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A NEW METHOD TO SIMULATE VERTICAL AND HORIZONTAL STRUCTURE IN GALACTIC DISKS

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ABSTRACT. We have modified the particles in an N-body treecode to have different softening lengths in the horizontal and vertical directions. This allows us to simultaneously have thin enough particles to resolve the vertical structure in galactic disks, and horizontally large enough particles to supress the vertical heating due to two-body effects.

1. Introduction

It has previously been difficult to use N-body techiniques to study the vertical structure in galactic disks. Because disk systems are usually at least 10 times larger horizontally than they are vertically, the height of the disk is only very sparsely sampled by particles. Furthermore, the large softening lengths that are needed to suppress two-body relaxation in the plane of the galaxy leave the vertical forces poorly resolved. By creating an N-body code that uses particles that have much larger effective softening lengths horizontally than they do vertically, we neutralize both of these problems.

2. Method

To create "flat" N-body particles, we modified the interparticle forces in Lars Hernquist's implementation of the Barnes and Hut tree code algorithm (Hernquist, 1990, Barnes & Hut, 1986). The modified forces are derived from an *ad hoc* potential and model approximately those of a flattened Plummer density distribution. Horizontally, the force between particles is the same as if the particles were simply spherically softened. Within the horizontal softening length, the vertical forces are roughly constant until a height above the plane on order of the horizontal softening length (as would be expected for a thin disk). Because the particles are extended horizontally, the vertical forces are effectively averaged over several particles, thus reducing vertical noise and two-body effects while maintaining vertical force resolution. The increase in relaxation time for N-body codes using flattened particles over standard N-body codes that have the same vertical scale as the flattened particles is roughly a factor of the ratio between the horizontal and vertical scale of the flattened particles, (about a factor of 10). The axis ratio of the flattened particles is adjustable.

To test the amount of vertical heating, we started with a horizontally very cold exponential disk (with constant Toomre's Q) embedded in a bulge and halo potential. The disk was designed to have the same scale length and surface density as the Galaxy, and bulge+halo system parameters were chosen to give a flat rotation curve of 220 km/sec. To suppress the firehose instability, to which such a vertically cold system is susceptible, we implemented a vertical force symmetrization routine. Preliminary runs were with 10^4 particles and ran for 2×10^9 years (about 8 disk rotations). All runs started with the same initial conditions. Larger simulations run for longer times are currently in progress.

3. Results

Figure 1 shows the initial conditions and the final states for two different simulations. One run used small spherically softened particles ($\epsilon = 75\,\mathrm{pc}$), and the other used flattened particles with a horizontal scale of 750 pc and a vertical scale of 75 pc. Clearly there is dramatically less vertical heating when the flattened particles are used. In the spherical case, the scale height increases from 15 pc to roughly 350pc, while in the flattened case, the scale height increases to not more than 17 pc. Likewise, the vertical velocity dispersion increases fivefold in the spherical case, and increases by at most 20% when using flattened particles, as can be seen in Figure 2.

4. Conclusions

With this new tool, we will be able to study numerically how the large scale horizontal structure of galactic disks (i.e. spiral structure) couples to the growth of vertical structure. The effects of gas infall and satellite infall can also be easily studied with this techinque.

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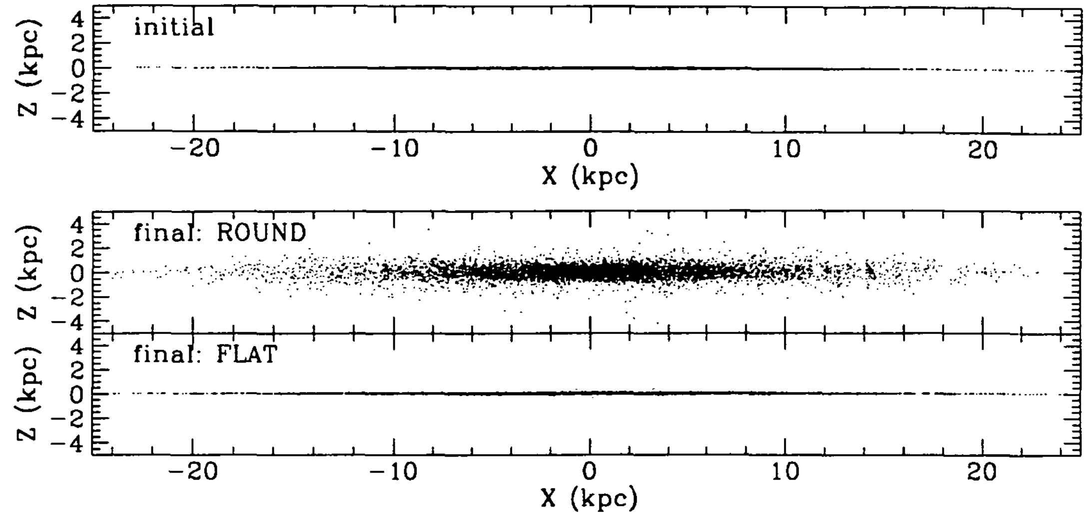

FIGURE 1. (top) Initial conditions, 10^4 particles. (bottom) Two simulations after 1.9×10^9 years, one using spherically softened particles and one using flattened ones.

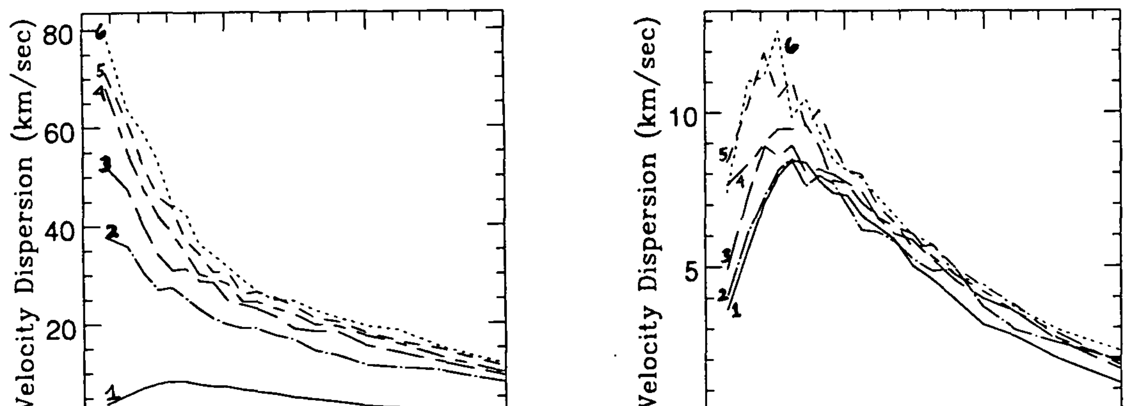

FIGURE 2. Growth of the vertical velocity dispersion with time, for the round particle and the flat particle simulations. Time steps are separated by 3.7×10^8 years. Note the different vertical scales.