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Modeling Evolution from Gas to Young Massive Star Clusters

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Despite their pervasive influence, many aspects of star cluster formation are poorly understood because they are difficult to model. Simulation of their formation requires modeling a multitude of physical processes, from magnetohydrodynamics (MHD) to stellar feedback and gravitational dynamics, on scales from binary orbits to the widths of molecular clouds. To address these issues, we use Torch: a code employing the Astrophysical Multipurpose Software Environment (AMUSE) framework to couple stellar evolution and N-body codes with the MHD code FLASH. We include star formation based on sampling of the initial mass function after sink particle accretion, ray-tracing for ionizing and non-ionizing radiation, and mechanical feedback in the form of winds and supernovae. Torch originally required excessive computational resources to model giant molecular clouds (GMCs) with masses exceeding 10^5 $M_\odot$, as it could not evolve the hundreds of thousands of stars that form in more massive clouds. This left a considerable gap, as the most massive GMCs in our galaxy exceed 10^6 $M_\odot$. To enable Torch to model more massive GMCs, we integrate the N-body code PeTar to more efficiently handle the stellar dynamics. We present results from new Torch simulations of star clusters forming from clouds of mass 10^4, 10^5, and 10^6 $M_\odot$. The most massive GMC forms over 100,000 stars within the first million years, making it one of the largest star cluster formation models resolving individual stars ever computed. We compare the global properties of each forming cluster over time and consider which remain constant as cloud mass is increased. We present the star formation histories and the time evolution of the gas properties, cluster mass, half-mass radius, and stellar velocity dispersion for each cloud.