Mass Distribution of the Molecular Phase of the ISM

Dense gas in the ISM

\[ \frac{M}{T/B/P} \ldots \text{distributions} \]

\[ \uparrow \]

processes in the ISM

cold, molecular gas

\[ \downarrow \]

star formation

cf., E. Vazquez-Semadeni’s talk

Audit & Hennebelle (2005)
Dense gas in the ISM

$\Sigma_{SFR} \sim (\Sigma_{H_2})^\beta$

Kennicutt (1998)

cold, molecular gas
↓
star formation

M/T/B/P/... distributions
↑
processes in the ISM

cf., E. Vazquez-Semadeni’s talk
Dense gas in the ISM

$M/T/B/P/\ldots$ distributions

↑

processes in the ISM

cold, molecular gas

↓

star formation

$\Sigma_{SFR} \sim (\Sigma_{H_2})^\beta$

Kennicutt (1998)

$\Sigma_{SFR} \sim f_{dg}(\Sigma_{\text{gas}})^\beta$

Lada et al. (2012)

This talk:

1. **Observations:** Quantifying dense gas fractions of MCs with dust extinction.

2. **Theory:** What parameters set how much dense gas molecular clouds have?

Lada et al. (2010)

cf., E. Vazquez-Semadeni’s talk

M/L/T/B/P/... distributions

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This talk:

1. **Observations:** Quantifying dense gas fractions of MCs with dust extinction.

2. **Theory:** What parameters set how much dense gas molecular clouds have?
1. Observing the Mass Distribution of the ISM?

- Column density $N(H_2) \times 10^{21} \text{ cm}^{-2}$, or $A_V$ [mag]

- HI $\rightarrow$ H$_2$

- Herschel/dust emission

- MIR dust extinction

- NIR dust extinction

- CO

- $<N(H_2)>$, low-M cores, high-M cores

- $\sim$ cold phase of the ISM
Near-IR Dust Extinction

- NIR photometry of background stars.
- FWHM \( \sim 2' \).
- \( N(H_2) \sim 1-25 \times 10^{21} \) cm\(^{-2} \).

Dobashi et al. (2010)

Kainulainen et al. (2009)

using 2MASS data
Dense Gas in Nearby Molecular Clouds

All (~20) molecular clouds within 500 pc distance:

\[
\log dM'(<A_v) \approx N(H_2) / 10^{21} \text{ cm}^{-2}
\]

Kainulainen et al. (2009)
**Combined NIR+MIR extinction mapping of IRDCs**

(Kainulainen et al. 2011; Kainulainen & Tan 2013)

- Spitzer 8 um imaging data (shadowing features).
- NIR photometry of background stars.
- Retain Spitzer imaging resolution (2")

**From Solar neighborhood to Galactic environment?**

0.05 pc at 3.5 kpc is 3"
Example: “The Snake”; D = 3.5 kpc

Dust extinction map
8 um + NIR photometry

FWHM = 2”

$N(H_2) \sim 2 - 150 \times 10^{21} \text{ cm}^2$

35’ ~ 35 pc at 3.5 kpc

Kainulainen et al. (2013)
Adapted from: Kainulainen & Tan (2013), Kainulainen et al. (2013), Kainulainen et al. (2011)
2) What affects the amount of dense gas?

Kainulainen et al. (2013)

**Analysis of numerical simulations**

- Isothermal, driven turbulence in a box (Federrath & Klessen 2012).
- Gravity and sink particles.
- $\alpha_{\text{vir}} = 1$ (also tested w/ mean-normalized data).
- Simulated observations mimicking dust extinction mapping
- **Varying:** driving mode ($b$), $M_s$, $B$, $SFE$ → **simulated DGMFs**

Federrath & Klessen (2012)
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→ simulated DGMFs

Solenoidal forcing: $b = 1/3$

Compressive forcing: $b = 1$
Example: “Observed” DGMFs from simulations

\[ dM' \sim e^{\alpha} \]

Kainulainen et al. (2013)
Nearby star-forming clouds
Nearby quiescent clouds
Massive IRDCs

Exponential slope of the DGMF

Kainulainen et al. (2013)
Summary: Dense Gas in the ISM

1) Observations:
   - Effects of SFE and environment on $f_{dg}$ (DGMF) (Kainulainen et al. 2009, 2011; Kainulainen & Tan 2013).
   - High-resolution (2’’), high-fidelity dust extinction mapping technique for IRDCs (Kainulainen & Tan 2013).

2) Predictions:
   - $f_{dg}$ (DGMF) can be affected by average gas compression (over SFE, random variations, $B$, $M_s$).
   - Variations in compression are needed to explain the observed range of DGMFs.
   - Control of dense gas by the Galaxy-scale (dynamical?) environment (e.g., Hughes et al. 2013, Meidt et al. 2013 in M51).