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EFFECTS OF GALAXY FORMATION ON DARK MATTER HALOES

S. E. Pedrosa,[1,2] P. B. Tissera,[1,2] and C. Scannapieco[3]

RESUMEN

Hemos estudiado seis halos del Proyecto Aquarius, encontrando, en acuerdo con resultados previos, que la acumulación de los bariones en la región central tiende a incrementar la concentración de la materia oscura. En todos los casos la velocidad de dispersión aumenta monótonamente con el radio. Los modelos de contracción adiabática existentes no reproducen correctamente la forma y concentración de los perfiles de densidad de la materia oscura, de halos galácticos en universos ΛCDM.

ABSTRACT

We have studied six galaxy-sized haloes of the Aquarius Project, finding, in agreement with previous results, that baryon condensation leads to an increase of the dark matter concentration. We find that in all cases the velocity dispersion increases monotonically with radius. The shape and concentration of the dark matter density profiles in ΛCDM universes are not well reproduced by adiabatic contraction models.

Key Words: cosmology: theory — galaxies: evolution — galaxies: formation

1. INTRODUCTION

Cosmological simulations has proven to be very succesfull at reproducing global properties of large scale structures. But there exists several problems that remain to be solved principally at galactic scale. The condensation of baryons within dark matter (DM) haloes modifies both their dynamics and their structure but the detailed mechanism of how this happens is still unknown. The simplest theoretical model to predict the contraction assumes that the halo is compresed radially and adiabatically by adding mass at its centre (Blumenthal et al. 1986, hereafter B86). More recent simulations found that the Adiabatic Contraction (AC) overestimates this effect (Gnedin et al. 2004, hereafter G04; Abadi et al. 2010, hereafter A10; Pedrosa et al. 2010). Recently Pedrosa et al. (2009, 2010) found that SN feedback plays a key role by regulating star formation activity and ejecting material not only from the main system but also from infalling satellites, concluding that knowing the distribution of baryons at the centre of the DM halo is insufficient to determine halo response to galaxy formation.

2. SIMULATIONS

The six haloes studied here were taken from the Aquarius Project (Springel et al. 2008). They were selected from the Millennium-II Simulation with only a mild criteria for isolation[4]. The dark matter only version of these haloes were then resimulated at a variety of much higher resolutions as part of the Aquarius Project. The lowest resolution version of each halo was also resimulated with detailed modelling of baryonic processes by Scannapieco et al. (2008). A version of GADGET-3, optimized for massively parallel simulations of highly inhomogeneous systems, was used. This code includes a multiphase model for the gas component with metal dependent cooling, star formation and phase dependent treatment of the SN feedback and chemical enrichment. The simulated haloes have $\approx 1\times10^6$ particles within the virial radius for the baryonic runs. The virial masses ranges between $5 \times 10^{11}\ M_\odot\ h^{-1}$ to $11 \times 10^{11}\ M_\odot\ h^{-1}$. Hence dark matter particles have masses of the order of $10^6\ M_\odot\ h^{-1}$ while gas particles initially have $\approx 2\times10^5\ M_\odot\ h^{-1}$. All the simulated haloes share the same baryonic physics. We compared our results with the purely dynamical versions run by Navarro et al. (2010) in order to unveil the effects of the presence of baryons.

3. RESULTS AND DISCUSSION

We calculated the DM density profiles within the virial radius, defined as the one where the mean density is $\sim$200 times the critical density. We calculated spherically averaged profiles using logarithmic binning. To characterise our DM profiles, we adopted

[1]Instituto de Astronomía y Física del Espacio, CONICET-UBA, CC 67, Suc 28 (1428), Buenos Aires, Argentina (patricia@iafe.uba.ar).

[2]Consejo Nacional de Investigaciones Científicas y Técnicas, Buenos Aires, Argentina.

[3]Astrophysikalisches Institut Potsdam, An der Sternwarte 16, D-14482, Potsdam, Germany.

[4]The assumed cosmology: $\Omega_m = 0.25$, $\Omega_\Lambda = 0.75$, $\sigma_8 = 0.9$ and $H_0 = 100\ h^{-1}$ km s^{-1} Mpc^{-1} with $h = 0.73$.

the three-parameter Einasto model (Einasto 1965) which Navarro et al. (2010) found to give a good fit to the profiles of the DM-only runs. We found that, in all cases, the formation of the galaxy increased the concentration of the halo producing approximately isothermal density profiles in the central regions. In all cases the SPH and DM-only profiles cross at, or slightly inside the baryonic radius defined as the one containing 83 per cent of its stars and cold gas. Inside the peak, they are relatively flat and approximately isothermal (Tissera et al. 2010).

The baryons also substantially affected the velocities of DM particles within the baryonic radius of the central galaxy. The resulting velocity dispersion in the central regions decreases monotonically with radius, in contrast to the behaviour seen in DM-only simulations which show “temperature inversion”.

We also analysed the shape of our DM haloes. When baryons condensed to form a galaxy in the inner regions, haloes become rounder and approximately oblate in agreement with several observational estimations. We measured the shapes of haloes by using the method of Dubinski & Calberg (2008). Initially triaxial shapes become much more oblate in the baryon dominated regions.

Finally, we compared our results with different analytical prescriptions. As expected we found that B86 largely overpredicts the level of concentration (up to 50 percent or so) and also changes the shape of the DM distribution; G04 and A09 provides a better representation where the disagreement is not so important.

The analysis of these high resolution simulations confirmed that the history of assembly of baryons is a crucial process which needs to be understood before being able to explain the DM properties at galactic scale.

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