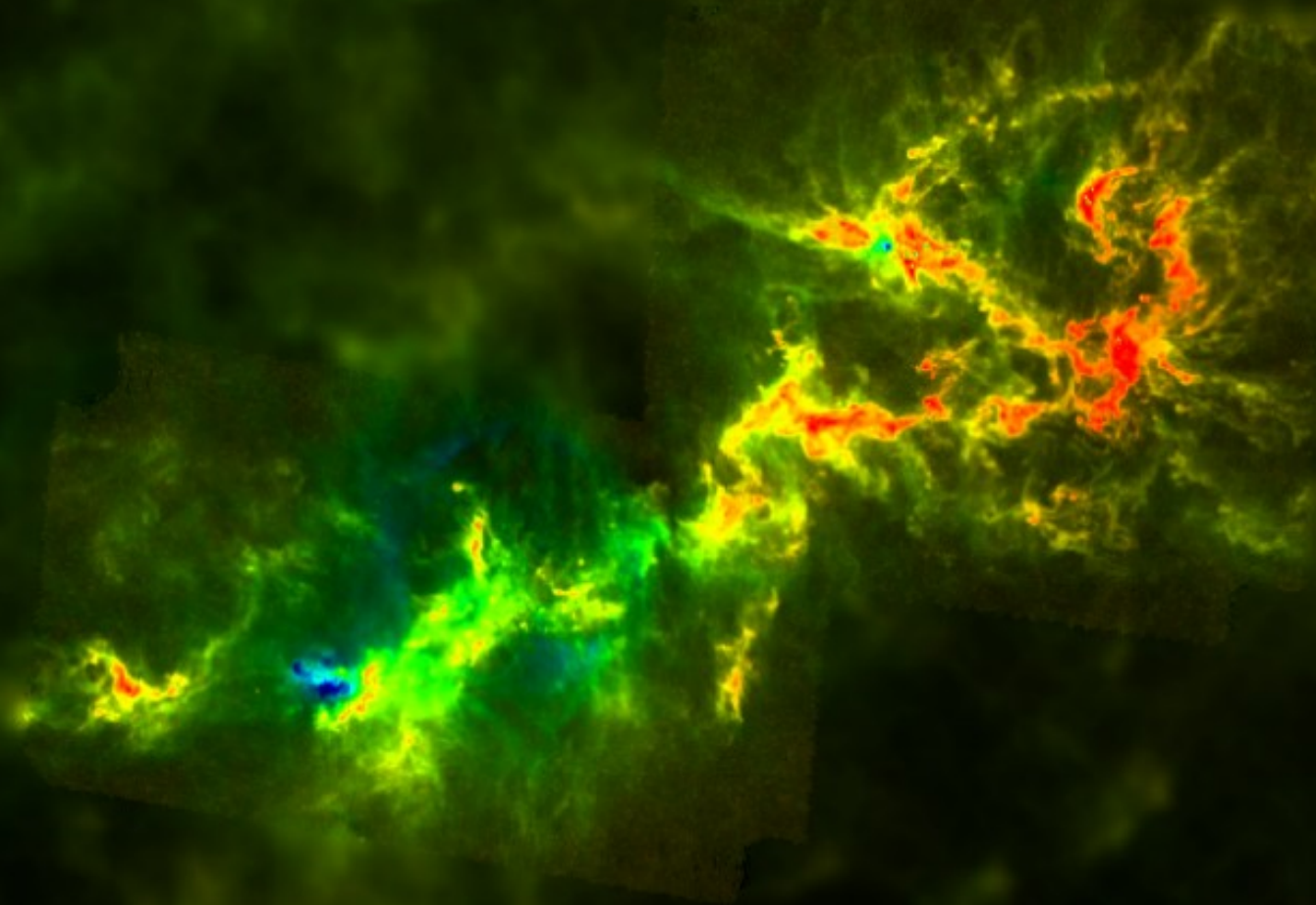


The internal state of molecular clouds

Can they be in free fall?

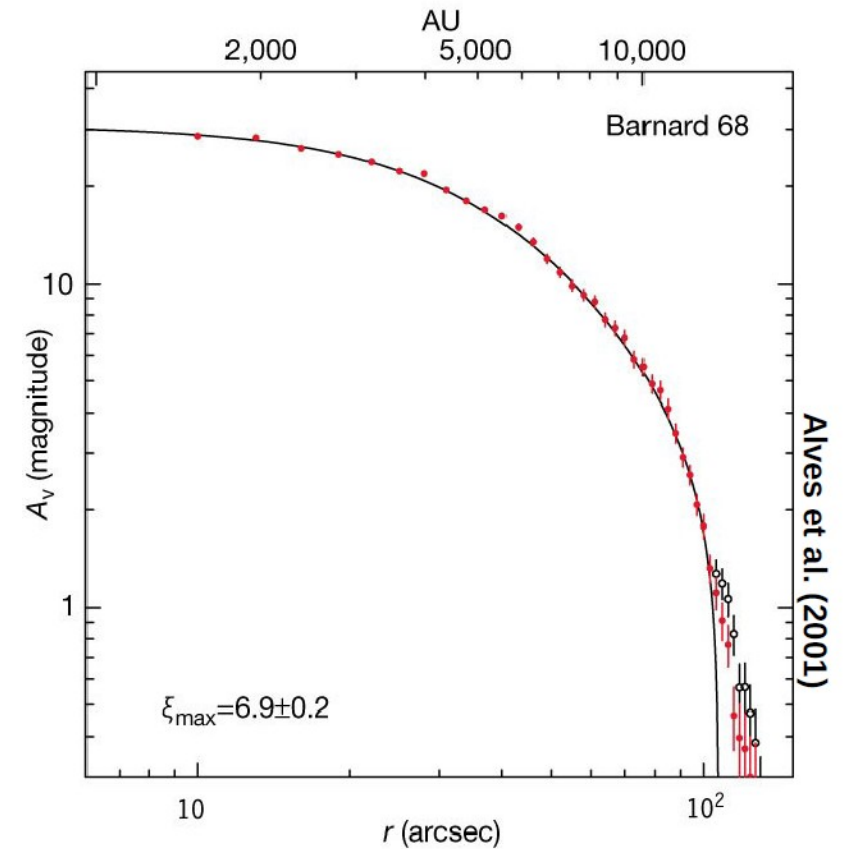
Mario Tafalla (OAN-IGN, Spain)



More immediate question:

**can we build a simple-but-
realistic model of a
molecular cloud?**

2000s: dense core (scales ~0.1 pc)

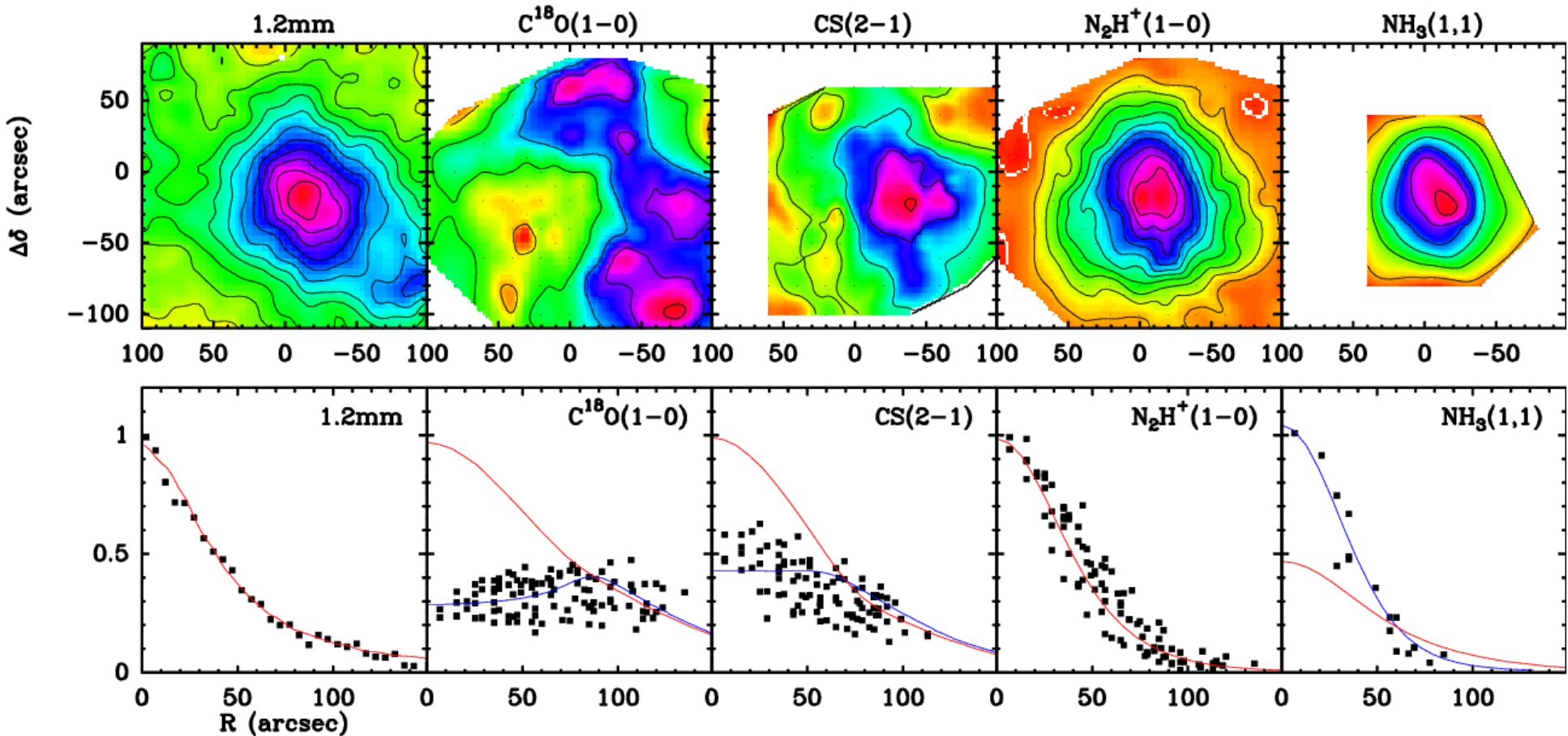


$$\xi^{-2} \frac{d}{d\xi} \left(\xi^2 \frac{d\psi}{d\xi} \right) = e^{-\psi}.$$

Bonnor (1956)
Ebert (1955)

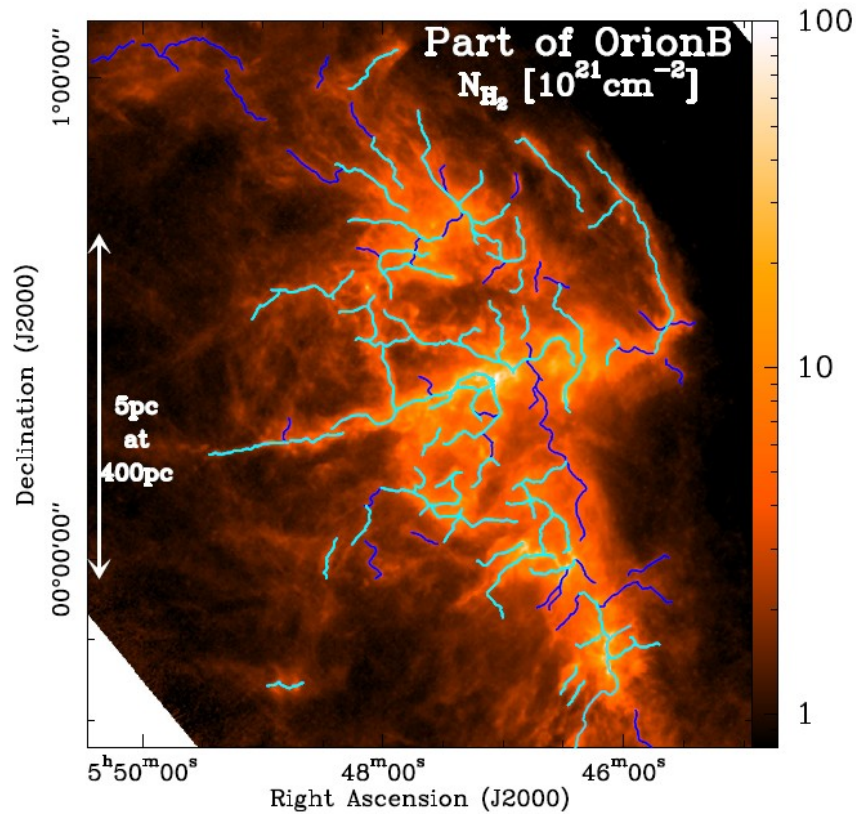
2000s: dense core (scales ~ 0.1 pc)

L1517B

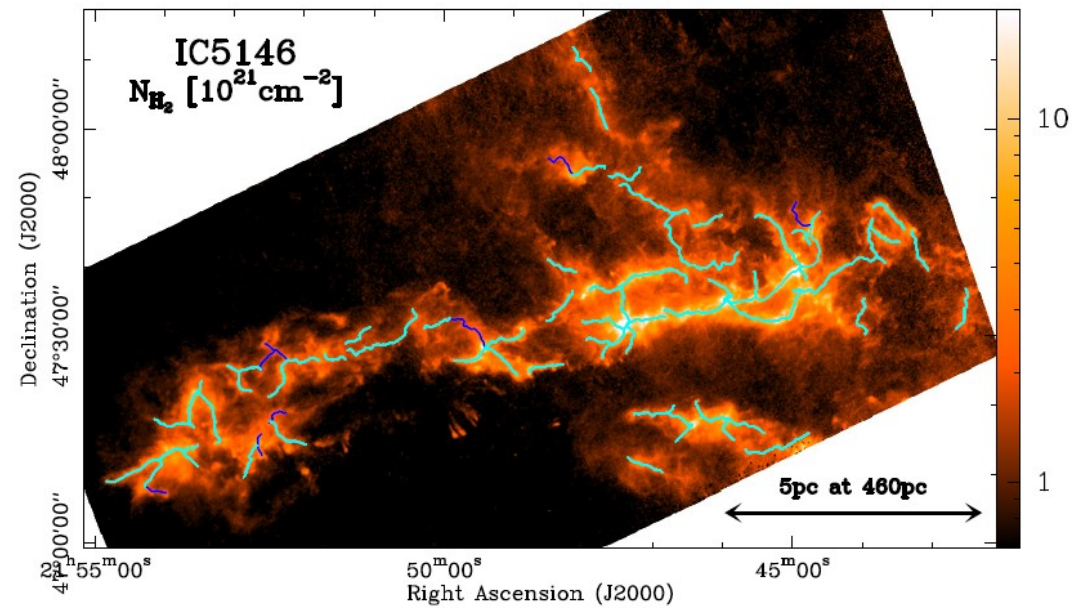


Tafalla et al. (2002)

2010s: filaments (~ 1 pc)



Arzoumanian et al. (2018)



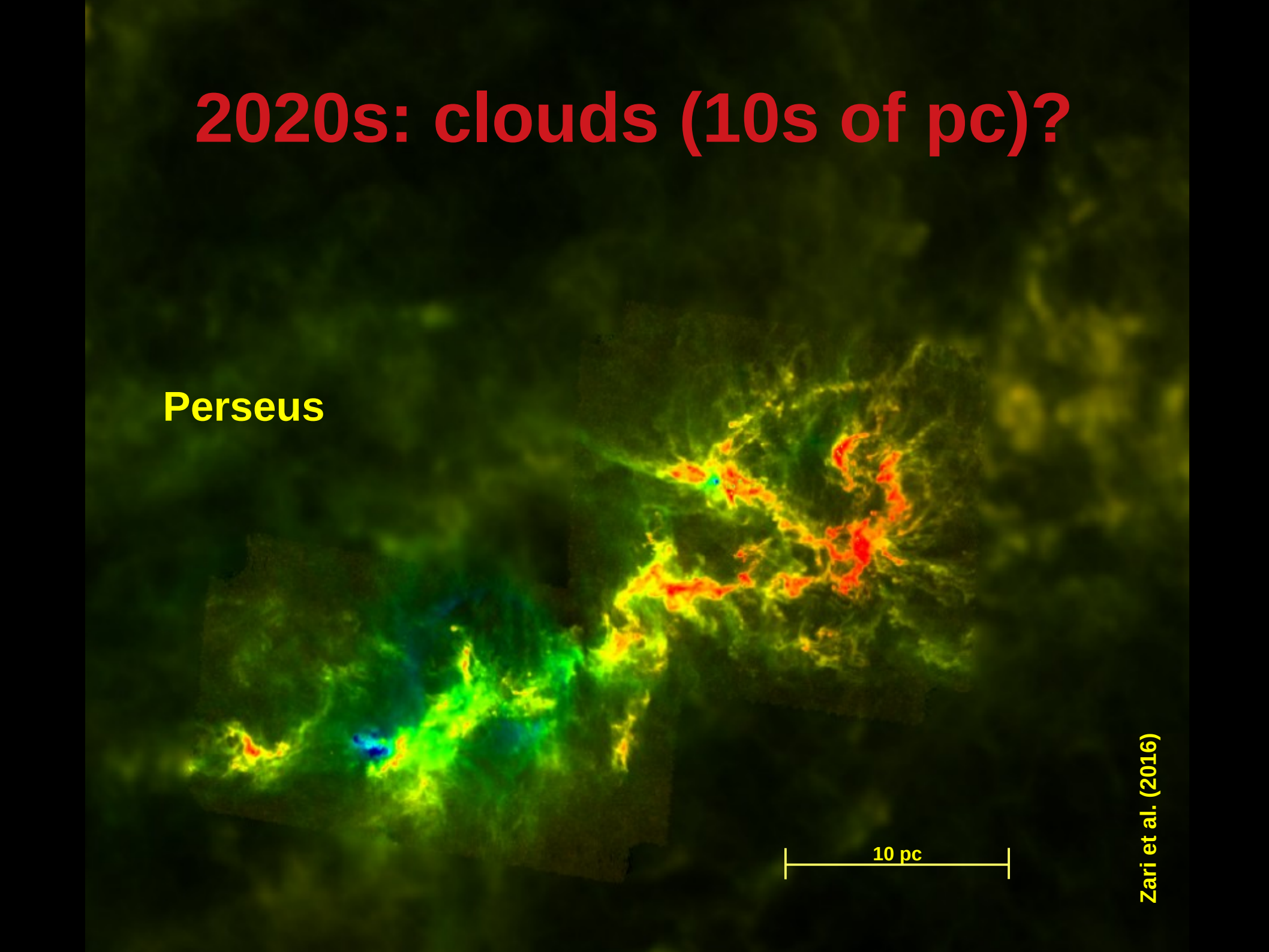
$$\rho = \rho_0 \frac{1}{\left(1 + \frac{1}{8} \xi^2\right)^2}$$

Stodolkiewicz (1956)
 Ostriker (1964)

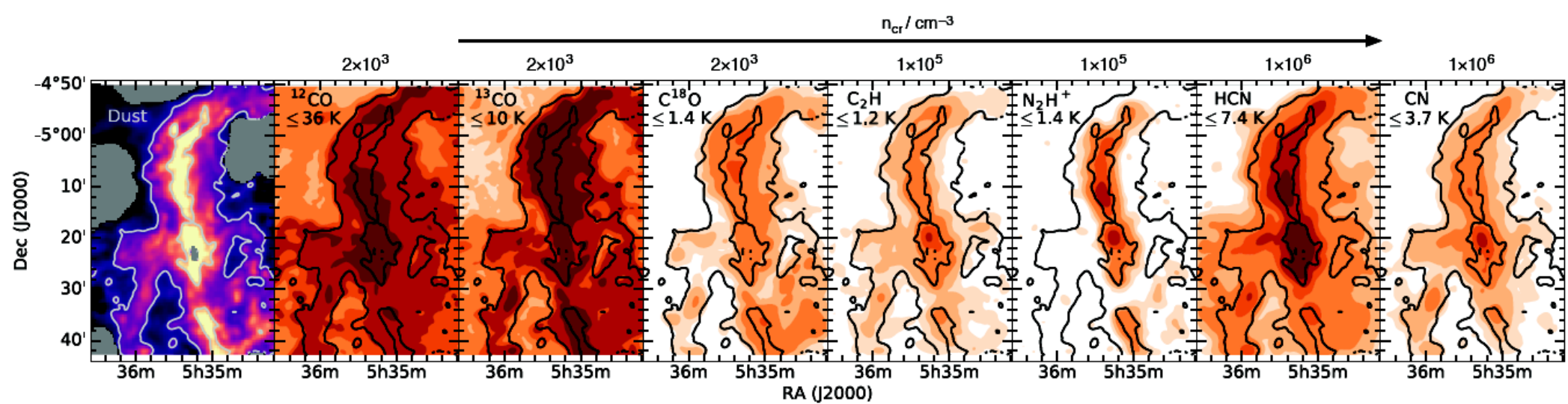
2020s: clouds (10s of pc)?

Perseus

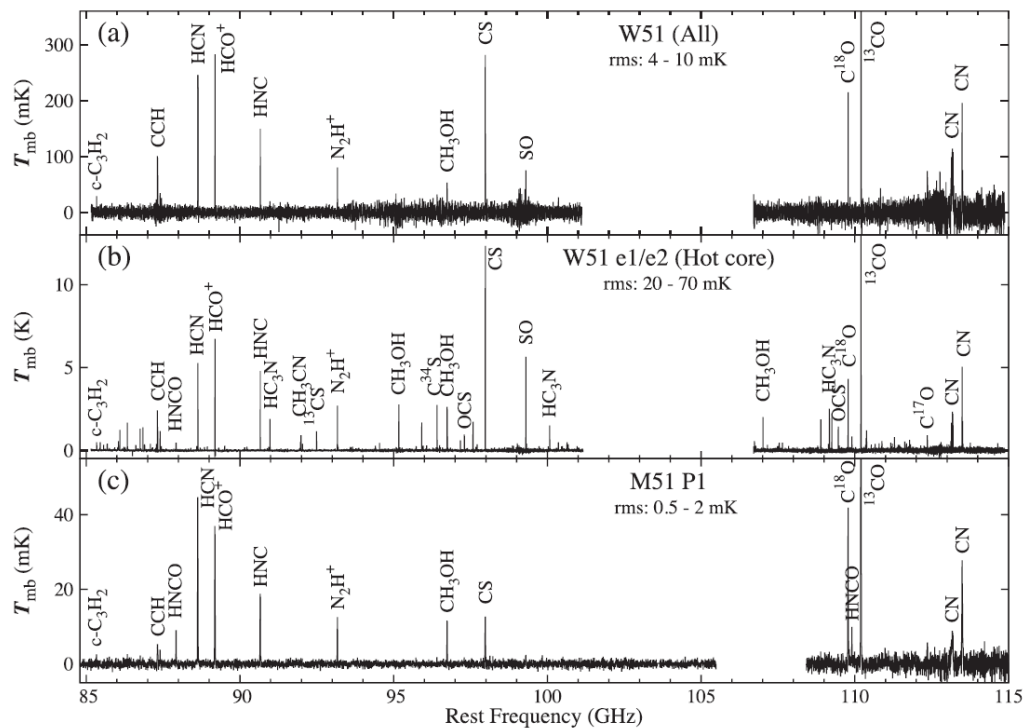
10 pc



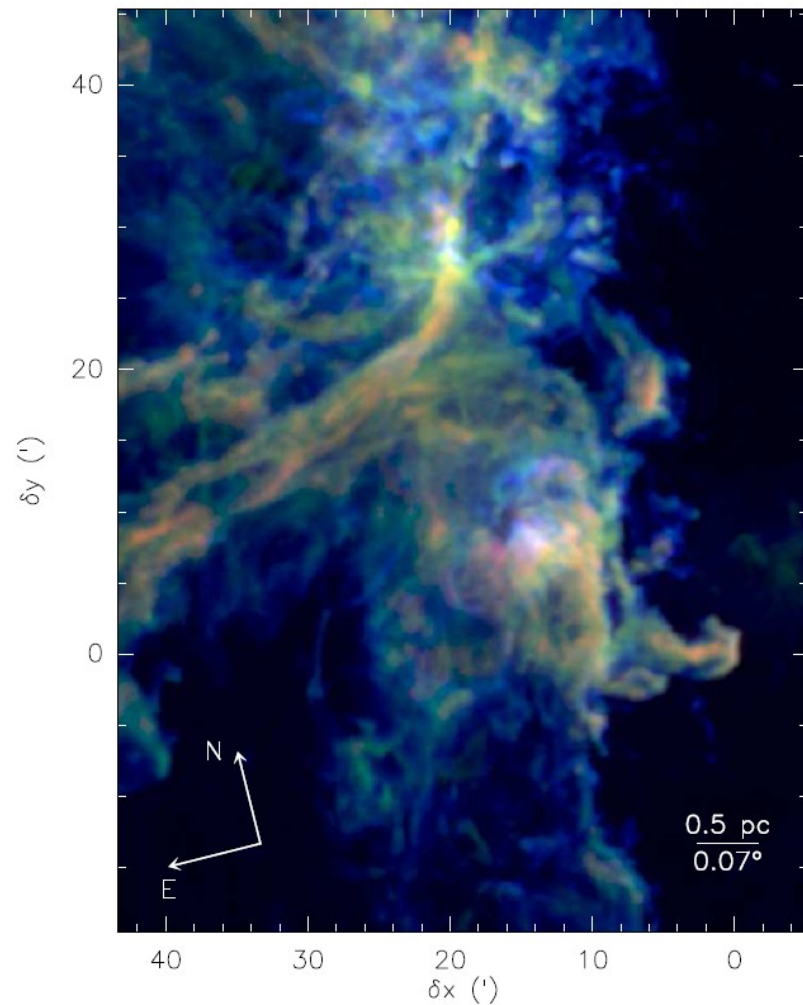
Zari et al. (2016)



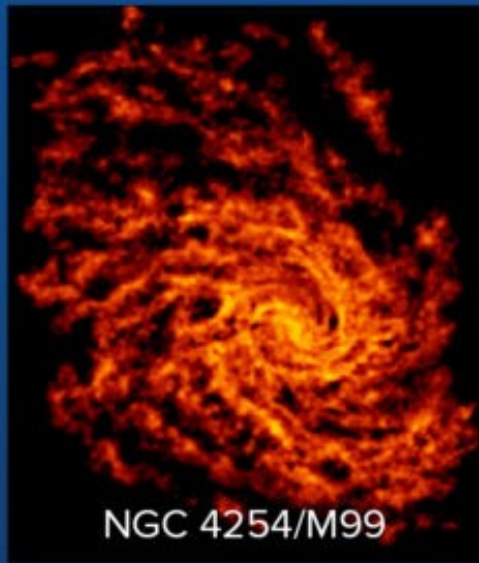
Orion A: Kauffmann et al (2017)



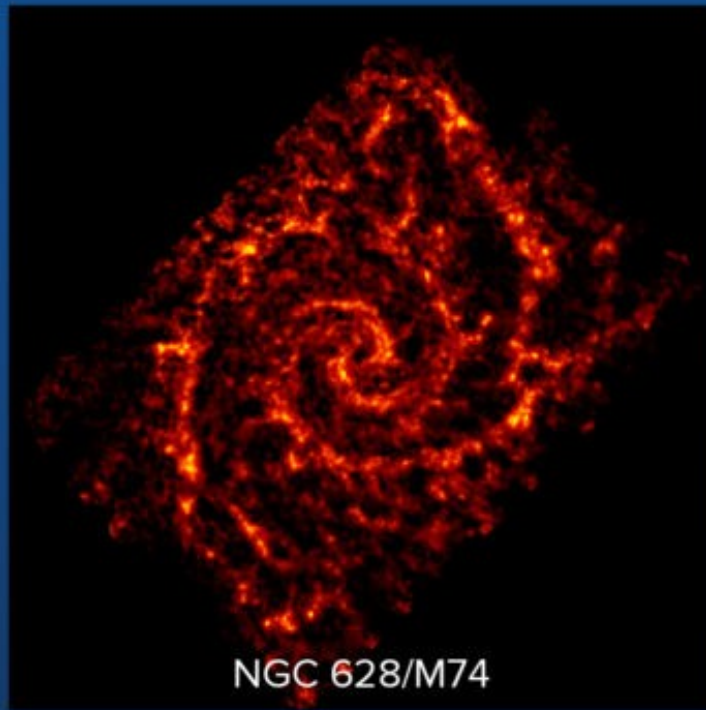
Watanabe et al (2017)



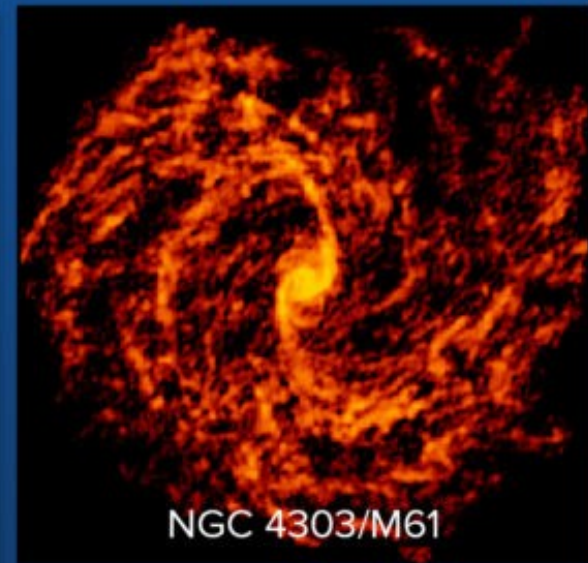
Orion B: Pety et al (2017)



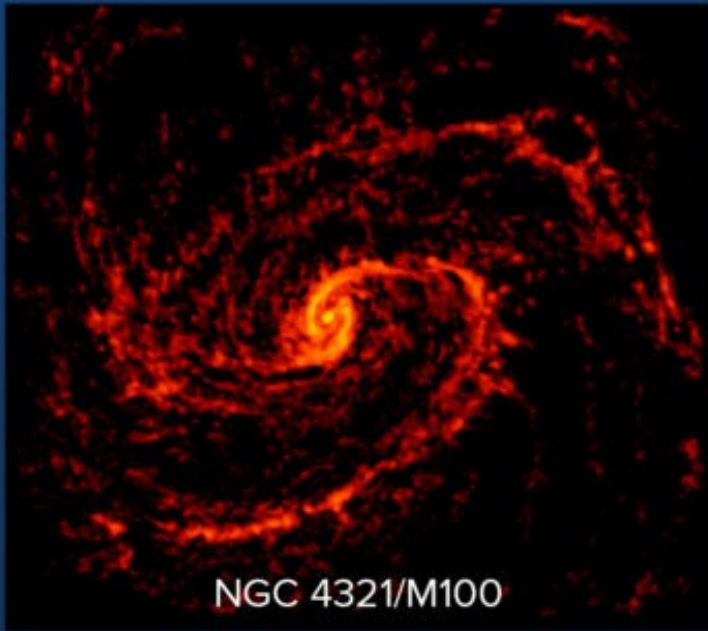
NGC 4254/M99



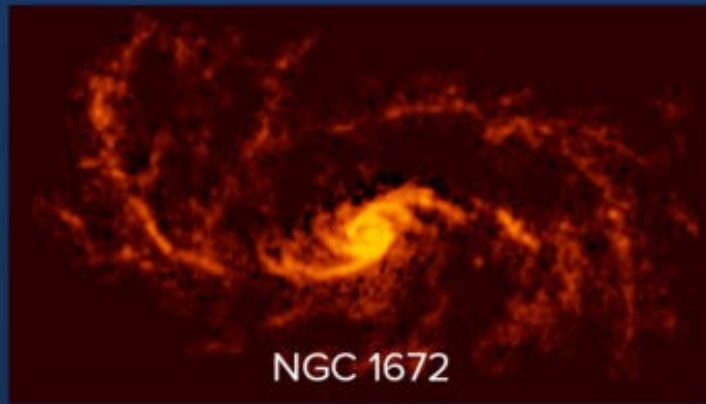
NGC 628/M74



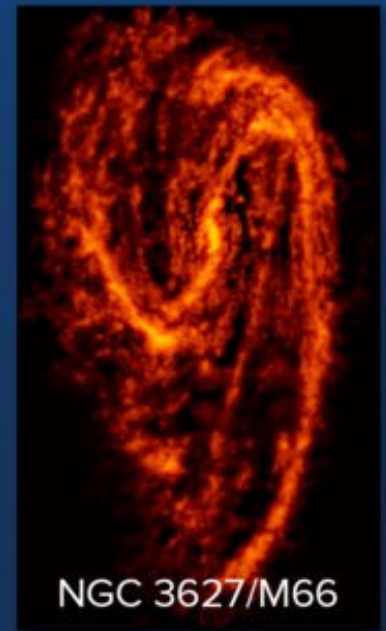
NGC 4303/M61



NGC 4321/M100



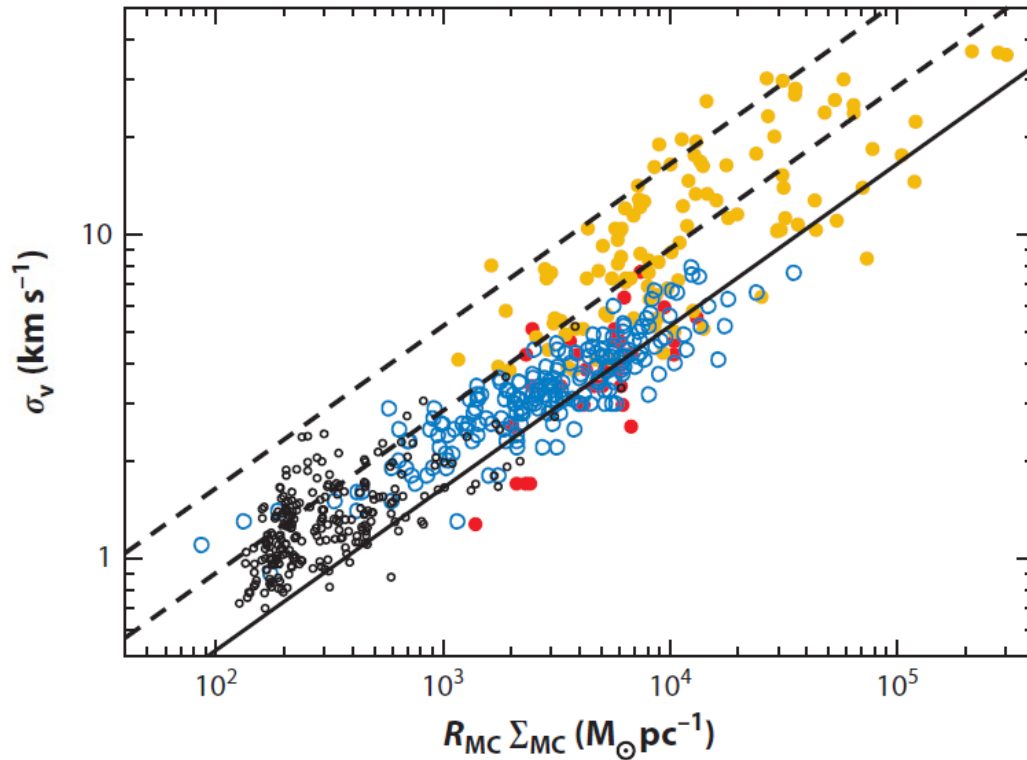
NGC 1672



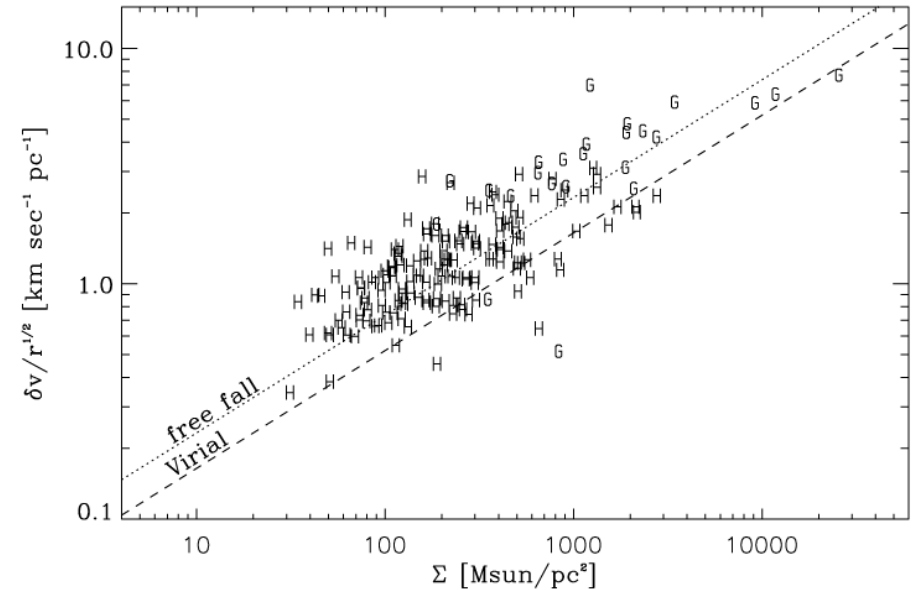
NGC 3627/M66

PHANGS: Schinnerer, Leroy, et al.

“Standard” cloud analysis

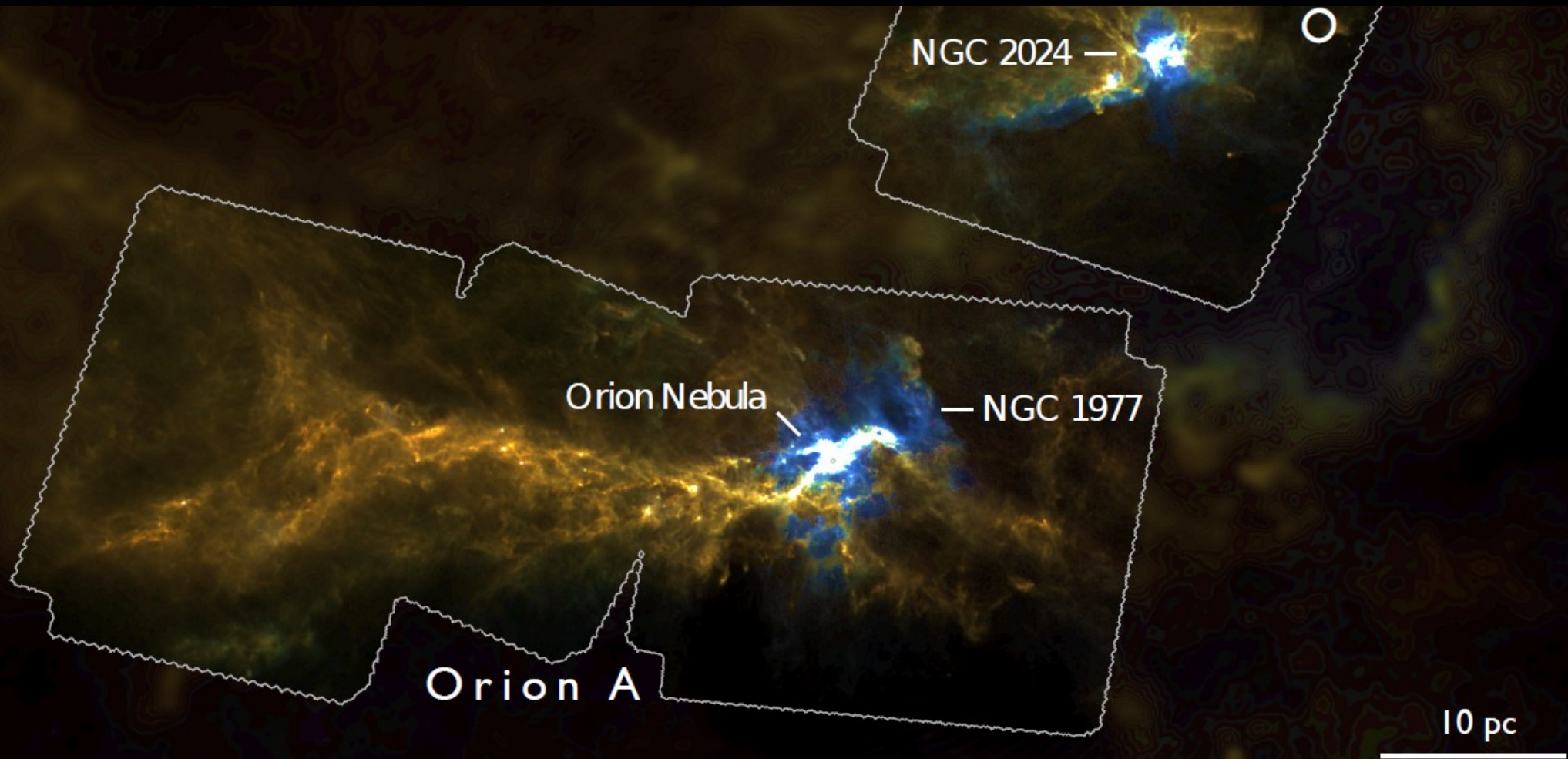


Heyer & Dame (2015)



Ballesteros-Paredes et al. (2011)

- Model: spherical cloud with well-defined radius and constant density.

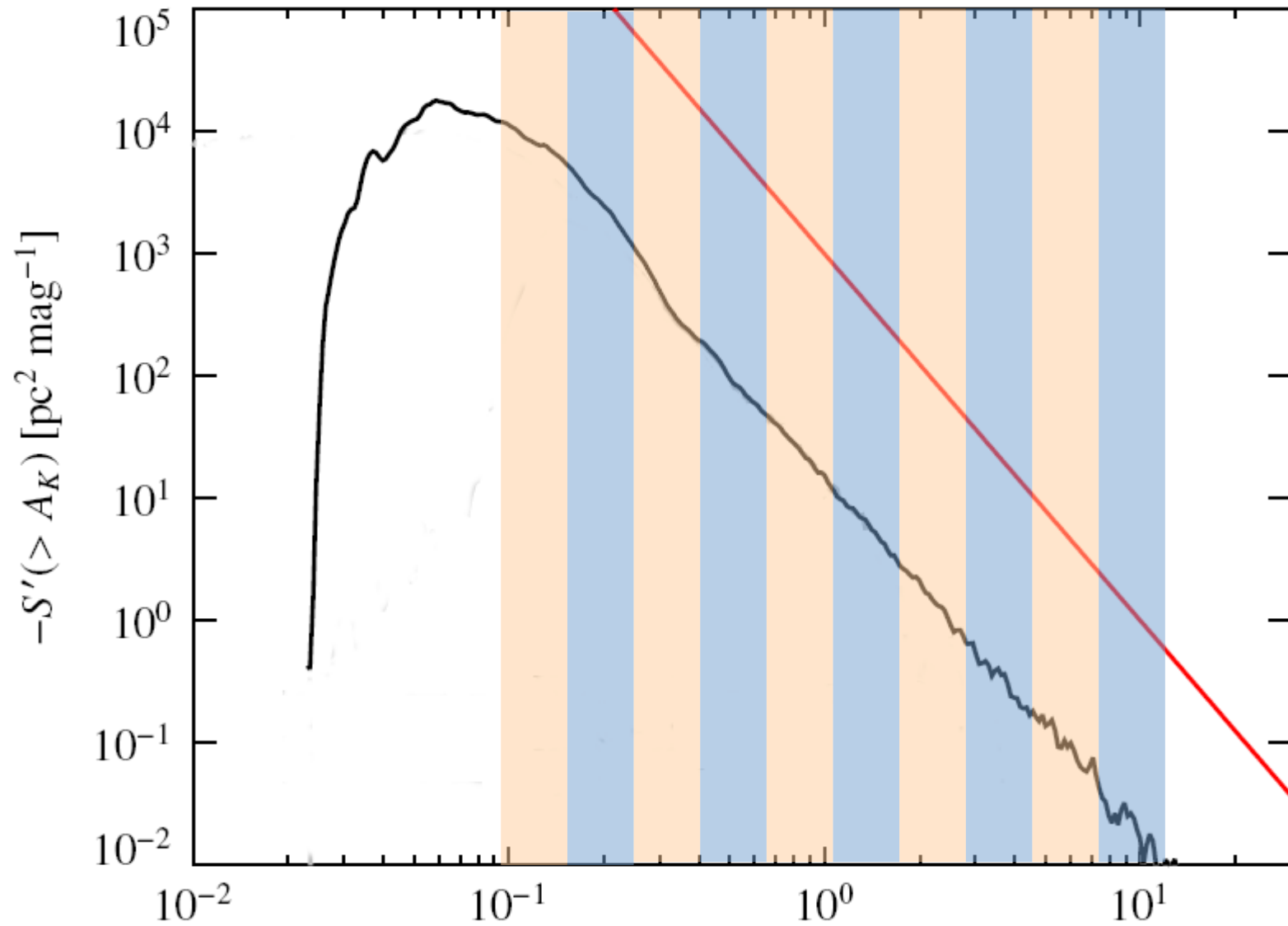


Lombardi et al. (2014)

Can we find a better cloud model?

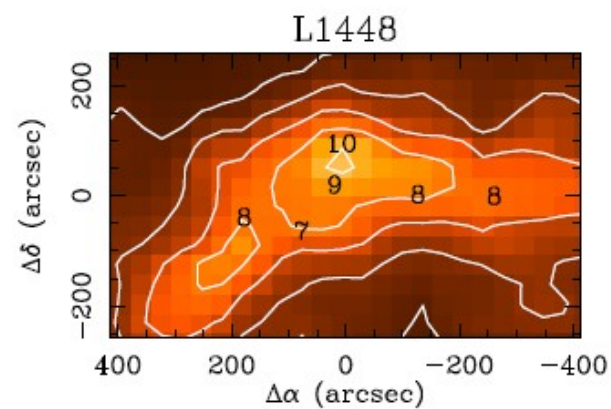
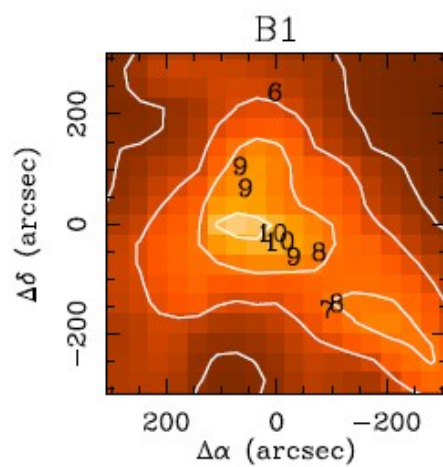
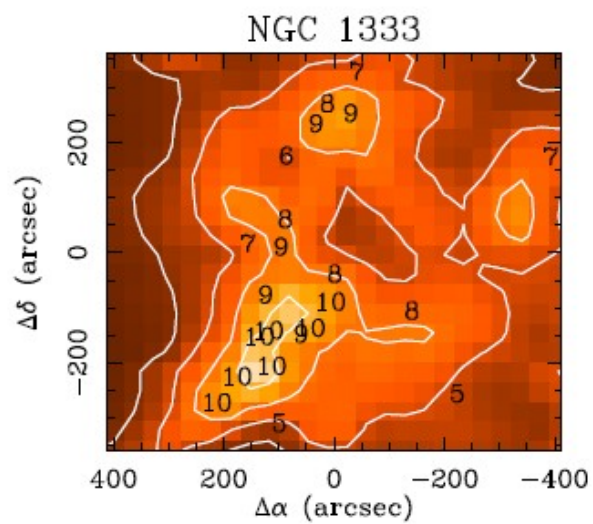
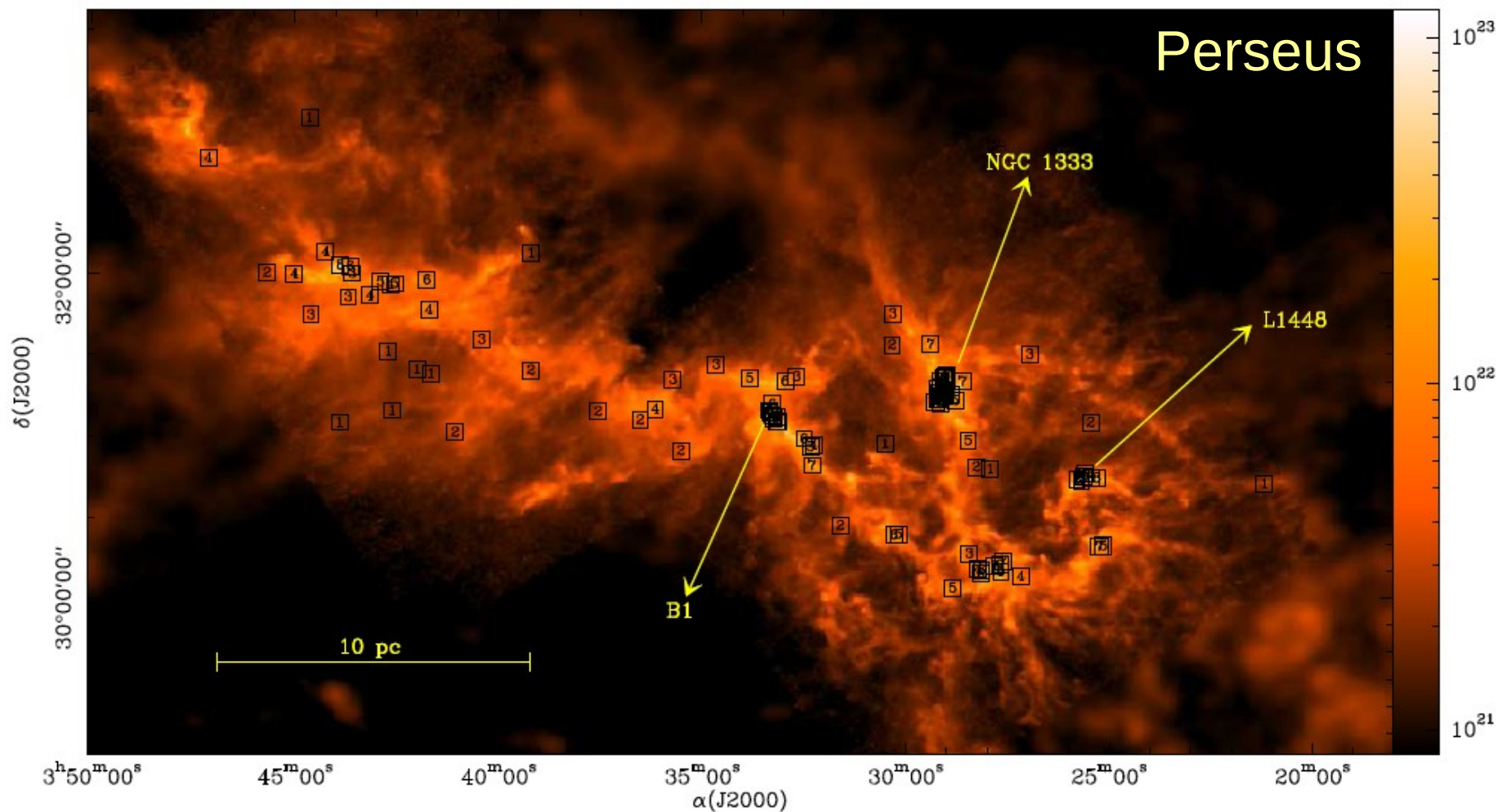
- Do clouds behave **systematically**?
 - large variety of clouds (masses, SFRs)
 - likely out of equilibrium
- Solution: **characterize** the emission of multiple molecular clouds
- Problem: mapping full clouds is **time-consuming** (100s h)
 - expensive to derive statistics
- Solution: **sampling**
 - mapping may not be necessary to determine general trends

Sampling clouds



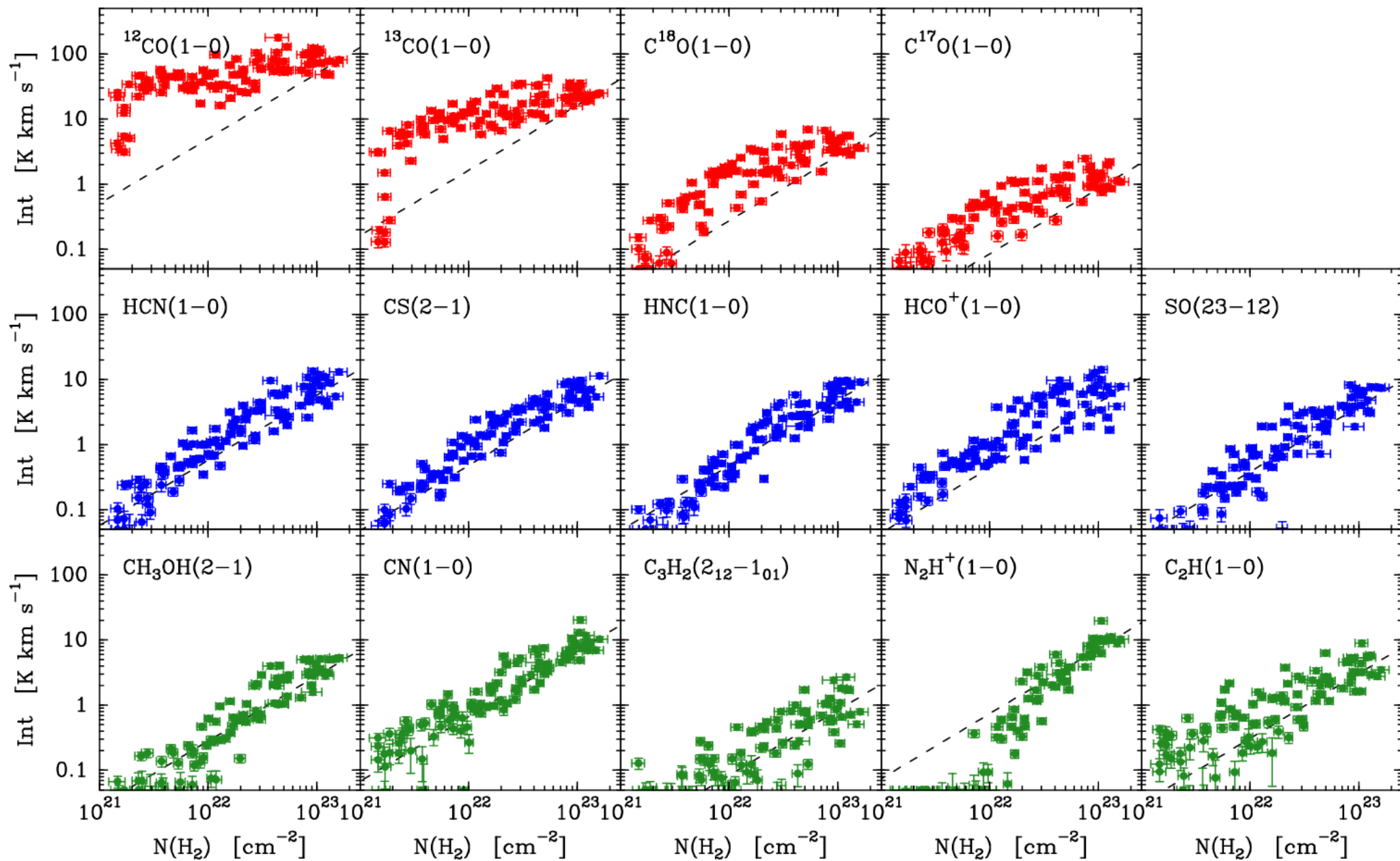
Zari, Lombardi, Alves, Lada, Bouy (2016)

A_K [mag]

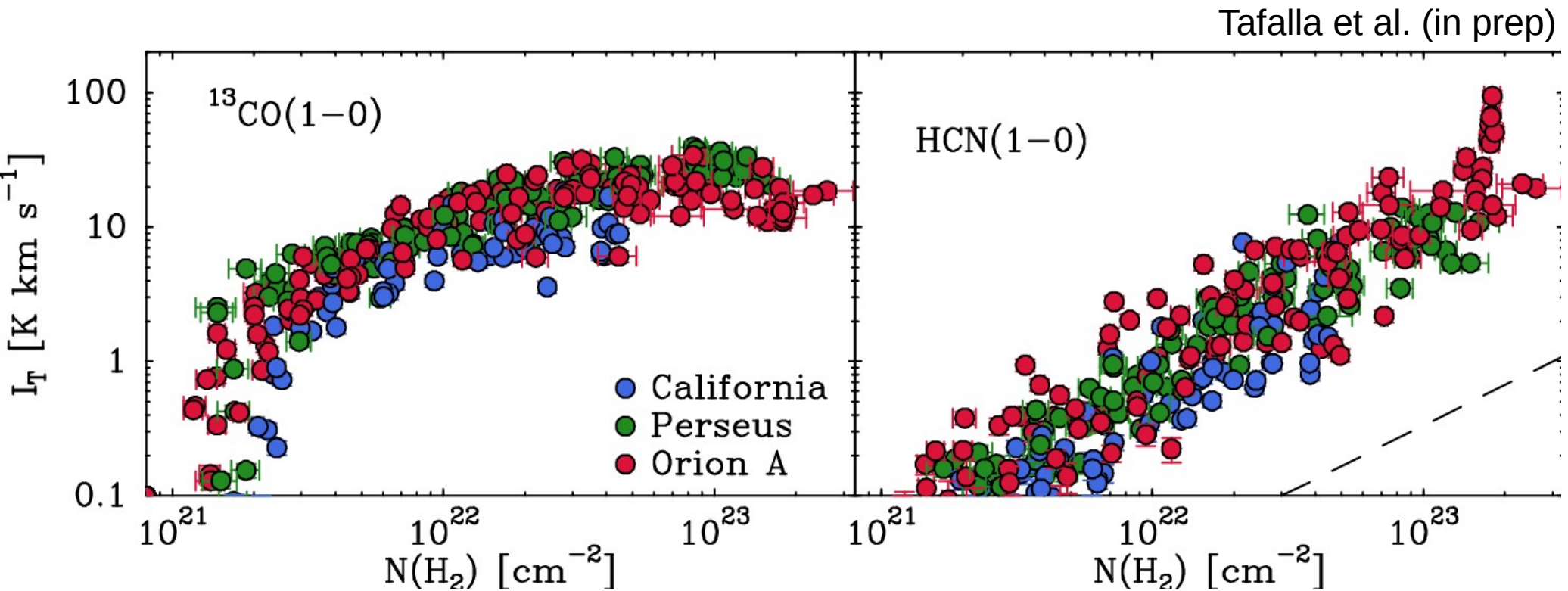


Tafalla, Usero, & Hacar (2021)

Systematic trends with $N(\text{H}_2)$

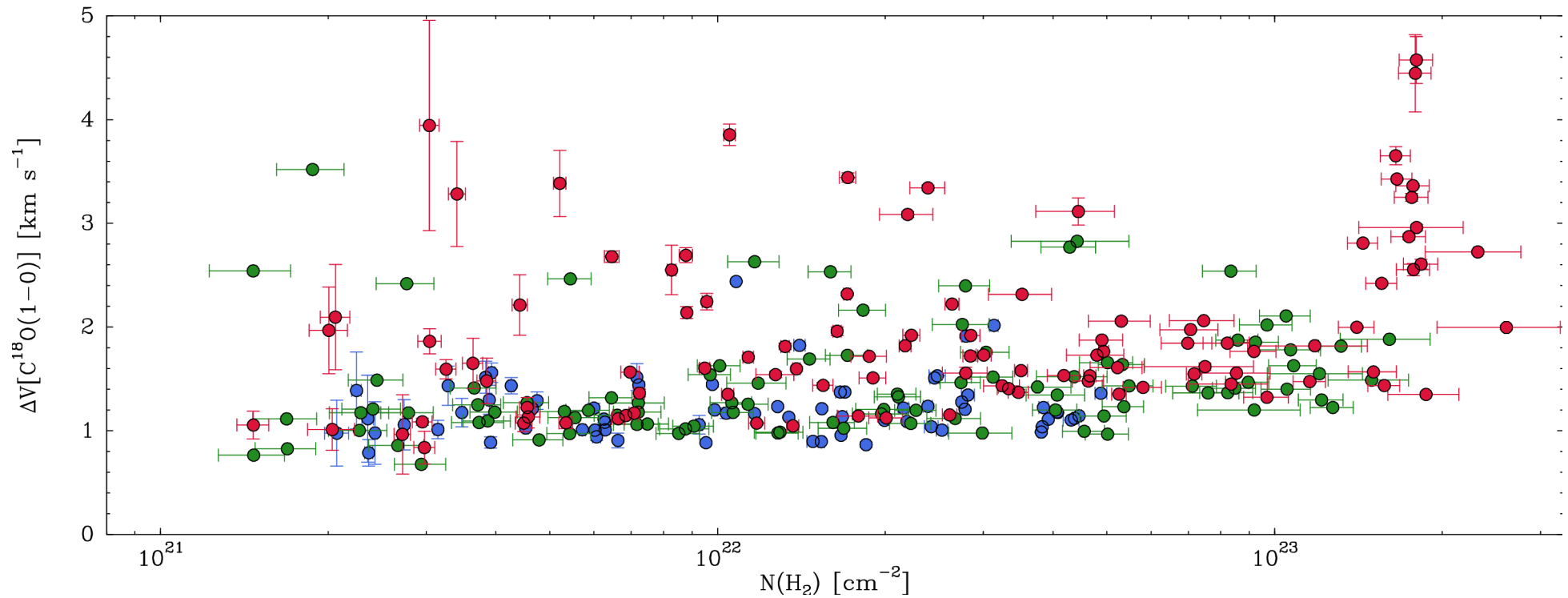


Systematic behavior across clouds



- Clouds look very similar when compared at the same $N(\text{H}_2)$
- Systematic behavior suggests simple cloud model should be possible

How about free-falling clouds ?



- We need model prediction from simulations
- Trends against $N(\text{H}_2)$ probably the most reliable constraint

Summary

- We find **systematic behavior** of cloud molecular emission
 - within and across clouds
- Behavior suggests that it may be possible to develop a **simple model** of cloud emission
 - will help address cloud conditions (like free fall)
- **How should the model be?**
 - fractal