

Limitations of Suppressed Variance Simulations

CHANGHOON HAHN^{1,2,*} AND FRANCISCO VILLAESCUSA-NAVARRO³¹*Lawrence Berkeley National Laboratory, 1 Cyclotron Rd, Berkeley CA 94720, USA*²*Berkeley Center for Cosmological Physics, University of California, Berkeley, CA 94720, USA*³*Center for Computational Astrophysics, Flatiron Institute, 162 5th Avenue, New York, NY 10010, USA*

(Dated: DRAFT --- c1c14e7 --- 2019-07-23 --- NOT READY FOR DISTRIBUTION)

ABSTRACT

Keywords: cosmology: —

1. THE QUIJOTE SIMULATION SUITE

We use a subset of simulations from the Quijote suite, a set of 43,000 N -body simulations that spans over 7000 cosmological models and contains, at a single redshift, over 8.5 trillion particles. The Quijote suite was designed to quantify the information content of cosmological observables and also to train machine learning algorithms. Hence, the suite includes enough realizations to accurately estimate the covariance matrices of high-dimensional observables such as the bispectrum as well as the derivatives of these observables with respect to cosmological parameters: Ω_m , Ω_b , h , n_s , σ_8 , and M_ν . For the derivatives, the suite includes sets of 500 simulations run at different cosmologies where only one parameter is varied from the fiducial cosmology ($\Omega_m=0.3175$, $\Omega_b=0.049$, $h=0.6711$, $n_s=0.9624$, $\sigma_8=0.834$, and $M_\nu=0.0$ eV). Along Ω_m , Ω_b , h , n_s , and σ_8 , the fiducial cosmology is adjusted by either a small step above or below the fiducial value: $\{\Omega_m^+, \Omega_m^-, \Omega_b^+, \Omega_b^-, h^+, h^-, n_s^+, n_s^-, \sigma_8^+, \sigma_8^-\}$. Along M_ν , because $M_\nu \geq 0.0$ eV and the derivative of certain observable with respect to M_ν is noisy, Quijote includes sets of 500 simulations for $\{M_\nu^+, M_\nu^{++}, M_\nu^{+++}\} = \{0.1, 0.2, 0.4$ eV $\}$.

The initial conditions for all the simulations were generated at $z = 127$ using second-order perturbation theory for simulations with massless neutrinos ($M_\nu = 0.0$ eV) and the Zel’dovich approximation for massive neutrinos ($M_\nu > 0.0$ eV). The initial conditions with massive neutrinos take their scale-dependent growth factors/rates into account using the Zennaro et al. (2017) method, while for the massless neutrino case we use the traditional scale-independent rescaling. From the initial conditions, the simulations follow the gravitational evolution of 512^3 dark matter particles, and 512^3 neutrino particles for massive neutrino models, to $z = 0$ using GADGET-III TreePM+SPH code (Springel 2005). Simulations with massive neutrinos are run using the “particle method”, where neutrinos are described as a collisionless and pressureless fluid and therefore modeled as particles, same as CDM (Brandbyge et al. 2008; Viel et al. 2010). Halos are then identified using the Friends-of-Friends algorithm (FoF; Davis et al. 1985) with linking length $b = 0.2$ on the CDM + baryon

* hahn.changhoon@gmail.com

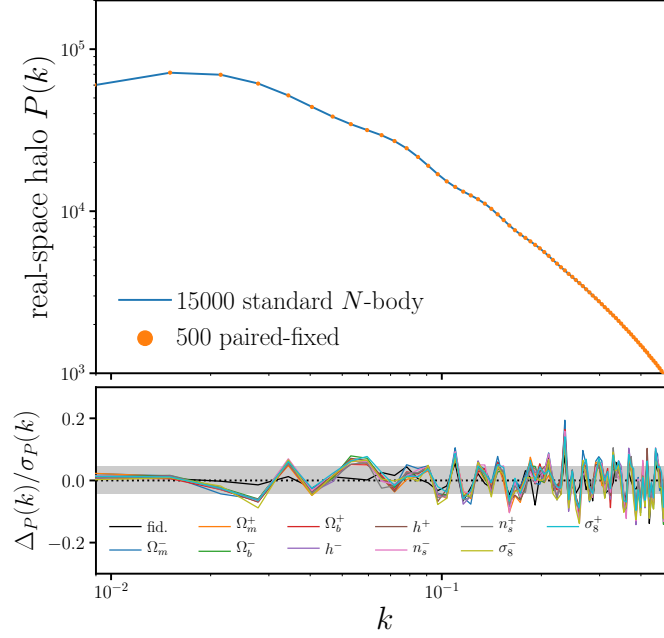


Figure 1.

distribution. We limit the halo catalogs to halos with masses above $M_{\text{lim}} = 3.2 \times 10^{13} h^{-1} M_{\odot}$. For the fiducial cosmology, the halo catalogs have $\sim 156,000$ halos ($\bar{n} \sim 1.56 \times 10^{-4} h^3 \text{Gpc}^{-3}$) with $\bar{n}P_0(k=0.1) \sim 3.23$. We refer readers to Villaescusa-Navarro et al. (in preparation) and Hahn et al. (2019) for further details on the Quijote simulations.

ACKNOWLEDGEMENTS

It's a pleasure to thank Arka Banerjee, Joseph DeRose, Thomas McClintock, Jeremy L. Tinker ... for valuable discussions and comments.

APPENDIX

REFERENCES

- Brandbyge, J., Hannestad, S., Haugbølle, T., & Thomsen, B. 2008, *Journal of Cosmology and Astro-Particle Physics*, 08, 020
- Davis, M., Efstathiou, G., Frenk, C. S., & White, S. D. M. 1985, *The Astrophysical Journal*, 292, 371
- Springel, V. 2005, *Monthly Notices of the Royal Astronomical Society*, 364, 1105
- Viel, M., Haehnelt, M. G., & Springel, V. 2010, *Journal of Cosmology and Astro-Particle Physics*, 06, 015
- Zennaro, M., Bel, J., Villaescusa-Navarro, F., et al. 2017, *Monthly Notices of the Royal Astronomical Society*, 466, 3244

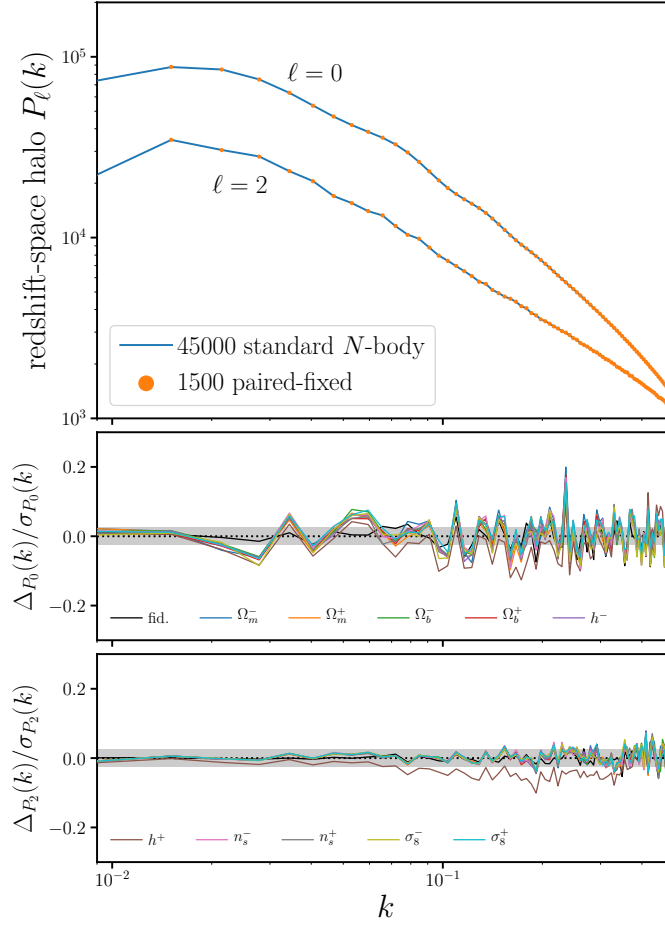


Figure 2.