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Tidal interactions in spherical galaxies

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Abstract. Numerical simulations of equal mass galaxies, moving initially on a parabolic orbit, have been performed to see how the total energy of the system changes in close and wide encounters. The results are compared with those obtained using impulse approximation.

Key words : Galaxies, interactions, numerical simulations

1. Introduction

The most important parameter in a galaxy-galaxy collision is the impact parameter. The dynamically significant quantity corresponding to the impact parameter is the distance of closet approach. We investigate by numerical simulations the effect of varying the distance of closet approach on the process of merging and also compare the results with those obtained analytically under the impulse approximation.

2. The simulations

The model consists of identical galaxies whose density distribution closely follows the Plummer model. A series of 11 simulations are performed with the ratio p/R_h = 0, 0.5, 1, 1.5, 2, 2.5, 3, 4, 5, 7.5, and 10 where p is the distance of closet approach and R_h is the half-mass radius. These models are designated as P1, P2, ..., P11 respectively. Each galaxy contains 1024 particles, has R_h=0.91 and extends to about $10R_h$. Barnes' *treecode* is used for the computation of orbits (Barnes & Hut, 1986).

3. Results

We use a merging criterion similar to the one used by Aarseth & Fall (1980) given by

$$\left[\frac{V_p}{1.16 v_e(p)}\right]^2 + \left[\frac{p}{2.5(R_{h1} + R_{h2})}\right]^2 \leq 1 \qquad (1)$$

where V_p and v_e are collision and escape velocities respectively at p. The main results are given in table 1. In our simulations models P1, P2 and P3 are prompt mergers and models P4, P5 and P6 are slow mergers. In models P7 - P11, the galaxies do not merge but servive the encounter by the end of our computation.

Table 1. Collision parameters and results

Model	$\frac{p}{R_h}$	$\frac{V_p}{ve}$	$\frac{\Delta U}{\lvert U\rvert}$	$\left(\frac{\Delta U}{\lvert U\rvert}\right)$	Model	$\frac{p}{R_h}$	$\frac{V_p}{v_e}$	$\frac{\Delta U}{\lvert U\rvert}$	$\left(\frac{\Delta U}{\lvert U\rvert}\right)_{IA}$
P1	0.0	0.25	0.985	13.000	P7	3.0	1.00	0.178	0.396
P2	0.5	0.73	0.995	85.620	P8	4.0	1.00	0.076	0.167
P3	1.0	0.87	0.998	10.706	P9	5.0	1.02	0.037	0.086
P4	1.5	0.88	0.870	3.172	P10	7.5	1.02	0.020	0.025
P5	2.0	0.93	0.346	1.338	P11	10.0	1.02	0.013	0.011
P6	2.5	0.95	0.263	0.685					

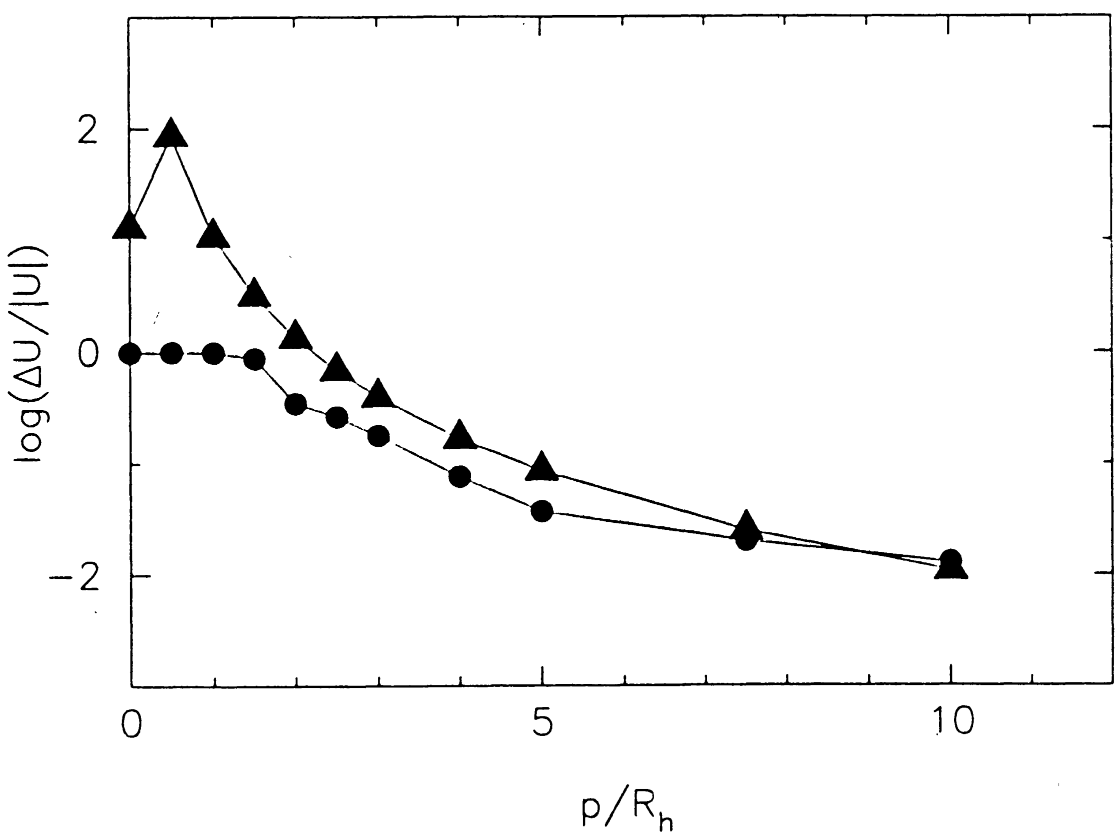

Figure 1. Plot of log $(\Delta U/|U|)$ against p/R_h. The filled circle corresponds to values obtained from simulations and the filled triangles represent those computed using IA.

4. Conclusion

The relative change in energy $\Delta U/|U|$ is computed using

$$\left(\frac{\Delta U}{|U|}\right)_{IA} = \frac{\pi^2}{2}\frac{G^2M^2}{P^4V_p^2}\left(\frac{R_{rms}}{V_{rms}}\right) \tag{2}$$

where subscript IA denotes the quantities obtained using impulse approximation, U is the initial energy of the galaxy and ΔU its change during an encounter (Namboodiri & Kochhar 1990). R_{rms} and V_{rms} respectively denote the root mean square radius and velocity. The value of $\Delta U/|U|$ is close to unity in merging cases indicating that the galaxies undergo considerable disruption during the encounter. In figure 1, we plot log $\Delta U/|U|$ obtained from simulations and IA as a function of p/R_h. It can be seen that the IA estimates do not agree with our simulation results in the merging cases. This is due to the fact that the impulse approximation neglects the motion of stars which is very important in penetrating collisions. However the IA estimates are better for wide encounters. For $p/R_h > 5$, the IA estimates agree, within a factor of two, with numerical simulation results.

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References

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