

Estimating the coalescence rates of double compact objects – perspectives for gravitational wave detections

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Abstract

The development of advanced gravitational wave observatories, such as Advanced LIGO and Advanced Virgo, provides impetus to acquire theoretical estimates for what these instruments might detect. In particular, with the range of these observatories constantly increasing the search for GW sources is extending beyond the “local” Universe and out to cosmological distances. Of such sources, the most promising are the double compact objects (neutron star-neutron star, black hole-neutron star and black hole-black hole systems).

In my thesis I aim to provide such estimates regarding double compact objects and their properties. This work is undertaken in order to learn, through gravitational wave observations, about the physical mechanisms governing stellar evolution and formation of double compact objects. Additionally, this work contributes to the scientific cases for existing gravitational wave projects and helps establish such cases for future ones.

The key element of my thesis is a detailed analysis consisting of three parts. In the first part I investigate a suite of models describing binary evolution in order to determine the most important physical mechanisms governing the formation of double compact objects. The second part builds on the results of the previous one and fuses binary evolution with cosmological aspects such as star formation rate, galaxy and metallicity evolution. The goal is to provide knowledge of the cosmic history of double compact objects since the beginning of time. The third and last part converts the cosmological results of the second part into quantitative and qualitative properties observable by modern day gravitational wave telescopes.

I find that double black hole systems will dominate the detection rates in advanced gravitational wave observatories. They will also provide a rich observational features such as the chirp mass distribution, which will allow to resolve several physical aspects of stellar binary evolution such as the sensitivity of the common envelope outcome on the stellar type of the donor or the mechanism of a supernova explosion. I also predict that most of the detectable double compact objects containing black holes were formed in the early Universe where metal abundance in stars was on average lower than today. Therefore, I find that the chemical evolution of the Universe plays a crucial role in developing populations of double compact objects.