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研究課題名 The mass function of dark matter halos in the early universe

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成果の概要を記入してください。必要に応じてページを加えても構いませんが、pdf のファイルサイズの上限は 2MB とします。
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1 Introduction

It is of significant scientific interest to predict the abundance of dark matter halos, which serve as hosts for observable clusters, groups and galaxies in the cold dark matter universe. The distribution of dark matter halo mass - termed the halo mass function - describes the number density of halos of a given mass. Traditionally the halo mass function has been widely studied in an effort to develop an analytic form which is essential for a wide array of models of galaxy formation, reionization and other phenomena, and is also required for the analysis of observable objects whose number density depends on the halo mass function. Since analytical models do not capture the entire complexity of halo formation which is a complicated nonlinear gravitational process, numerical simulations are crucial in deriving a reliable and accurate fit for the mass function matching the recent precision cosmological constraints.

Most of the effort to evaluate the mass function from N-body simulations has been focused on z=0 or lower redshift(z<1), not only because most observational constraints have been derived at low redshift, but also because evaluation of the mass function at high redshifts is challenging due to the small mass of the halos at early times. To capture these small-mass halos, high mass and force resolution are both required. We aim to obtain an accurate mass function for low-mass halos($< 10^{10}h^{-1}M_{\odot}$) at the redshift of z=6 in a large cosmological simulation of ΛCDM cosmology. The resulting mass function permits comparison with surveys of observable objects at z=5-6 such as Lyman-break galaxies, which are likely progenitors of groups or clusters. At z=6-20, the number density of low-mass halos is also important in probing quasar abundance and formation sites, reionization by the first galaxies, and early structure formation.

2 Simulation

We assume ΛCDM model with the most updated WMAP5 cosmological parameters: matter density $\Omega_m = 0.274$; dark energy density, $\Omega_\Lambda = 0.726$; fluctuation amplitude, $\sigma_8 = 0.812$; Hubble constant $h = 0.705$(in units of 100km$s^{-1}Mpc^{-1}$). The dark matter simulation was carried out with the parallel gravity solver L-GADGET2 (Springel 2005).

The box size was taken to be 300Mpch^{-1}, the softening length was set at 7.0kpch^{-1}, 2048^3 collisionless particles were sampled. The simulation was started at z=199 from "glass" initial conditions, and was evolved until z=6. We identified the halos and defined their mass using a friends-of-friends(FOF) halo finder with linking length b=0.2, which is widely adopted by many numerical practitioners as a standard convention. At z=6, there were about 3148563 halos above a detection threshold of 20 particles, covering a halo mass range of ($\sim 10^9 - 10^{11} h^{-1} M_{\odot}$). Our particle mass is $2.4 \times 10^8 h^{-1} M_{\odot}$, allowing us to resolve halos down to $4.8 \times 10^9 h^{-1} M_{\odot}$ with 20 particles.

3 Comparison with Analytic Models

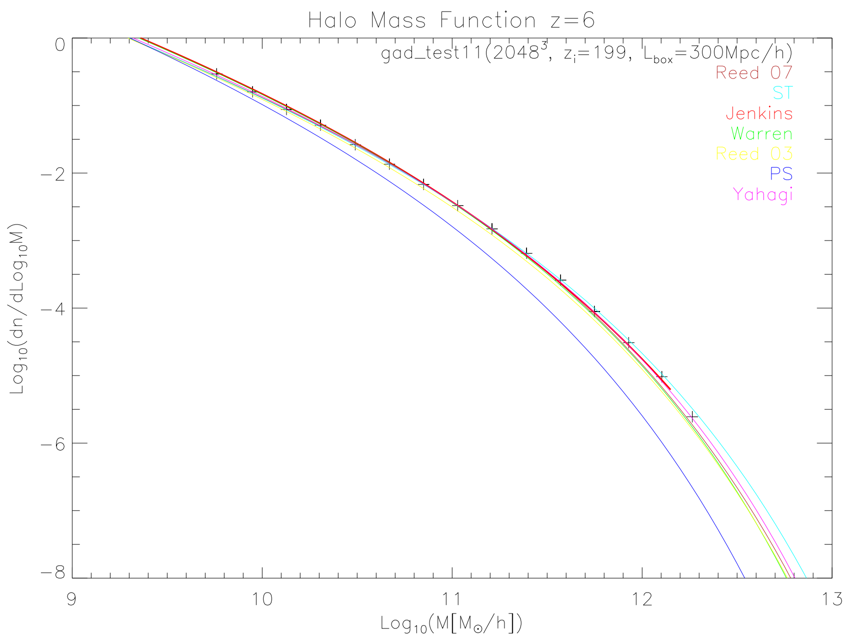

図 1: Compare the mass function derived from our simulation result(black cross) with various analytical fitting functions.

The differential halo mass function, or halo mass function for short, $dn/dlogM$ is defined as the number of halos of mass M per unit volume per unit interval in M. In Fig.1, we have plotted $dn/dlogM$ as a function of $logM$ from our simulation at z=6 and compared to several popular analytical versions of mass functions published in literature. Our results confirm previous findings that the analytic model of mass function developed by Press & Schechter(1974) dramatically underpredicts the number of halos over the whole mass range that is well sampled in our simulation at z=6, i.e.($\sim 10^9 - 10^{12} h^{-1} M_{\odot}$). The discrepancy is significantly more severe in the high-mass end. Other modern fits all give similar predictions in the low mass range below $\sim 10^{11} h^{-1} M_{\odot}$ and are consistent with our simulation results. However in the high-mass range, the various fitting functions diverge in their predictions. The fitting function provided by Yahagi et al.(2004) gives the best match to our simulation data. New simulations are planned to improve the mass resolution by reducing the simulation box. The main goal is to determine accurate halo mass function at z=6, and provide a fitting formulae which applies to our simulation data.