

分子雲衝突による 巨大分子雲質量関数の進化

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with various timescales

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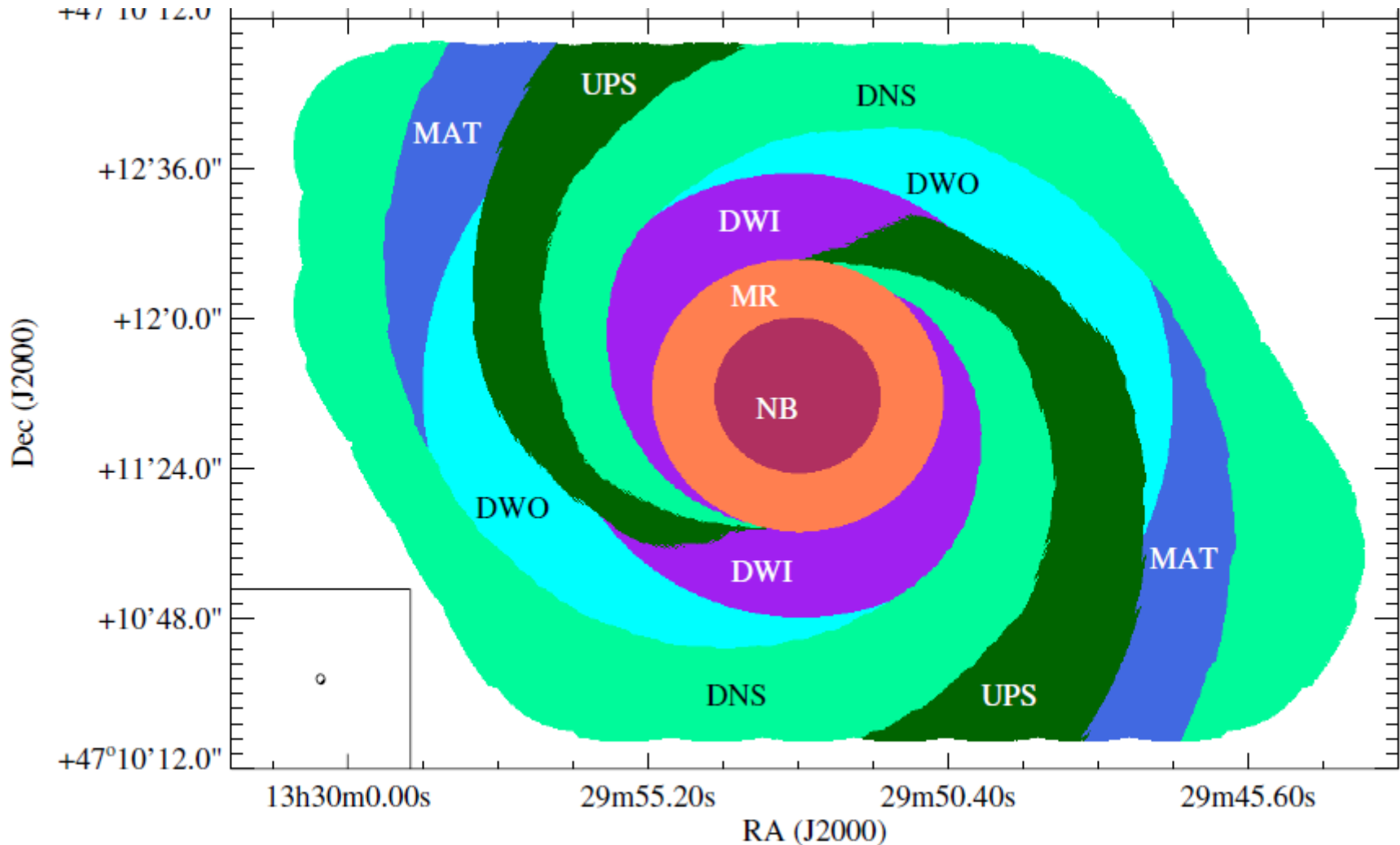
Backgrounds

- ✓ **Observed GMC MF**
- ✓ **Multiphase Simulations**
- ✓ **Multiple Episodes of Compression**

Observed Mass Functions

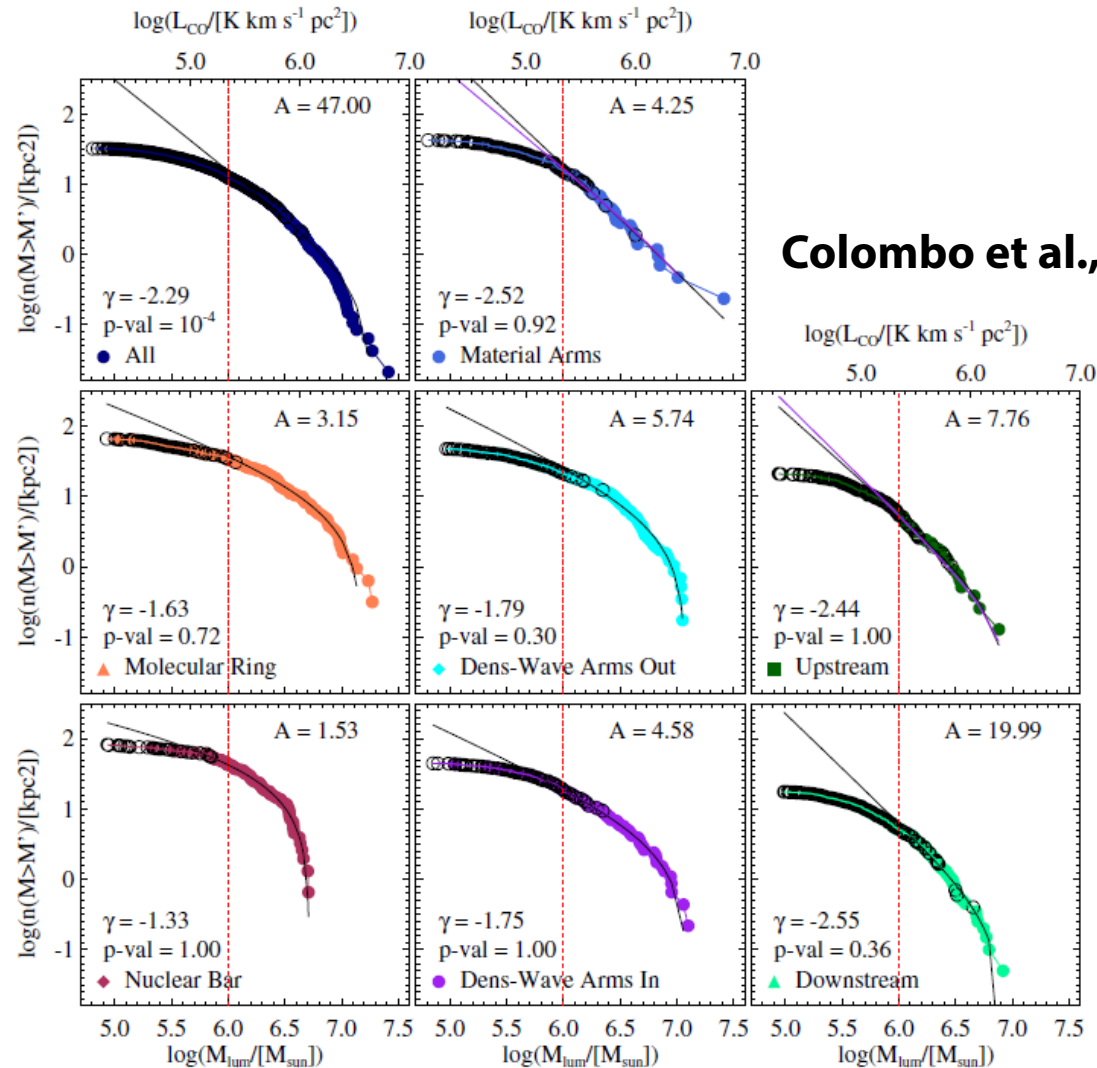
PAWS program observed M51

Colombo et al., 2014, MNRAS



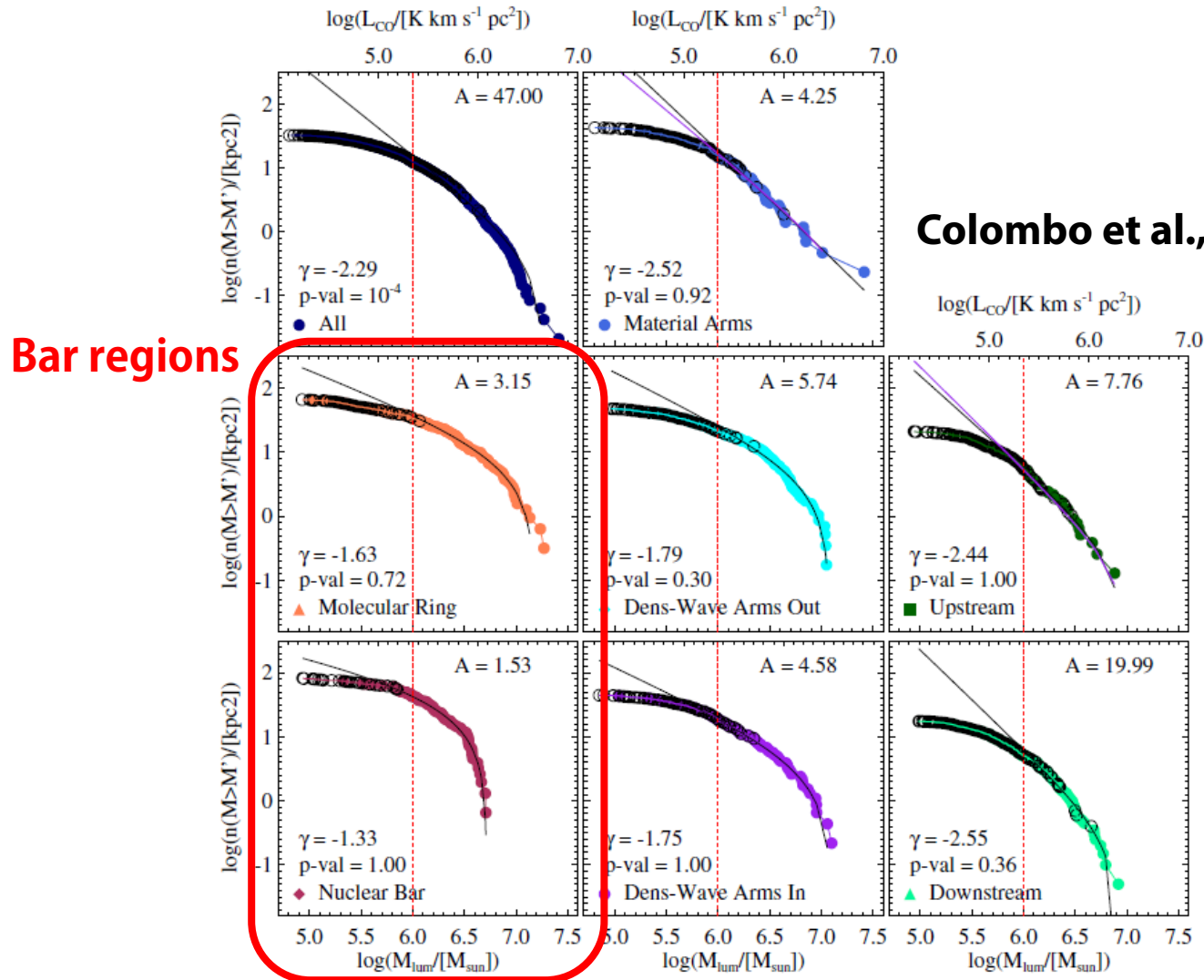
Observed Mass Functions

Variation of GMC Mass Functions (GMCMF)



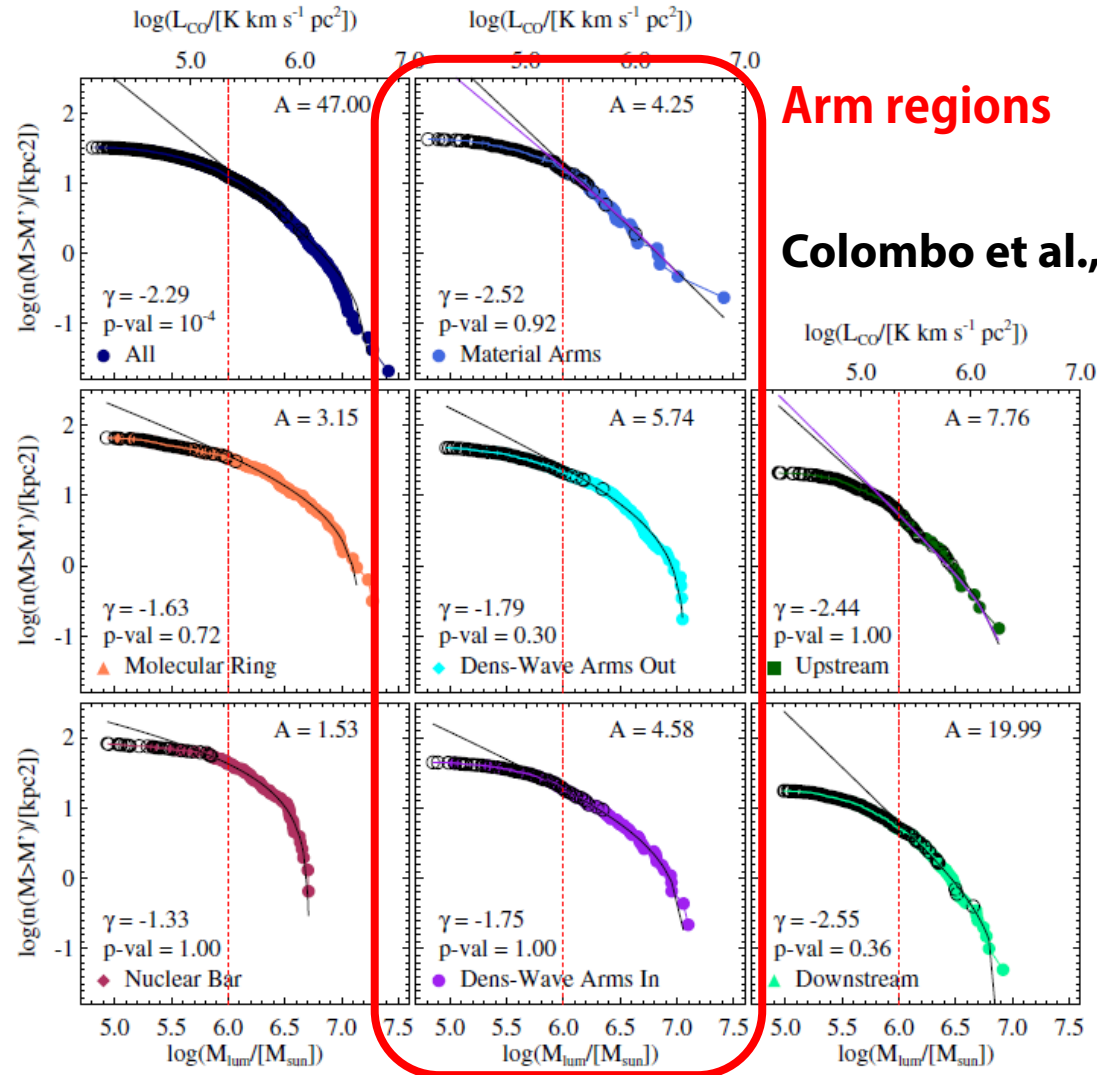
Observed Mass Functions

Variation of GMC Mass Functions (GMCMF)



Observed Mass Functions

Variation of GMC Mass Functions (GMCMF)

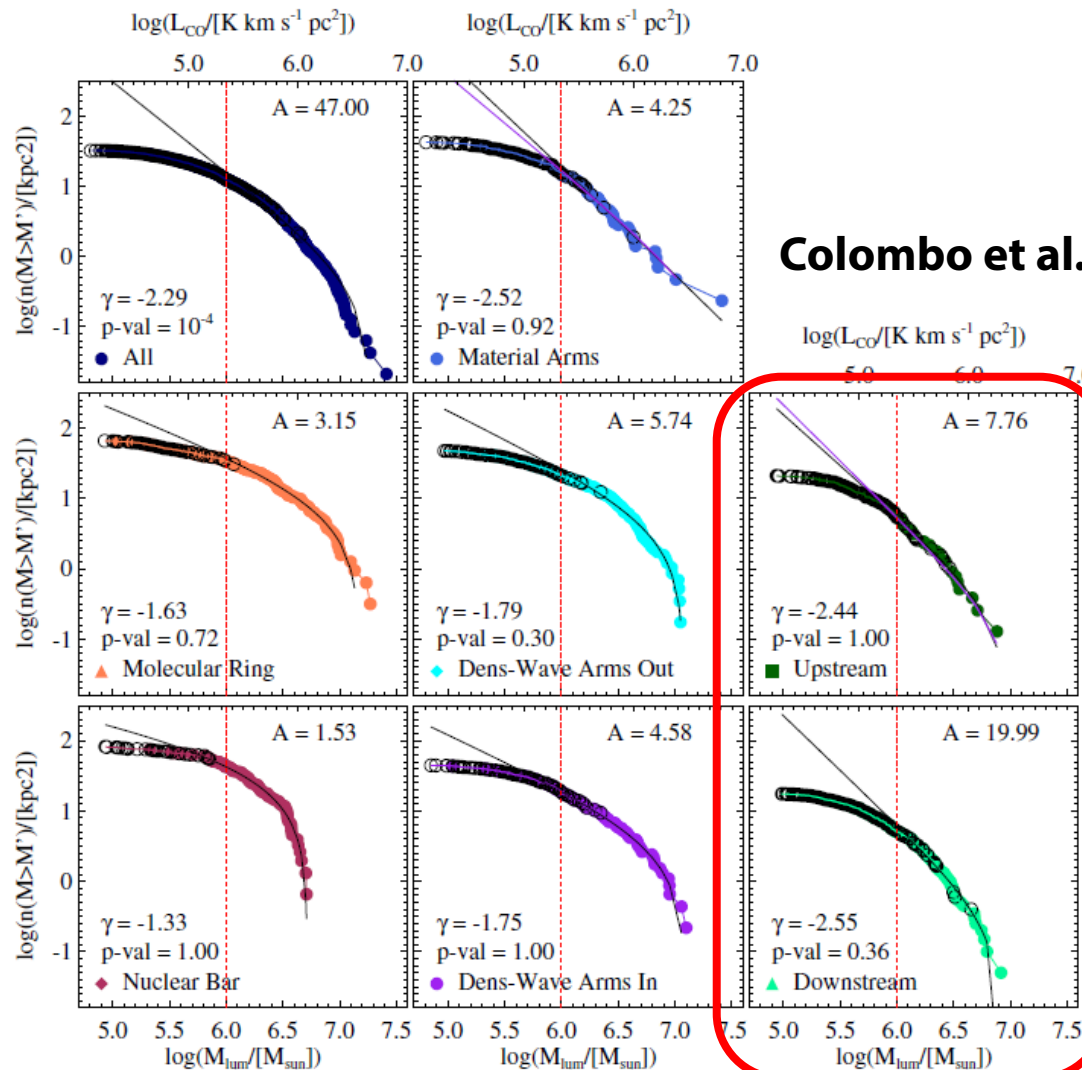


Arm regions

Colombo et al., 2014, MNRAS

Observed Mass Functions

Variation of GMC Mass Functions (GMCMF)

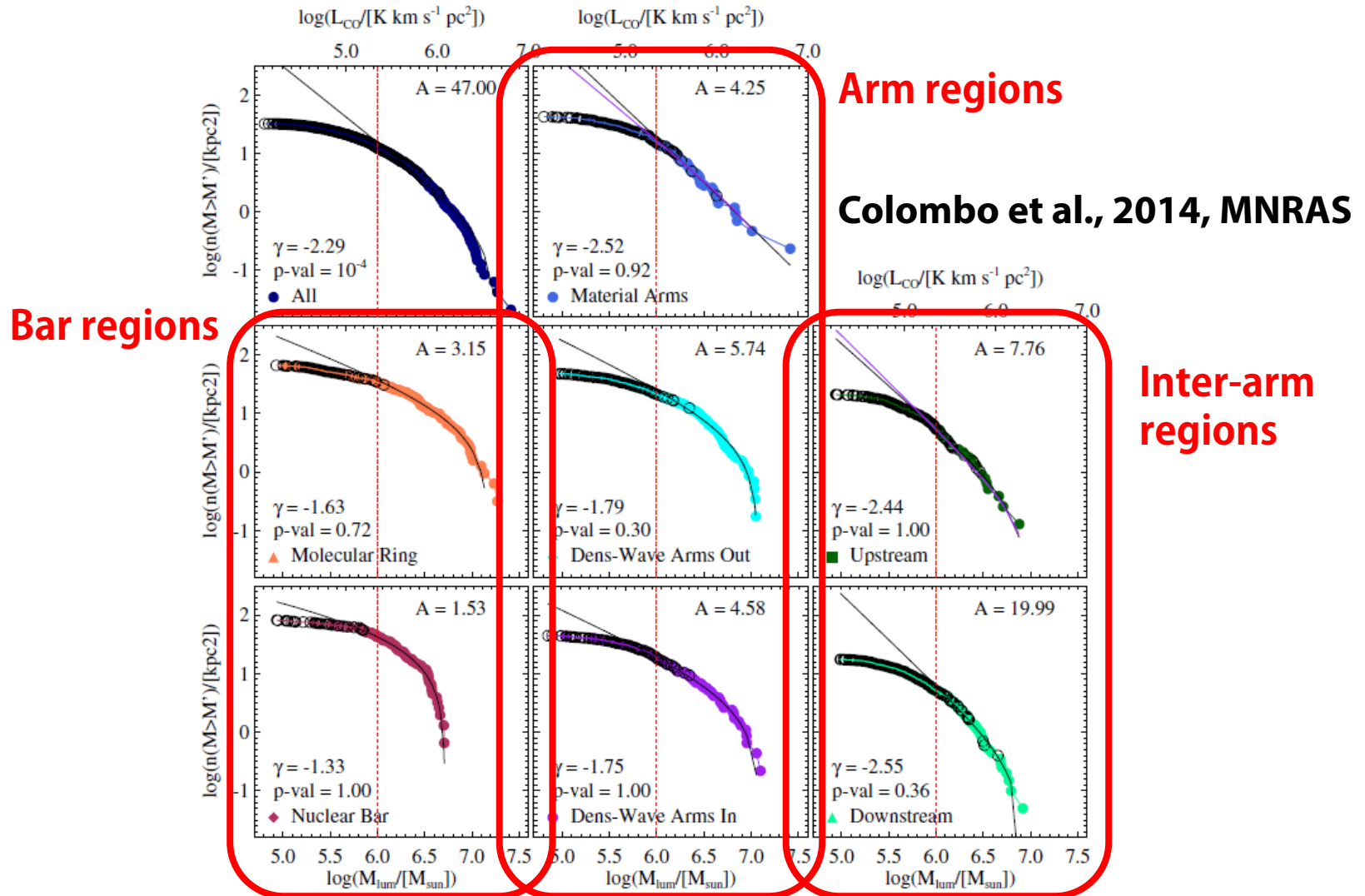


Colombo et al., 2014, MNRAS

Inter-arm regions

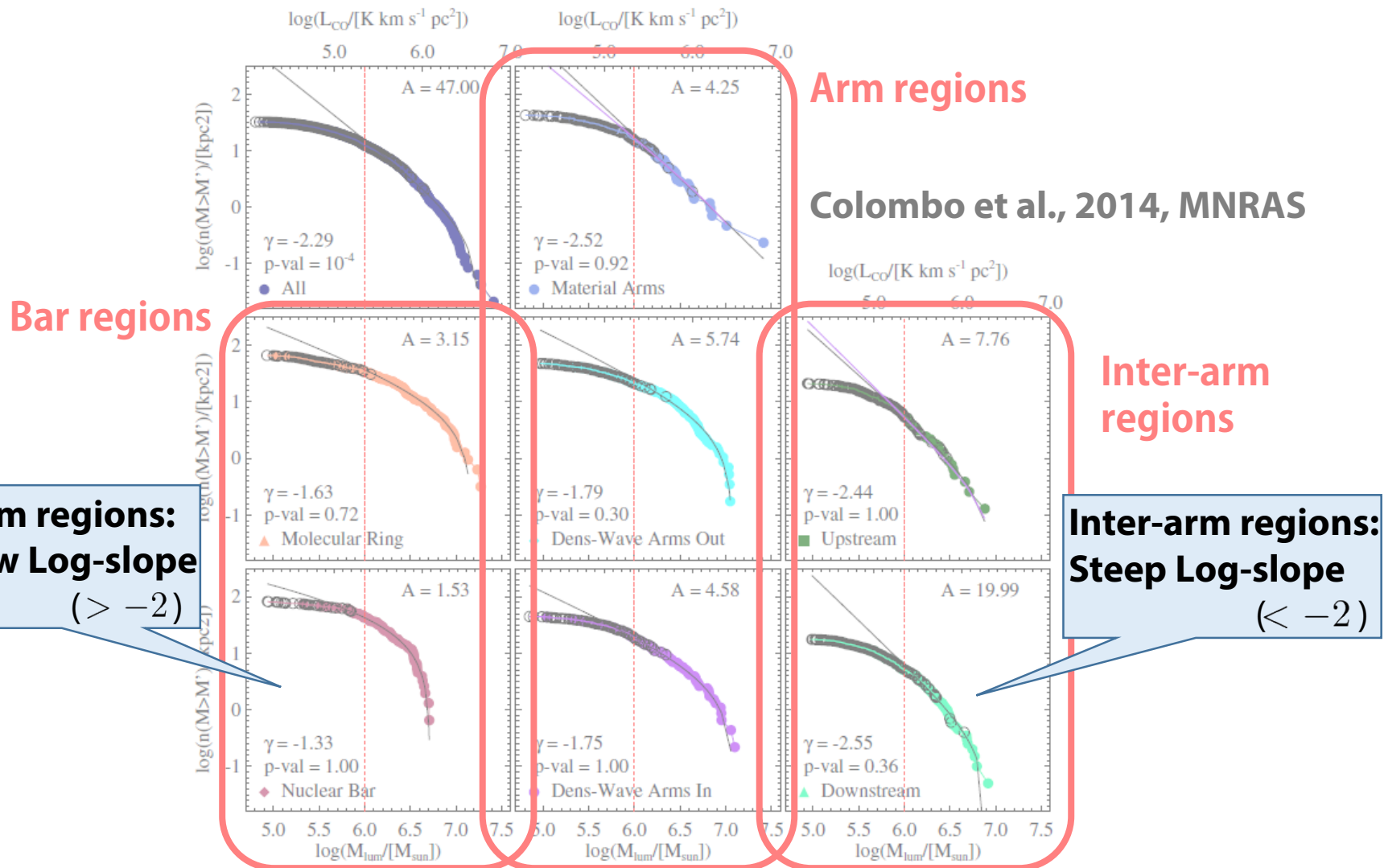
Observed Mass Functions

Variation of GMC Mass Functions (GMCMF)



Observed Mass Functions

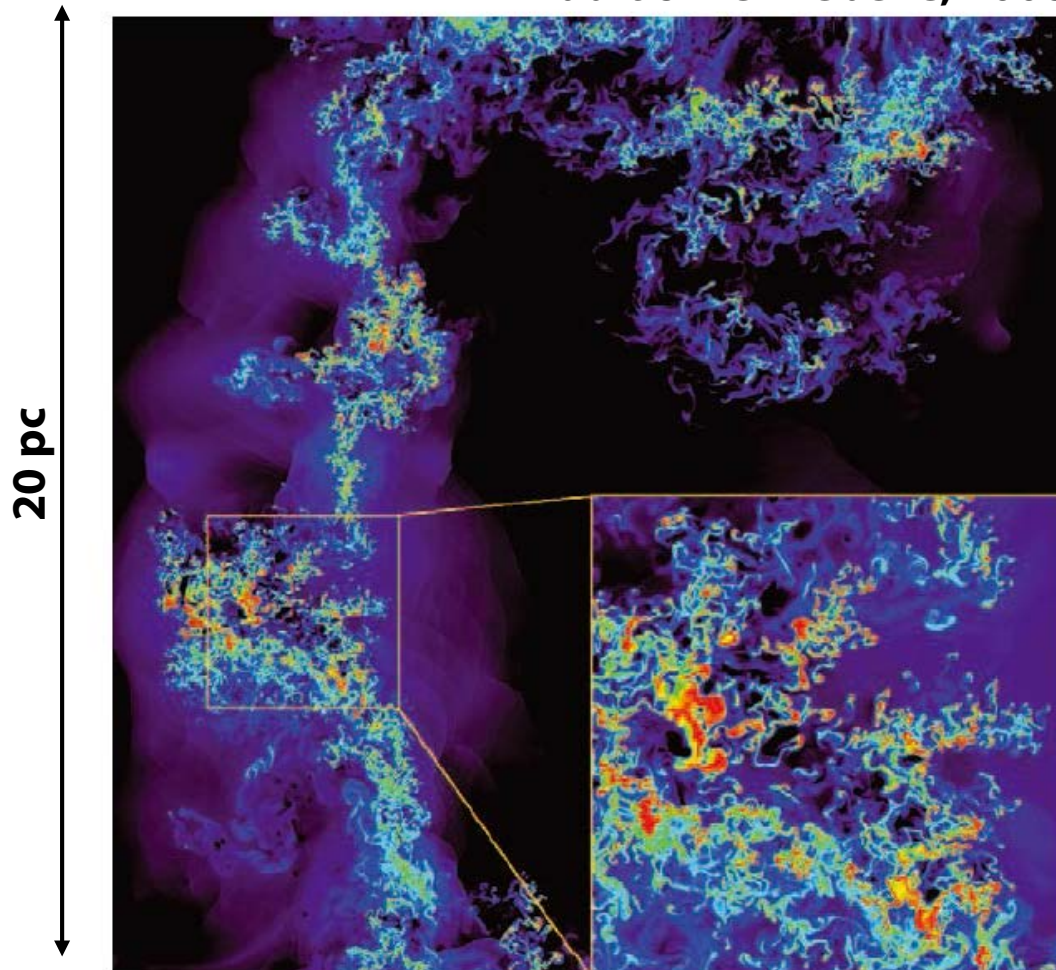
Variation of GMC Mass Functions (GMCMF)



ISM simulations

Multiphase Turbulent Structure

Audit & Hennebelle, 2008



See also;

Koyama & Inutsuka, 2002

Heitsch et al., 2006

Hennebelle & Audit, 2007
etc.

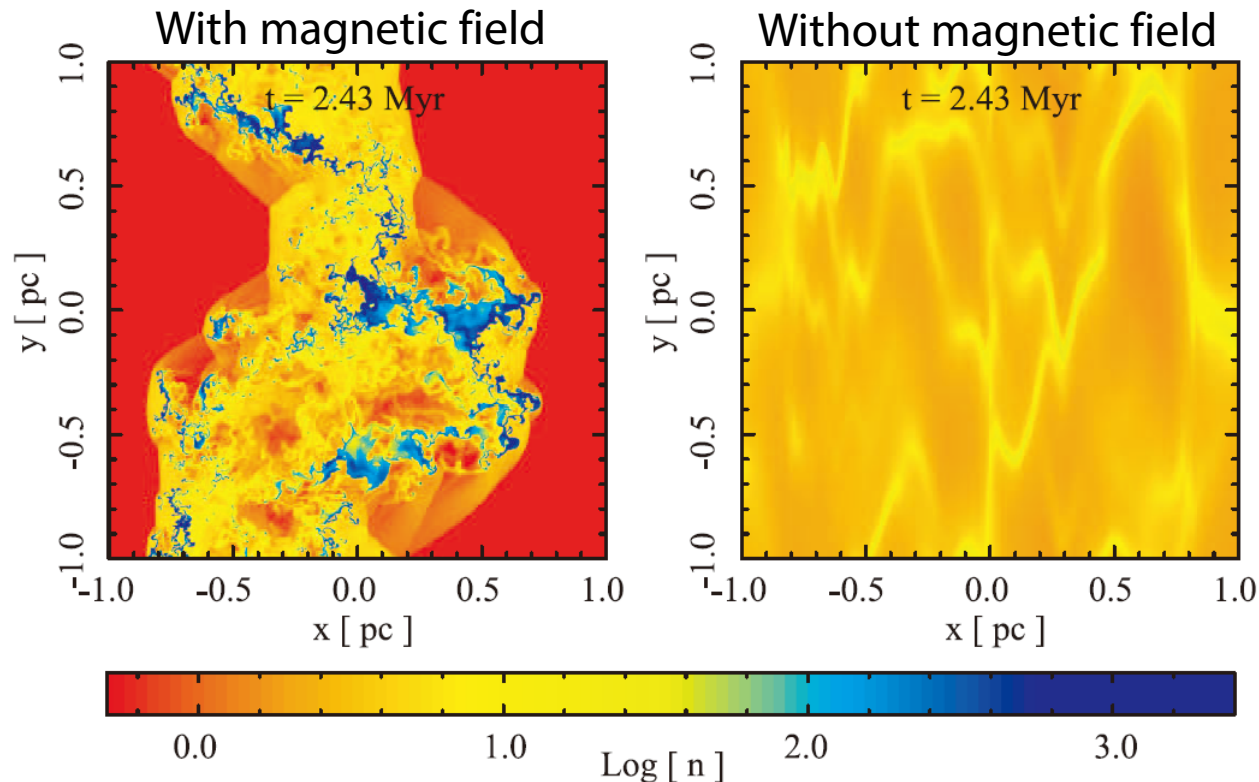


**What about
magnetic fields?**

ISM simulations

Magnetic Fields Prevent Cloud Formation

Inoue and Inutsuka, 2008



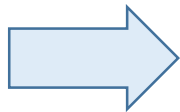
➔ **Molecular cloud formation is significantly prevented unless the shock wave propagates along the magnetic field...**

Similar results also obtained in other works, (e.g., Heitsch 2009)

ISM simulations

Multiple Episodes of Compression

To form molecular clouds from magnetized warm medium, **multiple episodes of compression** is essential.



A few 10 Myrs

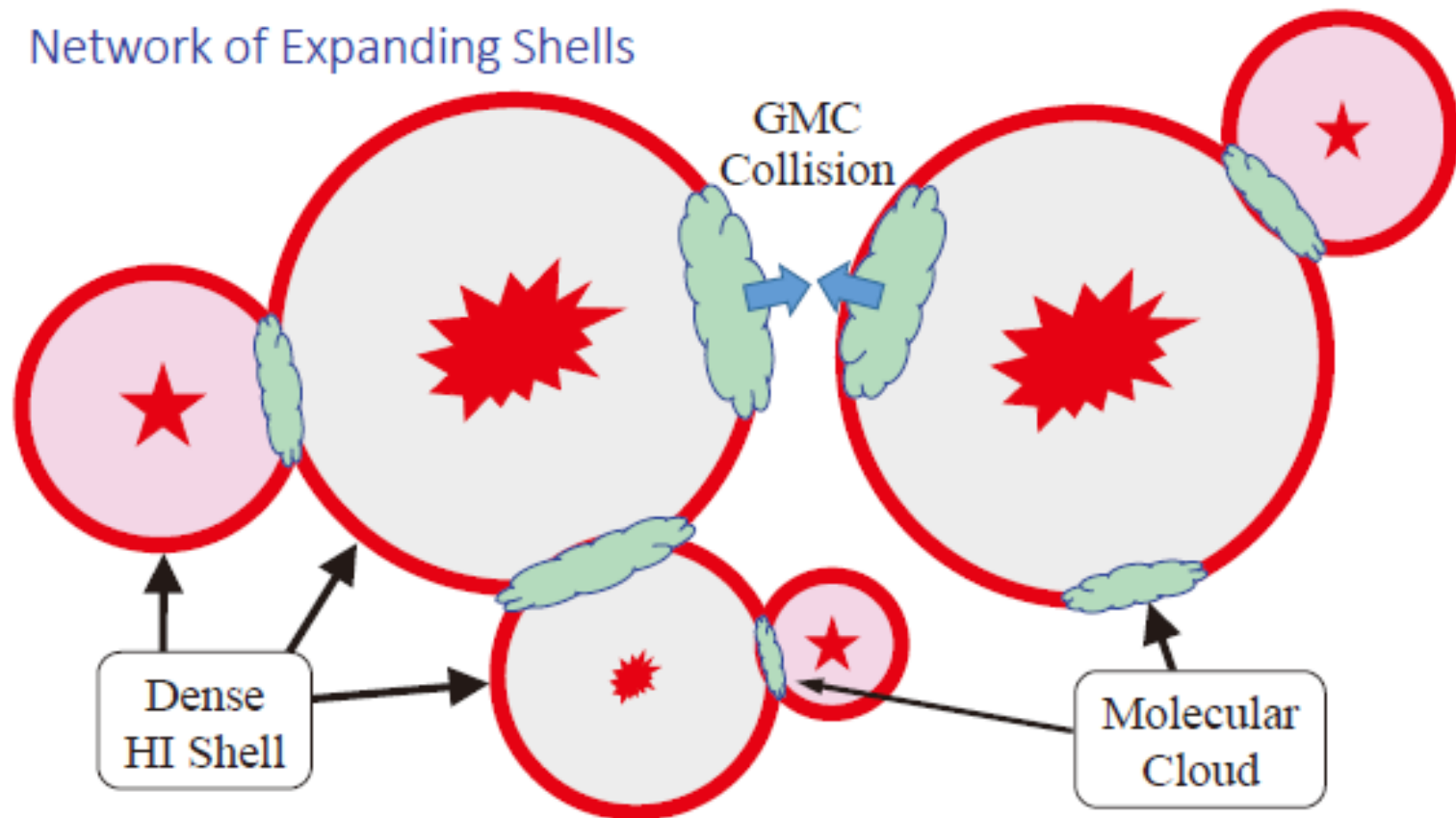
e.g., Inoue and Inutsuka, 2012

GMC Formation

- ✓ **Network of Expanding Shells**
- ✓ **Mass Continuity Equation with CCC**

GMC Formation due to Shells

Inutsuka+ 2015 A&A



GMC Formation due to Shells

Inutsuka+ 2015 A&A

Cloud-Cloud Collisions (CCCs)



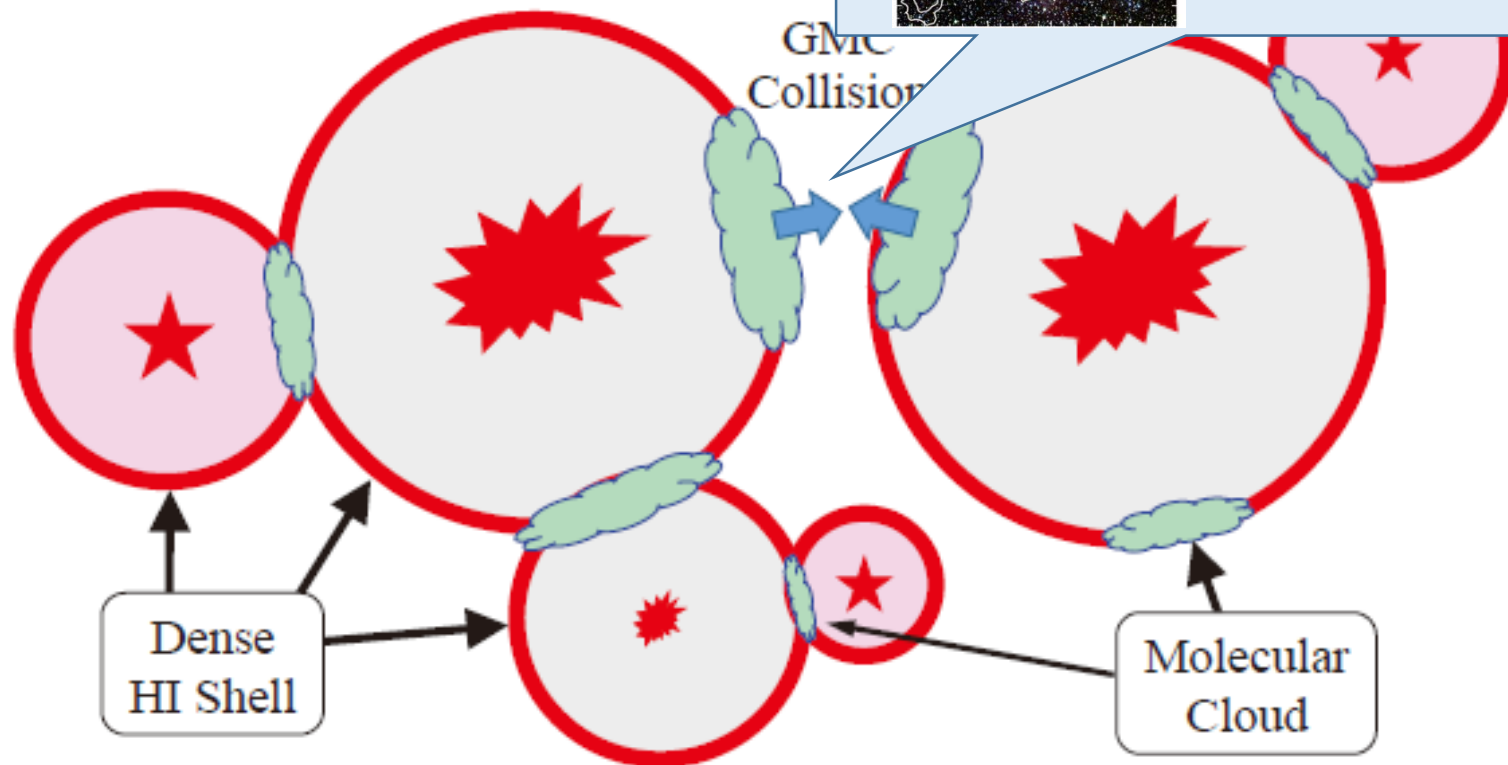
Fukui+ 2014

Nakamura+ 2012

Torii+2015

etc

Network of Expanding Shells



Evolution of GMC Mass Function

$$\frac{\partial n_i}{\partial t} + \frac{\partial}{\partial M} \left(n_i \frac{M_i}{T_f} \right) = -\frac{n_i}{T_d} - n_i \sum_{k=1}^{\infty} \alpha(i, k) n_k + \frac{1}{2} \sum_{k=1}^{i-1} \alpha(i-k, k) n_{i-k} n_k$$

Evolution of GMC Mass Function

$$\frac{\partial n_i}{\partial t} + \frac{\partial}{\partial M} \left(n_i \frac{M_i}{T_f} \right) = -\frac{n_i}{T_d} - n_i \sum_{k=1}^{\infty} \alpha(i, k) n_k + \frac{1}{2} \sum_{k=1}^{i-1} \alpha(i-k, k) n_{i-k} n_k$$



GMC **self-growth**
through **compressions**
(i.e. $T_f \sim 10$ Myr)

Evolution of GMC Mass Function

$$\frac{\partial n_i}{\partial t} + \frac{\partial}{\partial M} \left(n_i \frac{M_i}{T_f} \right) = - \frac{n_i}{T_d} - n_i \sum_{k=1}^{\infty} \alpha(i, k) n_k + \frac{1}{2} \sum_{k=1}^{i-1} \alpha(i-k, k) n_{i-k} n_k$$



GMC **self-dispersal** by
dissociating photon and
ionizing photon **due to OB stars**
(i.e. $T_d \sim 14$ Myr)

Evolution of GMC Mass Function

$$\frac{\partial n_i}{\partial t} + \frac{\partial}{\partial M} \left(n_i \frac{M_i}{T_f} \right) = -\frac{n_i}{T_d} - n_i \sum_{k=1}^{\infty} \alpha(i, k) n_k + \frac{1}{2} \sum_{k=1}^{i-1} \alpha(i-k, k) n_{i-k} n_k$$

Cloud-Cloud collisions (CCCs)

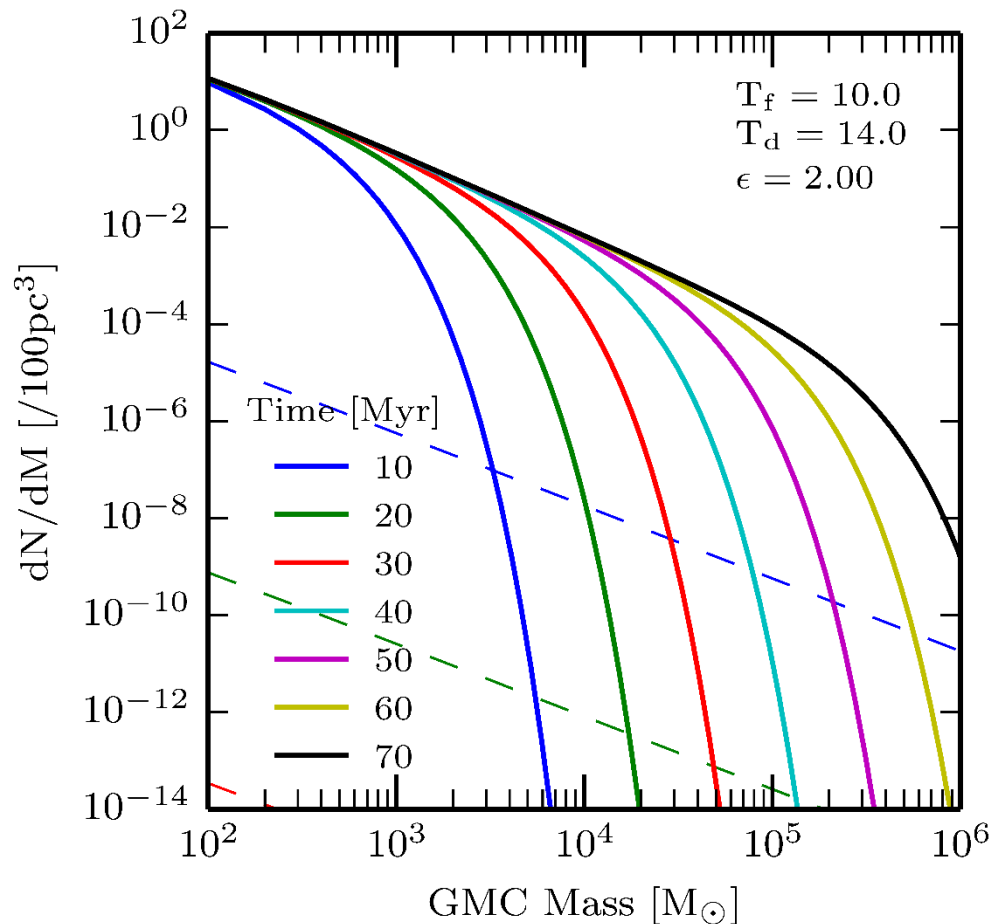


Results

- ✓ **With/without CCCs**
- ✓ **With Different Timescales**

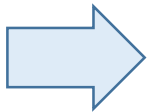
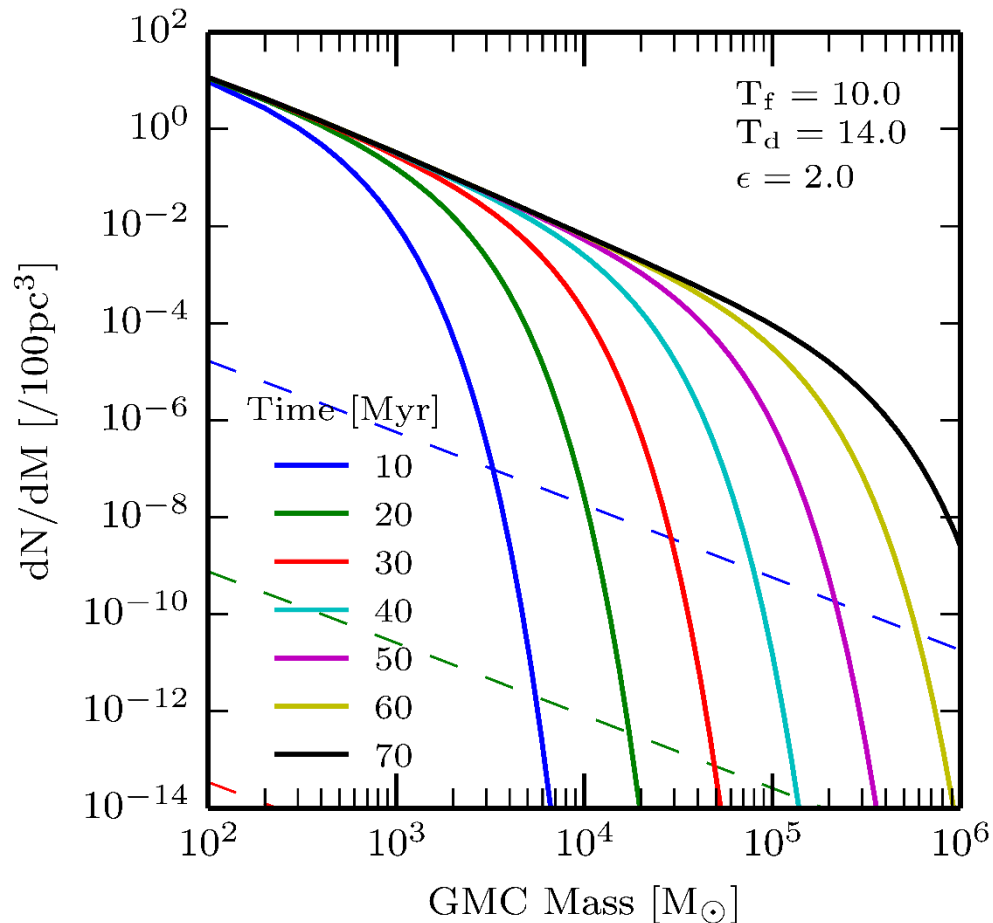
Resultant Mass Functions

Without CCC; only self-growth and self-dispersal



Resultant Mass Functions

With CCC, self-growth, and self-dispersal



CCC does not alter GMC mass function significantly

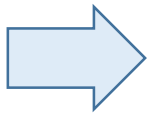
Steady State Solution

Inutsuka et al., 2015

$$\frac{\partial n_{\text{cl}}}{\partial t} + \frac{\partial}{\partial M} \left(n_{\text{cl}} \frac{dM}{dt} \right) = - \frac{n_{\text{cl}}}{T_d}$$

Steady state solution can be obtained as:

$$n_{\text{cl}}(M) = \frac{N_0}{M_{\odot}} \left(\frac{M}{M_{\odot}} \right)^{-1 - \frac{T_f}{T_d}}$$

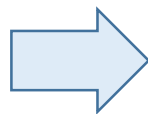
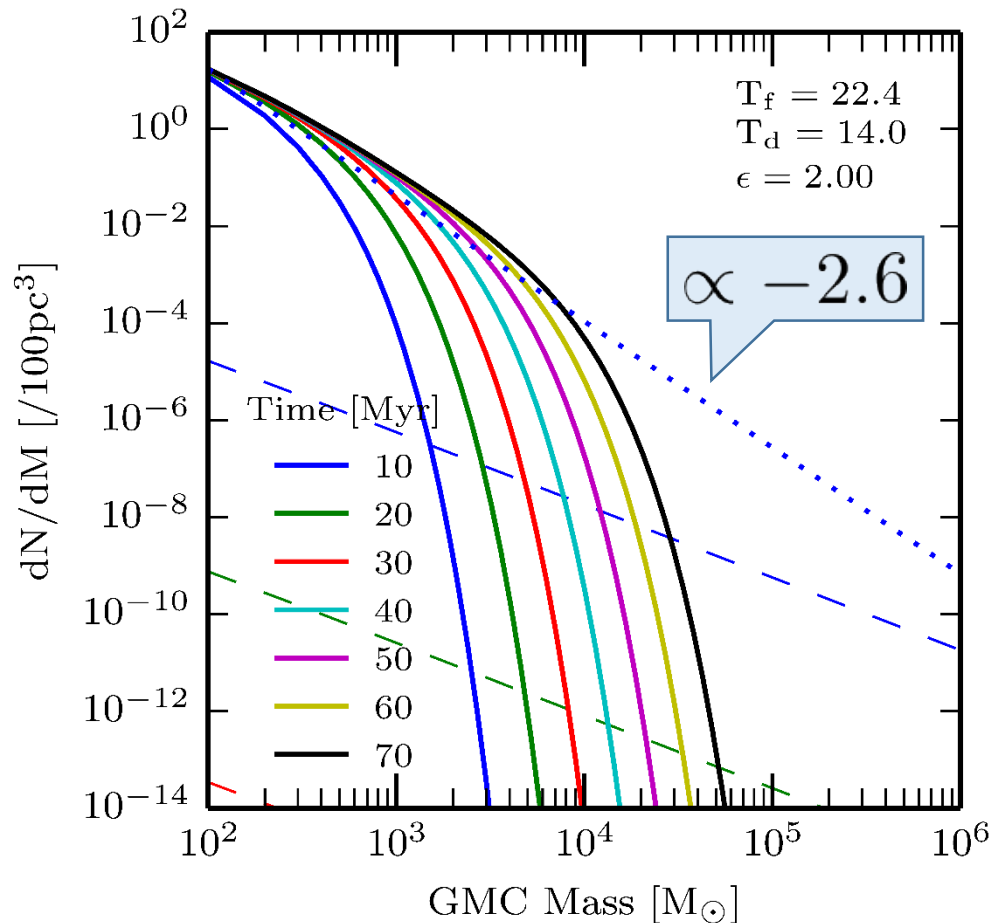


Observed T_f/T_d may put an unique constraint on relevant timescales.

$$\text{e.g., } \begin{cases} -1 - \frac{T_f}{T_d} \sim -1.7 & \text{for } T_* = T_f = 10 \text{ Myr} \\ -1 - \frac{T_f}{T_d} < -2 & \text{for longer } T_f \text{ regions} \end{cases}$$

Time Scales for GMC Formation

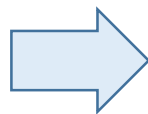
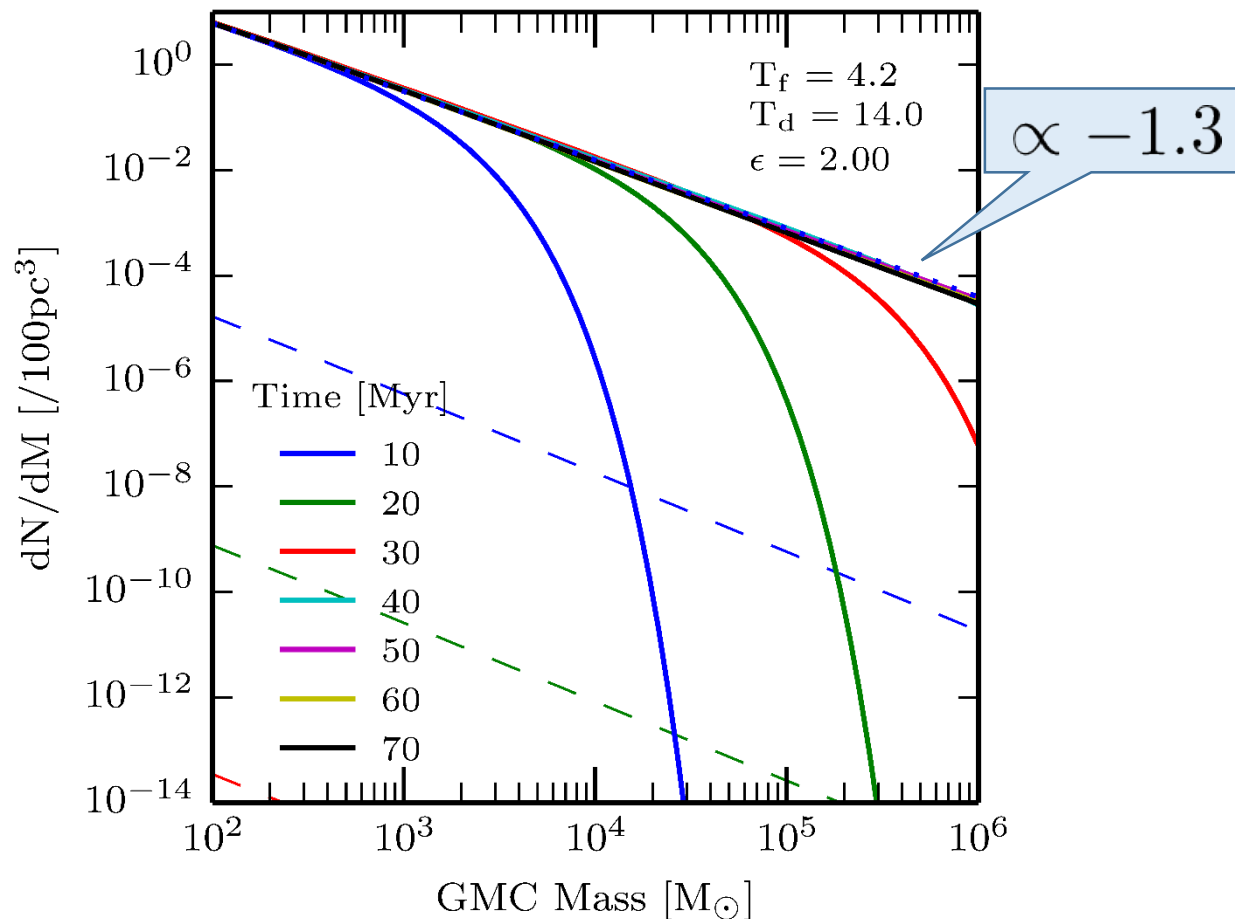
Long T_f (~ 22.4 Myr)



Inter-arm regions may have **longer** timescales for formation

Time Scales for GMC Formation

Short T_f (~ 4.2 Myr)



Arm regions may have **shorter** timescale for formation

Summary

✓ Background: Multiple episodes of compression

- Variation of GMC MF on galactic scales
- Magnetic fields retard molecular cloud formation

✓ Formulation: Mass continuity eq. with CCC

- CCC does not alter GMC MF significantly
- Cloud formation timescale may vary GMC MF slope

✓ Future Prospects

- T_d varying with CCC
- Tracking individual GMC star formation histories

