Linear growth in Gadget cosmology simulations

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Abstract

We compare the linear growth in Gadget-3 and MP-Gadget simulations to linear theory, reducing the perturbation amplitude by a factor of 100 in order to minimise non-linearities. In the case of having 2 fluids, the growth rate of each species is slightly inaccurate, with a deficiency in baryon power of 5% by $z = 3$

Introduction

In order to verify the growth of structure in Gadget simulations, we run a test where the initial perturbation amplitude is set to 1% of the Planck value, and compare the power spectra in simulations to the predictions by linear theory. This is done in order to minimise non-linearities so that the simulation growth can be tested against theoretical predictions. We run this test in 2 codes that are descendents of Gadget-2: P-Gadget3 and MP-Gadget[1]. Initial conditions are set at z=99, and in cases of multiple fluids (i.e. CDM & baryons), each fluid is seeded with a different power spectra given by linear theory.

For the MP-Gadget sims, linear theory power spectra are calculated using classylss[2], and power spectra from simulations are generated using GenPK[3]. For Gadget-3, we use reps[4] and Pylians[5]. In Fig 1, we show results for DM-only simulations for two box sizes, $L = 300\text{Mpc}/h$ and $L = 60\text{Mpc}/h$. In Fig 2, we show the same plot for a simulation with CDM and baryon particles.

All simulations start at $z = 99$ and use the same cosmology. For the DM-only sims (Fig. 1), MP-Gadget sims have 512^3 particles, with Nmesh = 1024, and Gadget-3 sims have 256^3 particles with Nmesh = 512. For the simulations with two fluids (Fig. 2, we use 2×256^3 particles with Nmesh = 512 in all sims.

[1] https://github.com/MP-Gadget/MP-Gadget
[2] https://github.com/nickhand/classylss
[3] https://github.com/sbird/GenPK
[4] https://github.com/matteozennaro/reps
[5] https://github.com/franciscovillaescusa/Pylians

Power spectra for DM-only

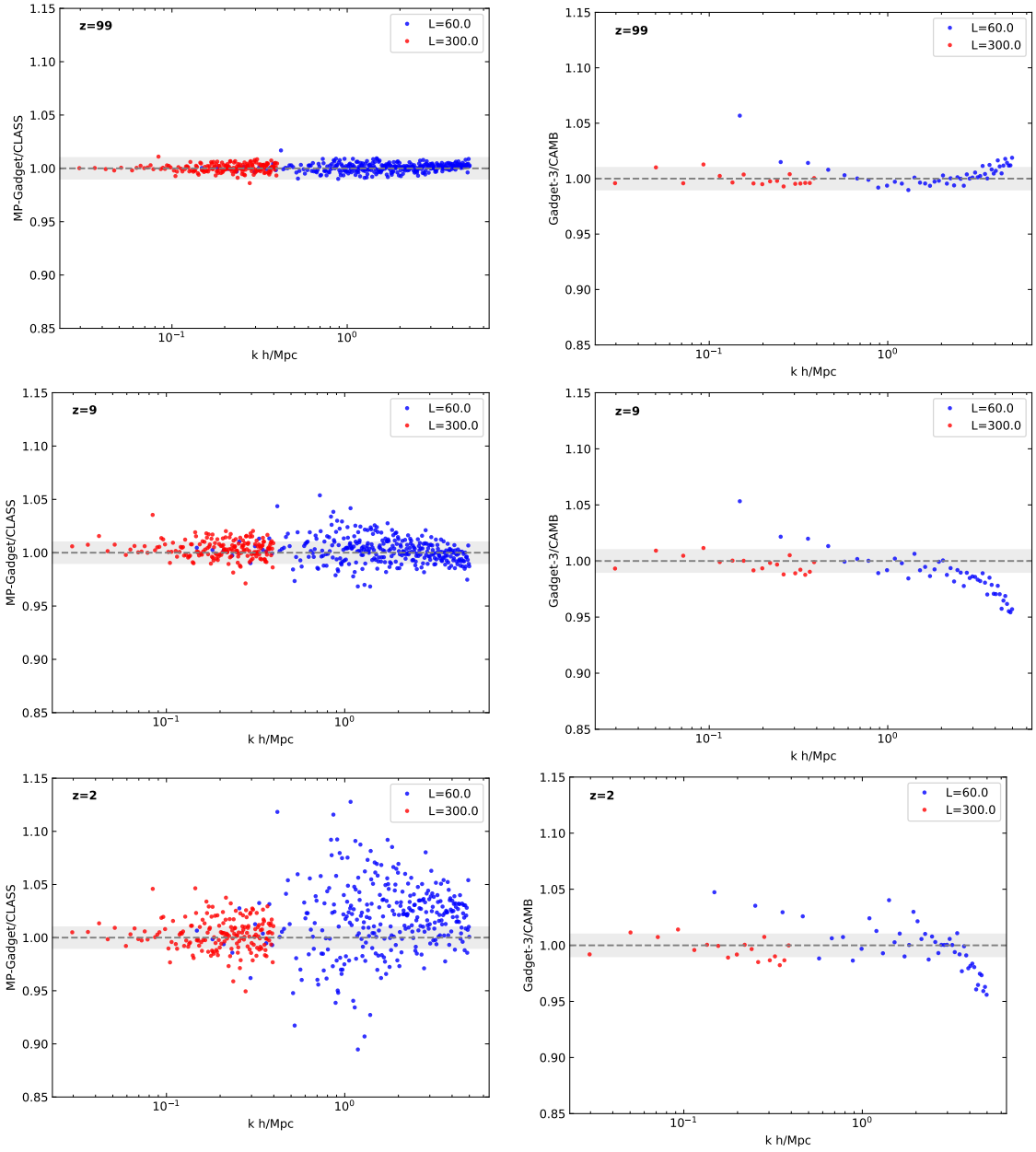

Figure 1: *Left:* MP-Gadget, 512^3 particle DM-only sim. *Right:* PGadget-3, 256^3 particle DM-only sim. Shaded area represents the 1% error region, and we show results for $L = 300h/\mathrm{Mpc}$ and $L = 60h/\mathrm{Mpc}$ boxes to cover a larger range of k values

Power spectra for two fluids

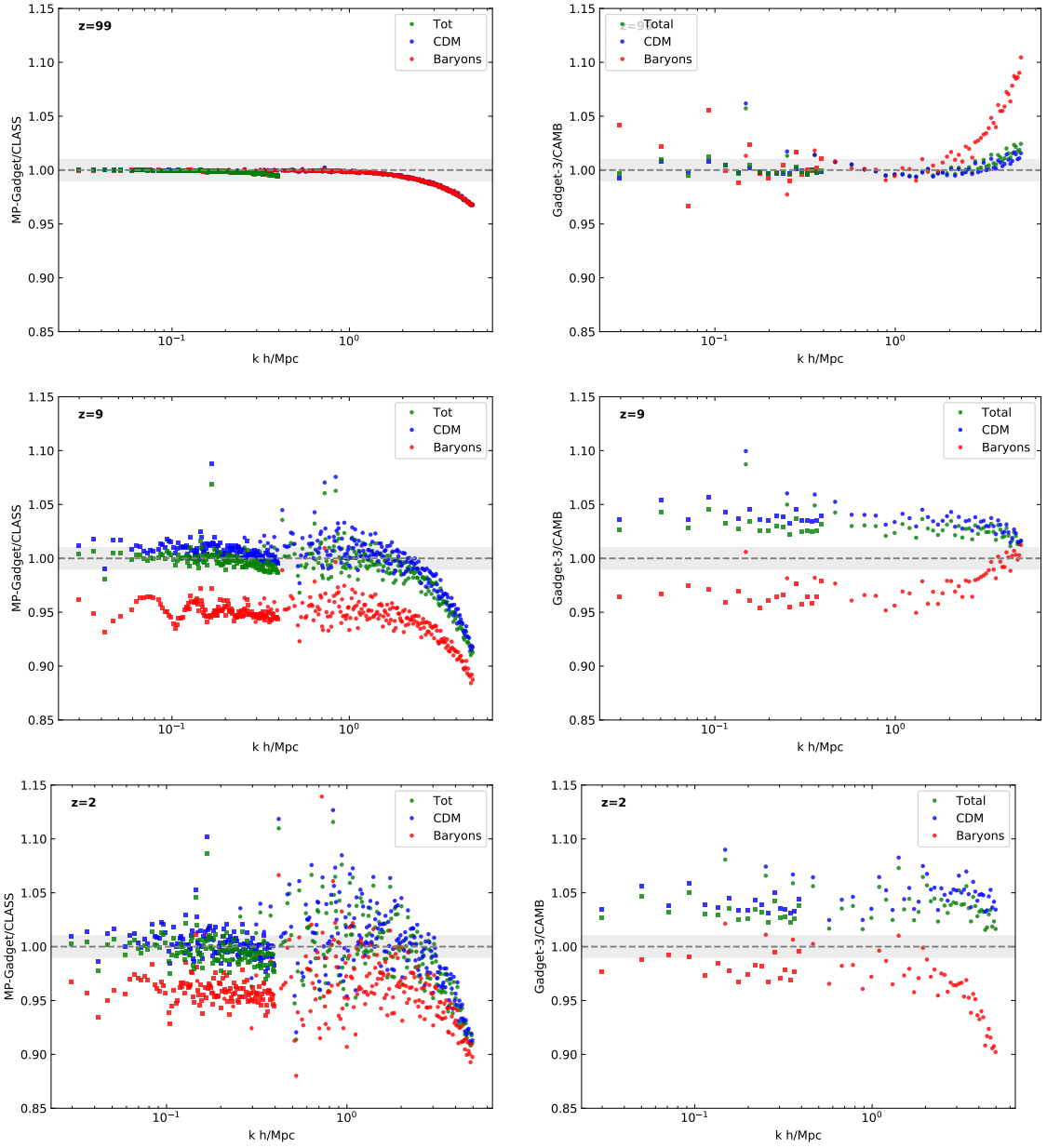

Figure 2: Same test but this time with DM and baryon particles, with MP-Gadget on left and Gadget-3 on the right. Again we have used two box sizes, with $L = 300h/\text{Mpc}$ shown in squares, and $L = 60h/\text{Mpc}$ in circles. We plot the power in each simulation divided by the linear theory prediction **for that individual species**.

Effect of Tree in multiple species simulations

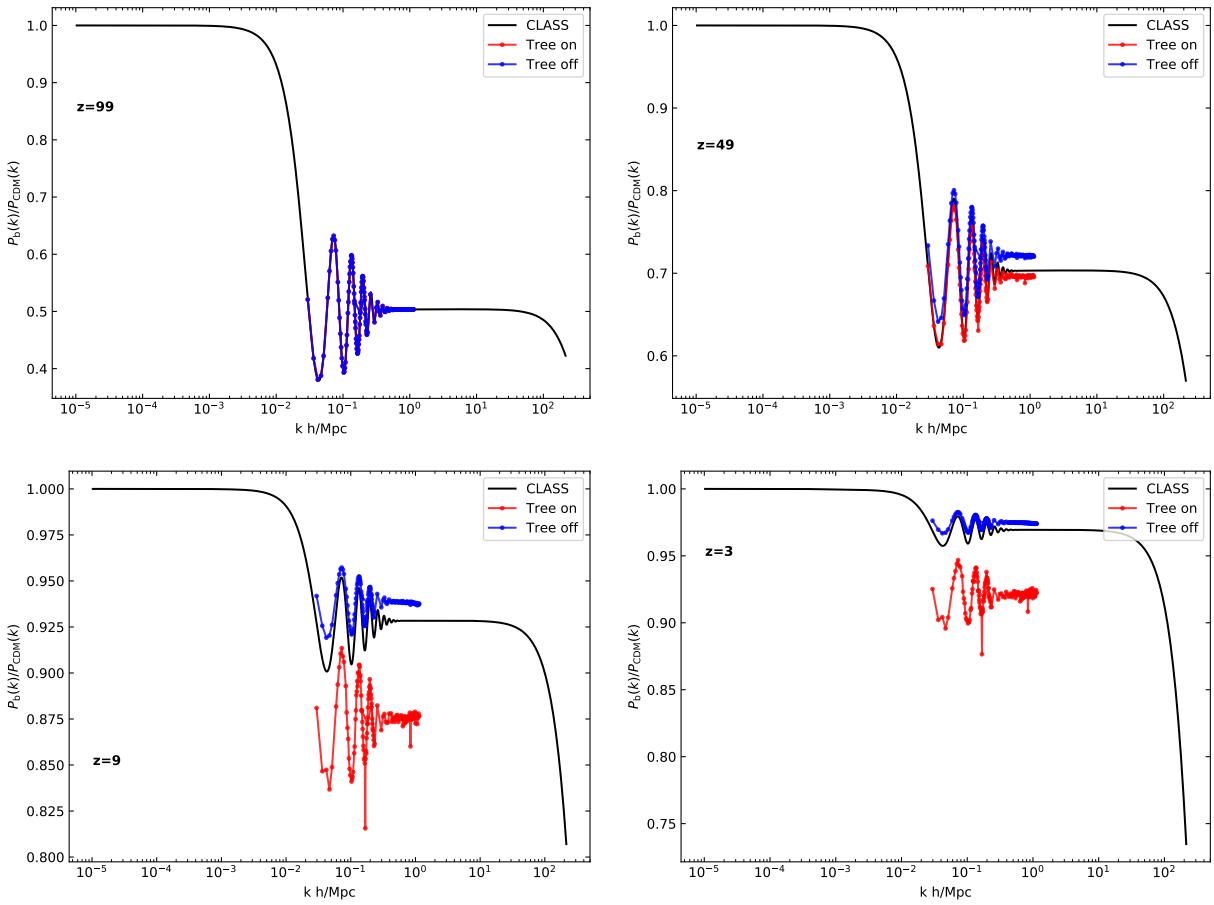

Figure 3: MP-Gadget results comparing the effect of the Tree on the growth of individual species.