SZ and baryonic properties of MareNostrum and MultiDark simulated clusters of galaxies

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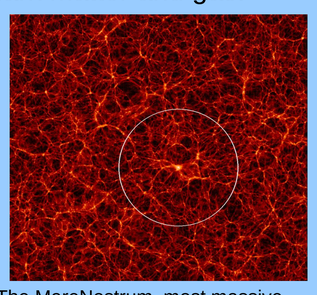
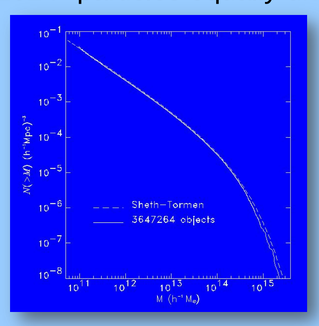
Dataset (1) : MareNostrum Universe resimulated clusters

The *MareNostrum Universe* (Gottlöber & Yepes 2007) is a non radiative SPH cosmological simulation of a cubic box with 500 Mpc/h on a side with cosmological parameters Ω_Λ=0.7,Ω_m=0.3, Ω_{bar}=0.045, h = 0.7, σ_8=0.9 and a slope n=1 for the initial power spectrum. It contains a total of 2 x 1024^3 particles equally divided between dark matter and gas.



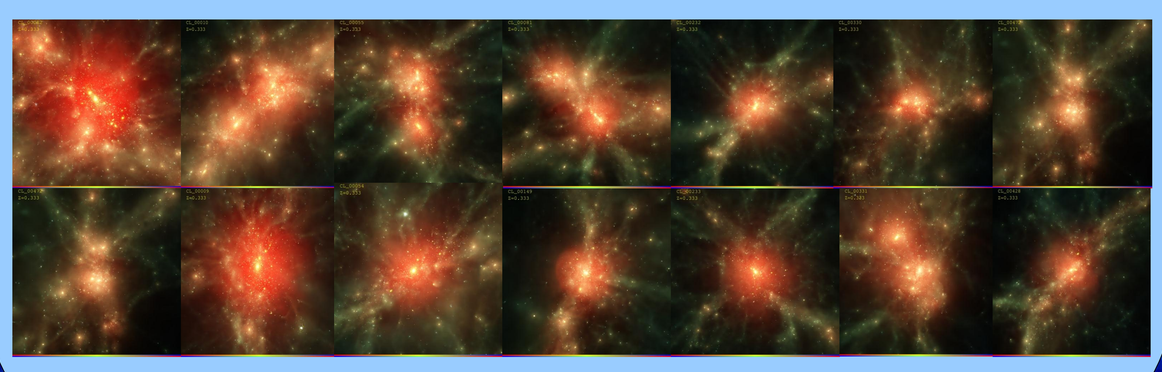
The MareNostrum most massive cluster (2.3x10^{15} M_{sun})



The MareNostrum FoF Mass function

Among the 4600 clusters of galaxies with M > 10^{14} h^{-1} M_{sun} contained in the MareNostrum Universe, we selected a sample of 82 '*bullet-like*' clusters and an equivalent number of relaxed clusters having the same total mass. We defined as 'Bullet-like' clusters as clusters with 2-D displacement of at least 200 kpc between the gas peak and the DM peak (see Forero-Romero et al 2010)

Using GADGET, we resimulated these 164 clusters with 8 times more particles (**m_{DM}=1.03 x 10^9 h^{-1} M_{sun}** and **m_{gas}=1.82 x 10^8 h^{-1} M_{sun}**) and adding radiative physics (i.e cooling , UV photionization, star formation and SN thermal and kinetic feedbacks). The most massive clusters of the dataset (10^{15} h^{-1} M_{sun}) contains more than 6 million particles (DM+gas+stars), the less massive (10^{14} h^{-1} M_{sun}) about 1 million. The gravitational smoothing was set to an effective Plummer ε=6 h^{-1} kpc.



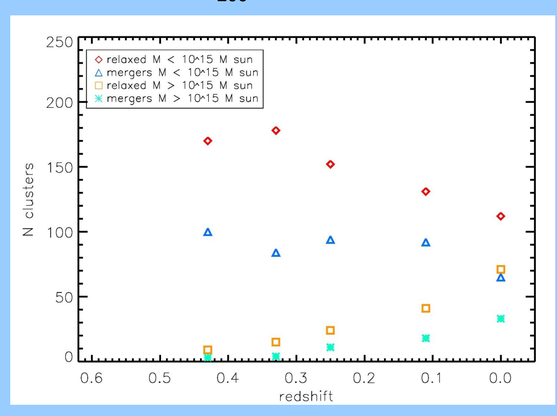
A sample of MareNostrum resimulated clusters: bullet-like clusters (top) and relaxed clusters (bottom). The gas density, color coded according to temperature, is shown together with the stellar particles using the SPLOTCH ray tracing program

Comparison of Gas and Baryonic properties of Merger vs. relaxed clusters

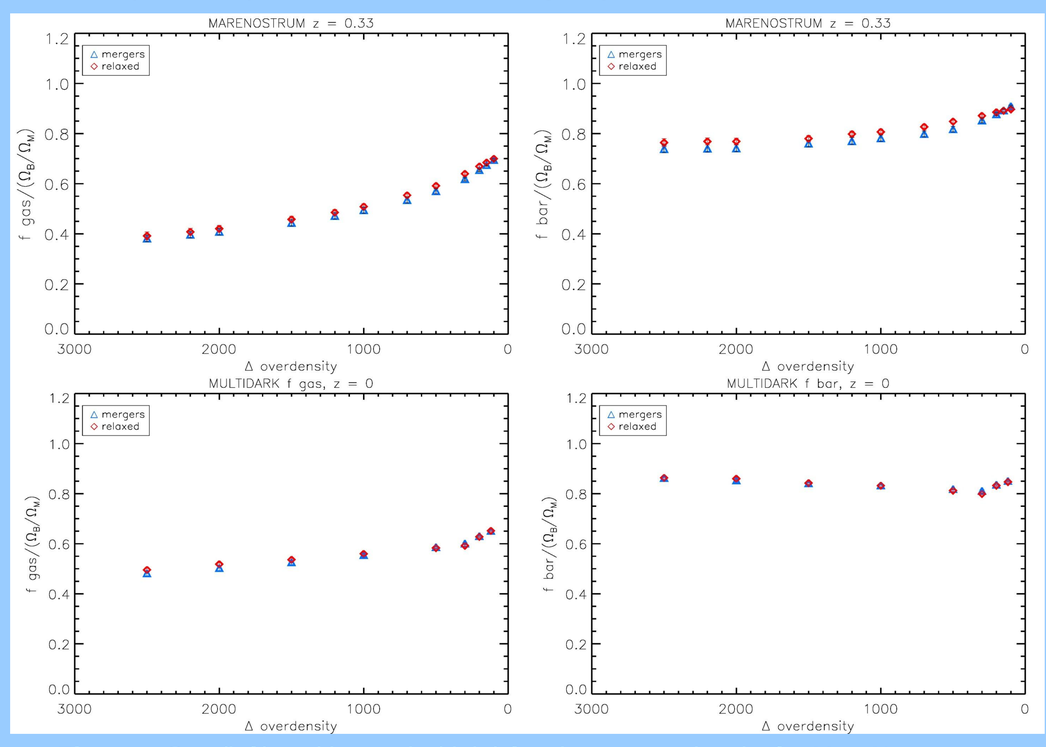
The radial dependence of gas and baryon fractions is studied for two classes of clusters: mergers and relaxed clusters. We label as mergers any cluster in which we are able to identify a companion structure inside R_{200} whose mass is greater than 0.1 M_{200}

	MultiDark		MareNostrum	
z	N mergers	N relaxed	N mergers	N relaxed
0	98	183	25	133
0.11	110	171	35	123
0.25	105	176	62	96
0.33	88	193	54	34
0.43	103	179	78	80

Table: *Number of merging clusters and number of relaxed clusters for each dataset at different redshifts*
Figure *: Number of mergers and relaxed clusters vs redshift for MultiDark clusters*



There are no significative differences between the two morphological classes (mergers and relaxed) as far as the mean gas and baryonic fractions are concerned. Nevertheless, there is still a potential problem with overcooling of gas at the cluster centers.



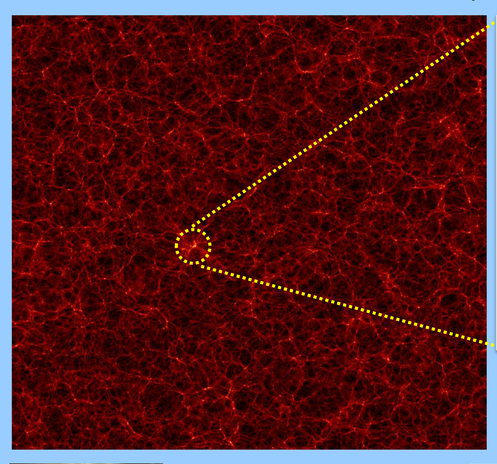
Figures: Gas (left) and baryonic (right) fraction vs overdensity for MareNostrum (top) and MultiDark (bottom) clusters. All values are normalized to the baryonic cosmic ratio of the simulation

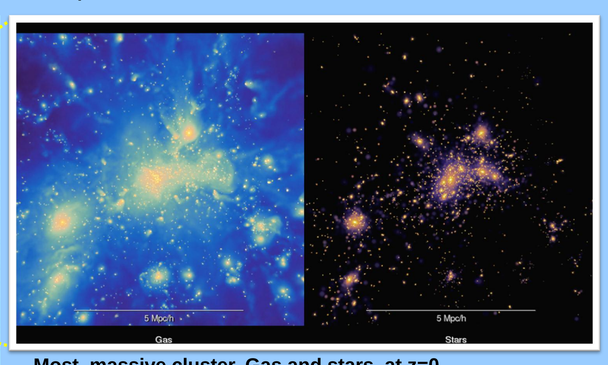
Dataset (2) : MultiDark resimulated clusters

The *MultiDark simulation* is an ART dark matter only simulation performed by Anatoly Klypin at NAS Ames, containing about 8.6 billion particles in a (1 Gpc/h)³ volume that was performed using WMAP7 cosmological parameters (Ω_Λ=0.73, Ω_m 0.27 Ω_b= 0.0469, n = 0.95, σ_8= 0.82).

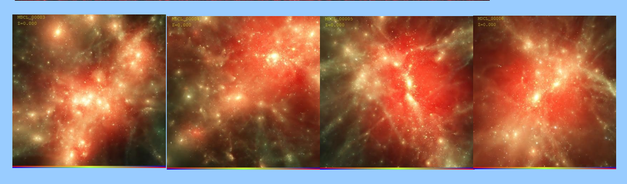
We have selected all the cluster-size halos more massive than M> 10^{15} h^{-1} M_{sun} *(283)* at z=0 and resimulated them with SPH gas particles and radiative physics (cooling, UV photoionization, star formation and galactic winds). The mass resolution was improved by a factor of 8 using the zooming technique (**m_{DM}=9.01 x 10^8 h^{-1} M_{sun} ; m_{sph}=1.9x10^8 h^{-1} M_{sun}).** For each cluster, we took a resimulated region of 6 h^{-1} Mpc radius. In some of these resimulated areas we found more than one cluster. The **total number** of resimulated clusters finally obtained was **343** with **M> 10^{14} h^{-1} M_{sun}**. The spatial resolution was set to 6 h^{-1} kpc comoving .

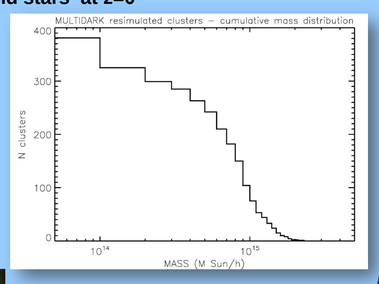
A subset of these clusters (150) have been resimulated also with same resolution and non-radiative SPH hydrodynamics. The GADGET code was used to run all these simulations in the MareNostrum Supercomputer at BSC.



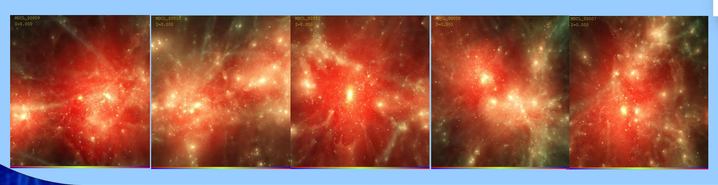


Most massive cluster. Gas and stars at z=0





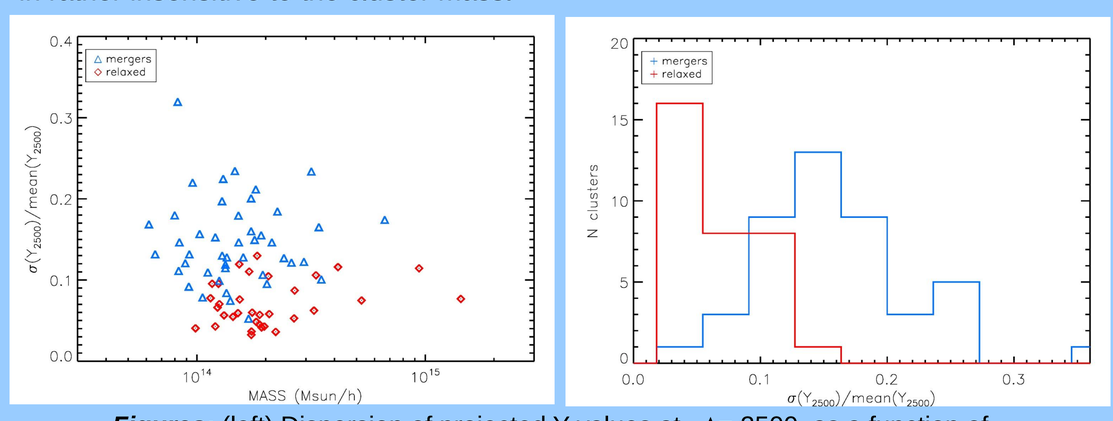
The cumulative mass distribution of resimulated MultiDark clusters



SZ properties of the MareNostrum clusters

We investigate the impact of cluster morphology, and so its projection effect, on the observed integrated comptonization parameter Y and consequently on the application of Y-M scaling law.
We performed more than 300 rotations for every cluster of the MareNostrum dataset, built the thermal SZ projected map for every cluster and estimated the Y parameter at various overdensities (Δ = 200, 500, 2500; see Flores-Cacho et al 2010)

We found that the morphology of the cluster affects the estimation of Y due to projection effects, leading to possible uncertainties in the scaling relations. At Δ = 2500 the merged clusters have a mean dispersion of more than 15% on the Y, in contrast to just a 7% of the relaxed clusters at the same overdensity. The dispersion in rather insensitive to the cluster mass.



Figures: (left) Dispersion of projected Y values at Δ= 2500 as a function of cluster mass. (right) Distribution of projected Y values: The merger clusters show a dispersion twice larger than the relaxed ones.

References

- I. Flores-Cacho et al, 2010, MNRAS, 400, 1868.
- J. Forero-Romero, S. Gottloeber, and G.Yepes - 2010 *ApJ* 725, 598
- S. Gottlöber and G. Yepes, 2007, ApJ, 664, 117.

Further information in these websites

- **The MultiDark Project: http://projects.ift.uam.es/multidark/**
- **MultiDark Simulation Database: http://www.multidark.org/**
- **MultiDark Resimulated Clusters: http://simugal2.ft.uam.es/MULTIDARK/**
- **The MareNostrum UNIVERSE: http://astro.ft.uam.es/marenostrum**
- **The MareNostrum resimulated Clusters: http://simugal2.ft.uam.es/MNCLUSTERS**