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Adaptive gravitational softening in GADGET

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Cosmological simulations of structure formation follow the collisionless evolution of dark matter starting from a nearly homogeneous field at early times down to the highly clustered configuration at redshift zero. The density field is sampled by a number of particles in number infinitely smaller than those believed to be its actual components and this limits the mass and spatial scales over which we can trust the results of a simulation. Softening of the gravitational force is introduced in collisionless simulations to limit the importance of close encounters between these particles. The scale of softening is generally fixed and chosen as a compromise between the need for high spatial resolution and the need to limit the particle noise. In the scenario of cosmological simulations, where the density field evolves to a highly inhomogeneous state, this compromise results in an appropriate choice only for a certain class of objects, the others being subject to either a biased or a noisy dynamical description. We have implemented adaptive gravitational softening lengths in the cosmological simulation code GADGET; the formalism allows the softening scale to vary in space and time according to the density of the environment, at the price of modifying the equation of motion for the particles in order to be consistent with the new dependencies introduced in the system's Lagrangian. We have applied the technique to a number of test cases and to a set of cosmological simulations of structure formation. We conclude that the use of adaptive softening enhances the clustering of particles at small scales, a result visible in the amplitude of the correlation function and in the inner profile of massive objects, thereby anticipating the results expected from much higher resolution simulations.

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