U12a Reliability of the dark matter clustering in cosmological N-body simulation on scales below the mean separation length of particles

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We critically examine the reliability of the dark matter clustering in high-resolution cosmological N-body simulations on scales below the mean separation length of particles. The particle discreteness effect imposes the two fundamental limitations on those scales; the lack of the initial fluctuation power and the finite mass resolution. We address this problem applying the dark halo approach and are able to discuss separately how those two limitations affect the dark matter clustering in N-body simulations at early epochs. We find that limitations of the dark matter clustering are primarily determined by the mass of particles. By a detailed comparison with three major cosmological simulations, we also find that in order to reproduce a proper amplitude of the dark matter clustering on small scales, halos with a characteristic nonlinear mass, $M_{\rm NL}(z)$ defined by $\sigma_R(M_{\rm NL};z) = 1$, must be resolved in the simulation. This leads to a critical redshift $z_{\rm crit}$ determined by $M_{\rm NL}(z_{\rm crit}) = n_{\rm halo}m_{\rm part}$ where $n_{\rm halo}$ is the number of particles necessary to resolve the typical nonlinear mass halo (~ 10). We conclude that, at least as far as the two-point correlation functions are concerned, the dark matter clustering in high-resolution N-body simulations on scales below the mean particle separation is reliable down to the gravitational force resolution length only for $z < z_{\rm crit}$, while it is strongly affected by the finite mass resolution for $z > z_{\rm crit}$.