Star cluster formation and feedback in different environments of a Milky Way-like galaxy

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Abstract
We extract 10⁶ M☉ cloud complexes from different regions of a Milky Way-like galaxy evolution model, zoom-in to higher resolution, then re-simulate. We keep the original galactic potentials, and add photoionization and SNe from cluster-sink particles. We model clouds in the bar, inner spiral arm, outer arm, and inter-arm region. Our results indicate that Young Massive Clusters (M >10⁴ M☉, R ~pc), which are potentially progenitors of globular clusters, may preferentially form near the bar/inner arm compared to outer arm/inter-arm regions.

1. Introduction
The thermodynamics of star-forming giant molecular clouds (GMCs) is primarily set by O stars via stellar feedback. The resulting heating, dispersal, and compression may affect the formation and properties of new stars/clusters.

Since GMCs/clusters interact with other GMCs/clusters, it is necessary to improve upon initial conditions of isolated spherical clouds.

2. Method: galaxy zoom-ins
- smoothed-particle hydrodynamics (sphNG; Bate et al.)
- extract regions from a MW-like galaxy model (Pettitt et al. 2020)
  - regions of 10⁶ M☉ / 100–300 pc
  - GMCs form self-consistently
  - but feedback is simple (SNe + low-mass stellar winds)
- enhance resolution from 600 to 0.43 M☉/particle (particle splitting)
- GMCs inherit motions (e.g. from galaxy potential, shear, tidal forces)

Then evolve with:
- cluster-sink particles (1 sink represents many stars)
- photoionization (ray-tracing)
- H₂/CO chemistry + ISM heating/cooling
- galactic potentials (e.g. bar, spiral arms, disc, bulge, halo)

3. Star formation rate

Left: Star formation rate surface density vs neutral gas surface density. Points are calculated every 0.047 Myr. Green points are from a spiral arm region from Ali et al. (2022). Dashed line shows power law fit with index 1.3 (consistent with Kennicutt law). Dotted lines show depletion timescale.

4. Clustering

Below: Results using INDICATE (Buckner et al. 2019) after ~4 Myr. Points are sink particles. The L₄ index (colour scale) shows the degree of clustering. Grey points are noise (not clustered).

Sinks in the bar are the most clustered, followed by the inner arm, outer arm, and inter-arm.

5. Cluster masses/radii

Clusters identified with HDBSCAN (Campello et al. 2013) after ~4 Myr.

Below: Almost all the clusters in the bar and inner arm are smaller than 5 pc. Half the clusters in the outer arm and a third in the inter-arm are larger than 5 pc, with radii more similar to associations.

Above: The most massive cluster is formed in the bar, the second most massive in the inner arm, followed by the inter-arm region, then the outer arm. Background colour scale and line show observed data from Brown & Gnedin (2021).

6. Cluster rotation

Right: Median angular velocity of each cluster identified with HDBSCAN.

The bar and inner arm regions are able to form faster rotating clusters, while the outer arm and inter-arm regions tend to produce slower rotators on average. The median of medians are (in Myr⁻¹):

0.57 (bar), 0.54 (inner arm), 0.18 (outer arm), and 0.22 (inter-arm).

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