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The Effects of Early Massive Star Formation: Gas Expulsion & Cluster Dynamics

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The first few million years of star cluster formation remain poorly understood in part due to the complex interactions between gas, gravity, magnetic fields, stars, and radiation. Massive stars play a significant role in the cloud-to-cluster star formation process through feedback in the form of winds, radiation, and supernovae, which together cause the final ejection of gas from stellar clusters. Massive stars are also important to the stellar dynamics within young star clusters as members of binary star systems and drivers of mass segregation and cluster expansion via ejection of stars from the cluster core. We hypothesize that the timing of massive star formation within a single giant molecular cloud significantly alters the resulting star cluster. To test this, we use TORCH: a coupled magnetohydrodynamical mesh and direct N-body star cluster formation code that incorporates FLASH into the AMUSE framework. With TORCH, we study the role of massive stars for ~7 Myr after formation — from birth to supernova and the expulsion of natal gas. First, we use the Wall et al. (2019) star formation routine to reproduce the Kroupa mass distribution and run with massive stellar winds, radiation, and supernovae turned on; we then repeat with winds turned off. Then, from identical initial conditions, we alter our star formation routine such that a 50, 70, or 100 solar mass star forms at around the first cloud free-fall time with massive star feedback turned on; then repeat these models with winds turned off. We show that early-forming massive stars are effective at removing gas and quenching star formation even before they go supernova. We also show that the formation of very massive stars during the first free-fall time of the gravitational collapse of a giant molecular cloud results in the formation of loose associations of stars while single clusters form from combining sub-clusters more readily in the absence of early massive star formation. Finally, we discuss the effects of wind feedback in our models.