Evolutionary Description of Giant Molecular Cloud Mass Functions across Galactic Disks

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1. Introduction

Observational / Simulation Facts

1) The slope of the observed giant molecular cloud (GMC) mass functions varies between regions in nearby galaxies. (e.g., Colombo+ 2014)

2) Multiphase magneto hydrodynamics simulations indicate that magnetic fields significantly prevent the molecular cloud formation, thus multiple episodes of supersonic compression of HI gas is essential for GMC formation. (e.g., Inoue & Inutsuka, 2008)

Key questions

- What determines/controls the variation in the GMC mass function slope?
- Cloud-Cloud Collisions (CCC) may alter ISM conditions as well? (e.g., Fukui+ 2014) (e.g., modifying GMC mass function?)

Inutsuka et al., 2015 proposed a scenario of global GMC/subsequent star formation on galactic scales driven by the network of expanding bubbles (expanding HII regions and supernova remnants). This scenario inherently includes multiple episodic compression (i.e. (2)) and CCC (i.e., (3)).

Our goal: Based on the scenario from Inutsuka et al., 2015, develop the evolutionary picture of GMC mass function by formulating the coagulation equation in GMC mass space.

2. Formulation: Coagulation Equation and the Fate of Dispersed Gas

GMC self-dispersion due to radiation by massive stars

\[
\frac{\partial n_{cl}}{\partial t} + \frac{\partial}{\partial m} \left( \frac{dm}{dt} \right) = - \frac{n_{cl}}{T_f} \\
+ \frac{1}{2} \int_0^{\infty} \int_0^{\infty} K(m_1, m_2) n_{cl,1} n_{cl,2} \times \delta(m - m_1 - m_2) dm_1 dm_2
\]

The fate of dispersed gas: “Resurrecting Factor”

When the gas becomes dispersed, they contribute to either the mass growth of pre-existing GMCs or regeneration of the minimum mass GMCs.

CCC modifies only the massive end.

If CCCs are ineffective, then a steady state solution without CCC terms can be obtained:

\[
\frac{\partial n_{cl}}{\partial t} + \frac{\partial}{\partial m} \left( \frac{dm}{dt} \right) = \frac{n_{cl}}{T_f} \Leftrightarrow n_{cl}(m) = \frac{N_0}{M_0} \left( \frac{m}{M_0} \right)^{-1} T_f
\]

Observed slopes may put unique constraints on \(T_f/T_d\).

Our survey (e.g., ALMA) may reveal the variation of GMC formation/dispersal timescales between different regions on galactic disks.

3. Results

With CCC terms

Arm regions (\(T_d \sim 4.2\) Myr)
Small resurrection (1\%)

Inter-arm regions (\(T_d \sim 22.4\) Myr)
Large resurrection (45\%)

Without CCC terms

Arm regions (\(T_d \sim 4.2\) Myr)
Large resurrection (45\%)

4. Summary

- Based on the GMC/subsequent star formation scenario from Inutsuka et al., 2015, we formulate the coagulation equation for the GMC mass function and compute its time evolution.
- Although CCC could be important for the formation of massive stars and star clusters, CCC may be effective only in the massive end.
- Almost 100\% of the dispersed gas accrete onto the pre-existing GMCs in arm regions whereas ~ 55\% in inter-arm regions.
- Large surveys may put unique constraints on GMC formation/dispersal timescales and resurrecting factor in different environment on galactic disks by slope of GMC mass function.