Dynamical Evolution of Dense Stellar Systems
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Mass-Loss Timescale of Star Cluster in External Tidal Field

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Abstract. We investigate evolution of star clusters in steady external tidal field by means of N-body simulations. We followed several sets of cluster models whose strength and Coriolis's contribution of the external tidal field are different. We found that the mass loss timescale due to the escape of stars, $t_{\rm mloss}$, and its dependence on the two-body relaxation timescale, $t_{\rm rh,i}$, are determined by the strength of the tidal field. The logarithmic slope $[\equiv d\ln(t_{\rm mloss})/d\ln(t_{\rm rh,i})]$ approaches unity for the cluster models in weaker tidal fields. We also found that stronger Coriolis force against others, produced by parent galaxy whose density profile is shallower, makes the mass loss timescale longer. This is due to the fact that a fraction of stars whose orbit are nearly regular increases as the Coriolis force becomes stronger.

Keywords. globular clusters: general, method: n-body simulations

1. Introduction

It has been clear that the mass-loss timescales of star clusters in an external tidal field are not proportional to the two-body relaxation times of the clusters (Heggie *et al.* 1998; Baumgardt 2001). This is due to escape time delay during which stars with the escape energy from the clusters (hereafter, “potential escapers”) remain inside the clusters before finding exits (Fukushige & Heggie 2000). However, the dependence of the mass-loss timescales on the external tidal field have not been investigated. We investigated the dependence on the strength of the external tidal field (in detail in Tanikawa & Fukushige 2005), and the mass profiles of the parent galaxies of the clusters.

2. Method

We investigate the evolution of star clusters in the external tidal field by means of N-body simulations. We considered a cluster that moves in a circular orbit under a spherically symmetric galaxy potential. We used standard units, such $M = G = -4E = 1$, where G is gravitational constant, M is the initial total mass of the cluster, and E is the initial total energy within the cluster. The cluster has $W_0 = 3$ King's profile. We set the eight initial models whose $(r_{\rm t,i}/r_{\rm kg}, \kappa^2/\omega^2)$ are $(0.8, 1)$, $(1.0, 1)$, $(1.3, 1)$, $(2.2, 1)$, $(4.5, 1)$, $(1.0, 2)$, $(1.0, 2.5)$, and $(1.0, 3)$, where $r_{\rm t,i}$ is the initial tidal radius of the cluster, $r_{\rm kg}$ is the radius beyond which the density is zero in the King's model, κ is the epicyclic frequency of the cluster, and ω is the angular velocity of the cluster. The external tidal field becomes weaker with $r_{\rm t,i}/r_{\rm kg}$ increasing. Coriolis force becomes stronger and the mass profile of the parent galaxy becomes shallower with κ^2/ω^2 increasing.

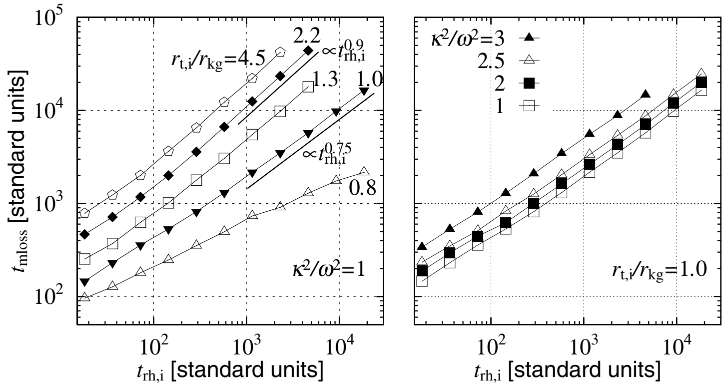

Figure 1. Mass-loss timescale of clusters as a function of initial half-mass relaxation time.

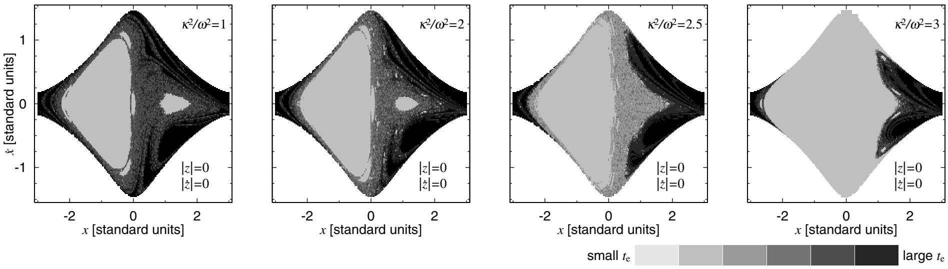

Figure 2. Escape time delay of the potential escapers as a function of their initial phase. The colors indicates the escape time delay, $t_e < 10^2$, $10^2 < t_e < 10^3$, $10^3 < t_e < 10^4$, $10^4 < t_e < 10^6$, and non-escaper, in order of the darkness.

3. Results

Fig. 1 shows the mass-loss timescale, t_{mloss}, of clusters as a function of the initial half-mass relaxation time, $t_{\mathrm{rh,i}}$. The mass-loss timescale is here defined as the time when 50 % of the initial total mass is lost. We found from the left panel of Fig. 1 that the mass-loss timescales, and the logarithmic slope, α [$\equiv d\ln(t_{\mathrm{mloss}})/d\ln(t_{\mathrm{rh,i}})$], depend on the tidal radii of the clusters. In the case of $r_{\mathrm{t,i}}/r_{\mathrm{kg}} = 1.0$, whose run parameters are set to be the same as that Baumgardt (2001), we could reproduce the asymptotic power, $\alpha \sim 0.75$. However, when the tidal radii were smaller the slope was smaller, and when it were larger, the slope was larger than $\alpha = 0.75$. The slope α in the case of larger tidal radii is seen to approach asymptotically to near unity, but roughly $\alpha \sim 0.9$.

We found from the right panel of Fig. 1 the mass-loss timescales become larger as κ^2/ω^2 become larger. Fig. 2 shows escape time delay of the potential escapers as a function of their initial phase. The larger mass-loss timescale in larger κ^2/ω^2 results from the fact that a fraction of stars whose orbit are nearly regular increases.

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