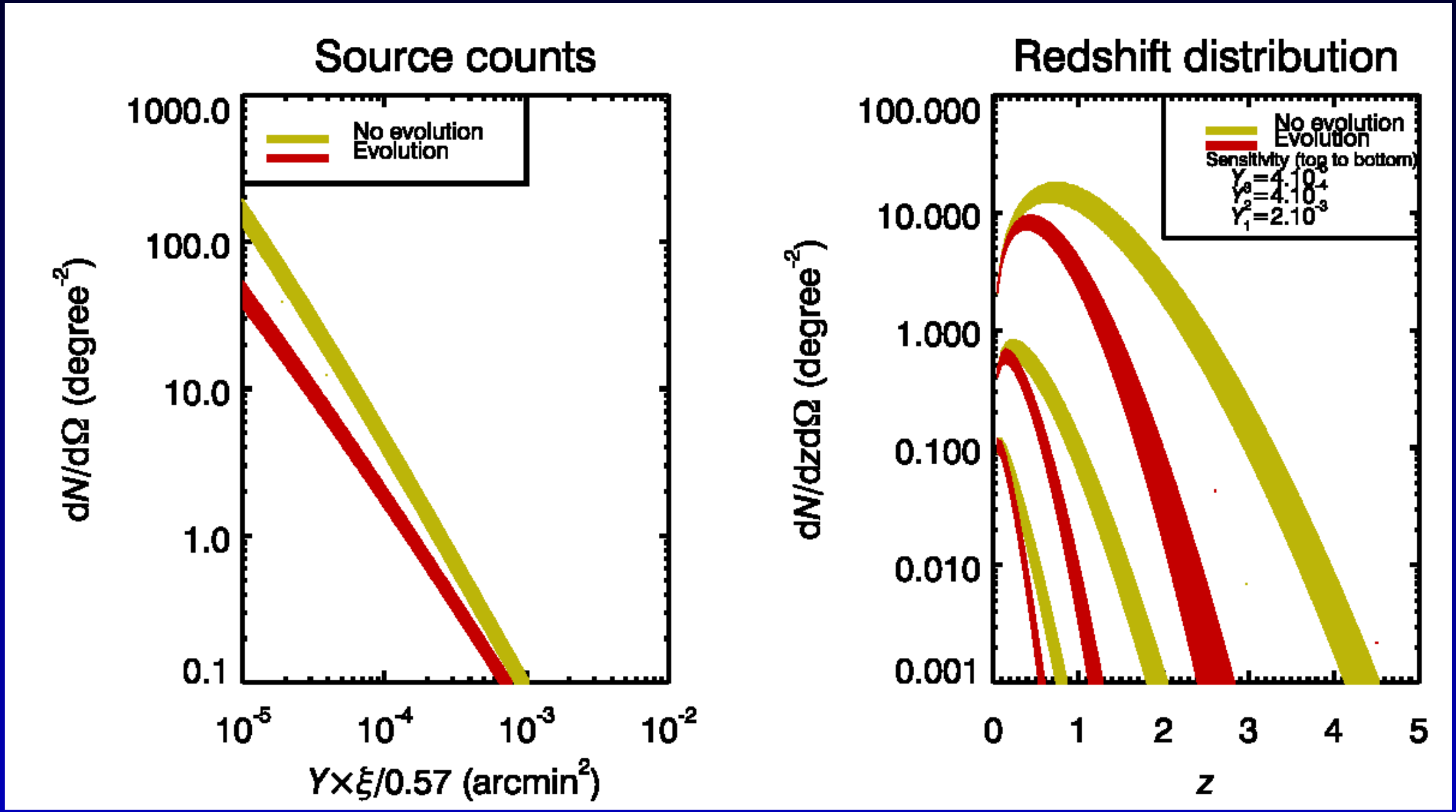

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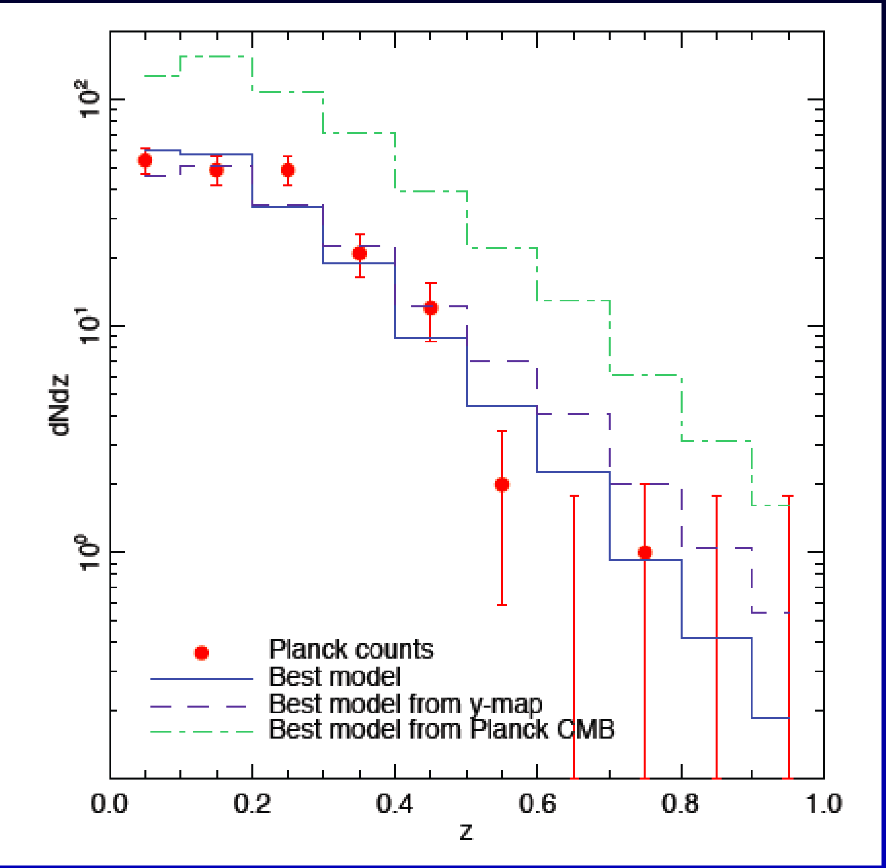

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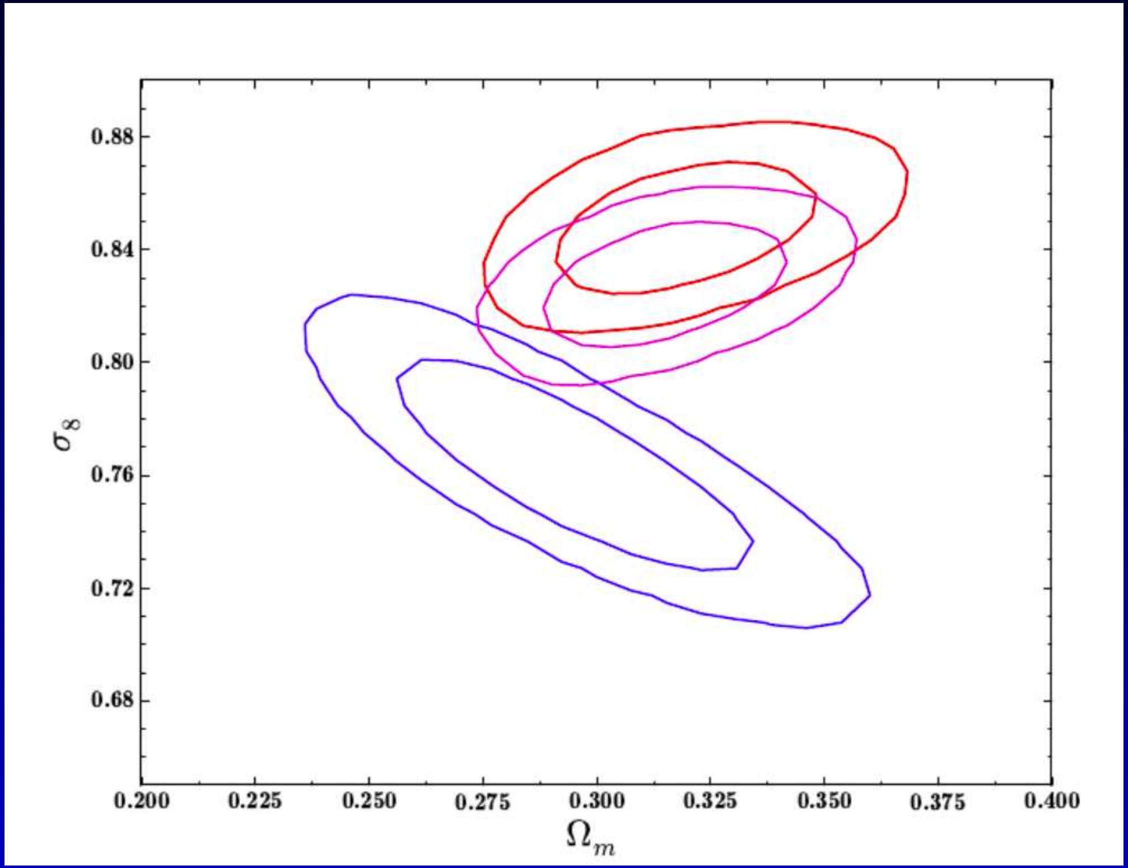

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Try to estimate A_{TM}

Cluster gas physics

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Use CosmoMC on SNIa+$P(k)$+CMB + $N(T_x)$

Cluster gas physics

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Estimates parameters inclusing A_{TM} :

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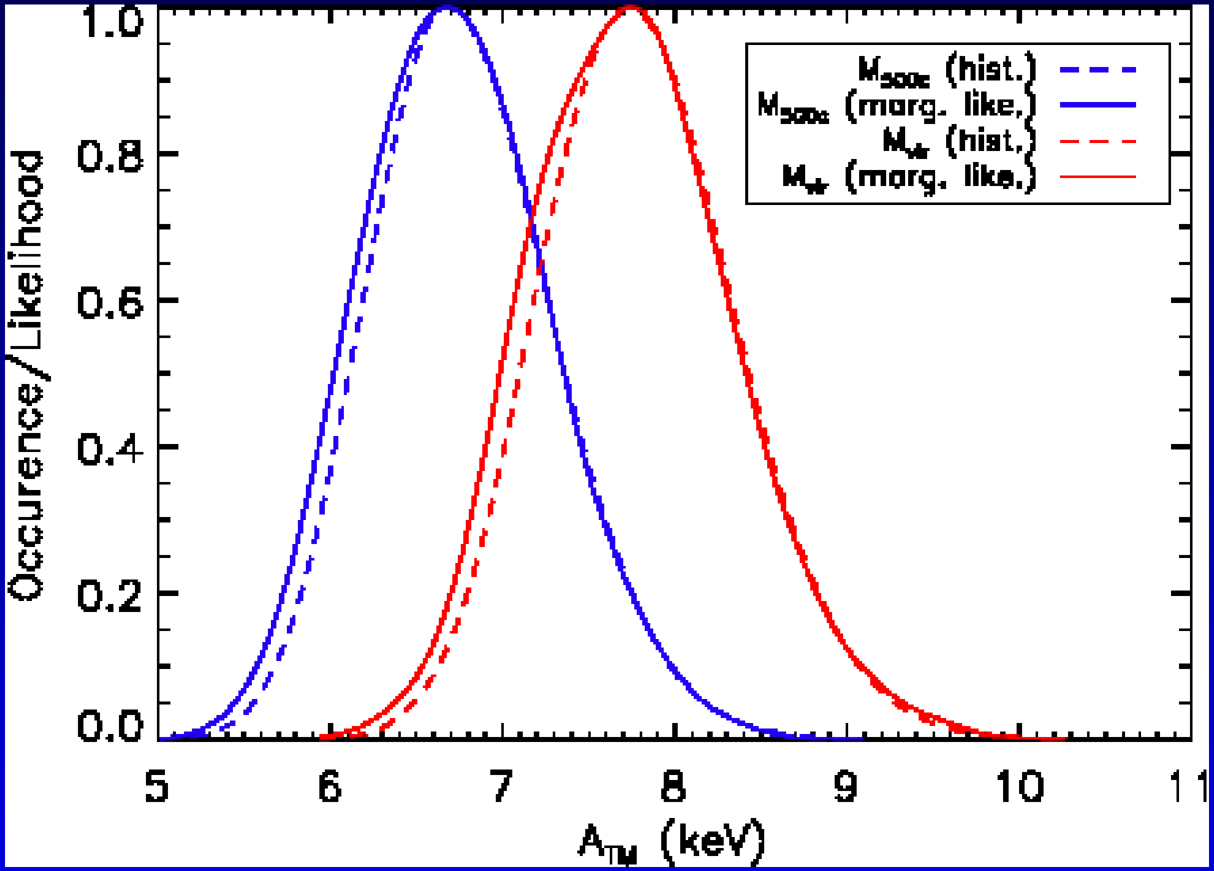

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Cluster gas physics

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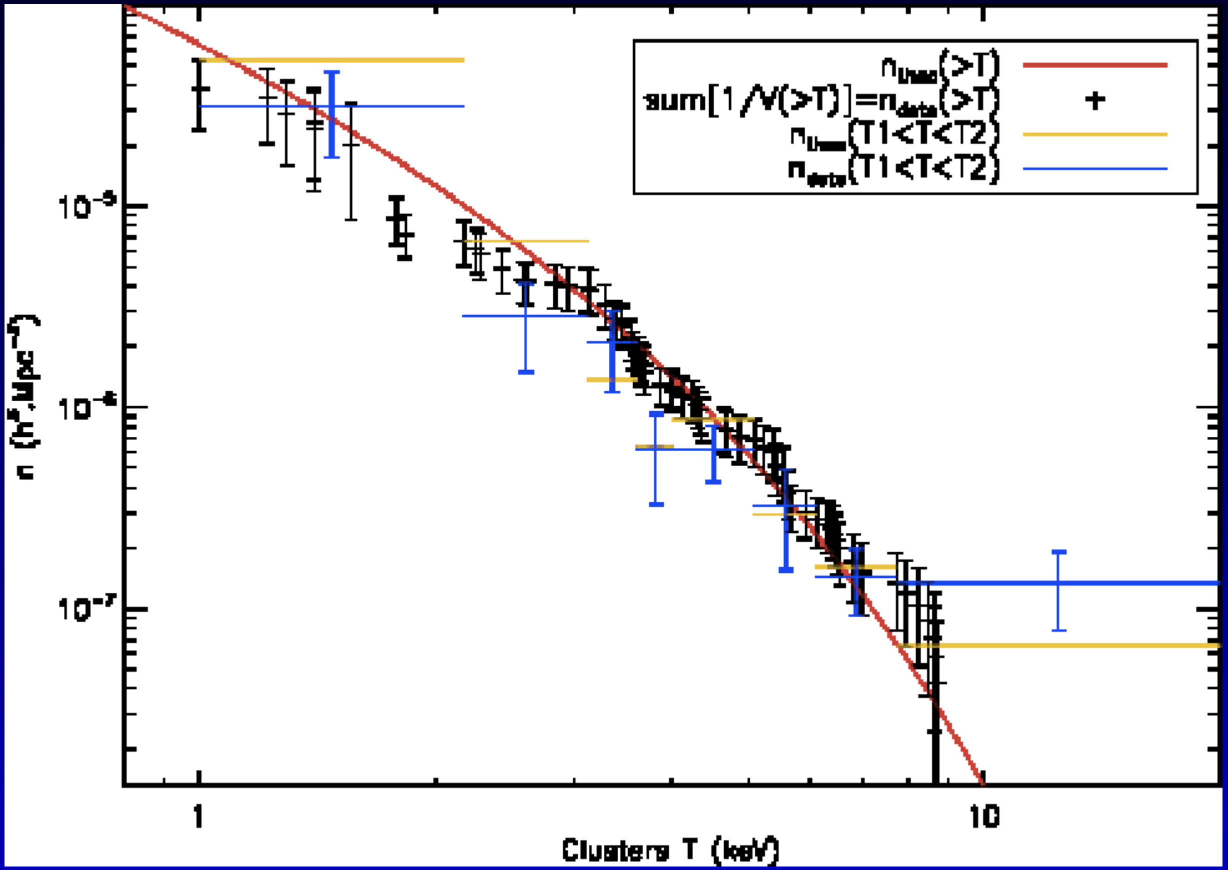
Estimates A_{TM} (Tinker)

$A_{TM} = 7.7 \pm 0.7$ keV (R_{vir})
$A_{TM} = 6.7 \pm 0.6$ keV (R_{500})

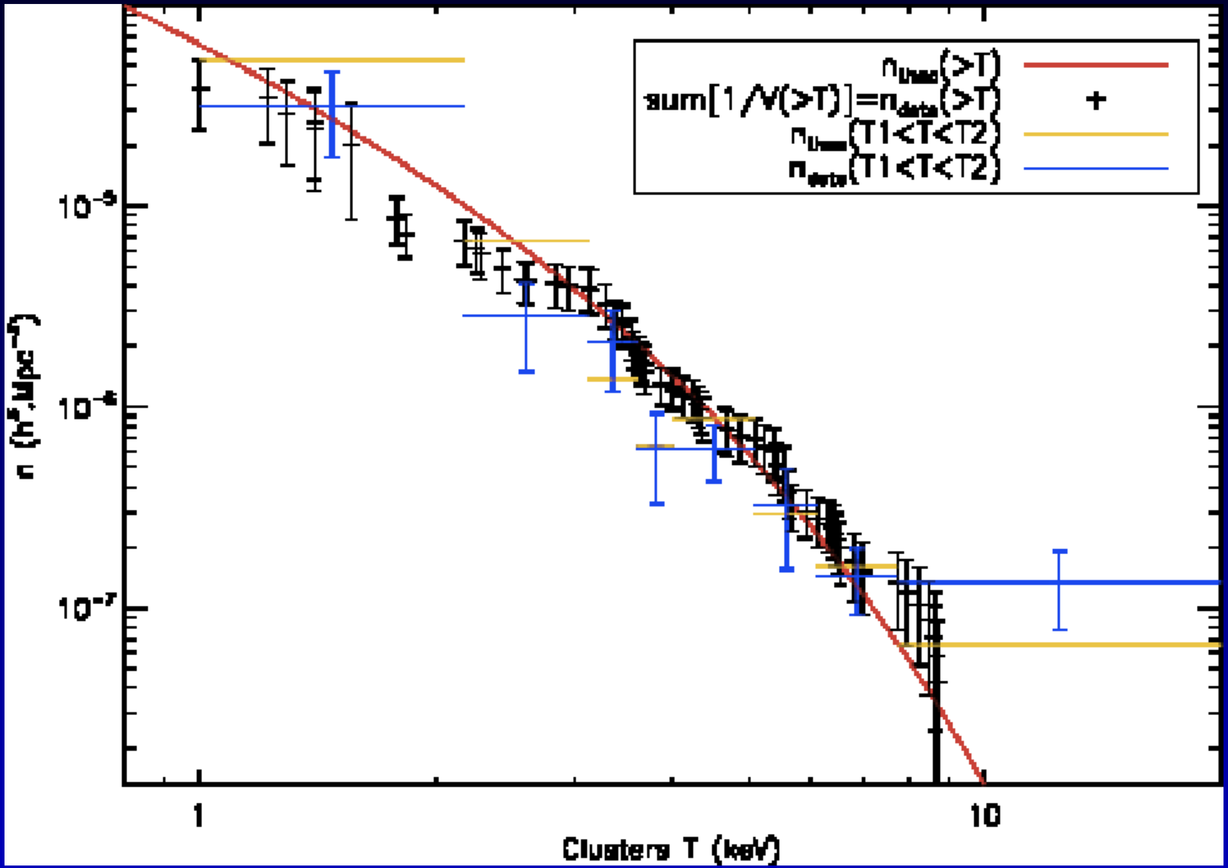
S.Ilic & A.B.

Cluster gas physics

Cluster gas physics

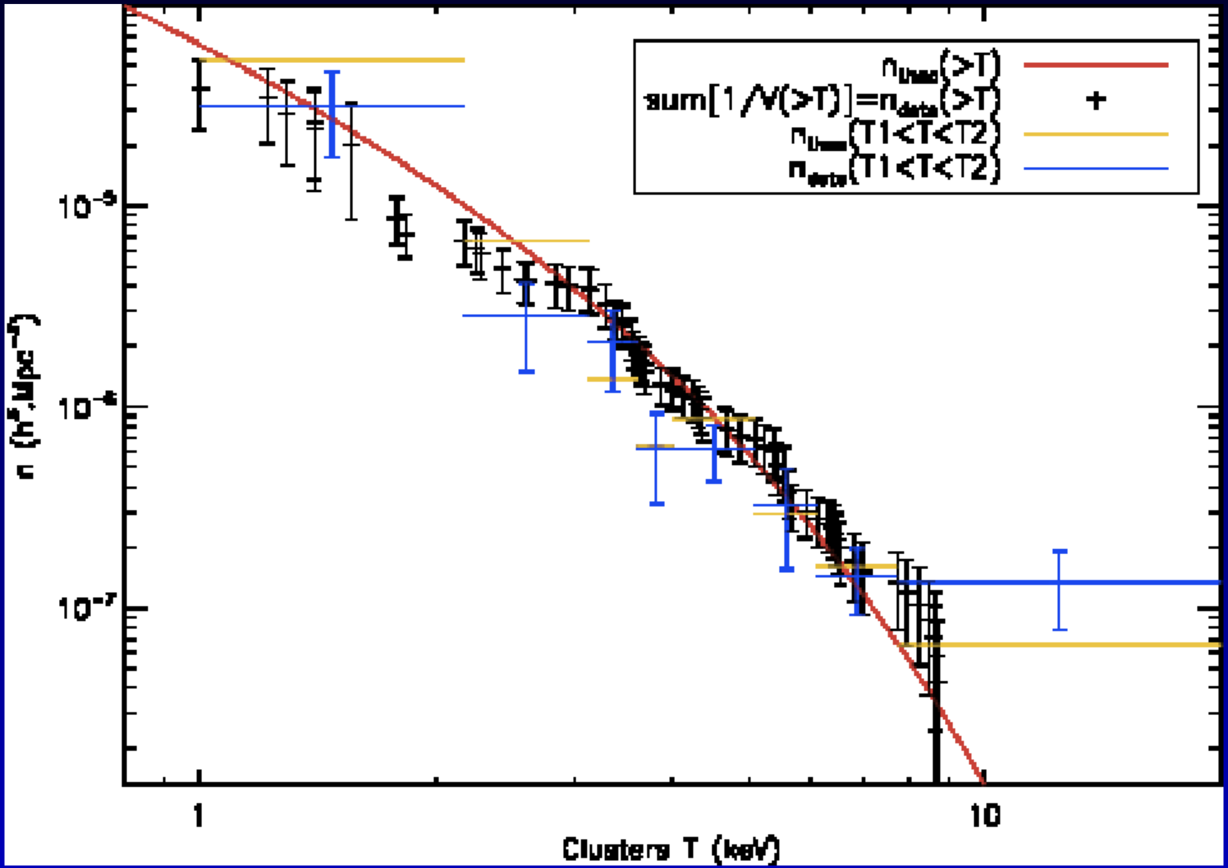


Cluster gas physics



We need large sample of clusters...

Cluster gas physics



We need large sample of clusters... X-ray, SZ, optical ?