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A fast code for the evolution of tidally limited star clusters and their binary black hole mergers

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Star clusters play a key role in shaping the population of compact-object binaries observed through gravitational waves, but modeling their long-term evolution across a wide range of initial conditions remains computationally challenging. Fast and physically motivated models are therefore essential.

I will present an updated version of the clusterBHBdynamics code, a rapid framework for evolving star clusters containing stars and stellar-mass black holes. The new version improves the treatment of tidal mass loss, incorporates the effects of metallicity and stellar mass function variations, and introduces a revised gravitational-wave module. In particular, it includes prescriptions for gravitational-wave captures during dynamical interactions and for inspirals triggered by eccentricity growth between encounters.

The model is calibrated against a large set of Cluster Monte Carlo and direct N-body simulations spanning a broad range of cluster masses, sizes, metallicities, and Galactic environments. With the calibrated parameters, the code reproduces the global evolution of clusters and their black hole populations to within ~15%, and predicts binary black hole merger rates consistent with numerical simulations at the ~20% level. Owing to its sub-second runtime per cluster, clusterBHBdynamics enables efficient exploration of star cluster populations and their contribution to gravitational-wave sources.

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