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Population Properties of Binary Black Holes from Star Clusters and Active Galactic Nuclei

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Disentangling the astrophysical origins of gravitational waves requires confronting population properties of observed source catalogs with theoretical predictions. We investigate the formation of merging binary black holes in two distinct environments: stellar clusters and active galactic nuclei (AGNs). In clusters, repeated three-body interactions determine the dynamical assembly of binaries. Using binary population synthesis combined with post-Newtonian N-body simulations, we quantify the occurrence of highly eccentric mergers in the LVK and Einstein Telescope bands, identifying them as potential diagnostics of the cluster channel. In AGNs, we model the migration of stellar-mass black holes embedded in gaseous disks. We map the regions of parameter space where single–single encounters can occur, leading to binary formation, versus regimes where black hole pairs are trapped in mean-motion resonances, suppressing binary assembly.

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