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The relaxation time in spherical galaxy simulations

P.M.S.Namboodiri
Indian Institute of Astrophysics, Bangalore 560034 India

Abstract. The relaxation time of a spherical galaxy with various density distributions has been evaluated using numerical simulations. The results indicate that the relaxation time is weakly dependent on the density of the galaxies in these simulations.

1. Introduction

The mean relaxation time of a group of stars has been defined as the time required for the mean square energy change accumulated by the stars in successive encounters to become equal to the square of the mean kinetic energy of the group. Several workers performed numerical simulations using a small value for N to determine the relaxation time in galaxies (Smith 1981, Mc Millan, Casertano & Hut 1988, etc.). Huang, Dubinski & Carlberg (1993) considered King model galaxies with N in the range 10^2 to 4 x 10^5 and showed that the relaxation time depends on N and ϵ, the softening parameter.

2. Numerical simulations and results

The density distribution of the galaxy in the models corresponds to that of a polytrope of index n in the range 0 - 5. The relaxation time at half-mass radius is evaluated using the formula

$$T_{rh} = \frac{E_h^2(t_2 - t_1)}{\sum_{i=1}^{i=N/2} [E_i(t_2) - E_i(t_1)]^2}. \tag{1}$$

Here E_h is the kinetic energy of all particles within the half-mass radius and $E_i(t)$ is the kinetic energy of the i^{th} particle at time t. A series of simulations i.e., R1,R2,... ,R9, has been performed using the GRAPE system computer and the important results are given in table 1.

Our result shows that there is a strong linear relation between T_{rh} and N of the form $T_{rh} \propto N/\ln(\alpha\ N)$ for α =0.4 which is consistent with analytical results. Figure 1 shows the relaxation time as a function of n for the various models. The three curves represent relaxation times in three regions; i.e, radii containing 10, 50 and 100 % mass of the system. It can be seen that a change in density does not strongly affect the relaxation time implying that it is weakly dependent on the density of the galaxy. The relaxation time shows tendency to decrease as n increases.

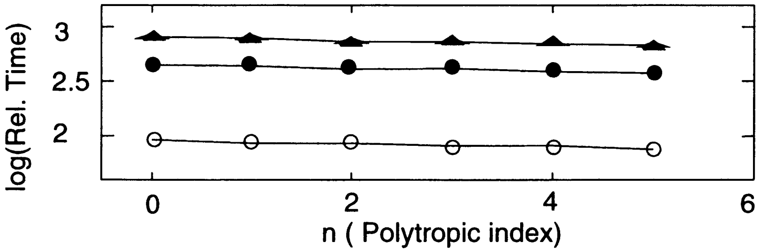

Figure 1. Plot of relaxation time vs polytropic index n. The three curves respectively represent regions containing 100, 50 and 10 % mass of the galaxy from top to bottom.

Table 1. **Simulation parameters and results**

Model	R_h	n	N	T_{rh}	T_{fr}	$\frac{T_{rh}}{T_{fr}}$
R1	0.955	0	16384	446.5	695.3	0.64
R2	0.932	1	16384	437.6	698.3	0.63
R3	0.897	2	16384	420.3	645.4	0.65
R4	0.853	3	16384	414.6	592.7	0.70
R5	0.821	4	16384	387.7	562.3	0.69
R6	0.765	5	16384	376.5	494.5	0.76
R7	0.850	3	32768	822.1	1160.3	0.71
R8	0.850	3	65536	3290.7	706.7	0.92
R9	0.854	3	100000	3457.4	3699.4	0.93

An examination of the Fokker-Planck relaxation time obtained using the formula $T_{fr} = 0.34\sigma^3/G^2 m\rho ln(\Lambda)$ (Binney & Tremaine 1987) given in table 1, shows that T_{rh} and T_{fr} are comparable and T_{fr} is always slightly higher than T_{rh}. More over the agreement is seen to be remarkably good for values of $N \geq$ 64K which underlies the importance of using large N ($N > 10^4$) for numerical simulations.

References

Binney,J. & Tremaine,S., 1987. Galactic Dynamics, Princeton University, Press, Princeton, New Jersy.

Huang,S., Dubinski,J & Carlberg,R.G., 1993. ApJ. 404, 73.

McMillan,S., Casertano,S. & Hut,P., 1988. in IAU Colloq. 96, The Few Body Problem, ed. M.J.Valtonen, Dordrecht, Kluwer, 113.

Smith,H., 1981, MNRAS, 195, 35.