Globular Cluster Simulation by MOCCA code

Dongming Jin, Matthew Benacquista
Dept. of Physics, University of Texas at Brownsville
Contact: dongming.jin120@utb.edu

Abstract

The MOCCA code is one of the most advanced codes which has the capacity to simulate a realistic sized star cluster with a full dynamical history including star evolution using Monte Carlo methods for the cluster evolution and the Fewbody code for scattering. The dynamical evolution of a cluster can result in the formation of many binary system. Some of these binaries may be very close. Close white dwarf binaries may be promising gravitational wave sources.

Our work uses MOCCA to simulate 90 globular clusters of different number of stars, binary fraction, metallicity and initial mass function parameter. After ruling out models which evaporate before 9 Gyrs and uninteresting models with a very low number of white dwarf binaries, we do multiple runs of the remaining models for around a Hubble time in order to get statistics on the overall white dwarf binary population of different component types, orbital periods and cluster radii in the time range from 8 Gyrs to 10 Gyrs. We consider that white dwarf binaries which exist within a specified time range & Lagrangian radius range and have orbit at periods less than a day are observable. Thus we set up a map of potential white dwarf binary detection rates for different types of globular clusters. I also conducted a 600k simulation to present to capability to study the cluster evolution by MOCCA code.

Free Parameters

To get a general estimate of the statistics for white dwarf binaries, simulations for globular clusters with a different total number of stars N, initial binary fraction f_b, metallicity Z and initial mass function parameter α are performed.

Parameter	Value
N	24000, 100000
f_b	0.1, 0.2, 0.3, 0.4, 0.5
Z	0.02, 0.0002, 0.00001
α	2, 2.35, 3

α is the factor for the power-law mass function [**?**]:

$$\xi(m) \propto m^{-\alpha} \tag{1}$$

where m is the stellar mass in solar units and $\xi(m)dm$ is the number of stars in the mass interval m to $m + dm$.

Potential Detectable Rate Mapping

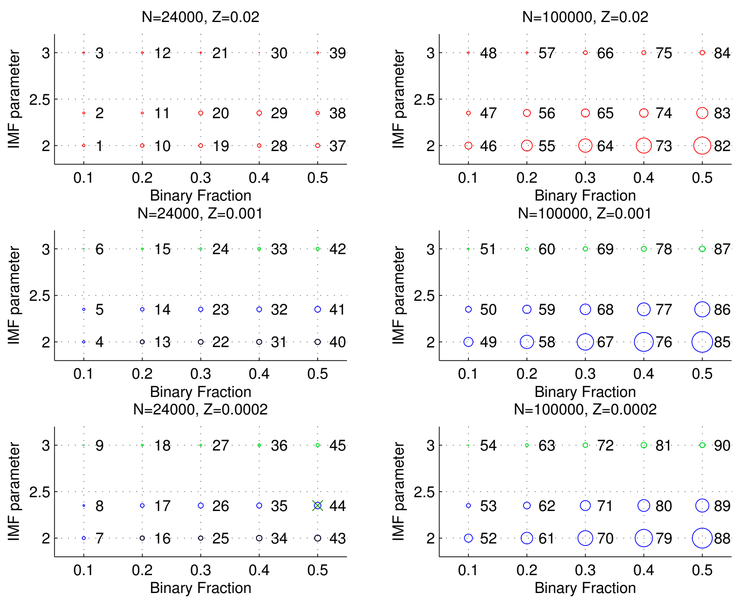
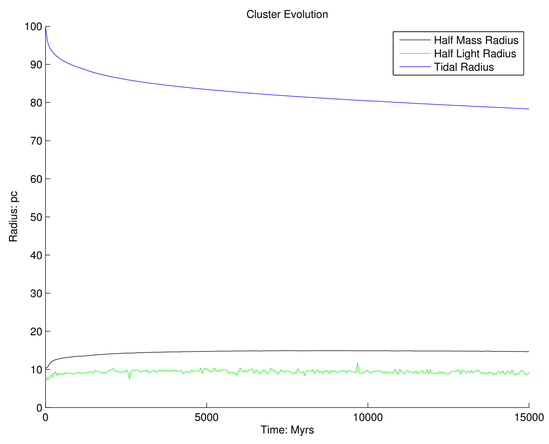


Figure 1: Size indicates the number of WD-WD binaries under following conditions of a certain model:

1. Exists during 8 Gyr to 10 Gyr,
2. has a orbital period less than 1 day,
3. locates between 30% to 70% Lagrangian radii.

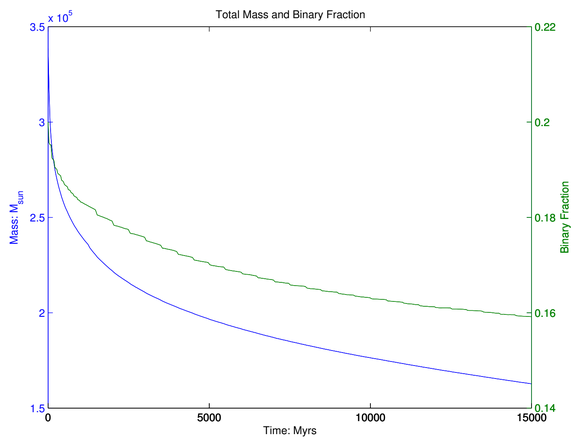
The marked models are plotted for more detail information.

Cluster Evolution



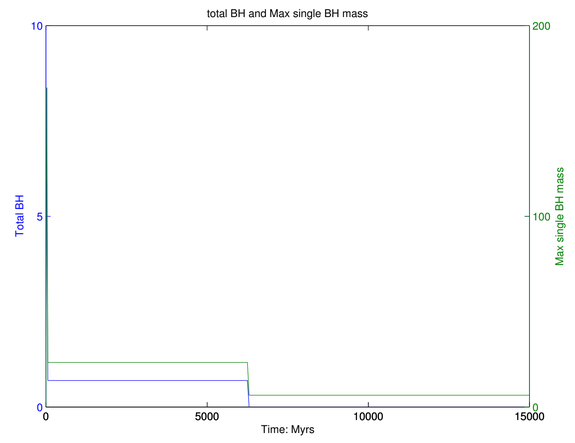
600k Model. This model is a globular cluster with 600k stars and 20% of them are initial binaries. The power-law index of the initial mass function is 2.35 and the metallicity is 0.001. The tidal radius is 100.0 pc. The black line is the half mass radius. The green line is the half light radius and the blue line is the tidal radius.

Total Mass and Binary Fraction



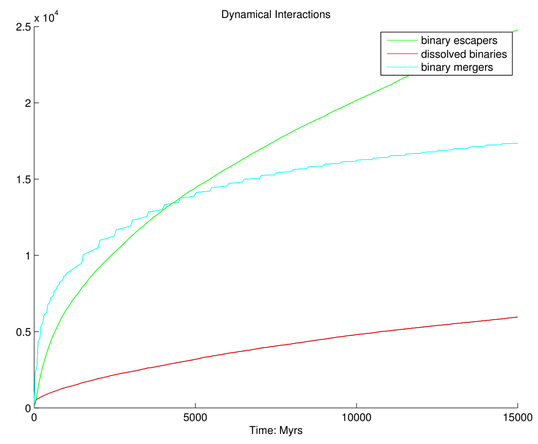
600k Model. This model is a globular cluster with 600k stars and 20% of them are initial binaries. The power-law index of the initial mass function is 2.35 and the metallicity is 0.001. The tidal radius is 100.0 pc. The blue line is the total mass and the green line is the binary fraction.

Total BH and max single BH mass



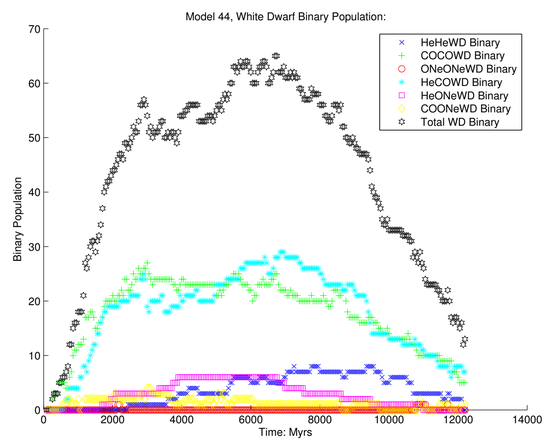
600k Model. This model is a globular cluster with 600k stars and 20% of them are initial binaries. The power-law index of the initial mass function is 2.35 and the metallicity is 0.001. The tidal radius is 100.0 pc. The blue line is the total number of Black Holes and the green line is the maximum single Black Hole mass.

Dynamical Interactions



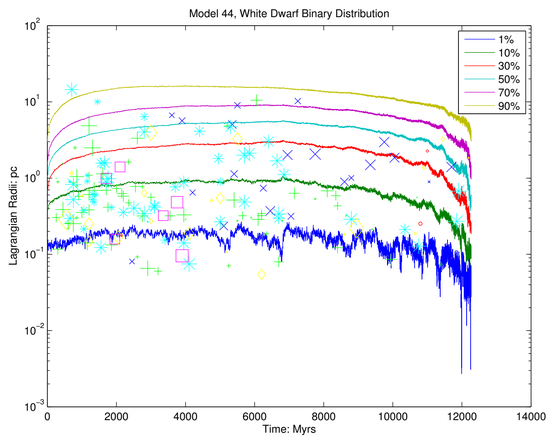
600k Model. This model is a globular cluster with 600k stars and 20% of them are initial binaries. The power-law index of the initial mass function is 2.35 and the metallicity is 0.001. The tidal radius is 100.0 pc. The green line is the number of binary escapers. The red line is the number of dissolved binaries. The cyan line is the binary mergers.

White Dwarf Binary Population



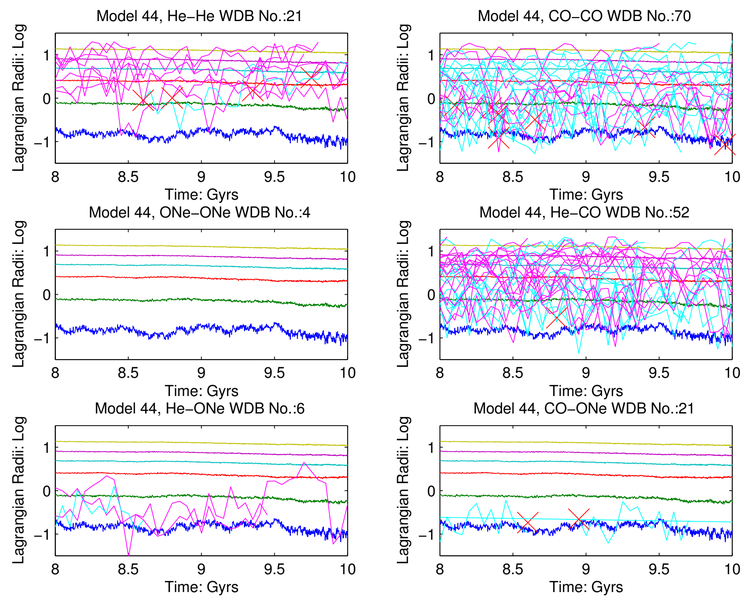
WDB populations for model 44. Model 44 is a globular cluster with 24000 stars and half of them are initially binaries. The power-law index of the initial mass function is 2.35 and the metallicity is 0.0002. Different types of double WDBs are marked according to the legend. The total WDB is just a sum of all the others.

White Dwarf Binary Distribution



Double WDB distributions for model 44. Model 44 is a globular cluster with 24000 stars and half of them are initially binaries. The power-law index of the initial mass function is 2.35 and the metallicity is 0.0002. Different types of double WDBs are plotted with corresponding marks according to the legend in previous figure. Each double WDB is only plotted at the formation time. The size of the marker indicates the lifetime of the WDB.

White Dwarf Binary Orbital Period



Double WDB orbital periods for model 44. The y-axis is logarithmic. The 'x' mark indicates the time a WDB is formed. The following trajectory shows the positions of the WDB during its lifetime. The color of the trajectory indicates the orbital period range, see table below. The No. in title is the amount of certain WDB for the whole stellar history.

Color	Green	Magenta	Cyan
Orbital period	less than 10^{-2} day	10^{-2} to 1 day	larger than 1 day

Acknowledgements: MJB and DJ acknowledge the support of IAU and LOC, the support of NASA grant NNX08AB74G and the Center for Gravitational Wave Astronomy, supported by NSF Cooperative Agreements HRD-0734800 and HRD-1242090.