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

Ahmad Ali[1]

C. L. Dobbs[1], T. J. R. Bending[1], A. S. M. Buckner[1] and A. R. Pettitt[2]

[1]University of Exeter, UK; [2]California State University, Sacramento, USA

Abstract

We extract 10^6 $M_\odot$ 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 >10^4 $M_\odot$, R ~pc), which are potentially progenitors of globular clusters, may preferentially form near the bar/inner arm compared to outer arm/inter-arm regions.

Contact

A.Ali2@exeter.ac.uk
a-a-ali.github.io
@plingaling

Related papers

- Bending, Dobbs, Bate, 2020, MNRAS, 1691, 1672
- Ali, Bending, Dobbs, 2022, MNRAS, 510, 5592

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.

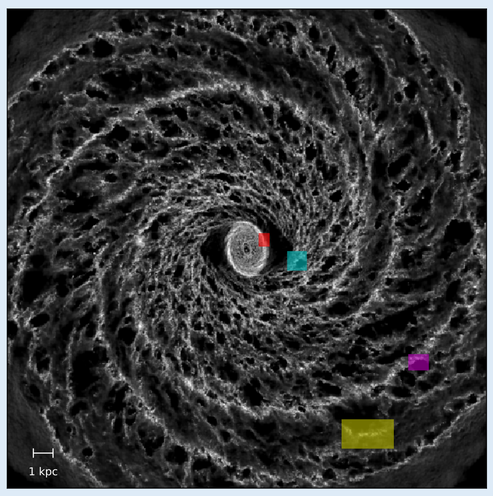
Since GMCs/clusters interact with other GMCs/clusters, it is necessary to improve upon initial conditions of isolated spherical clouds.

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 **10^6 $M_\odot$ / 100-300 pc**
  - GMCs form self-consistently
  - but feedback is simple (SNe + low-mass stellar winds)
- **enhance resolution** from 600 to 0.43 $M_\odot$/particle (particle splitting)
- GMCs inherit motions (e.g. from galaxy potential, shear, tidal forces)

Then evolve with:

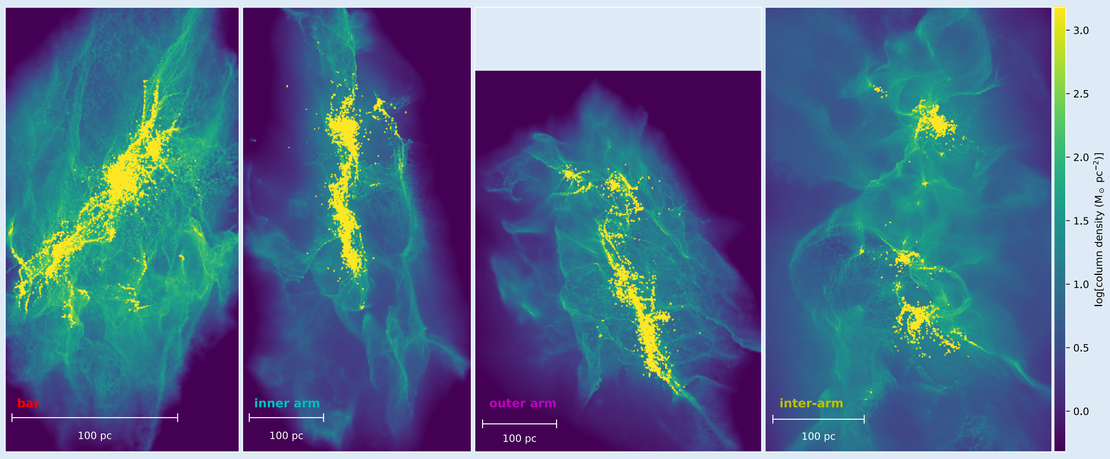
- cluster-sink particles (1 sink represents many stars)
- **photoionization (ray-tracing)**
- H_2/CO chemistry + ISM heating/cooling
- **galactic potentials (e.g. bar, spiral arms, disc, bulge, halo)**



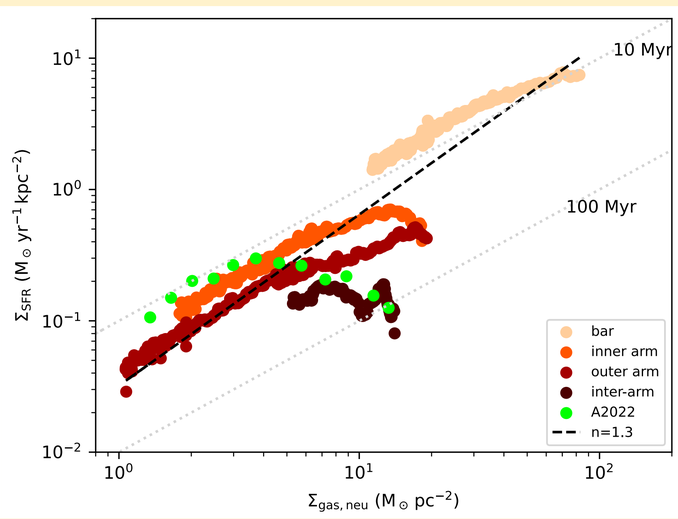
Top: *Original galaxy simulation (Pettitt et al. 2020) with bar and 4-arm potentials.*

Bottom: *Zoom-ins after 2-4 Myr of evolution with photoionization.*

Both are top-down projections. Colour scale shows column density. Yellow points show sink particles.



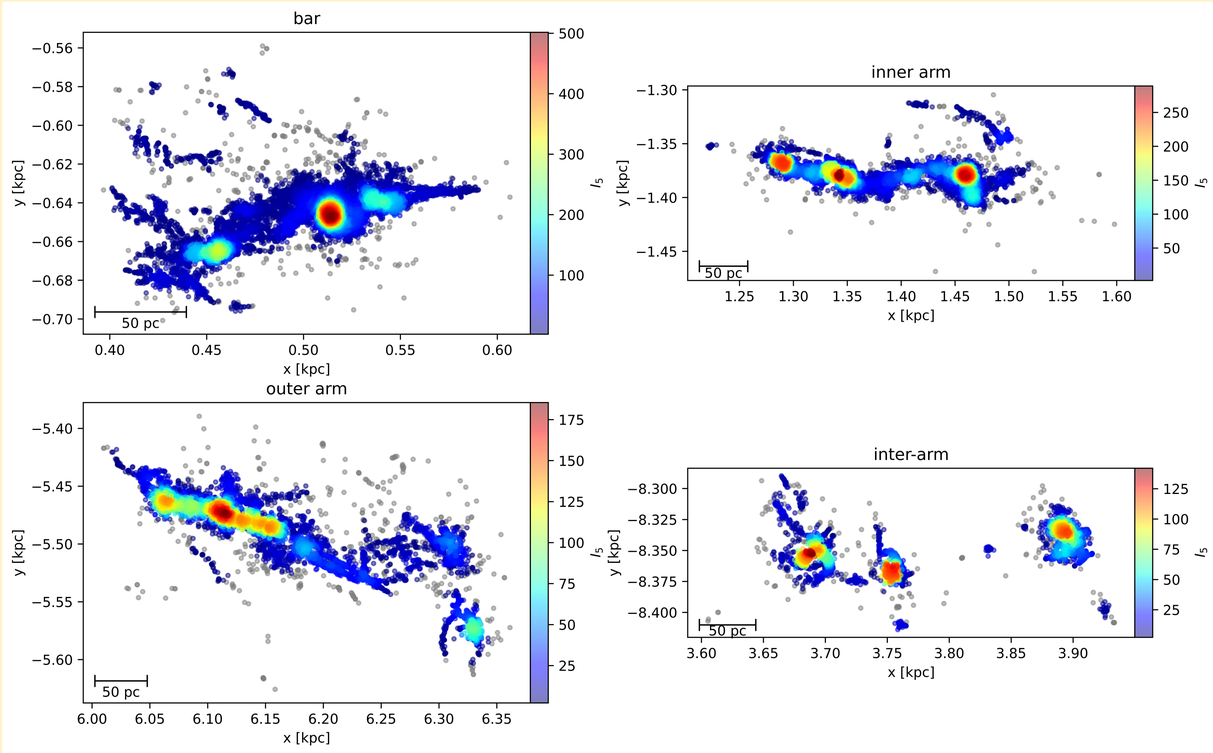
3. Star formation rate



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

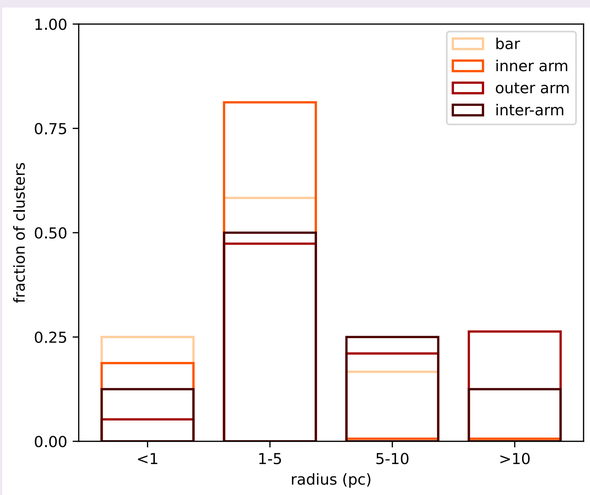
Below: Results using INDICATE (Buckner et al. 2019) after ~4 Myr. Points are sink particles. The I_5 index (colour scale) shows the **degree of clustering**. Grey points are noise (not clustered). Sinks in the bar are the most clustered, followed by the inner arm, outer arm, and inter-arm.

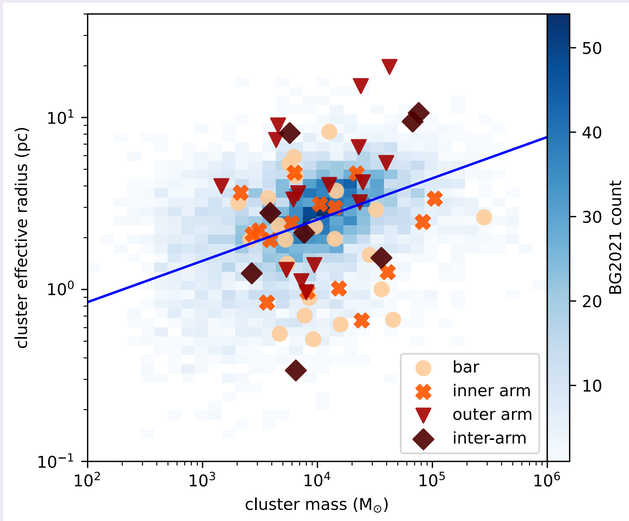


5. Cluster masses/radii

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.





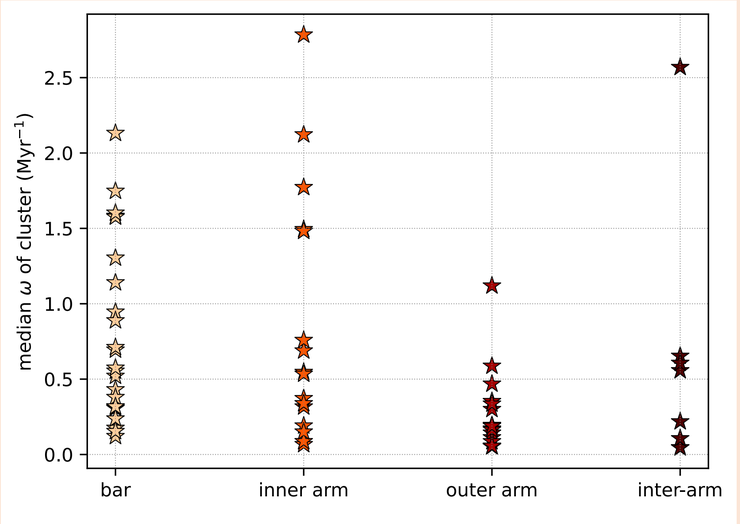
Above: The most massive cluster is formed in the bar, the second most massive in the inner arm, followed by the inter-arm region, then the outer arm. Background colour scale and line show observed data from Brown & Gnedin (2021).

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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