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Evolution of a globular cluster with a two-component BH mass spectrum

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Abstract. Globular clusters (GCs) is dominated by behaviors of high-mass components such as neutron stars (NSs) and black holes (BHs). In this work, we perform direct N-body simulations of a GC assuming two BH masses. We used the BH masses of 10 and 20 $M_\odot$ with total math ratio between those two populations is assumed to be 2:1 and 5:1. Our results show that the heavier BHs (20 $M_\odot$) are depleted in the early stage of cluster evolution. The existence of heavier BH components increase the retention rate of lighter BHs during the cluster evolution. About 30% of ejected BHs are in binaries.

Keywords. Globular Clusters, Black Holes, Gravitational wave.

1. Introduction

During an evolution of GCs, massive components such as BHs and NSs quickly segregate into the cluster core due to dynamical friction. At the center of the cluster, the enhancement of the BH number density causes dynamical interactions between those massive components to form binaries. Some BHs are ejected from the cluster through three-body interactions. Among those ejected, BH-BH binaries in tight orbits are expected to merge with strong GW emission. A global network of GW detectors on Earth will be capable of detecting BH-BH binary mergers.

Recently, Bae *et al.* (2014) investigated formation and ejection NS-NS and BH-BH binaries, fixing BH masses to be 10 $M_\odot$. They suggested that about 30% of ejected NSs and BHs are in a form of binaries.

As an extension of Bae *et al.* (2014), we study the evolution of a GC and ejection of BH-BH binaries assuming two mass components for the black holes: 10 and 20 $M_\odot$. This is a simplification of models suggested by Tanikawa (2013) and Belczynski *et al.* (2006).

2. Models and Results

GC model. We use NBODY6 code for our simulation (Aarseth 2003). We employed the King model with $W_0 = 6$ and central velocity dispersion of 5 km/s as the initial model. We assumed static tidal field by the Galaxy. A cluster is composed of 3 mass components, 20 $M_\odot$, 10 $M_\odot$, and 0.7 $M_\odot$ particles, where the BH mass fraction is fixed to be 2.5% of the total mass. We investigated three models (A, B and C) with different BH mass ratios. Stellar evolution and primordial binaries are not included in our models. More specific model information is given in Table 1.

Table 1. Models used in this work.

Model[1]	$N_{\rm total}(\times 10{\rm k})$[2]	**BH mass ratio**[3]	$N_{\rm run}$[4]
A	5(10)	2:1	13(1)
B	5(10)	5:1	13(1)
C	5(10)	10 $M_\odot$ BH only	13(1)

Notes: [1]Model names, [2]the total number of particles used in each run ($N_{\rm total}$) in a unit of 1000, [3]the BH mass ratio ($\equiv$ total mass of 10 $M_\odot$ BHs/total mass of 20 $M_\odot$ BHs), [4]the number of simulations performed.

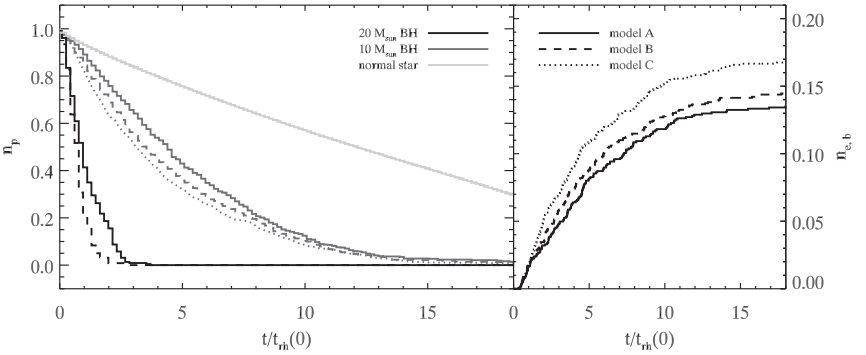

Figure 1. *Left :* Number fraction of retained BHs normalized by their initial number. *Right :* Cumulative number of ejected BH-BH binaries, regardless of binary mass.

BHs retained in the cluster. The left panel of Figure 1 shows the number of stars and BHs in a cluster normalized by their initial number ($n_{\rm p}$) with time. During the cluster evolution, heavier 20 $M_\odot$ BHs are quickly depleted before $t/t_{\rm rh}(0) \sim 3$, while a number of 10 $M_\odot$ BHs decreases slower. After enough evolution time ($t/t_{\rm rh}(0) \sim 10$), about 10% of initial 10 $M_\odot$ BHs can be retained in the cluster.

BH-BH binaries ejected from the cluster. The right panel of Figure 1 shows the cumulative number of ejected BH-BH binaries ($n_{\rm e,b}$), normalized. The result shows about 30% of initial BHs are ejected in binaries. $n_{\rm e,b}$ is inversely proportional to the initial portion of 20 $M_\odot$ BHs. We find 10 $M_\odot$ $-$ 10 $M_\odot$ binaries are ejected only after the depletion of 20 $M_\odot$ BHs. Unequal mass binaries (10 $M_\odot$ $-$ 20 $M_\odot$) are rare (less than 3% of the total number of ejected BHs).

Acknowledgements

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