# Baryons and Dark Matter halo distributions in ΛCDM Cosmology

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**Abstract.** We analyse the dark matter (DM) distribution in a $\approx 10^{12} M_\odot$ halo extracted from a simulation consistent with the concordance cosmology, where the physics regulating the transformation of gas into stars was allowed to change producing galaxies with different morphologies. Although the DM profiles get more concentrated as baryons are collected at the centre of the haloes compared to a pure dynamical run, the total baryonic mass alone is not enough to fully predict the reaction of the DM profile. Our findings suggest that the response of the DM halo is driven by the history of assembly of baryons into a galaxy. The accretion of satellites could be associated with an expansion of the dark matter profiles, triggered by angular momentum transfer from the incoming satellites. However, we also found that these mechanism have different efficiencies which are set by the history of formation of the structure.

**Keywords.** galaxies: halos, galaxies: structure, cosmology: dark matter

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## 1. Introduction

We have studied in detail the effects of the galaxy formation on the dark matter (DM) distribution of $\approx 10^{12} M_\odot$ halo within the framework of ΛCDM cosmology. The contraction of the DM haloes due to the infall and condensation of baryons in the central regions is a well accepted process (Tissera, P. B. *et al.* 1998, Gnedin, O.Y., *et al.* 2004). However, theoretical models based on the adiabatic contraction (AC) hypothesis missed the hierarchical characteristic of the structure assembly in a hierarchical scenario. Recent studies of cosmological grown galactic haloes show that the final structure of the DM halo depends on the way baryons are put together and not solely on the amount of baryons gathered in the centre of haloes (Pedrosa *et al.* 2009). The accretion of satellites is found to correlate with a decrease in the central DM concentration in agreement with previous works (Debattista, V. P. *et al.* 2008, Romano-Díaz, E. *et al.* 2008).

## 2. Analysis and Results

We analysed a set of six simulations (Scannapieco *et al.* 2008) of a $\approx 10^{12} M_\odot$ halo, run with an extended version of the code GADGET2 (Scannapieco *et al.* 2006) which includes a new multiphase model for the gas component, metal-dependent cooling, chemical enrichment and energy feedback by Supernovae (SN) events. The initial condition corresponds to a halo extracted from a cosmological simulation and re-simulated with higher resolution. The simulations are consistent with a ΛCDM Universe with: $\Omega_\Lambda = 0.7$, $\Omega_m = 0.3$, $\Omega_b = 0.04$, $\sigma_8 = 0.9$ and $H_0 = 100h$ km s$^{-1}$ Mpc$^{-1}$, with $h = 0.7$. The DM particle mass is $1.6 \times 10^7 h^{-1}$ M$_\odot$ while initially the gas mass particle is $2.4 \times 10^6 h^{-1}$ M$_\odot$.

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The maximum gravitational softening used is $\epsilon_{\mathrm{g}} = 0.8h^{-1}$ kpc. We have also performed a pure gravitational run (DM-o) of the same initial condition. The simulations were run varying the physics of baryons. As a result, DM haloes host baryonic structures with different morphologies since the transformation of gas into stars has been regulated differently in each run, although they all follow the same underlying DM tree.

We calculated the spherically-averaged DM profiles of the DM distribution cleaned of substructure. When baryons are present the DM concentrations increase in the central regions. Almost all haloes present a nearly isothermal behaviour in the region dominated by baryons, in agreement with results from the higher resolution simulations of the Aquarius project (Tissera *et al.* 2009 in preparation). We take two experiments as examples: NF (spheroid dominated) and E-07 (disk dominated). The galaxy in the NF run is dominated by old stars, determining a spatially extended spheroid with an outside-in formation. While the system in E-0.7 has a compact old spheroid and an important disc component populated by younger stars. We found that the DM halo in E-07 is more concentrated than the NF one, although it hosts a galaxy a factor of two less massive: the response of the DM to the presence of baryons not only depends on the total amount collected within the central regions. To analyze the connection between the DM evolution and the history of formation of the baryonic structures, we calculated the concentration parameter $\Delta_{v/2}$ (Alam *et al.* 2002) as a function of redshift. This parameter measures the mean DM density normalized to the cosmic closure density within the radius at which the circular rotational speed due to the DM alone rises to half its maximum value. We found that all haloes increase their concentration as they grow with time, but follow different paths. As expected, the DM-o run has the lowest concentration, at all times. In general, the relation flattens between $z \approx 1$ and $z \approx 1.8$, coinciding with the approaching of satellites. The NF run is always more concentrated than the DM-o one but it has a stronger flattening of the relation during the same period of time. The E-07 run has a weaker flattening during the same period and then it gets to larger level of central concentration although the galaxy efficiency is always weaker than the NF run. The SN feedback has not only regulated the SF activity in the main galaxy but also in the satellites systems. In the NF case, the satellites are clearly more massive and have been able to survive further in the halo since stars are more gravitationally bounded. E-0.7 shows smaller stellar satellites. We have also compared our results with the theoretical ones predicted by different Adiabatic Contraction prescriptions finding that Blumenthal *et al.* (1986) largely overpredicts the level of concentration, as expected; In agreement with previous works our results confirm the non-adiabatic contraction of the haloes and the key role played by the history of galaxy formation on the final distribution of DM at galactic scales.

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