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Binary black hole mergers in young star clusters

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Over the last six years, the LIGO and Virgo interferometers detected an increasing number of gravitational wave events. At the end of the third observing run, the wealth of GW candidates, most of which consist in the merger of binary black holes (BBHs), makes it possible to try to disentangle the formation channels of BBHs, thanks to their peculiar imprints.
In particular, the dynamical evolution in stellar clusters leaves a deep imprint on their BBH population, which turn out to present distinctive signatures with respect to the case of isolated evolution.

In my contribution, I will describe the properties of the population of BBH mergers from a new sample of N-body simulations of young star clusters. The simulated stellar systems present fractal initial conditions to mimic the clumpiness of the observed star forming regions and include a realistic primordial population of binaries, characterized by observation-based orbital properties and a mass-dependent binary fraction. Two sets of star are considered to study the evolution of BBHs in stellar environments characterized by different dynamical activity: low-mass clusters (500-800 MSun) and high-mass clusters (5000-8000 MSun). Also, in order to take into account all the possible dynamical effects, the star clusters are evolved for 1500 Myr.

My study shows that the formation channels of BBHs in low-mass and high-mass star clusters are extremely different and lead to two completely distinct populations of BBH mergers. Low-mass clusters host mainly low-mass BBHs born from binary evolution, while BBHs in high-mass clusters are relatively massive (with chirp masses up to 50 MSun) and driven by dynamical exchanges.

Also, high-mass clusters produce a non-negligible number of BBH mergers with primary mass in the pair-instability mass gap, born either via stellar collisions, in which a main-sequence star merges with a more evolved star, or via BH mergers. A fraction of these massive BBHs also leave a merger remnant in the intermediate-mass BH range. These differences are crucial for the interpretation of the formation channels of gravitational-wave sources.

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