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Progenitors of low-mass binary black-hole mergers in the isolated binary evolution scenario

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The formation history, progenitor properties and expected rates of the binary black holes discovered by the LIGO-Virgo collaboration, through the gravitational-wave emission during their coalescence, are now a topic of active research. We aimed at studying the progenitor properties and expected rates of the two lowest-mass binary black hole mergers, GW151226 and GW170608, detected within the first two Advanced LIGO-Virgo observing runs, in the context of the classical isolated binary evolution scenario.
We used the publicly-available 1D-hydrodynamic stellar-evolution code MESA, which we adapted to include the black-hole formation and the unstable mass transfer developed during the so-called common-envelope phase. Using more than 50 000 binary simulations, we explore a wide parameter space for initial stellar masses, separations, metallicities and mass-transfer eficiencies. We obtained the expected distributions for the chirp mass, mass ratio and merger time delay by accounting for the initial stellar binary distributions. We predicted the expected merger rates that we compare with the detected gravitational-wave events, and studied the dependence of our predictions with respect to (yet) unconstrained parameters inherent to binary stellar evolution.
Our simulations for both events show that, while the progenitors we obtain are compatible over the entire range of explored metallicities, they show a strong dependence on the initial masses of the stars, according to stellar winds. All the progenitors found follow a similar evolutionary path, starting from binaries with initial separations in the 30-200 Rsun range, experiencing a stable mass
transfer interaction before the formation of the first black hole, and a second unstable mass-transfer episode leading to a common-envelope ejection that occurs when the secondary star crosses the Hertzsprung gap. The common-envelope phase plays a fundamental role in the considered low-mass range: only progenitors experiencing such an unstable mass-transfer phase are able to merge in less
than a Hubble time. We find that all the integrated merger rate densities are below 0.5/yr/Gpc^3 in the local Universe, the highest rate density being compatible with the observed rates. The common-envelope eficiency CE has a strong impact on the progenitor populations. A high-eciency scenario with CE = 2.0 is favored when comparing the expected rates with observations.

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