Evolution of Baryon Density Fluctuations in Multi-Component Cosmological Simulations

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1 Comparison with theoretical prediction

We critically examine how the evolution of the matter density field in cosmological simulations are affected by details of setting-up of the initial conditions. We show that it is non-trivial to realize an initial matter distribution in N-body/hydrodynamic simulations such that the baryon and dark matter density fluctuations and their velocities evolve consistently as theoretically predicted. We carry out a set of cosmological simulations and use them to distinguish and verify an appropriate method for generating initial conditions. We find that a straightforward way of applying the Zel'dovich approximation to each components using distinct transfer functions results in an incorrect growth of the density fluctuations and that it is necessary to correct velocities at the initial epoch. The unperturbed uniform particle distribution must be also generated appropriately to avoid tight coupling of the baryonic and dark matter components. In the Figure shown below we plot the evolution of the matter (baryons and CDM) power spectra for two simulations. For Run A, an identical "glass" distribution is used for both the gas and dark matter particles. Using distinct initial power spectra in this configuration results in a false coupling of the particles. As is seen in the bottom portion of the plot, the growth of baryon fluctuations is unphysically accelerated due to this coupling. For Run C we used two independent glass files for the gas and dark matter particles. The right panels show that the initial set-up in Run C avoid the problem. Indeed, the density fluctuations are correctly reproduced in Run C as manifested in comparison with theoretical predictions (the solid and the dashed line).

In summary, we recommend to use independent "glass" particle distributions, to use distinct transfer functions for baryons and dark matter, *and* to take the difference in the velocity fields at the initialization epoch into account. The proposed method will be useful for studies on the evolution of the inter-galactic medium and the formation of the first cosmological objects using numerical simulations.