New Cosmological Data and the Values of the Fundamental Parameters
IAU Symposium, Vol. 201, 2005
Anthony Lasenby and Althea Wilkinson, eds.

The Initial Condition of Cosmological High-Resolution Simulations

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Abstract. Recently, High-resolution algorithms such as the adaptive mesh refinement (AMR) method have been applied to cosmological simulations by several authors. However, the resolution of their INITIAL conditions is not high. We argue the need for cosmological high-resolution simulations to use a high-resolution initial condition or an initial condition including high-frequency components. Then we present the method of creating such initial condition, and estimate its computational cost.

1. Introduction

High-resolution algorithms such as the adaptive mesh refinement (AMR) method are useful for cosmological simulations which should treat the small size (~10kpc) objects in the large scale (~10 or 100Mpc) computational box. Recently, cosmological simulations using high-resolution algorithm have been performed by several authors. However, the resolution of their INITIAL conditions is not high.

As initial density perturbations grow by self-gravity, high-density regions collapse to halos, then galaxies and clusters of galaxy are formed. Growth of small-scale perturbations may play a important role of formation of small-scale objects such as galaxies. Initial conditions which resolution is not high, however, neglect such small-scale perturbations.

In following section, we present the method of creating the initial conditions with high-resolution.

2. Method

The initial condition of cosmological simulations is given as power spectrum, $P(k)$. The real space density distribution, $\rho(x)$, is created from $P(k)$ using the fast Fourier transform (FFT) technique. The resolution of these initial conditions are constrained by the mesh size, high-frequency components of $\rho(x)$ are neglected.

https://doi.org/10.1017/S0074180900216859 Published online by Cambridge University Press

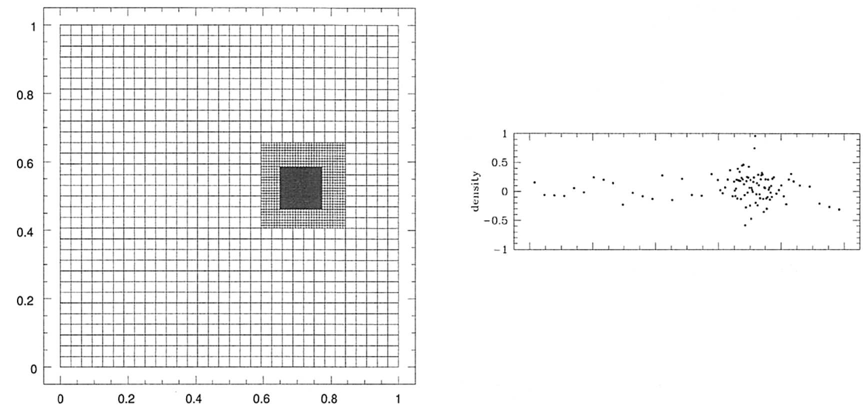

Figure 1. Left panel, the mesh structure sliced on the plane of z=0.5. Right panel, the density plot of white noise on the line of {z=0.5,y=0.5}. The coarsest cell size is $boxsize/32$ and the finest cell size is $boxsize/512$.

We create first a usual density distribution $\rho_0(x)$ which neglect high-frequency components. Secondly, we divide the cells in a part of computational box. Finally, we add the higher-frequency components $\rho_1(x)$ to the divided part. In numerical formula expressions, $\rho(x \subset divided\ region) = \rho_0(x) + \rho_1(x)$ and $\rho(x \subset outer\ part) = \rho_0(x)$. $\rho_i(x)$ are created from $P_i(k)$ using the FFT technique. Here, $P_0(k) \propto k^n$, $P_1(k) \propto k^n$ for $k > k_{th}$ and $P_1(k) = 0$ otherwise. k_{th} is decided by the resolution of $\rho_0(x)$. Recurrently adding higher-components $\rho_2(x)$,$\rho_3(x)$,..., exceedingly higher-resolution can be achieved.

3. Results

We created the white noise distribution of density with the coarsest cell size of $boxsize/32$ and the finest cell size of $boxsize/512$. The mesh structure sliced on the plane of z=0.5 and the density plot on the line of {z=0.5,y=0.5} are demonstrated in Figure 1.