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Dynamical formation of binary black holes in massive star clusters: a cosmological approach

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With nearly 200 hundred gravitational-wave detection candidates reported by the LIGO-Virgo-KAGRA Collaboration over the past decade, we are now entering an era where the statistical analysis of the properties of double compact objects provides us with a better understanding of the physical processes behind these extreme objects. However, the question of the astrophysical origin of merging binary black holes (BBHs) remains unsolved. The two main formation channels generally considered are the isolated evolution of binary stars and the dynamical assembly in dense star clusters.
Here we focus on the dynamical formation channel and on understanding the role played by the galactic environment in shaping the population of merging binary black holes. To this end, we apply a sub-grid model for cluster formation in giant molecular clouds to a series of zoom-in simulations of galaxies from the FIRE-2 project, and to individual galaxies in the cosmological volume simulation FIREbox. Combined with the code for star cluster evolution CMC, we are able to produce populations of star clusters and dynamically formed merging BBHs across cosmic time in a large sample of galaxies.
As massive star clusters preferentially form in the densest massive gas clouds, which are rarely found in low-mass galaxies, we expect these galaxies to make a limited contribution to the global production of dynamically formed merging BBHs. Furthermore, we find that massive clusters can host hierarchical BBH mergers: a massive second-generation BH, formed from an earlier BBH merger, pairing with a first-generation BH. These particular events are expected to have clear, identifiable physical properties. Identifying the formation channel of some of the observed BBH mergers could be the first step towards identifying their host galaxies, thus providing valuable information about their astrophysical origin.

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