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A Massive Star Photoionization Feedback Model Considering Density Inhomogeneity: Applicability to Star Cluster Formation Simulations and Larger Scale System Simulations

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Feedback mechanisms in massive stars are thought to have important implications for the evolutionary process of star clusters. Among them, photoionization feedback is the process by which ionized photons emitted by massive stars influence subsequent star formation in the surrounding environment.
In star cluster formation simulations, ionized regions can be correctly treated using a direct radiation hydrodynamics approach, but this requires very large computational resources. We aim to adopt a more simplified model for use in large-scale, high-resolution simulations to reduce computational costs.
In star cluster formation simulations by Fujii et al. (2021b) for galaxy simulations, an approximate strögren spherical model was used to evaluate the ionized region. However, due to the inhomogeneity of the density distribution in the actual star formation field, this mere approximation is usually considered inaccurate.
In this study, we introduce a model that independently evaluates the extent of the ionization structure in each direction of the icosahedron, incorporating the spatial inhomogeneity of the star-forming region in a simplified manner. This model is implemented and evaluated in the N-body/smoothed particle hydrodynamics code ASURA+BRIDGE (Saitoh et al. 2008, 2009; Fujii et al. 2021b). We conducted a series of comparative simulations using molecular clouds with an internal turbulence velocity field as initial conditions. Simulations using a spherical model based on the Strömgren sphere were also synchronized for comparison.
The simulations reproduced anisotropic ionized structures with corresponding anisotropic outflows during the evolution of star formation. In contrast, the spherical model exhibited only a purely spherical structure for the ionized region. Statistical results from multiple sets of simulations indicate that the purely spherical model exhibits a stronger suppression of star formation than the icosahedral model, which we attribute to its unidirectional energy accretion accelerating the termination of star formation.

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