Super Star Clusters

Super star clusters (SSCs) are the most extreme star-forming sites in the Universe: massive stars at the cluster nuclei form from gas surface densities of $10^3 - 10^4 \ M_\odot \ pc^{-2}$, with star formation rates above $10 - 100 \ M_\odot$ yr$^{-1}$. The intense radiation field from the dense population of young, massive stars is expected to be dynamically important in altering the star-forming gas. The resultant massive star densities are so high that stellar merging may be common, providing a potential pathway for massive black hole formation.

Large distances to these extreme objects and dust obscuration have been limiting our observational access; theoretical models must realize the multidimensional complexity of dust, radiation-dominated gas on scales < 0.1 pc inside the nucleus actively forming massive stars.

Simulating their Births

We simulate the formation of super star clusters from a $10^8 \ M_\odot$ giant molecular cloud, focusing on the feedback by stellar radiation pressure. Physics included are:

- Initial density/velocity distributions set by driven turbulence;
- Gas self-gravity and star-gas gravity;
- Star particles created as formed clusters and radiation sources;
- Frequency-dependent transfer of non-ionizing UV and dust-reprocessed IR radiation;
- Full coupling of radiation pressure with gas dynamics.

What is the Role of Radiation?

Studies have shown that radiation pressure could dominate the disruption of parent molecular clouds in forming massive clusters (Krumholz & Matzner 2009, Murray et al. 2010, Kim et al. 2016). However, these predictions were based on one-dimensional models.

- Does stellar radiation pressure from young stars inhibit or terminate star formation in actual SSC?
- How long does star formation last in SSC?
- Does stellar radiation drive intense outflows?

Radiation Transport Matters

We implemented a closure-free, Monte Carlo radiation transfer scheme coupled with the hydrodynamic code FLASH. We confirmed that the accuracy of the radiation transport method could have a huge impact on the global behaviors of gas dynamics when radiation pressure is dominant and steep transitions in optical thickness is present.

- Initially static layer of dusty gas subject to a constant upward radiation flux and a constant downward gravity;
- Same exact setup has been tested with three other radiation transport methods, listed in increasing accuracy: flux-limited diffusion (FLD), M1 closure, and the variable Eddington tensor approximation (VET).

Results

The stellar radiation field can be super-Eddington locally around the massive clusters. It does not seem to effectively limit the infall of gas or terminate star formation due to the turbulent nature of the clouds and the strong infall of gas towards the growing clusters.

References:
