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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

This is a simple template for authors to write new MNRAS papers. See `mnras_sample.tex` for a more complex example, and `mnras_guide.tex` for a full user guide.

?.

2 ILLUSTRIS SIMULATION

Illustris-1, also known as Illustris, is a highly resolved cosmological simulation. It reproduces large-scale statistical features of the Universe, such as the galaxy population of massive clusters, as well as small-scale properties such as the morphology of galaxies and detailed values for their stellar and gas content.

This was achieved by following the evolution of 2×1820^3 elements with dark mass resolution of $m_{\rm DM} = 6.26 \cdot 10^6 {\rm M}_\odot$ and initial baryonic mass resolution of $\overline{m_{\rm b}} = 1.26 \cdot 10^6 {\rm M}_\odot$ from a glass-like configuration in a periodic box of 106.5Mpc. The ΛCDM cosmology of this run follows: $\Omega_\Lambda = 0.7274$, $\Omega_{\rm m} = 0.2726$, $\Omega_{\rm b} = 0.0456$, $\sigma_{\rm s} = 0.0809$, ${\rm n_s} = 0.963$ & ${\rm H_0} = 70.4{\rm kms^{-1}Mpc^{-1}}$ which is consistent with the (last) Anisotropy Probe (WMAP)-9 **?**. Illustris has a constant spatial resolution of 1.4kpc for DM particles in comoving units, and for baryonic particles it has the same spatial resolution of DM for z $\geq$ 1, which is later modified to 0.7kpc in physical units for the rest of the simulation.

The evolution in time was performed with the hydrodynamic code AREPO **?**, which combines a moving Voronoi tessellation with the finite volume approach. Included in the evolution algorithm, there are galaxy formation models which account for the evolution of stars and SMBHs. Specifically, the physics followed by this model includes energetic feedback from supermassive black holes and supernovae, as well as stellar evolution and chemical enrichment. This level of detail in Illustris is advantageous for the analysis of the effect of the environment in barionic properties of galaxies. This level of resolution is hard to find among other simulations, i.e. post-processed runs with semi-analytical models which do not directly simulate baryons.(Expand) Describe Arepo more

The output of this simultaion consists of 136 snapshots. 61 of them were taken at $z < 3$ spaced with a cosmological scale factor $\Delta a \approx 0.02$. The remaining 75 were taken at $z > 3$ with spacing $\Delta a \approx 0.01$. Each snapshot was post-processed with a modified version of FOF **?** to identify DM haloes with more than 32 particles using a linking length of 0.2 times the mean particle separation. Each output group from the 7,713,601 post-processed halos (FOF) is analyzed with the SUBFIND algorithm **?** to generate, at z=0, and 4,366,546 (sub)halo catalogues with their respective characterization properties.

(HERE TALK ABOUT ILLUSTRIS-2,3 FOR RESOLUTION PURPOSES)

3 THE METHODOLOGY

3.1 Characterizing Mass Functions

A mass function is the number density $n(M)$ of objects of determined mass M. Due to the large range of orders of magnitud in which these quantities span, the mass function is often represented in logarithmic scales on both sides. The discretization of these mass functions is simply the histogram of the logarithmic masses of the studied group of

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objects. In Illustris, as in all simulations, we have clear determination of volumes. This volume is constant over all the sample of galaxies studied and is to be taken the constant volume of the simulation $V = (106.5\text{Mpc})^3$. In this sense, the relation expressed by a mass function is

$$n(M)V d\log(M) = dN \tag{1}$$

To characterize specific properties of these mass functions, we use the Press-Schechter function 2. It comes from an elaborated formalism of hierarchical formation of DM structures in an expanding Friedmann universe arriving to a self-similar state of "equilibrium" for its mass function **?**. Although its ansatz has been demonstrated to be inaccurate for our observable universe **?**, the final expression is very well fitted to the mass functions of the local universe **?**.

$$n(M) = n_* \left(\frac{M}{M_*}\right)^{-\alpha+1} \exp^{-\left(\frac{M}{M_*}\right)} \tag{2}$$

The Schechter function 2 is fully defined by the three parameters (n_*, M_*, α). The number density factor n_* is just a normalization factor which vary depending on the studied system. The mass scale factor M_* may be interpreted as the mass that separates the power-law regimen $M \ll M_*$ and the exponential regimen $M \gg M_*$. This transition graphically resemnles a knee, which is the reason why M_* is referred as the knee-mass. The faint-end slope α is directly related to the exponent of the power-law at the low-mass regime. In logarithmic scales, it is clearly interpreted as the slope of the low-mass regime.

We characterize each mass function with a Schechter function **??**. It is . These parameters and their respective estimated errors are determined with a MCMC fit applied directly to the MF.

The principal purpose of this work is to verify if the results obtained observationally by Jones et al. **?** are supported by a similar analysis in the cosmological simulation Illustris. Specifically, we focus on the *local* environment definition of the 3^{rd} nearest neighbor (NN), which we want to adapt as closely as possible to our computational application.

3.2 Defining the environment

3.2.1 The 3^{rd} nearest neighbor definition of environment

Jones et al. **?** analyze the dependence of the HIMF's Schechter parameters on the cosmological environment.

They used the SDSS **?** catalogue to define the environment of galaxies in the ALFALFA **?** survey.

This SDSS catalogue was constituted of pre-selected galaxies brighter than $M_r = -18.9$.

To obtain a quantification the environment, for each reference galaxy in ALFALFA they found the projected distance in the sky to the third NN belonging to the pre-selected SDSS catalogue.

This projected distance in the sky defines a numeric-surface density for each reference galaxy.

They filtrated candidate neighbors by their radial velocity relative to the reference galaxy which had to be within $450km/s$.

According to Hubble's law, this effectively restricts the candidate galaxies to a smaller radial range, reducing apparent closer galaxies arising from the use of projected distances.

Once quantified the environment for each ALFALFA galaxy with the distance to the 3rd NN definition, they divided the group in four quartiles according this quantity.

For each quartile, the respective HIMF was calculated, and with this, a Schechter fit was obtained.

The analysis was specifically performed over the Schechter parameters of the Knee-mass M^* and the faint-end slope α.

As we want to replicate as closely as possible the method effectuated by Jones et. al **?**, we use the same specifications to calculate the environment.

We perform the analysis of the Schechter functions to gas, DM, stellar and BH mass functions.

We do not perform the study directly on HIMFs because this would require some extense calculations although we take the gas mass function as a first approximation.

As Illustris is a cosmological simulation, it is subject to resolution and numerical biases.

The most important bias in this study is related to the minimum mass of discrete elements in the simulation.

Each mass considered here is subject directly or indirectly this resolution restriction, and the effect it causes is specially evident in the produced mass functions.

We used Illustris-2,3, which are less resoluted copies of Illustris-1, to show this effect on the mass functions **??**.

Taking this into account, mass functions are heavily affected for masses below a certain cut and for this reason, only galaxies above said cut are considered in this study.

This mass cut has no apparent systematical way to be calculated and therefore, we choose it having into account the performance of the respective Schechter fit.

3.2.2 The cosmic web method

To complement and verify the analysis performed with the third nearest neighbor method, we chose a complementary method of completely different nature.

The chosen method was developed by Forero et al. **?**.

It uses the Hessian 3 of the gravitational potential obtained from the DM density field to classify galaxies into four morphological environments.

$$E = mc^2 \tag{3}$$

Specifically, we diagonalize the Hessian matrix obtaining three eigenvalues.

These eigenvalues determine the concavity of the gravitational potential on the principal axes, at each point. We use these eigenvalues to interpret the tendence of mass to cluster with reference with some given threshold λ.

Table 1. This is an example table. Captions appear above each table. Remember to define the quantities, symbols and units used.

A	B	C	D
1	2	3	4
2	4	6	8
3	5	7	9

Eigenvalues bigger than λ are interpreted as a local tendence of mass to expand? in the respective eigenaxes, and viceversa.

With this characterization, clusters, sheets, fillaments and voids can be defined with the number of axes above λ.

Forero et. al. found in **?** that the critical value that better reproduces the correct morphological pulations was $\lambda = 0.2$.

With these specifications, we could obtain mass functions for galaxies belonging to clusters, fillaments and sheets. The amount of galaxies belonging to voids was strongly affected by the mentioned mass cuts and could not produce reasonable mass functions to analyze.

4 RESULTS

4.1 Preliminaries

4.2 Mass functions comparison

Figures and tables should be placed at logical positions in the text. Don't worry about the exact layout, which will be handled by the publishers.

Figures are referred to as e.g. Fig. **??**, and tables as e.g. Table 1.

5 CONCLUSIONS

The last numbered section should briefly summarise what has been done, and describe the final conclusions which the authors draw from their work.

ACKNOWLEDGEMENTS

The Acknowledgements section is not numbered. Here you can thank helpful colleagues, acknowledge funding agencies, telescopes and facilities used etc. Try to keep it short.

APPENDIX A: SOME EXTRA MATERIAL

If you want to present additional material which would interrupt the flow of the main paper, it can be placed in an Appendix which appears after the list of references.

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

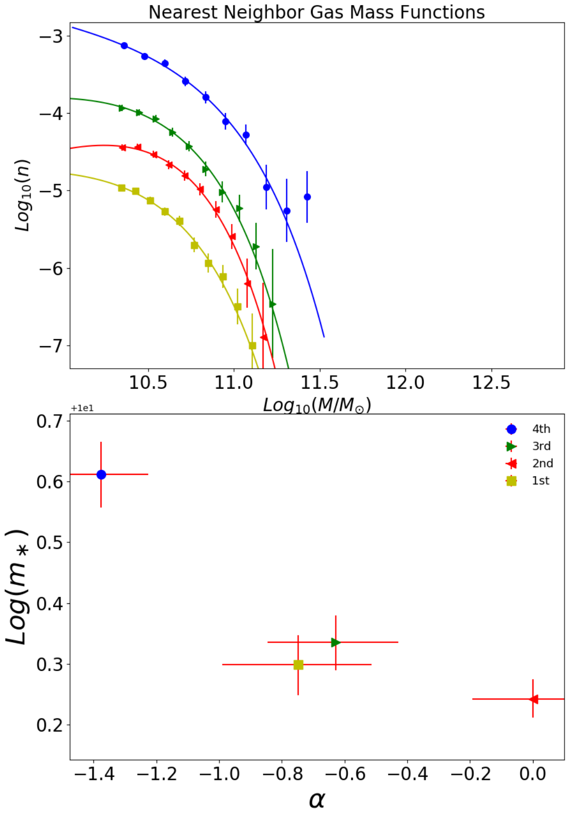

Figure 1. Upper side: Schechter fits of each gas mass function for each environmental quartile (tendence) using the 3rd nearest neighbor definition.**Down side**: Knee-mass m_* and the faint end slope α values obtained from the Schechter fits for each curve shown above.

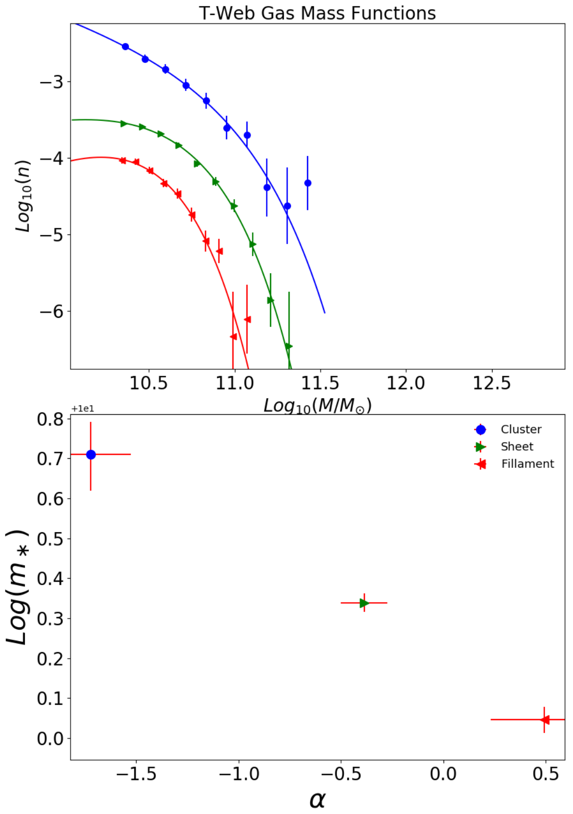

Figure 2. Upper side: Schechter fits of each gas mass function for each morphological environment characterized by the T-Web algorithm proposed by Forero et al.**Down side**: Knee-mass m_* and the faint end slope α values obtained from the Schechter fits for each curve shown above.

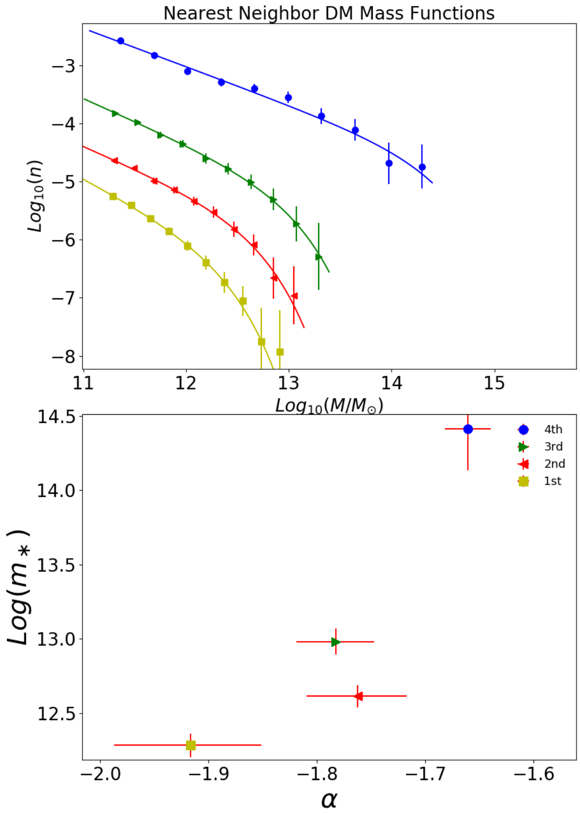

Figure 3. Similar to figure 1 using DM.

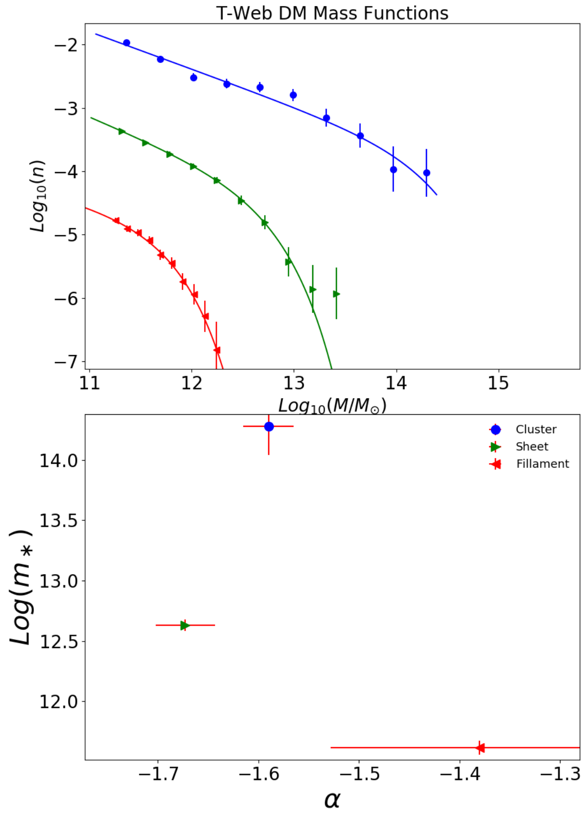

Figure 4. Similar to figure 2 using DM.

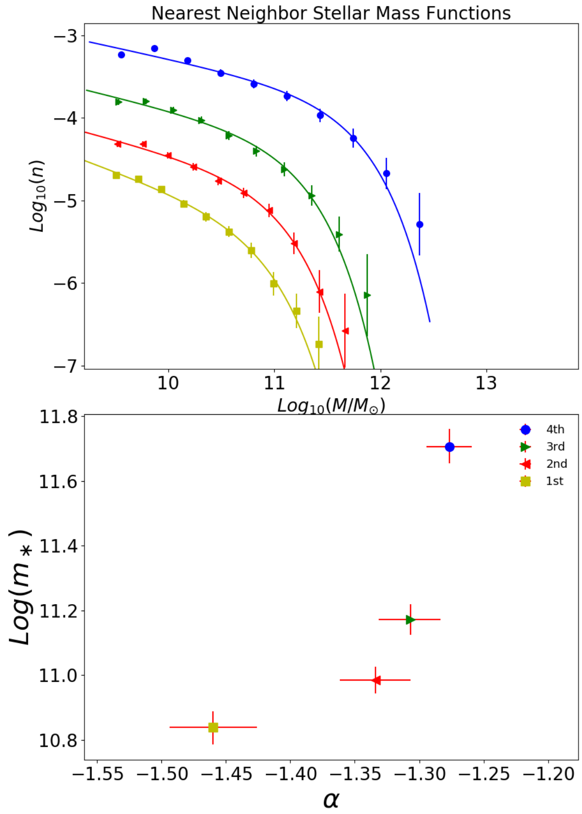

Figure 5. Similar to figure 1 using stellar mass

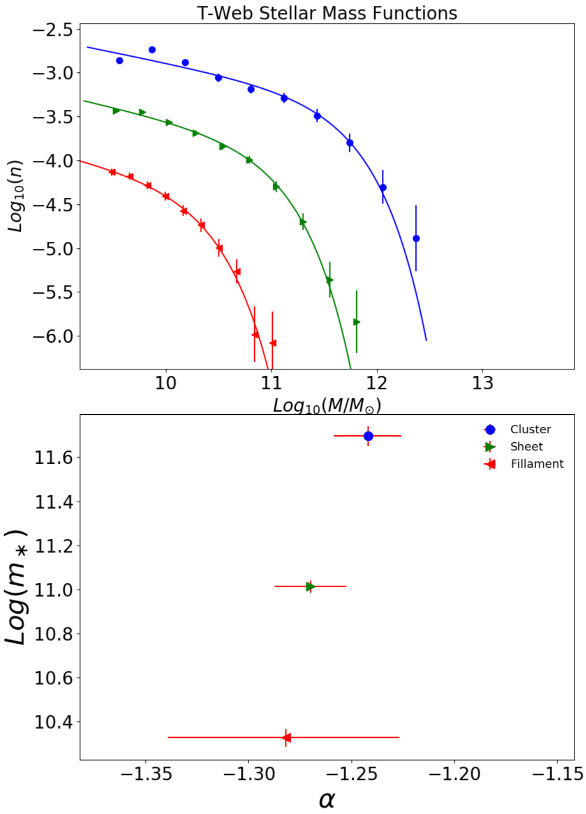

Figure 6. Similar to figure 2 using stellar mass

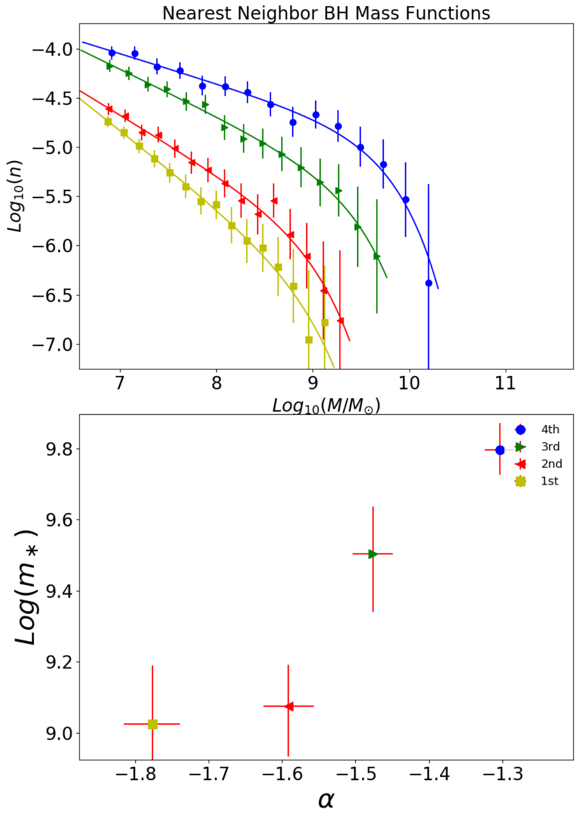

Figure 7. Similar to figure 1 using BHs mass.

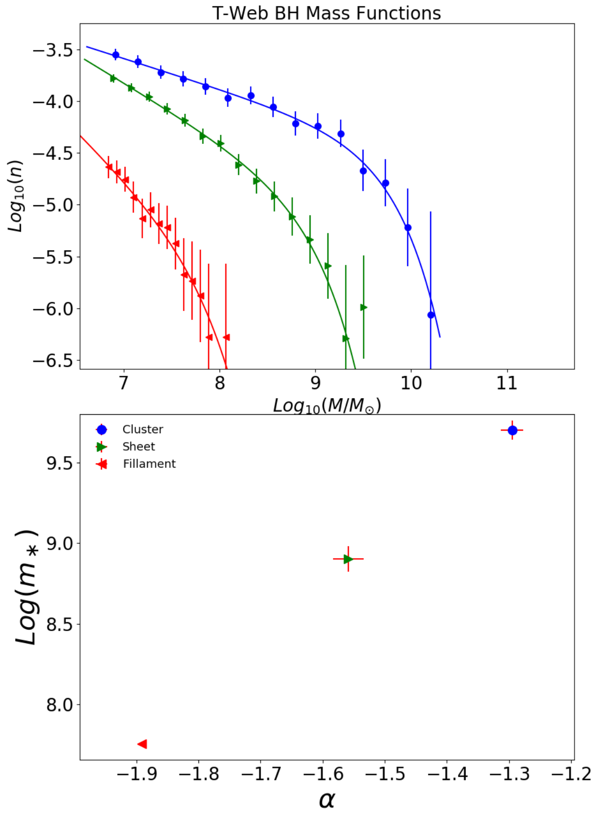

Figure 8. Similar to figure 2 using BHs mass.