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More Than a Sidekick: Secondary Black Holes in Hierarchical Mergers

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Stellar clusters are efficient factories of dynamical interactions and play a crucial role in shaping the black hole (BH) mass distribution accessible to gravitational-wave (GW) observatories. Their ability to retain and repeatedly pair BHs enables the formation of remnants well beyond the pair-instability mass gap, a feature that distinguishes dynamical formation channels from isolated binary evolution. This is highlighted by recent events such as GW231123, possibly the first merger involving an intermediate-mass black hole (IMBH, mass above 100 solar masses), a mass range where decihertz observatories such as LGWA are expected to provide unique sensitivity.

In this work, we investigate the hierarchical assembly of binary BHs, focusing on the formation and evolution of secondary branches within BH merger trees. We introduce a new formalism in our semi-analytical population-synthesis code BPOP to track the growth of structured hierarchical chains. We find that, without these chains, the probability of forming IMBH binaries in the 300–1000 solar mass range, that lies well within the LGWA band, is essentially negligible: hierarchical secondary mergers are the dominant channel populating this mass range, while also leaving distinct signatures in spin. Notably, these systems sit at the interface between the ET and LGWA frequency bands, making them prime candidates for multiband GW observations. I will present the main results of this work and the merger rates expected for current and next-generation GW observatories, including ET and LGWA. I will show that tracking the full hierarchical structure of secondary mergers is essential to interpret the high-mass tail of the BH population, and that these hierarchical IMBH binaries offer a concrete multiband target linking ET and LGWA science.

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