A New Parameter free Method for the Fast Generation of Halo Catalogues

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Abstract

We develop a new fast way, without free parameters, to construct a halo catalogue. This method only use the linear power spectrum and the density threshold for the halo formation, in the linear theory, to construct a halo catalogue with the correct abundance and linear bias. The catalogues can be used to construct mock galaxy catalogues in a small time what possibility the computation of covariances of any observable of interest. Moreover, this method can be easily change to work in non standard cosmologies.

Introduction and Motivation

In the era of the large redshift surveys the creation of mock galaxy catalogues is essential to understand the observations and to compute the covariances involved.

The most standard and reliable technique used is the N-body simulations (like the DEUS [1] that simulate the full universe), but this way to construct galaxy mocks require a lot of time and memory what impossibility its usage for the upcoming large surveys and for the evaluation of covariances that need a large number of mocks.

There are several methods in the literature that aim the creation of galaxy mock catalogues in a fast way, to do it they create halo catalogues and populate these halos with galaxies using some HOD (see [3] for a comparison between these methods).

In this work we propose a new method for the fast generation of halo catalogues that, different from others LPT based methods, does not have any free parameter to fit using simulations. Our method recover the correct halo abundance and linear bias, and have a good behavior as function of the scale.

Another great advantage of our method is that it is very easy to modify for other cosmology and can be easily modified for non standard cosmologies.

Method Description

To construct the halo catalogues we only use the excursion set theory ideas [2] to find the halos in linear theory together with the Lagrangian perturbation theory (LPT) to put the halos in the correct place. We explicitly implement this idea in the following way:

- Fist we construct a density grid with a Gaussian realization of some matter power spectrum;
- Then we grow structures, around the density peaks, up to its mean density is smaller than δ_c (the density threshold for the halo formation in the linear theory);
- Finally we displace the halos using 2LPT in the same way as in the generation of N-body simulations initial conditions.

In the end of this process we have a halo catalogue with the position and the mass of each halo inside the box.

Results

To test our method we construct 20 halo catalogues for 5 different box sizes using 256 divisions per dimension in the grid with the same cosmology of the lcdmw5 simulation of the DEUS [1] ($\omega_m = 0.304$, $h = 0.71$ and $\sigma_8 = 0.79$ at $z = 0$). The theoretical value for the virial overdensity in this cosmology is 338, then we show the Tinker's predictions for $\Delta = 300$ and 400.

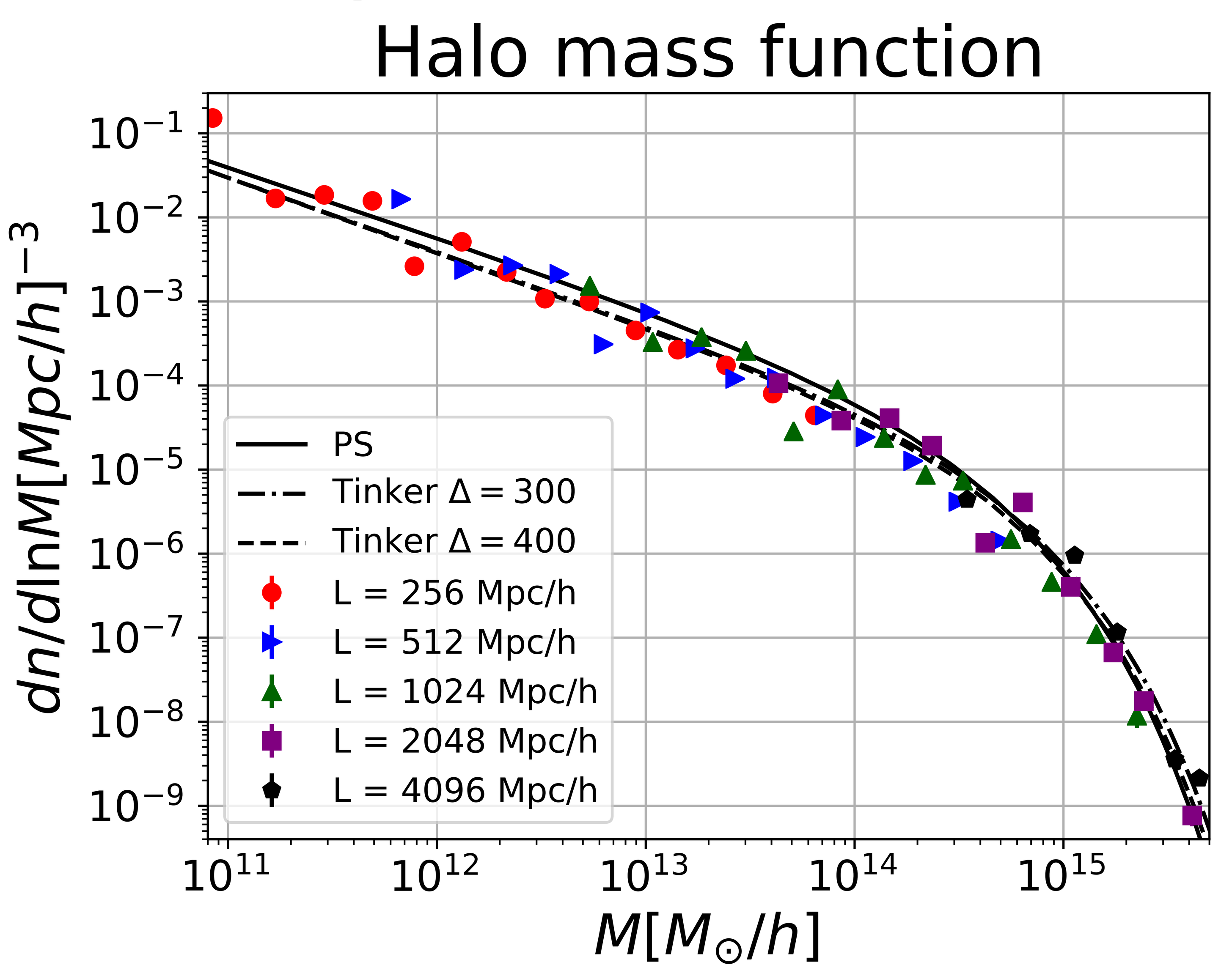

Figure 1: The halo mass function for the five box sizes of 256, 512, 1024, 2048 and 4096 Mpc/h in red, blue, green, purple and black dots respectively. The dots represent the mean number count of the four realizations and the errorbars its standard deviation. We also plot the theoretical predictions of Press-Schechter and Tinker with $\Delta = 300$ and 400 in solid, dashed-dotted and dashed black lines.

Note that, In figure 1, the first points of each box size only have a few number of particles (we do not put a cut in the halo richness) but do not have the resolution problems of halos found in N-body simulations.

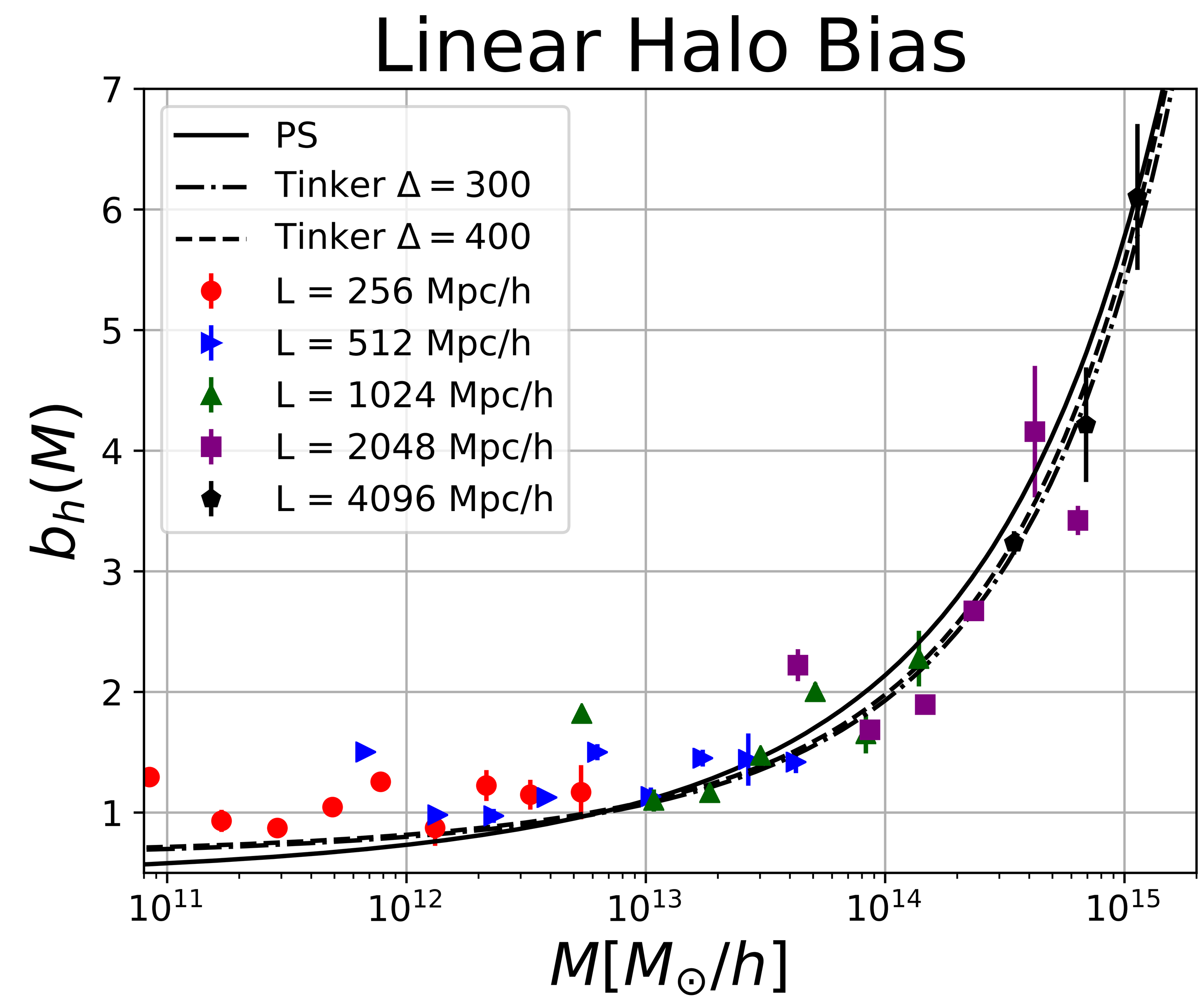

Figure 2: The same of the halo abundance but for the halo linear bias.

In figure 2 the linear bias was computed as the square root of the ratio between P_{hh} and P_{mm} for $k < 0.05$ where P_{mm} was measured from the Gaussian density grid. Note that the small boxes have only few points with $k < 0.05$ then its linear bias estimation is worse.

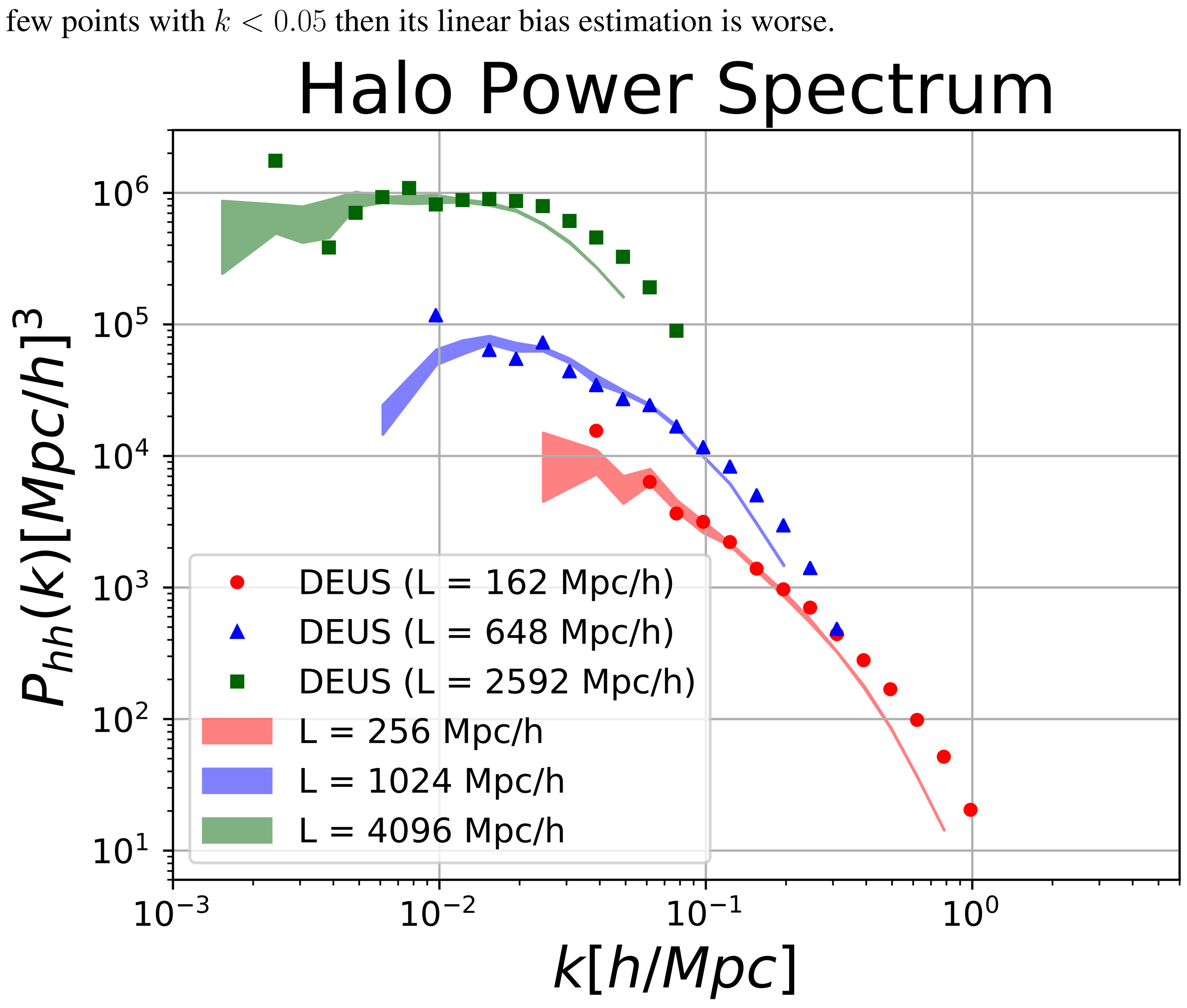

Figure 3: Comparison of the full k-dependence of the P_{hh} between the mean of our four realizations with $\pm 1\sigma$ (hatched regions) and the measured from three different box size simulations of DEUS (dots).

In figure 3 we compute P_{hh} for the mass range of intersection between our catalogues and the DEUS's halos.

Next Steps

- To construct a galaxy catalogue using some HOD;
- To compute the one and three point functions of the catalogues and compare with N-body simulations;
- To test some modifications like RSD, primordial non-gaussianities and different barriers for the halo identification;
- To use the catalogues to compute the covariance of some observables.

References

[1] J.-M. Alimi, V. Bouillot, Y. Rasera, V. Reverdy, P.-S. Corasaniti, I. Balmes, S. Requena, X. Delaruelle, and J.-N. Richet. DEUS Full Observable {\Lambda}CDM Universe Simulation: the numerical challenge. *ArXiv e-prints*, June 2012.

[2] J. R. Bond, S. Cole, G. Efstathiou, and N. Kaiser. Excursion set mass functions for hierarchical Gaussian fluctuations. *Astrophys. J.*, 379:440–460, October 1991.

[3] C.-H. Chuang, C. Zhao, F. Prada, E. Munari, S. Avila, A. Izard, F.-S. Kitaura, M. Manera, P. Monaco, S. Murray, A. Knebe, C. G. Scóccola, G. Yepes, J. Garcia-Bellido, F. A. Marín, V. Müller, R. Skibba, M. Crocce, P. Fosalba, S. Gottlöber, A. A. Klypin, C. Power, C. Tao, and V. Turchaninov. nIFTy cosmology: Galaxy/halo mock catalogue comparison project on clustering statistics. *Mon. Not. R. Astron. Soc.*, 452:686–700, September 2015.