CAN WE IGNORE BARYONS IN HALO MODELING?

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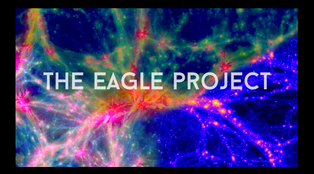
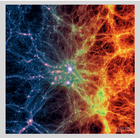


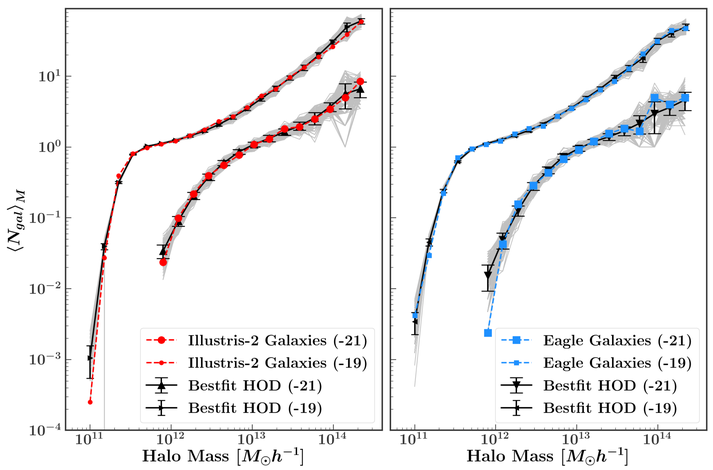
1. ABSTRACT

Halo models provide a simple and computationally inexpensive way to investigate the connection between galaxies and their dark matter halos. However, they make the assumption that the role of baryons can be easily parameterized in the modeling procedure. I examine the accuracy with which halo occupation distribution (HOD) modeling can predict galaxy clustering statistics when compared to two different hydrodynamic simulations, Illustris and EAGLE. I find that the HOD model *is* able to accurately reproduce clustering statistics, but only after a correction is made to the halo mass function, and after the effects of spatial, velocity, and assembly bias are removed from the simulations. These results demonstrate the need for any future work involving HOD modeling to apply a correction to their dark matter halo mass function, to include parameters for spatial, velocity, and assembly bias in their HOD model, and to utilize a number of galaxy clustering statistics that are sensitive to different effects.

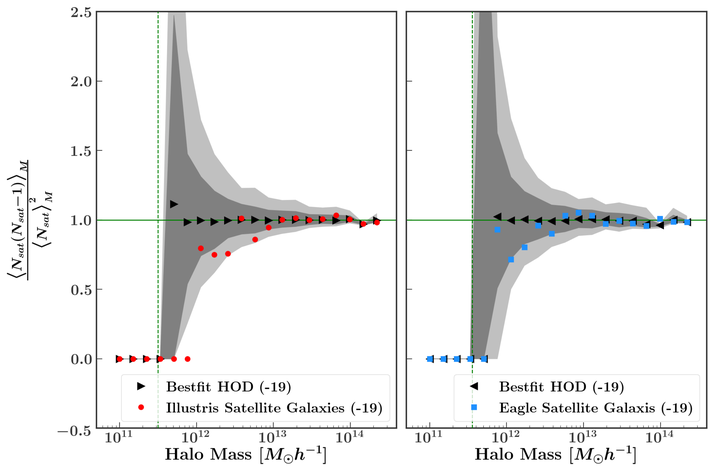
2. CONNECTING GALAXIES TO DARK MATTER HALOS

- 2 hydrodynamic simulations; 2 brightness samples
  1. Calculate average number of galaxies in bins of halo mass
  2. Start with a **fiducial** 5 parameter model
  3. Generate **300 realizations** of this model and average
  4. Calculate **chi-square**
  5. Use **Nelder-Mead** algorithm to find best-fit model by **minimizing chi-square**
- The model is a good fit to the simulations; the second moment is consistent with Poisson
- Generate 1000 galaxy catalogues by populating DMO simulations using best-fit model



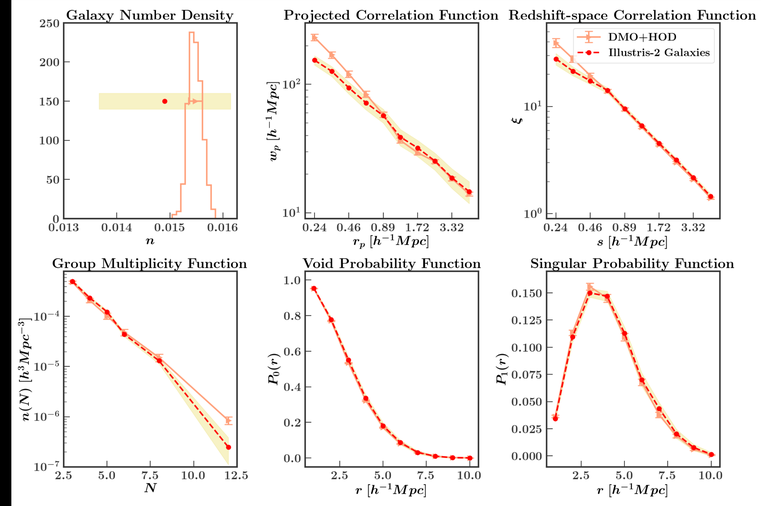


Best-fit HOD for Illustris (left) and EAGLE (right) galaxies. The gray lines in each case show 300 realizations of the best-fit HOD model for that sample, and the black line is their average.

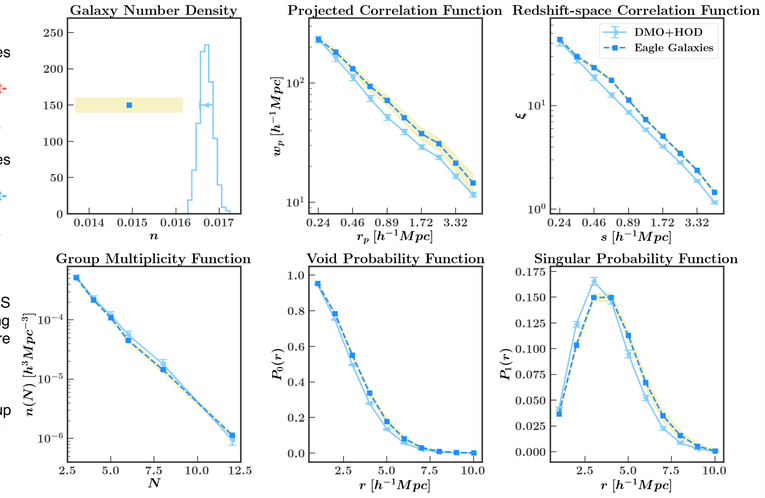


The second moment of the best-fit HOD for Illustris (left) and EAGLE (right) M_r-19 galaxies. The dark and light gray shaded regions show the inner 68 and 95% of 300 realizations of the best-fit HOD model for that sample, and the black points are the median.

3. GALAXY CLUSTERING STATISTICS



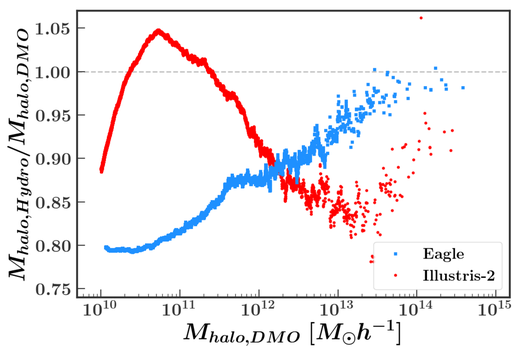
LEFT: Clustering statistics for M_r-19 galaxies from the **Illustris simulation** and the **best-fit HOD model applied to the DMO simulation.**
RIGHT: Clustering statistics for M_r-19 galaxies from the **EAGLE simulation** and the **best-fit HOD model applied to the DMO simulation.**
The **shaded regions** show errors from 400 SDSS mocks, indicating the sensitivity of an SDSS like survey. The clustering measurements shown are galaxy number density, projected correlation function, redshift-space correlation function, group multiplicity function, void probability function, and singular probability function.



4. CAUSES OF DISCREPANCIES

HMF: Halo masses are too large in the dark matter only simulations

Shown here are the ratios of halo masses from the hydrodynamic simulations to halo masses from the DMO simulations, as a function of DMO halo mass. Halos are matched based on mass rather than positions. We use this relationship to correct our DMO halo masses, which reproduces the HMF from hydro.



Spatial Bias: Galaxy positions may not be distributed like dark matter

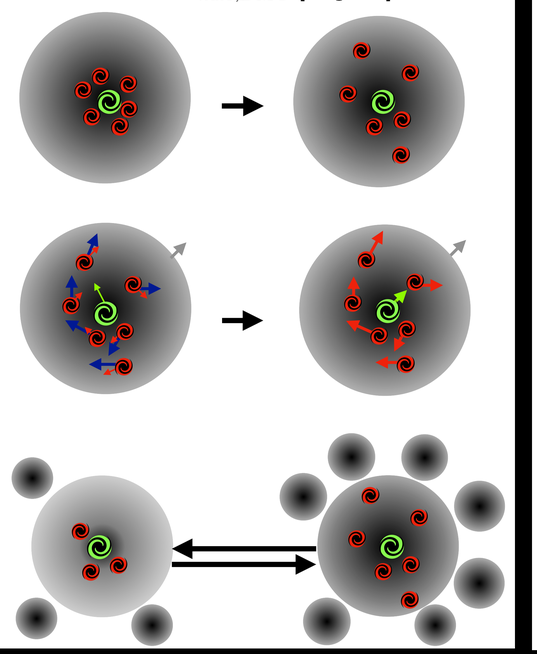
To test for the presence of spatial bias in the hydro simulations, we move the central galaxy to the center of the halo and assign the satellite galaxies to random dark matter particles.

Velocity Bias: Galaxies may not move like dark matter

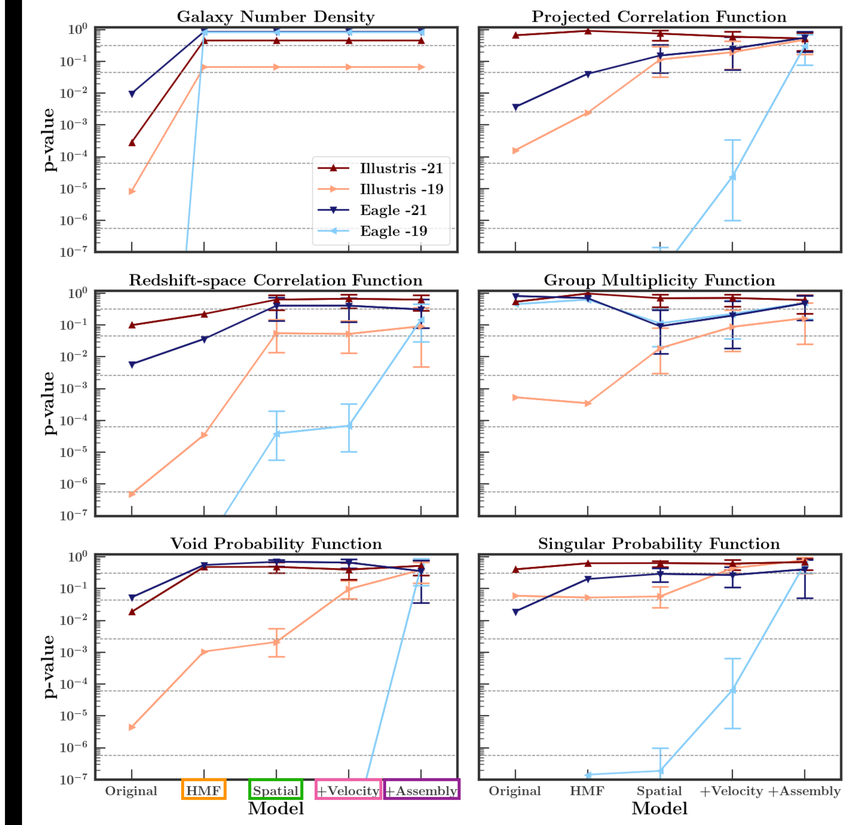
To test for the presence of velocity bias in the hydro simulations, we give the central galaxy the velocity of the halo and give the satellite galaxies the velocities of random dark matter particles.

Assembly Bias: Galaxy clustering might depend on properties other than halo mass

To test for the presence of assembly bias in the hydro simulations we swap galaxies in halos of similar mass.



5. ACCURACY OF THE MODEL



P-values for different clustering measurements on Illustris and EAGLE galaxies, after different modifications to the halo model and simulations. The horizontal dashed gray lines are the 1 - 5 sigma confidence levels. The clustering measurements shown are galaxy number density, projected correlation function, redshift-space correlation function, group multiplicity function, void probability function, and singular probability function. The x-axis in each panel corresponds to different extensions of the original halo model. From left to right, it shows the original model; the same model applied after adjusting the halo masses; additionally removing spatial bias from the simulation galaxies; additionally removing velocity bias from the simulation galaxies; and additionally removing assembly bias from the simulation galaxies. The last three p-values in each panel are the median of many realizations, with error bars showing the 16th and 84th percentiles.