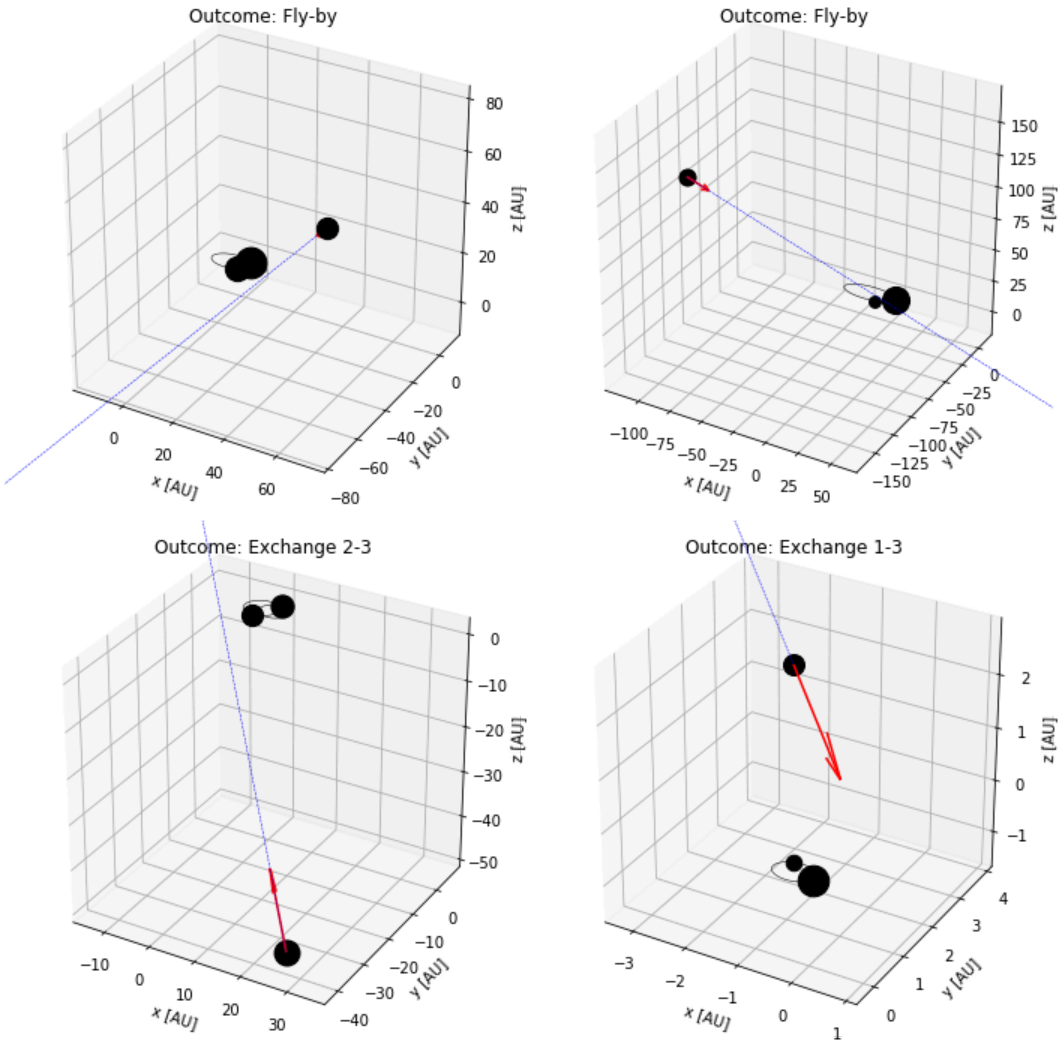
Can AI solve the 3-Body problem?

The 3 body problem has puzzled for centuries physicists and mathematicians alike. The chaotic nature of these systems has made it difficult to predict the trajectories of objects subject to each others gravitational pulls starting from arbitrary initial conditions (J. Samsing et al (2017)) . These calculations have required considerable resources from the era of Newton all the way to the present day, where N-body simulations are still extremely computationally expensive and, if compact objects are involved, need to include full numerical relativity simulations

This can be a serious problem in the field of Computational astrophysics, particularly when computing the evolution of star clusters, where chaotic 3 body encounters between compact objects can be common (D. Pooley et al (2003)). The centers of these star clusters are very interesting to science, since they harbor the condition possible for the formation channels for some of the most puzzling system observed by the LIGO-Virgo-KAGRA collaboration (M. Dall'Amico et al (2021)) (B. Abbot et al (2021))

Image from JWST of a Globular Cluster. Credit : NASA,ESA

The code of ARWV produces a pretty accurate computation of the orbits of 3 body encounters of black holes, that are likely found in the densest parts of Nuclear and Young Star Clusters. These encounters, also referred to as black hole scattering, represent cases when a binary system is approached by a 3rd single body, disrupting and changing chaotically the system. The computations needed to predict the outcome of a statiscally significant sample size can require months of computational time.



This is where the possibility to apply machine learning principles comes in. Since Neural Networks require a finite and predictable amount of linear operations to produce an output, it could be possible to cut computational times by several orders of magnitude if it could be proven that a machine learning algorithm is capable of correctly modelling the differential equations that govern gravitational relativistic interactions. Some works already showed some success in a limited number of cases (P. G. Breen et al (2019)).

The aim of the project is to train machine learning model on a set of ~ 1e5 simulations of 3 body Black Holes encounters performed with the code ARWV and to predict the correct outcome. You will be provided with a dataset containing the initial conditions of the simulation of a 3-body encounter, and their outcome after 1e5 years of simulated time.

The learning objective is not at all easy, the problem is stochastic by its very nature and the dataset contains many asymmetries, so think about ways to deal with these problems.