MNRAS 000, 1–4 (2015) Preprint 21 June 2019 Compiled using MNRAS LATEX style file v3.0

– title goes here

Keith T. Smith,[1★] A. N. Other,[2] Third Author[2,3] and Fourth Author[3]
[1]Royal Astronomical Society, Burlington House, Piccadilly, London W1J 0BQ, UK
[2]Department, Institution, Street Address, City Postal Code, Country
[3]Another Department, Different Institution, Street Address, City Postal Code, Country

Accepted XXX. Received YYY; in original form ZZZ

ABSTRACT
This is a simple template for authors to write new MNRAS papers. The abstract should briefly describe the aims, methods, and main results of the paper. It should be a single paragraph not more than 250 words (200 words for Letters). No references should appear in the abstract.

Key words: keyword1 – keyword2 – keyword3

1 INTRODUCTION

The matter distribution in the universe is not uniform neither random, the galaxy is distributed in cluster, supercluster, voids and filamentary structure web-like distribution. In ΛCDM the galaxies has been conformed within a dark matter halos generated from gravitational collapse of dark matter particles at inflationary times. Gas mixture condesation inside its massive halos results in the galactic structure White (1997), thus, the galaxy distribution is related to the underlying distribution of dark matter. The relation between galaxy distribution and dark matter (DM), is known as bias (Desjacques, Jeong & Schmidt 2018). According to Kaiser (1984) cluster of galaxies have a large bias as result of being rare objects which are formed in the highest density peaks of the mass distribution (Coil 2013). The goal of the galaxy bias theory is to finding the local number density of galaxies and gas, the most general function of the properties of the large-scale environment that is allowed by general covariance under coordinates transformations (Desjacques, Jeong & Schmidt 2018)

La relacion entre

Tradicionalmente se asume que la poblacion de galaxias es independiente de la posicion en la red cosmica que ocupa un halo que

2005MNRAS.363L..66G

The objective of this paper is study si al igual que en el caso de los halos de materia oscura el galaxy bias es influenciado por la red cosmica anÃălizando las historias de formaciÃşn de las galaxias en tÃľrminos del lugar en la red cosmica donde residen, usando las simulaciones Illustirs e illustris TNG300 para caracterizar las historias de formaciÃšn

★ E-mail: mn@ras.org.uk (KTS)

2 METHODS AND SIMULATIONS.

2.1 Simulations

The simulation used in this study is the cosmological magnethohydrodynamical simulations of galaxy formation Illustris (Nelson, et al. 2015) and IllustrisTNG300 (Nelson, et al. 2019). The Illustris and IllustrisTNG are a set of large-scale cosmological simulations in a box size of 75 $Mpc\, h^{-1}$ and 205 $Mpc\, h^{-1}$ respectively. The Illustris and IllustrisTNG simulations assumed ΛCDM cosmology with the parameters (Vogelsberger, et al. 2014) $\Omega_m = 0.2726$, $\Omega_b = 0.0456$, $\Omega_\Lambda = 0.7274$, $\sigma_8 = 0.809$ and $h = 0.704$ for Illustris, these parametres are consistent with WMAP-9 (Hinshaw, et al. 2013) and IllustrisTNG $\Omega_m = 0.38089$, $\Omega_b = 0.0486$, $\Omega_\Lambda = 0.6911$ and $h = 0.6774$ consistent with Planck2015 (Planck Collaboration, et al. 2016).

2.2 Power spectrum and Bias (Methodology) traditional estimates of anisotrpy

The galaxy distribution is biased of underlying mass density field, therefore we estimates the bias factor as:

$$b^2 = \frac{P_g(\vec{k})}{P_m(\vec{k})} \tag{1}$$

Where $P_g(\vec{k})$ and $P_m(\vec{k})$ are the power spectrum of galaxies and power spectrum of DM respectively. To calcule the power spectra fisrt we obtain the density field and using the Cloud In Cell interpolation (CIC) in a cubic grid with $N = 256^3$ used the Python module NBODYKIT (Hand, Feng, Beutler, Li, Modi, Seljak & Slepian 2018) (see fig. 1) and finally we calculated the bias factor using the equation (1).

In Illsutris and IllustrisTNG simulations the DM haloes are identified using the Friends-of-Friends (FoF) algorithm with a linking lenght of 0.2 times the mean interparticle separation. Substructure is identified with the SUBFIND algorithm modified, this consist in calculted the density field for all particles and gas cells using an adaptative smoothing lenght corresponding to the distribution of

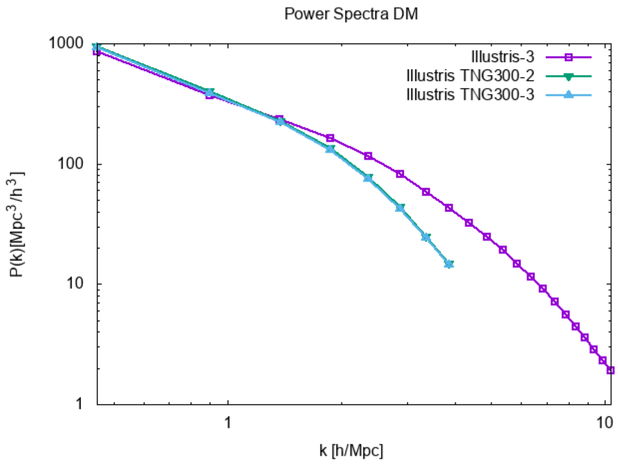

Figure 1. Dark matter power spectrum for Illustris-3, Illustris TNG300-2 and Illustris TNG300-3.

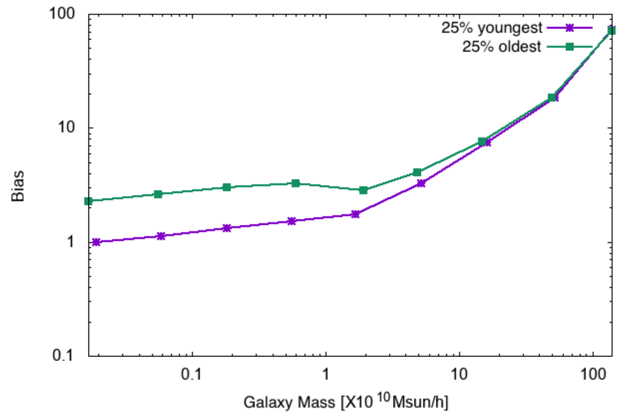

Figure 2. Bias at as a funcition of galaxy mass and formation time. for 25% youngest galaxies 25% oldes galaxies for TNG300-1.

DM particles, the subhalos candidates are define determinating the first isodensity contour that passes through a saddle point of the density field then the subhalo candidate is subject to a gravitational unbinding procedure but during this process the gas thermal energy is also take into account (Rodriguez-Gomez, et al. 2015).

For galaxies of given mass and redshift we calculated the power spectrum and galaxy bias, for this we estimated the redshift ($z_{formation}$) when the galaxies had a half of its final mass for galaxies with a range mass between $10^{8.0}M_\odot/h$ to $10^{13.0}M_\odot/h$ with a mass bins of width $\Delta M = 0.5$. For the dark matter, we used the dark matter particles in $z = 0$, thus in each galaxy mass bin we obtain the power spectra and bias factor for the 25% of the oldest galaxies and 25% youngest galaxies. We referred galaxies are "youngest" as recent galaxy formation time, i.e. galaxies into first 25% in each galaxy mass bin and "oldest" galaxies as early galaxy formation time, i.e. in the last 25% in each galaxy mass bin. In fig. 3 we show how the formation time dependence of clustering varies with the galaxy mass for youngest and oldest for all Illustris and IllustrisTNG300 simulatons, in fig. 2 we show this relation for IllustrisTNG300-1 in both figures is evident the effects on dependence of the galaxy clustering on formation time become very large for the lowest galaxy mass.

In fig. 4 we show a visual impresion of galaxy distribution of youngest and oldest galaxies in a slice through some Illustris and IllustrisTNG300 simulations 30 Mpc/h thick to given galaxy mass and is clear that galaxies that form early tend to be located in cosmic-web environments with higher anisotropy than its late-forming counterparts.

Cosmic Web

The tidal tensor T_{ij} is given by the Hessian of the gravitational potential

$$T_{ij} = \frac{\partial\phi}{\partial r_i \partial r_j} \tag{2}$$

where ϕ is the gravitational potential renormalized from de matter density distribution via Poisson equation $\nabla\phi = 4\pi G\bar{\rho}\delta$, where $\bar{\rho}$ and δ respectively denote the mean mass density of the universe and the overdensity field using CIC scheme into a cubic grid of 256^3 cells and smooth a Gaussian kernel , to obtain the potential gravitational in the Fourier space and finite differences to compute the Hessian. The web classification is based on the algebraic sign of autovalues of the tidal tensor (eq. 2), the scheme assume that the local neighbourhood of the given grid point collapses along the corresponding eigenvector. Forero-Romero, Hoffman, Gottlöber, Klypin & Yepes (2009) performed a detailed study for the topology of the cosmic web. The autovalues of the tidal tensor are used to classify four possible enviroments (Hahn, Porciani, Carollo & Dekel 2007):

- Voids: The region of the space where T_{ij} has no positive eigenvalues,
- Sheets: The set of points with one postive and two negative eigenvalues,
- Filament: The sites with two positive and one negative eigenvalue,
- Cluster: The points with three possitive eignevalues.

Diagonalising the tidal tensor, the overdensity in terms of its eigenvalues λ_1, λ_2, λ_3 is:

$$\delta_R = \lambda_1 + \lambda_2 + \lambda_3 \tag{3}$$

To characterized the anisotropy of the cosmic web we need the tidal shear sometimes referred as tidal torque q_R^2 as proposed (Heavens & Peacock 1988) (Catelan & Theuns 1996) defined as:

$$q_R^2 = \frac{1}{2}[(\lambda_3 - \lambda_1)^2 + (\lambda_3 - \lambda_2)^2 + (\lambda_2 - \lambda_1)^2] \tag{4}$$

In general, q_R^2 reflects the anisotropy of tidal enviroment at scale R, if q_R^2 then the enviroment is perfectly isotropic (Paranjape, Hahn & Sheth 2018), (**preguntar como calcular la escala R**). Paranjape, Hahn & Sheth (2018) introduced a variable α_R (tidal anisotropy) as main indicator of no-linear local enviroment which defined as:

$$\alpha_R \equiv (1 + \delta_R)^{-1}\sqrt{q_R^2} \tag{5}$$

This variable remove the correlation between the tidal

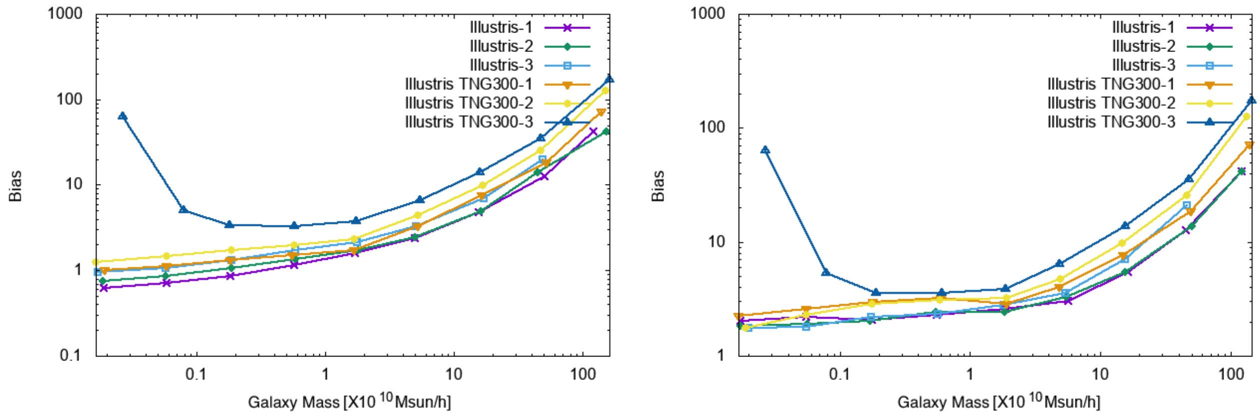

Figure 3. Gaxaly Bias as a function of galaxy mass for 25% oldest galaxies right panel and 25% younges galaxies left panel for Illustris and IllustrisTNG300 simulations.

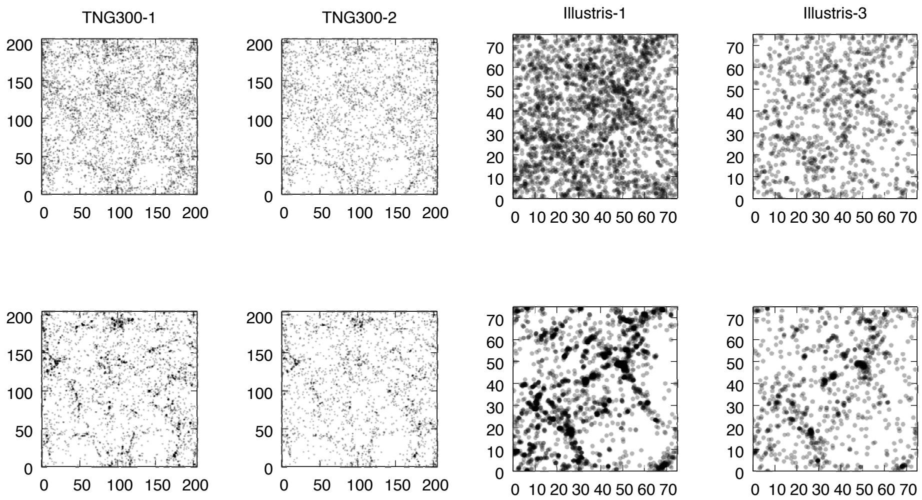

Figure 4. Distribution of "youngest" galaxies upper panels and "oldest" galaxies in lower panels for some Illustris and IllustrisTNG300 simulations in a slice $30\,Mpc/h$ thick for $10^{8}M_{\odot}/h \leq M \leq 10^{8.5}M_{\odot}/h$

anisotropy and overdensity. The value of α_R determines the spherical symmetry of the tidal and density field, small values of α_R correspond to isotropic regions contain voids and clusters, intermediate values correspond to sheets and filaments and large values correspond to anisotropic regions (filaments) (Alam, Zu, Peacock & Mandelbaum 2019). We obtain δ_R and α_R for each galaxy bin for IllustrisTNG300-1, in fig. 5 we show the tidal anisotropy, here it can be seen that for lowest mass exist a strong dependence of formation time and its enviroment, namely the oldest galaxies are found in environments with higest clustering in comparaison with the youngest ones but as the masses increases this dependence is less, for higest mass youngest and oldest galaxies are in regions with higest clustering.

3 CONCLUSIONS

In this paper, we used the Illustris and Illustris3TNG300 simulations to study the galaxy clustering dependence on time formation for a galaxies with a range mass between $10^{8.0}M_{\odot}/h$ to $10^{13.0}M_{\odot}/h$ and we found a strong dependence between galaxy clustering on formation time become very large for the lowest galaxy mass, i.e. there is a strong correlation between galaxy formation history and the cosmic web (this fact is clear in fig. 4) **where they are as has been show to haloes by many authors**.

Fig. 2 shows that while the mass increases the bias factor also grows (it is not linear), but for a lowest mass galaxies the bias factor is small for young galaxies than for the older ones. However, as the mass increases, this difference in the bias factor become smaller and for a larger mass can not be distinguished the time of formation of the galaxy by the bias. This is not only seen for the Illustris TNG300-1 simulation this fact is repeated in all simulations as we can seen in fig. 3. In fig. 4 it is clearly seen that oldest galaxies follow the

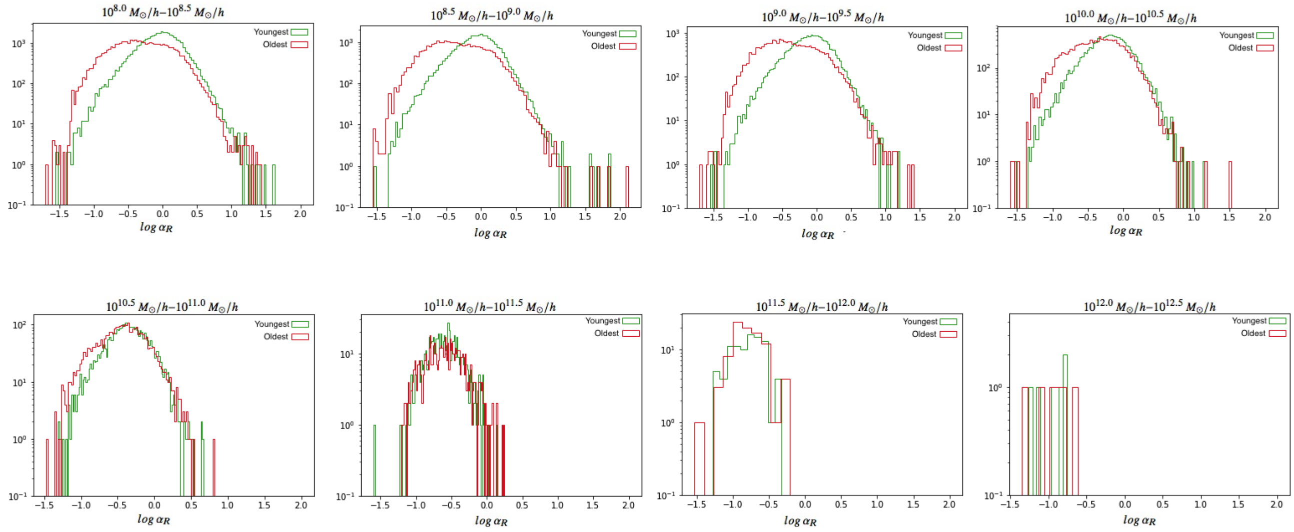

Figure 5. Distribution of tidal anisotropy α_R for IllustrisTNG300-1 for galaxies masses of $10^8 M_\odot/h \leq M \leq 10^{12.5} M_\odot/h$

large-scale cosmic web, while the distribution of youngest galaxies looks almost uniform for all simulations similar to obtain by Gao, Springel & White (2005) for dark haloes, they suggest that galaxy properties should depend significantly on the assembly history of their haloes, we concluded that youngest galaxies are dominated by DM with lowest anisotropy that its early-forming counterparts, this effect is evident for the lowest galaxies mass, so that the age dependence of galaxy clustering can not be ignored. Very large masses are found in overdensed regions without correlated with the formation time.

ACKNOWLEDGEMENTS

RatÃşn Perez

REFERENCES

Vogelsberger M., et al., 2014, Natur, 509, 177
Hinshaw G., et al., 2013, ApJS, 208, 19
Hand N., Feng Y., Beutler F., Li Y., Modi C., Seljak U., Slepian Z., 2018, AJ, 156, 160
Planck Collaboration, et al., 2016, A&A, 594, A13
Rodriguez-Gomez V., et al., 2015, MNRAS, 449, 49
Hand N., Feng Y., Beutler F., Li Y., Modi C., Seljak U., Slepian Z., 2018, AJ, 156, 160
White S. D. M., 1997, The Evolution of the Universe: report of the Dahlem Workshop on the Evolution of the Universe, 227, evun.work
Desjacques V., Jeong D., Schmidt F., 2018, PhR, 733, 1
Coil A. L., 2013, Planets, Stars and Stellar Systems. Volume 6: Extragalactic Astronomy and Cosmology, 387, pss6.book
Kaiser N., 1984, ApJ, 284, L9
Nelson D., et al., 2019, Computational Astrophysics and Cosmology, 6, 2
Nelson D., et al., 2015, A&C, 13, 12
Gao L., Springel V., White S. D. M., 2005, MNRAS, 363, L66
Forero-Romero J. E., Hoffman Y., Gottlöber S., Klypin A., Yepes G., 2009, MNRAS, 396, 1815
Hahn O., Porciani C., Carollo C. M., Dekel A., 2007, MNRAS, 375, 489
Catelan P., Theuns T., 1996, MNRAS, 282, 436
Heavens A., Peacock J., 1988, MNRAS, 232, 339
Paranjape A., Hahn O., Sheth R. K., 2018, MNRAS, 476, 3631
Alam S., Zu Y., Peacock J. A., Mandelbaum R., 2019, MNRAS, 483, 4501

This paper has been typeset from a TEX/LATEX file prepared by the author.