Our fascinating universe contains many interesting and exotic objects that have been discovered and studied during the last century. Among these interesting objects are black holes in binary systems. A black hole is a region of space in which matter is so compact that not even light can escape from it. Our understanding of the evolution of massive stars predicts that black holes are formed when an extremely massive star dies in a supernova event. Detecting black holes is difficult because they do not radiate any light. In our universe there are binary star systems in which at least one of the objects is a black hole. In such systems the presence of the black hole can be observed if matter from the companion stars is being accreted by the black hole. Such systems are very interesting from the point of view of high energy astrophysics and gravitational wave physics.

The main objective of this project is to study black hole binaries in globular clusters using numerical simulation code. Globular clusters are compact groups of up to a million stars that move around together in galaxies. These extremely dense clusters of stars are among the oldest objects known in the universe. This makes them ideal sources to understand the history and evolution of our universe. Globular clusters contain many interesting stars, binary systems and exotic objects. There has been considerable debate as to whether globular clusters in our Galaxy contain stellar-mass black holes. For a very long time, theoretical predictions had suggested that there should be virtually no stellar-mass black holes left in globular clusters today. However, recent observational discoveries and new developments in stellar dynamics theory provide compelling evidence for the presence of black hole binary systems in globular clusters. So the goal of our study is to address these unresolved questions with regards to black holes and black hole binary systems in star clusters. The project will involve evolving many models of globular clusters to estimate the number and mass distribution of black holes that present-day globular clusters could harbour and what initial conditions and environments could be conducive to forming, retaining and sustaining black hole populations in globular clusters.

Globular clusters are fascinating from the point of view of stellar dynamics as they are very dense self-gravitating systems of stars that are interacting according to Newton's laws. The dynamical evolution of these old structures remains an interesting problem in astrophysics and with advancements in computational technology over the past couple of decades, there has been extensive work done in modelling the evolution of star clusters using numerical simulation codes like direct N-body and Monte Carlo codes. These codes can effectively compute the dynamical evolution of the star cluster and need to take into account a variety of physical processes that occur in dense star clusters like collisions, mergers, interactions, stellar and binary evolution. For this project, we plan on using the Monte Carlo code for star cluster evolution called MOCCA which was developed at the NCAC in Warsaw. It is one the fastest and most sophisticated numerical codes for evolving star clusters and provides detailed history for each star in the system. These features of MOCCA make it perfectly suited to investigate black hole binaries in star clusters.

Results from MOCCA simulations of hundreds of models of globular clusters with different parameters and initial conditions will be analyzed to systematically identify models which form, retain and sustain sizeable populations of black hole binaries. This will allow us to constrain the dependency of formation and retention of black hole binary populations on specific cluster parameters that can be given as an input to MOCCA. The globular cluster models that harbour populations of black hole binaries will be further analysed to study details of individual black hole binary system's parameters. We also plan on estimating whether the black hole binaries retained in our systems up to Hubble time can be potential sources for gravitational wave detectors. A Calculations and constraints for detection rates of these elusive sources will also be made. To determine the probability of black hole binary observations in radio and X-ray wavelengths, the number and properties of black hole binaries in which accretion onto the black hole may occur, will also be estimated.

The recent discoveries of black hole binaries in globular clusters has rekindled an interest in understanding the role of black holes in the evolution of dense stellar systems. With the results of this project it will be possible to constrain the dependency of present-day black hole populations and binary formation on cluster parameters and initial conditions. The results of these simulations will also help in understanding the mechanisms via which populations of black hole binaries can be formed and retained in present-day globular clusters. Black hole formation channels other than stellar and binary evolution like merging compact binaries will be explored. The impact of the presence of retained populations of black hole binaries on the dynamical evolution of the globular cluster will also be studied. This project will assist in determining which globular cluster could have a high number of compact binaries that could be potential sources of gravitational waves. Finding globular cluster models which sustain significant number of black hole binaries in which there is accretion onto the black hole will also be helpful for observers using radio and X-ray observations to find such sources in our universe.