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A regularized N-body algorithm for gravitational collapse clustering

Jun Hidaka

Department of Physics, University of Utah, 115S. 1400E., RM201, Salt Lake City, UT 84112, USA

Abstract. In N-body problem, it is necessary to regularize forces between close encountering particles to conserve their total energy. Without regularization, these particles has rapid change of their energy. We can, therefore, select close encountering particles looking at their energy and apply regularization to them. We discuss application of this scheme to spherically collapsing case.

1. Introduction

In N-body gravitational simulation, one of dificulties is how to treat close encountering particles. Calculation using finite time step causes huge error for them because of singularity of potential. In the two-body problem, KS regularization is popular and useful. In N-body case, chain regularization was used sucessfully. There also exists global regularization scheme by Heggie(1974). Recently Mikkola&Tanikawa(1999) and Preto&Tremaine(1999) independently developed new regularization technique for few body encounter which can treat softened potential. Here we applied this new scheme to N-body problem based on the assumption that force may consist of slow varing and fast varing parts following the idea by Skeel(1999). Fast varing part is defined as force from particles near particles which need regulariztion. Rest of particles creat slow part. We tried to calculate spherical collapse problem, and our initial condition is random distribution of particles with uniform density and zero initial velocity.

2. Method

Several features of our method are the followings.(1) Find close encountering particles,"bad particles", looking at huge difference in their energy with 4th order Runge-Kutta calculation comparing with that at the previous step . Its typical behavior can be seen in Figure 1(2) Construct "clusters" adding several particles near "binaries". Here the definition of binary is a pair of particles in which they are nearest neighbor each other and bad particles.(3) Calculate slow varing force acting on members in clusters just eliminating contribution from members. With these slow varing field, following D.Skeel, we use scheme, $(\Delta t/2)U^{slow}$,$(\Delta t)(U^{fast}+K)$,$(\Delta t/2)U^{slow}$, in which we apply new regularization method on calculations which include fast varing forces.(4) For "good" particles, we accept the original results by Runge-Kutta calculation.

3. Results

The new feature of our code is method to identify close encountering particles and application of new regularization(Mikkola&Tanikawa,Preto&Tremaine 1999) to them. Results are, (1) We can eliminate huge error during close encounter using new regularization method(see Figure 2). Also our simple way to identify close encountering particles works with clustering around them. (2) The total energy decrease during collapse and its relative error is about 1%.

4. Future

(1)Introduce variable time stepping to justify small size clusters in dense region.(2) Explore many cases with different small softening parameters.

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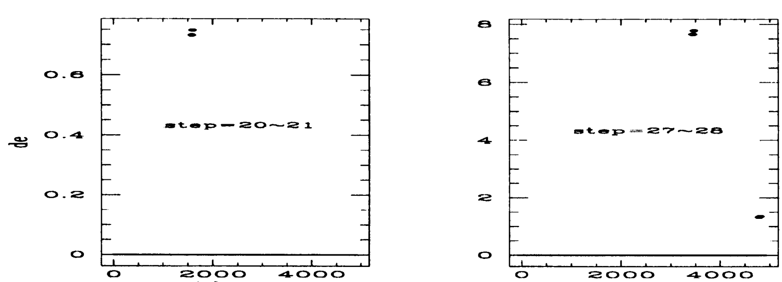

Figure 1. Typical behavior of close encounter

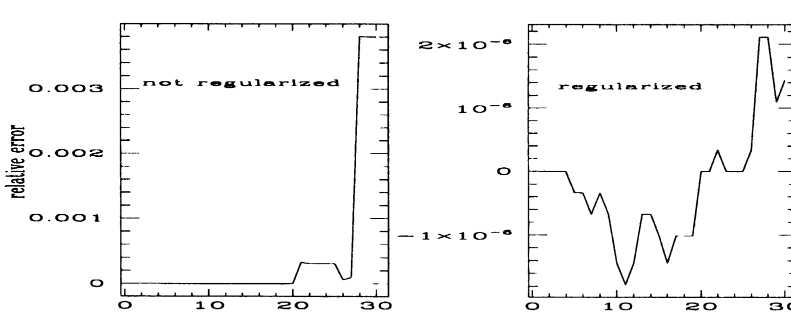

Figure 2. Effect of regularization

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