Abstract

In this thesis, I present the machinery that has been developed to reproduce globular cluster (GC) populations around galaxies. The machinery combines the semi-analytical MASinGA code with the results from the MOCCA-Survey I Database. The ability to model both the large scale dynamics (0.01–10 kpc) controlling their orbital evolution and the small scale dynamics (sub–pc–AU) controlling the internal dynamics of each GC is necessary for a thorough study of the co-evolution of GC systems in galaxies.

In a preliminary work, we have shown that MOCCA models can be used to identify GCs' properties that could be used to identify the dynamic state of a GC also in extra-galactic GC populations. To achieve this, a sub-sample of the MOCCA-Survey Database I was selected in order to mimic the observational limits of extra-galactic GCs. The sub-sample has also been compared with the observations of Milky Way GCs, finding good agreement with previous studies for the considered properties.

The second paper presented in this thesis introduces our machinery for the first time and presents its main features along with that of the MASinGa code. We compared the distributions of global properties of our simulated GC populations with those observed in both the Milky Way and Andromeda galaxies. We found that our models can recover the spatial and mass distributions of GCs in both galaxies, together with the half-light radius distribution. Also, we compared the total mass of the nuclear star cluster (NSC) and super-massive black hole (SMBH) found in our simulations with the observed values, with the masses reported in our simulations being about two orders of magnitude smaller compared to the observations.

In the third paper, we investigated the BH populations in Milky Way and Andromeda - like galaxies. The number, mass, and half-light radius distributions of GCs in different dynamical states (that is, the presence of an intermediate-massive BH, a BH subsystem, or neither) have been studied. We also show that the nature of the dynamical formation of BH binaries would be imprinted onto the orbital properties of the binaries. Depending on the adopted assumptions, the merger rate of BH-BH binaries found in our simulations in the local Universe is $1.0 - 23\ \mathrm{yr}^{-1}\,\mathrm{Gpc}^{-3}$. The orbital parameter distributions for the BH-BH binaries that would survive until the present-day have been investigated. Finally, we found that the dynamics in GCs can considerably enhance the efficiency of BH binary formation, being nearly twice as efficient compared to isolated stellar/binary evolution in the Galactic field.

In another paper presented in this thesis, the study of the embedded gas phase in the evolution of GCs has been carried out in the framework of the Monte Carlo method. In this study, the survival of GCs after the removal of primordial gas s been followed. The results have been compared to N-body simulations, finding good agreement for the Lagrangian radii and mass evolution. Our study outlines the range of initial conditions that can cause clusters to dissolve as well as those that can help them survive this early stage of their evolution. Initially, it was expected to use the prescription introduced in this work to create MOCCA-Survey Database II. However, due to issues with the integration of the most recent upgrades to the MOCCA code, the development of the MOCCA-Survey Database II was strongly

delayed. Nonetheless, this work involved the development of an important feature in the MOCCA code.

I also briefly discuss works that have been submitted and are in progress which deal with the updates to the MOCCA code related to the upgrades of the stellar/binary evolution in the BSE code and the introduction of the possibility to follow the evolution of multiple stellar populations and the first application of the machinery introduced in this thesis to other projects. These updates introduced in these works (including the prescription presented in the forth paper) were intended to be used to create a new MOCCA-Survey Database. This was initially planned to be used to populate GCs in external galaxies in the local Universe. Also, a mass growth prescription for the NSC and SMBH has been applied to the results presented in the second paper for the Milky Way and Andromeda galaxies. Our results show that in order to explain the observed masses in the studied galaxies, an *in-situ* accretion has to be considered in the mass-growth evolution of the NSC and SMBH. The SMBH would accrete the pristine gas in the central region of the galaxy, and trigger star formation events that would contribute to the NSC mass too.