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Runaway and Hyper-runaway Stars from Merging Star Clusters with Massive Black Holes

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We investigate the impact of massive black holes (MBHs) in merging star clusters of $M_\star = 5.3 \cdot 10^4 M_\odot$ on the escaping population of high-velocity stars and compact objects (COs) incorporating relativistic effects (up to 3.5PN order) , utilizing the GPU-accelerated N-Body code BIFROST. If the merging clusters host central MBHs of $M_\bullet = 10^3 M_\odot$, a fraction of 6.5% of the stars, 42% of the stellar black holes and 7% of the white dwarfs escape the merger remnant after 100Myr, with velocities up to 650 $\mathrm{km\ s^{-1}}$. The ejection is driven by the formation and hardening of a MBH binary (MBHB) . Specifically the production of runaway stars (RSs) with $40 \leq \mathrm{v_{ej}} \leq 200\ \mathrm{km\ s^{-1}}$ and hyper-runaway stars (HRSs) with $\mathrm{v_{ej}} > 400\ \mathrm{km\ s^{-1}}$ is initiated when the binary semi-major axis falls below the binary hard separation threshold after 3.2 Myr. With only one MBH the total number of RSs is reduced significantly and becomes even lower for HRSs, while in the absence of MBHs the number of RSs is very low and for the HRSs negligible. The MBHB also contributes to a wide spread of the ejection velocities distribution, in contrast to single or absence of MBHs in the remnant. We also investigate the impact of MBHs on the stellar densities, kinematics and structure of the remnants. Our simulations introduce an additional mechanism contributing to the generation of runaway, hyper-runaway and potentially hyper-velocity (HVS) stars and compact objects within galaxies, providing an alternative explanation for their origin. Finally, by varying the MBHB mass ratio, we study the hardening rate and coalescence timescale and its effect on the escaping population and discuss the implications for current (LVK) and future (LISA) observations of gravitational wave (GW) signals from such systems.

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