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On the Galaxy Size–Halo Connection

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ABSTRACT

We derive empirical modeling constraints on the connection between dark matter halos and the half-mass radius $R_{1/2}$ of galaxy bulges and disks. We show that both $R_{1/2}^{\rm disk}$ and $R_{1/2}^{\rm bulge}$ are well-described by power law scaling relations with halo virial radius, $R_{1/2} = AR_{\rm vir}^{\alpha}$. Novel to this work, we use new SDSS measurements of the $R_{1/2}-$dependence of galaxy clustering to constrain the model parameters, $A_{\rm bulge}, A_{\rm disk}, \alpha_{\rm bulge}, \alpha_{\rm disk}$, and log-normal scatter $\sigma_{R_{1/2}}$. Even when only coarsely tuning these parameters to the observed one-point functions $\langle R_{1/2}^{\rm disk} | M_{*}^{\rm disk}\rangle$ and $\langle R_{1/2}^{\rm bulge} | M_{*}^{\rm bulge}\rangle$, our model accurately predicts the observed two-point clustering on small- and large-scales. This success non-trivial, as we show that galaxy clustering is highly sensitive to the physics that shapes satellite galaxy profiles. We find no evidence for the commonly assumed relation between halo spin $\lambda_{\rm halo}$ and $R_{1/2}^{\rm disk}$, and show that this assumption cannot be meaningfully constrained with either the clustering or lensing of L_{*} galaxies. Our results provide simple boundary conditions for more complex and fine-grained models of galaxy size. We make our python code publicly available to support cosmological surveys that require realistic synthetic galaxy populations.

1 INTRODUCTION

Some introduction goes here.

2 DATA AND SIMULATIONS

2.1 Galaxy Sample

2.2 Clustering Measurements

2.3 Baseline Mock Catalog

3 GALAXY PROFILE MODEL

4 RESULTS

5 DISCUSSION

5.1 Relation to Previous Work

6 CONCLUSION

6.1 Summary

ACKNOWLEDGMENTS

REFERENCES

Hearin A. P., Watson D. F., Becker M. R., Reyes R., Berlind A. A., Zentner A. R., 2014, MNRAS , 444, 729

Meert A., Vikram V., Bernardi M., 2016, MNRAS , 455, 2440

Mo H. J., Mao S., White S. D. M., 1998, MNRAS , 295, 319

Watson D. F., Berlind A. A., Zentner A. R., 2012, ApJ , 754, 90

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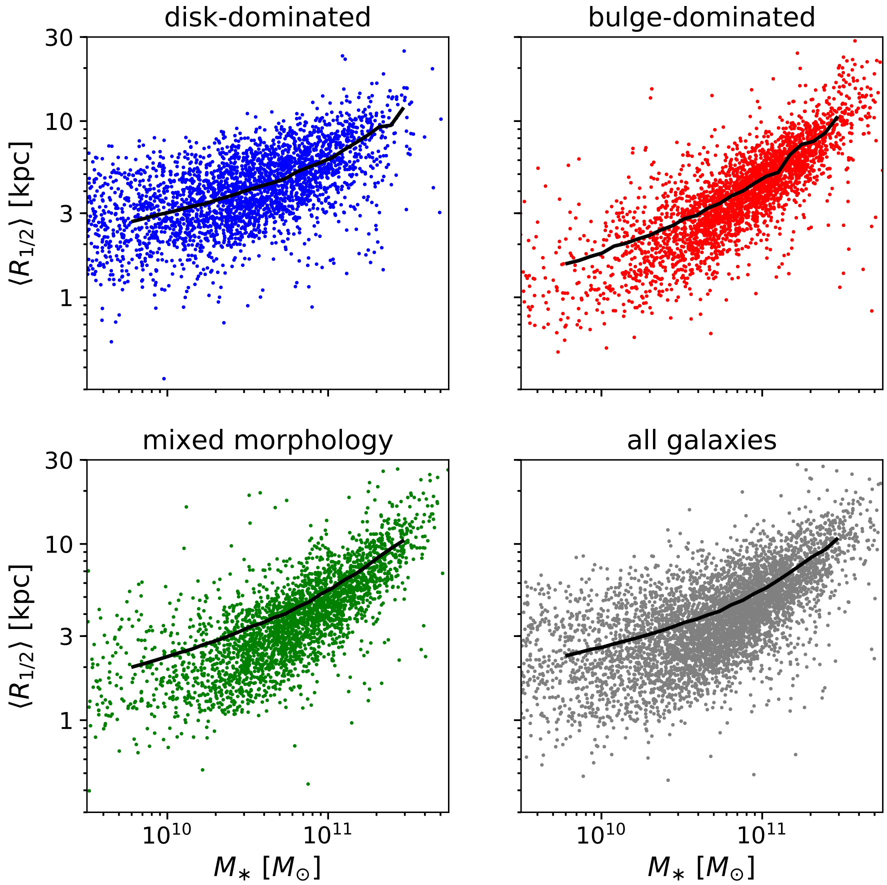


Figure 1. One-point data used to fit the fiducial model. Scattered points show the $R_{1/2} - M_*$ relation for SDSS galaxies as measured in Meert et al. (2016). Bulge-dominated galaxies are defined in terms of the bulge-to-total stellar mass ratio B/T >= 0.75, disk-dominated galaxies B/T < 0.25, mixed morphology as 0.25 < B/T < 0.75. The black curve in each panel shows the $R_{1/2} - M_*$ relation implied by our fiducial model, in which $R_{1/2} = AR^{\alpha}_{\rm vir}$, with $A_{\rm disk} = 0.14 = 7A_{\rm bulge}, \alpha_{\rm disk} = 1, \alpha_{\rm bulge} = 5/4$, and uncorrelated log-normal scatter of 0.2 dex about these relations.

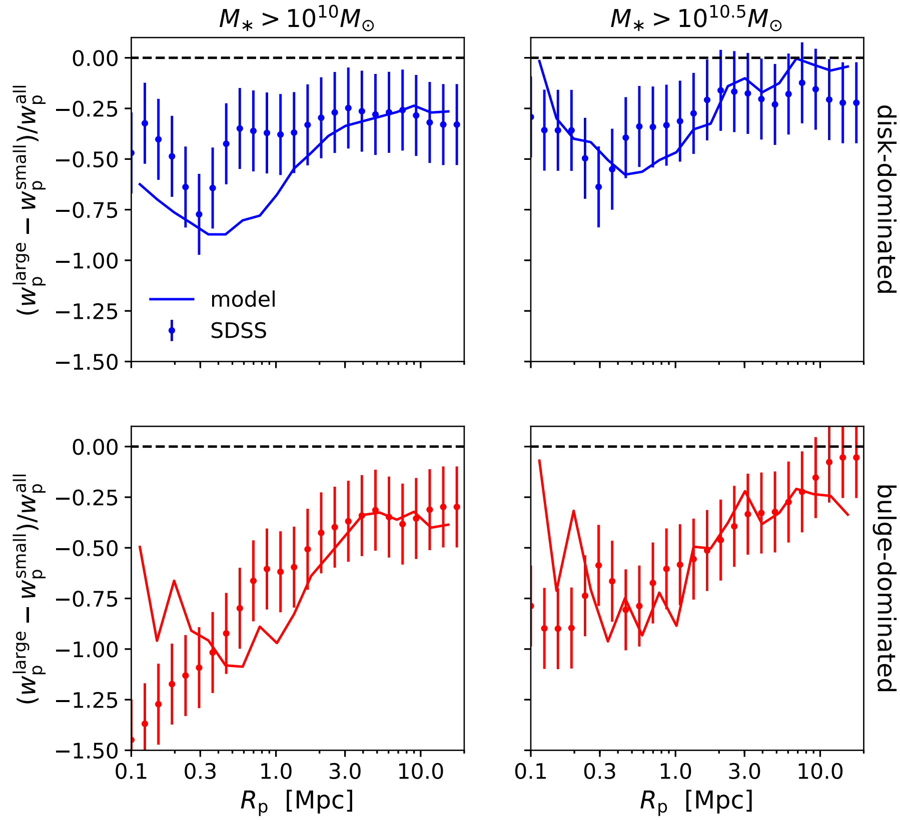


Figure 2. Two-point clustering data used to validate the fiducial model. Points with error bars show new SDSS measurements of the $R_{1/2}$−dependence of projected galaxy clustering, w_p, compared to predictions by the model tuned to the measurements shown in Fig. 2. We define a disk or bulge as "large" or "small" according to whether it is above or below the median size for its stellar mass. The y-axis shows clustering strength ratios, so that, for example, a y-axis value of −0.5 corresponds to small galaxies being 50% more strongly clustered than large galaxies of comparable stellar mass. We show results separately for disk-dominated galaxies (*top* panels) and bulge-dominated galaxies (*bottom* panels), and different thresholds in total stellar mass in the *left* and *right* panels. The successful prediction shown here is remarkable because the model was not fit to these data, and because two-point clustering is highly sensitive to the physics that shapes satellite galaxy profiles (see Fig. 3).

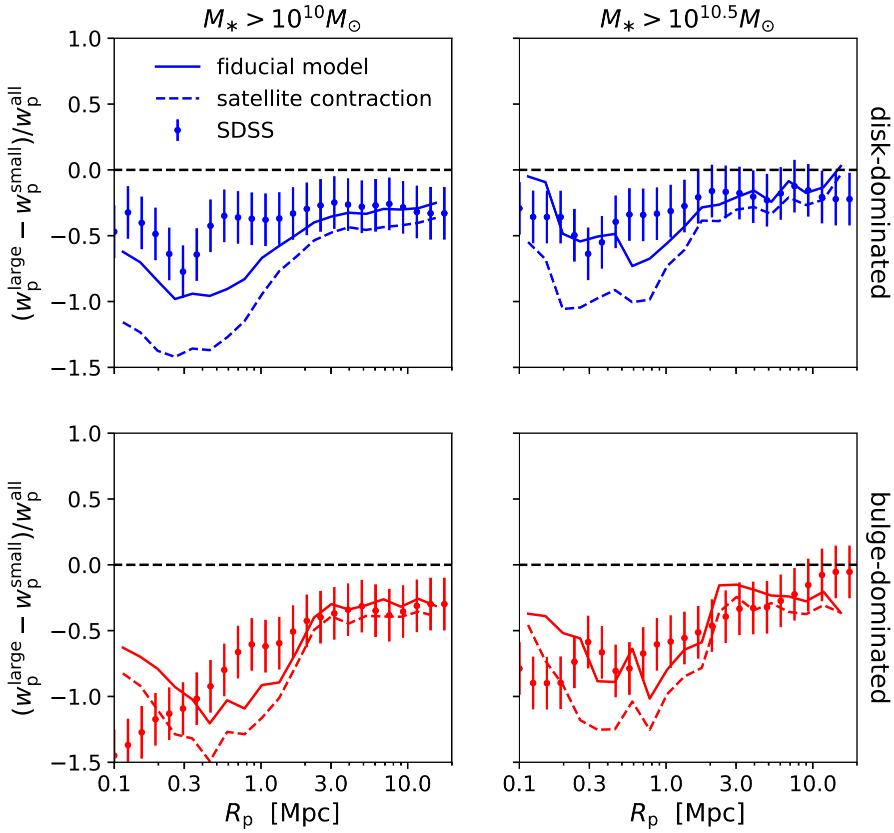
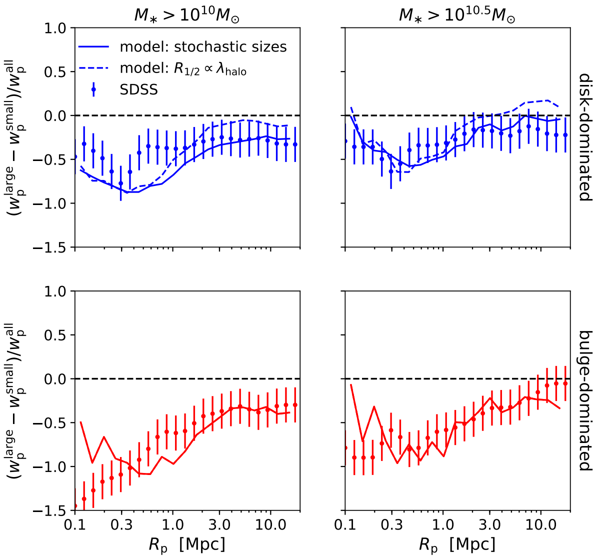


Figure 3. Clustering provides tight constraints on the relative sizes of centrals and satellites. Here we compare our fiducial model, in which satellite galaxy size is set by $R_{\rm vir}$ at the time of infall, to an alternative model analogous to Watson et al. (2012) in which satellite sizes contract in proportion to $(M_{\rm vir}/M_{\rm acc})^{1/3}$. The large differences between solid and dashed curves in the top panels show that the $R_{1/2}-$dependence of galaxy clustering ratios is highly sensitive to the post-infall evolution of satellite galaxy profiles. The successful prediction of our fiducial model, in which satellite galaxies neither contract nor puff up after infall, places tight constraints on satellite-specific physical processes, which must be either negligible or conspiratorially produce little-to-no size change after accretion.



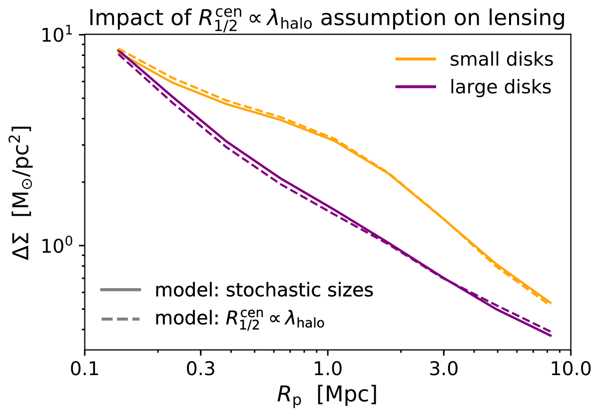


Figure 4. Clustering and lensing provide no constraining power on the assumption that $R_{1/2}^{\rm disk} \propto \lambda_{\rm halo}$. We compare the predictions between our fiducial model in which sizes are purely stochastic, and an alternative model motivated by Mo et al. (1998) in which central galaxy disk size is maximally correlated with host halo spin at fixed stellar mass (implemented via conditional abundance matching, e.g., Hearin et al. 2014). The tiny differences between the solid and dashed curves imply that conventional large-scale structure measurements cannot even in principle provide compelling evidence pertaining to the assumption that $R_{1/2}^{\rm disk} \propto \lambda_{\rm halo}$.