RevMexAA (Serie de Conferencias), **40**, 17–18 (2011)

ASSEMBLY BIAS: CLUES FROM A ΛCDM COSMOLOGY

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RESUMEN

Estudiamos el efecto llamado "assembly bias", que consiste en que el agrupamiento a gran escala de halos de materia oscura de igual masa virial (que se asume es un indicador del "peak height") varía significativamente con su historia de formación, aspecto que no es esperado a partir de los actuales modelos teóricos. Nuestros resultados indican que si se incluye el efecto global a gran escala en la estimación del "peak height" que da origen a la formación de estructuras, las regiones de sobredensidad con la misma masa no muestran diferencias significativas con respecto a propiedades como la edad en la amplitud del agrupamiento para grandes escalas.

ABSTRACT

We present a new proxy for the overdensity peak height for which the large-scale clustering of haloes of a given mass does *not* vary significantly with the assembly history. The peak height, usually taken to be well represented by the virial mass, can instead be approximated by the mass inside spheres of different radii, which in some cases can be larger than the virial radius and therefore include mass outside the individual host halo. At large scales, i.e. in the two-halo regime, this model properly recovers the simple prescription where the bias responds to the height of the mass peak alone, in contrast to the usual definition (virial mass) that shows a strong dependence on additional halo properties such as formation time. The population of galaxies whose "peak height" changes with this new definition consists mainly of old stellar populations and are preferentially hosted by low-mass haloes located near more massive objects. The latter is in agreement with recent results which indicate that old, low-mass haloes would suffer truncation of mass accretion by nearby larger haloes or simply due to the high density of their surroundings, thus showing an assembly bias effect. The change in mass is small enough that the Sheth et al. (2001) mass function is still a good fit to the resulting distribution of new masses.

Key Words: cosmology: theory — dark matter — galaxies: formation — galaxies: statistics — large-scale structure of Universe

1. INTRODUCTION

Many recent models of galaxy formation assume that galaxy properties are determined by the haloes in which they form and not by the surrounding larger-scale environment (e.g. Kauffmann et al. 1997; Berlind et al. 2003; Baugh et al. 2005). This is justified by the standard description of structure formation (Bond et al. 1991; Lacey & Cole 1993; Mo & White 1996) and by simulation results as recent as Percival et al. (2003) which indicated that the halo clustering should only depend on the mass.

However, Gao et al. (2005) found that haloes assembled at high redshift are more strongly correlated at large scales than those of the same mass that assembled recently. This effect, which is not expected from the excursion set theory, was termed "assembly bias" (Gao & White 2007).

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The aim of this work, presented in full detail in Lacerna & Padilla (2011), is to understand the origin of the assembly bias and its role in the development of the large-scale structure and on the galaxy population, beyond the halo mass dependence.

2. DATA

We use the SAG2 model galaxies (Lagos, Cora, & Padilla 2008), which result from the combination of a cosmological N-body simulation of the concordance ΛCDM universe within a periodic box of 60 h^{-1} Mpc on a side, which contains 256^3 dark matter (DM) particles with a mass resolution of $\sim 10^9\ h^{-1}\ M_{\odot}$, and a semi-analytic model of galaxy formation generated using the merger histories of DM haloes.

3. REDEFINITION OF AN OVERDENSITY PEAK HEIGHT

We propose to extend the proxy for peak height to larger scales so that it does not show the as-

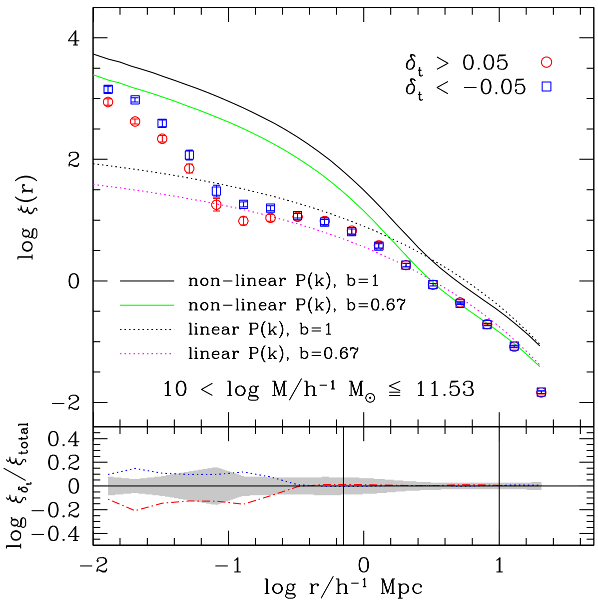

Fig. 1. Correlation functions for old (red circles) and young (blue squares) objects selected by using the radius parametrization in equation (1) given by the best-fitting parameters $a = 0$ and $b = -0.07$. The vertical lines in the lower box mark the range in which the reduced $\chi^2_{\xi(r)}$ is calculated. Note that the assembly bias is not present at large scales ($r > 1\ h^{-1}$ Mpc). For smaller scales, the differences in the clustering amplitude between old and young populations are typically below a factor of 2.

sembly bias effect (Lacerna & Padilla 2011). This will be equivalent to a new definition of "halo". We parametrize the radius of each galaxy as a function of both virial mass, $M_{\rm vir}$, and relative stellar age, δ_t. We then measure the masses inside spheres defined by this radius and calculate their relative ages with respect to this mass.

The radius for each galaxy is parametrized as

$$r = a\delta_t + b\ \log\left(\frac{M_{\rm vir}}{M_{\rm nl}}\right), \qquad (1)$$

where $M_{\rm nl}$ is the non-linear mass defined by Seljak & Warren (2004) with $\log(M_{\rm nl}/h^{-1}\ M_\odot) = 13.38$ for our choice of cosmological parameters. The free parameters are a and b. It is assumed that if r is smaller than the virial radius $r_{\rm vir}$ or if M is smaller than the virial mass, then $M = M_{\rm vir}$. The correlation functions for a best-fitting parameter set is shown in Figure 1, where at scales $r > 1\ h^{-1}$ Mpc the amplitude of clustering is similar for old and young galaxies.

We obtain similar results for the case $a = 0.2$ and $b = -0.02$, although with slight amplitude differences. However, the mass function changes only slightly with respect to that of the virial mass when using this second-best fitting values. None of the two parametrizations change the mass function at $M \geq 10^{12}\ h^{-1}\ M_\odot$, and therefore in this range their mass functions and the one resulting from the virial mass are all consistent with the Sheth, Mo, & Tormen (2001) model.

4. CONCLUSIONS

Our method consisted in redefining the overdensity that characterizes each galaxy using the information of its virial mass and the relative stellar age. This new definition is proposed as a better alternative than the virial mass to account for the assembly bias effect. Galaxies do not show significant differences in the two-halo regime for objects of a given mass range but different age using this formalism.

The best parameters are those that yield median sphere radii in the range of 1–4$r_{\rm vir}$. Neighbouring massive haloes that are out to these distances are probably responsible for these effects. These could disrupt the normal growth of small objects and, therefore, affect their ages.

To summarize, we stress the apparent fact that particularly for low-mass objects, the *virial* mass is not an adequate proxy for peak height in the standard picture, because equal virial mass objects can actually belong to initial density peaks of very different amplitude. It is necessary to include a more global environmental component, i.e. the mass of the region that effectively characterizes the peak height.

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