GALACTIC DISK SHOCKS ON GLOBULAR CLUSTERS

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Abstract. We study tidal shocking on globular clusters by N-body simulation. The results, which cover a range of cluster and disk parameters, are compared with the impulsive approximation.

1. Introduction

Disk shocking is thought to be a significant mechanisms affecting the dynamical evolution of globular clusters. Usually it is treated with an impulsive approximation, but here we use N-body simulations. About 150 crossings (with various parameters) have been studied using the special-purpose computers GRAPE-3A and HARP-2.

2. Model Parameters and the Impulsive Approximation

We adopted the model of Kuijken and Gilmore (1989) for the acceleration at a distance z from the plane of the disk, i.e. $a = -2\pi Gkz/(z^2 + D^2)^{1/2}$. Guided by data in Mihalas and Binney (1981) we have used the values $k = 50, 100$ and $200\ M_\odot$ for the disk surface density, $D = 90, 180$ and 360 pc for the disk scale height and $V_z = 50, 100$ and 200 km/s for the perpendicular component of the space velocity of the cluster. Based on the ranges for real clusters in Webbink (1985), we adopted the values $M = 10^4, 10^5$ and

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$10^6\ M_\odot$ for the cluster mass, $W_0 = 4, 6$ and 8 for the scaled central potential of the cluster (taken to be a King model) and $4 \leq R_{vir} \leq 22$ pc for the cluster virial radius.

For each simulation we measured $\Delta E_n/E$, the fractional change in the internal energy of the cluster, and the fractional mass loss by escape. The number of stars in each simulation, N, was chosen large enough to reduce statistical errors to an acceptable level ($N = 1024$ equal-mass particles on GRAPE-3A and $N = 4096$ on HARP-2). In order to suppress two-body relaxation on time scales up to $\simeq 200\ t_{cr}$, and to obtain satisfactory results on GRAPE-3A, we employed a standard softening with radius of $R_{vir}/64$. The clusters started at $z = 2D$ and the integration was ended after four disk crossing times, $t_{sh} = D/V_z$.

The change in energy may also be calculated theoretically using the impulsive approximation (Binney and Tremaine 1987). This gives $\Delta E_{ia} = 8(\pi Gk/V_z)^2 \sum m_i z_i^2$, where the summation is over all the stars in the cluster. As a measure of impulsiveness we define $T = t_{sh}/t_{cr}$, the ratio of the disk crossing time and the crossing time of the stars in the cluster (t_{cr}).

3. Results and conclusions

For each simulation the value of $\gamma = \Delta E_n/\Delta E_{ia}$ was calculated. For $W_0 = 4$ and 6 and for constant V_z^2/KD, γ approaches zero asymptotically. For $W_0 = 8$, γ decreases linearly with T up to $T \simeq 140$.

The relative mass loss $\Delta M/M$ was obtained from stars with positive energy with respect to the cluster centre after the encounter. We find that $\Delta M/M = (0.185 \pm 0.004)\Delta E_n/E$ and $(1.126 \pm 0.004)\Delta E_n/E$ for $W_0 = 4$ and 6 respectively. For $W_0 = 8$, we get $\Delta M/M = (0.3635 \pm 0.02)\Delta E_n/E + (0.216 \pm 0.05)(\Delta E_n/E)^2$.

The agreement with the impulsive approximation is good and poor, respectively, for fast and slow encounters, as expected. The mass loss depends only on the energy changes, whose functional form depends on W_0.

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References

Binney J., Tremaine S., 1987, Galactic Dynamics. Princeton UP, Princeton.
Kuijken K., Gilmore G., 1989, MNRAS, 239, 571.
Mihalas D., Binney J., 1981, Galactic Astronomy. Freeman, San Francisco.
Webbink R.F., 1985, in Goodman J., Hut P., eds, Dynamics of Star Clusters, IAU Symp 113. Reidel, Dordrecht, p. 541.