Galactic Scale Star Formation
Heidelberg, July 30 – Aug 3, 2012

# The *Molecular* Interstellar Medium of Andromeda at 20 pc Scales

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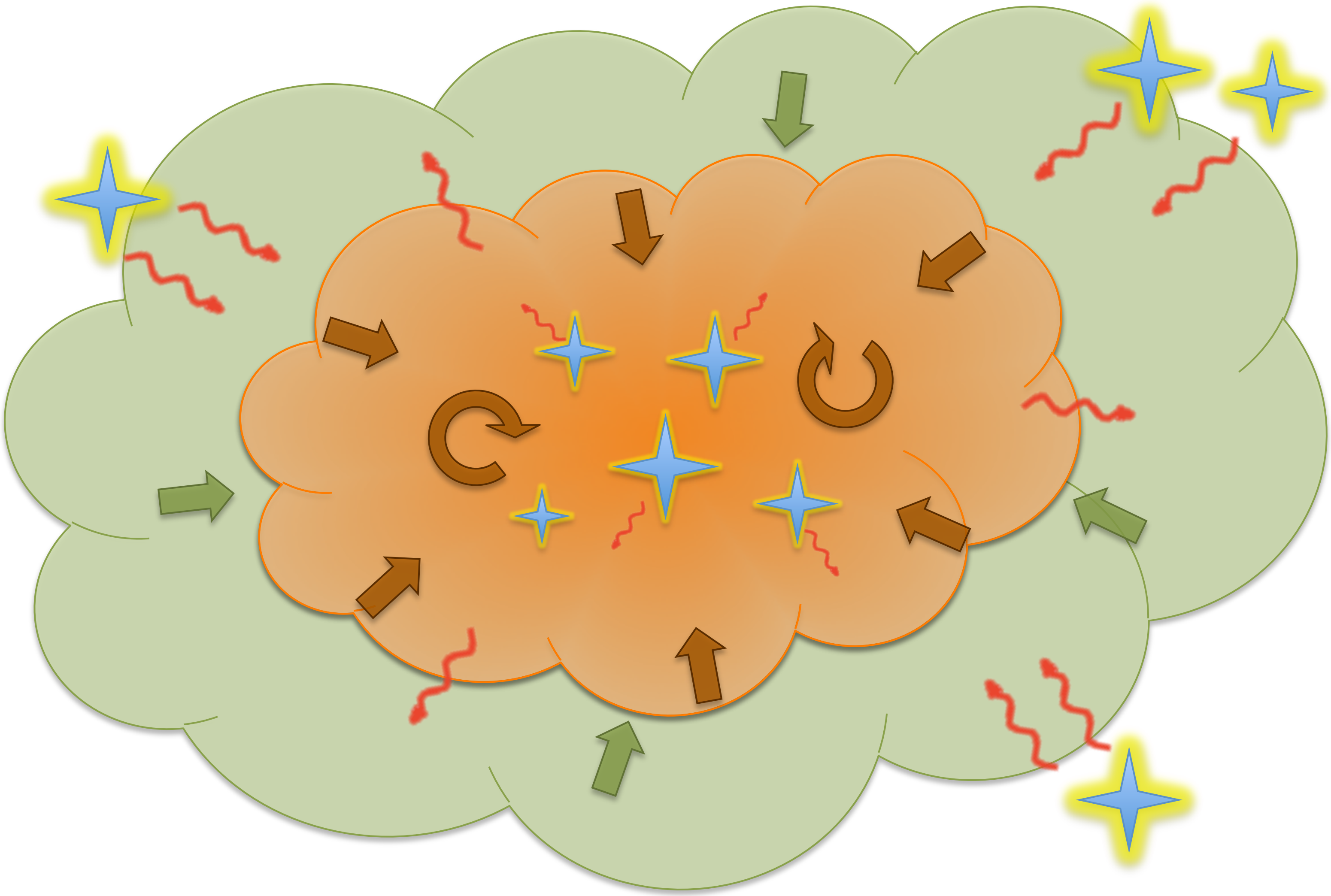
Julianne Dalcanton and Dan Weisz (U Washington)

# Molecular Clouds in a Nutshell



# Molecular Cloud Fundamentals

*Mon. Not. R. astr. Soc.* (1981) **194,** 809–826

## Turbulence and star formation in molecular clouds

Richard B. Larson *Yale University Observatory, Box 6666, New Haven, Connecticut 06511, USA*

**Summary**. Data for many molecular clouds and condensations show that the internal velocity dispersion of each region is well correlated with its size and mass, and these correlations are approximately of power-law form. The dependence of velocity dispersion on region size is similar to the Kolmogoroff law for subsonic turbulence, suggesting that the observed motions are all part of a common hierarchy of interstellar turbulent motions. The regions studied are mostly gravitationally bound and in approximate virial equilibrium. However, they cannot have formed by simple gravitational collapse, and it appears likely that molecular clouds and their substructures have been created at least partly by processes of supersonic hydrodynamics. The hierarchy of subcondensations may terminate with objects so small that their internal motions are no longer supersonic; this predicts a minimum protostellar mass of the order of a few tenths of a solar mass. Massive 'protostellar' clumps always have supersonic internal motions and will therefore develop complex internal structures, probably leading to the formation of many pre-stellar condensation nuclei that grow by accretion to produce the final stellar mass spectrum. Molecular clouds must be transient structures, and are probably dispersed after not much more than $10^7$ yr.

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# Previous Surveys – Milky Way

First $^{12}CO$ survey in 1980's: 315 (80) clouds

Dame, Sanders, Solomon, Scoville, and many more …

⇒ spiral structure of molecular gas and HII regions

⇒ overall scaling relations

BU-FCRAO $^{13}CO$ survey in 2000's, 830 (580) clouds

Jackson, Heyer, Rathborne, Roman Duval, and many more …

⇒ variations in cloud mass surface density

⇒ offset in velocity dispersion – size relation

Hampered by crowding and distance ambiguity.

# Previous Surveys – External Galaxies

LMC/SMC: ~275 clouds

Bolatto, Israel, Fukui, Hughes, Mizuno, Muller, Rubio, Wong,…

M31, M33, local group dwarfs, ~250 clouds

Blitz, Bolatto, Engargiola, Leroy, Rosolowsky, Scoville, Wilson,…

N6946, M51,… ~few 100 clouds (ongoing)

Donovan Meyer, Koda, Schinnerer, Hughes,…

⇒ extragal & MW clouds have same scaling relations
deviations in LMC/SMC (fainter and lower vel disp)

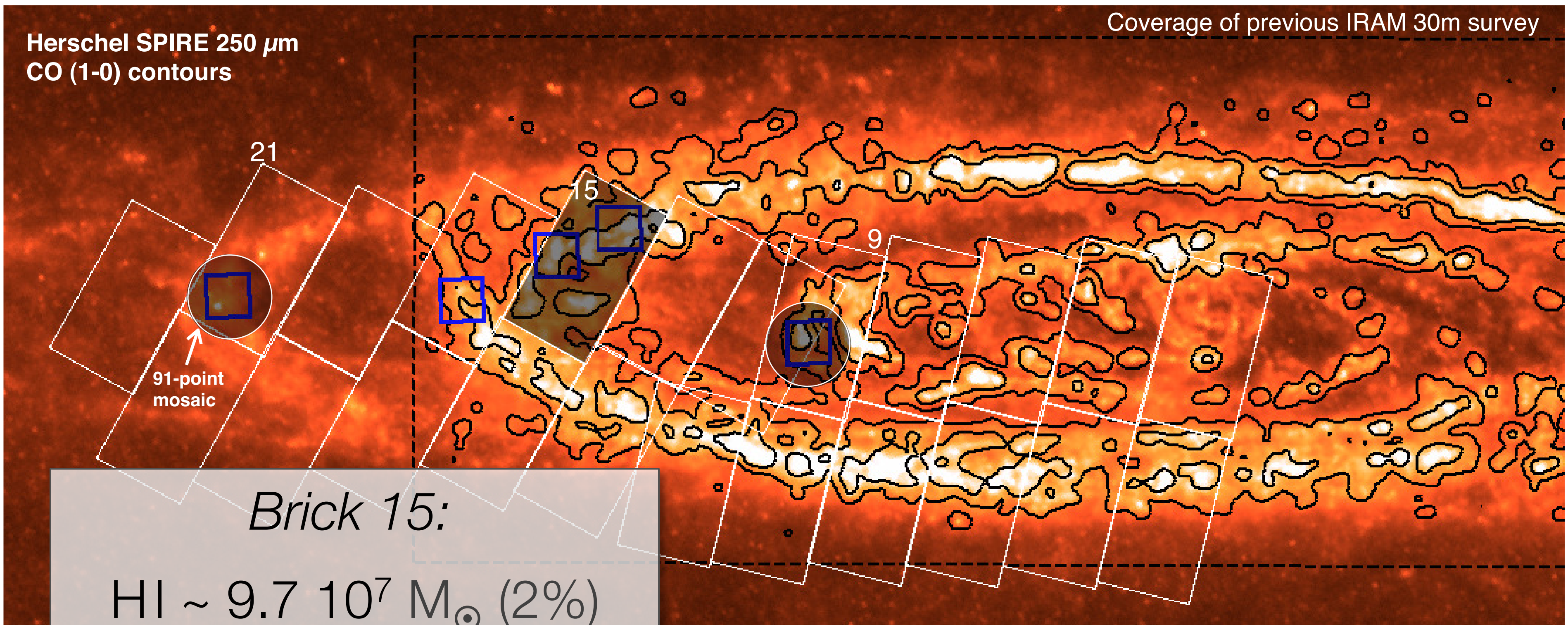
⇒ approx virial equilibrium: fundamental or coincident?

⇒ association w/ young stars suggest time evolution

# Open Questions

- What molecular gas is CO (not) tracing?
- How do molecular clouds form?
- Do clouds share universal properties?
- Are clouds long-lived or transient?
- What sets the star formation efficiency?
- …

# Molecular Gas in Andromeda



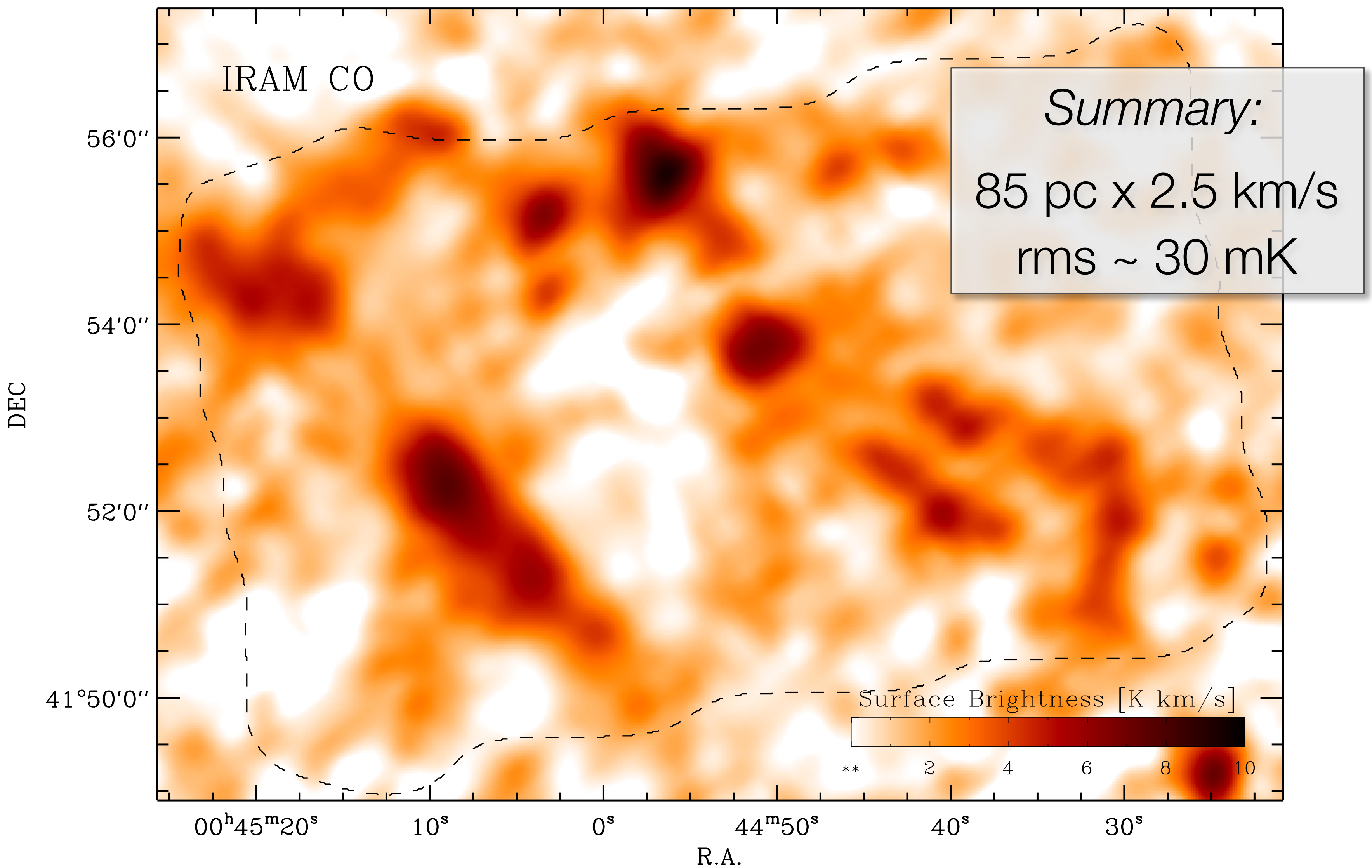

*Brick 15:*

HI ~ 9.7 $10^7$ $M_\odot$ (2%)

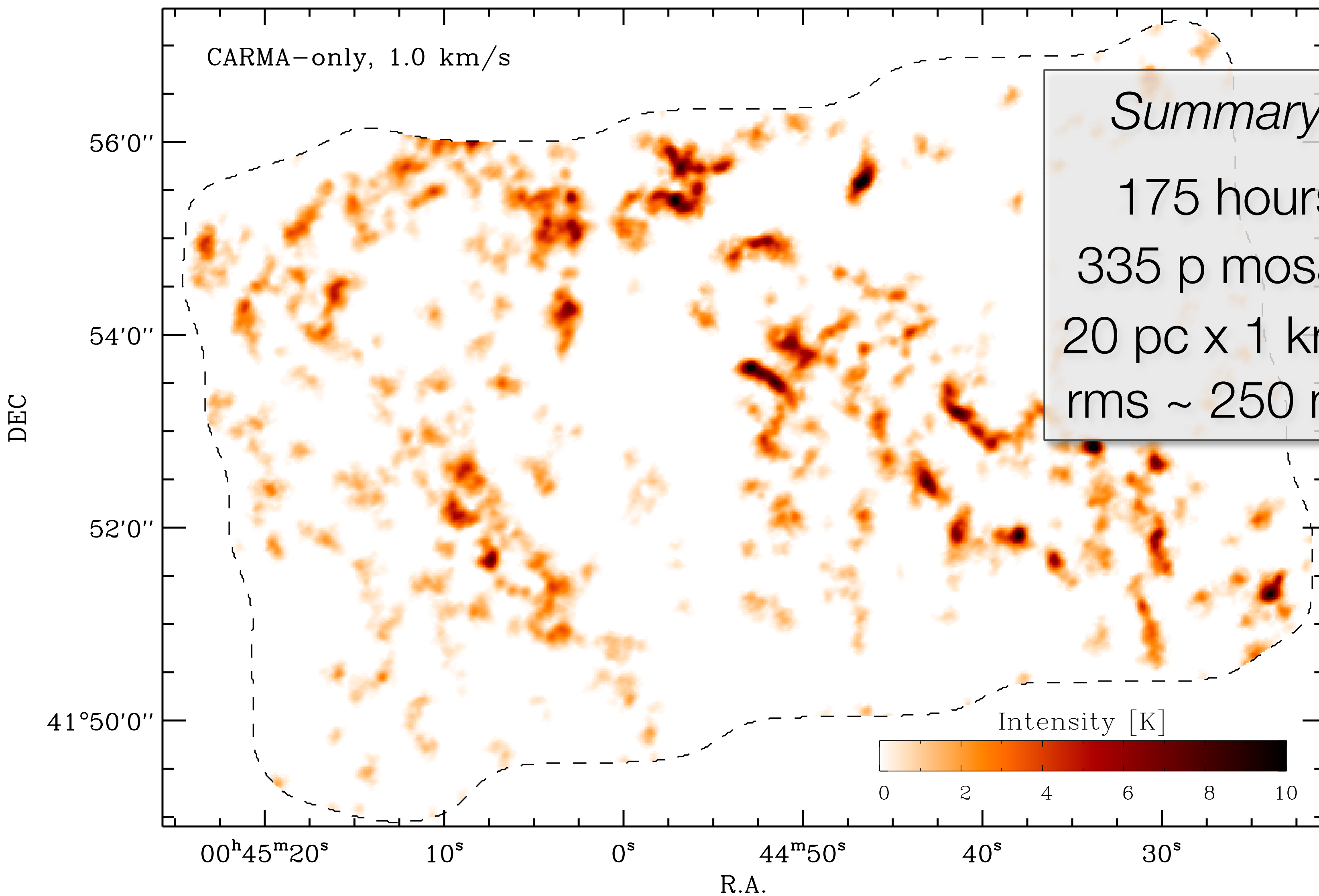
$H_2$ ~ 2.8 $10^7$ $M_\odot$ (6%)

SFR ~ 0.012 $M_\odot yr^{-1}$ (4%)

# CO Map from IRAM 30m



# CO Map from CARMA




*Summary:*

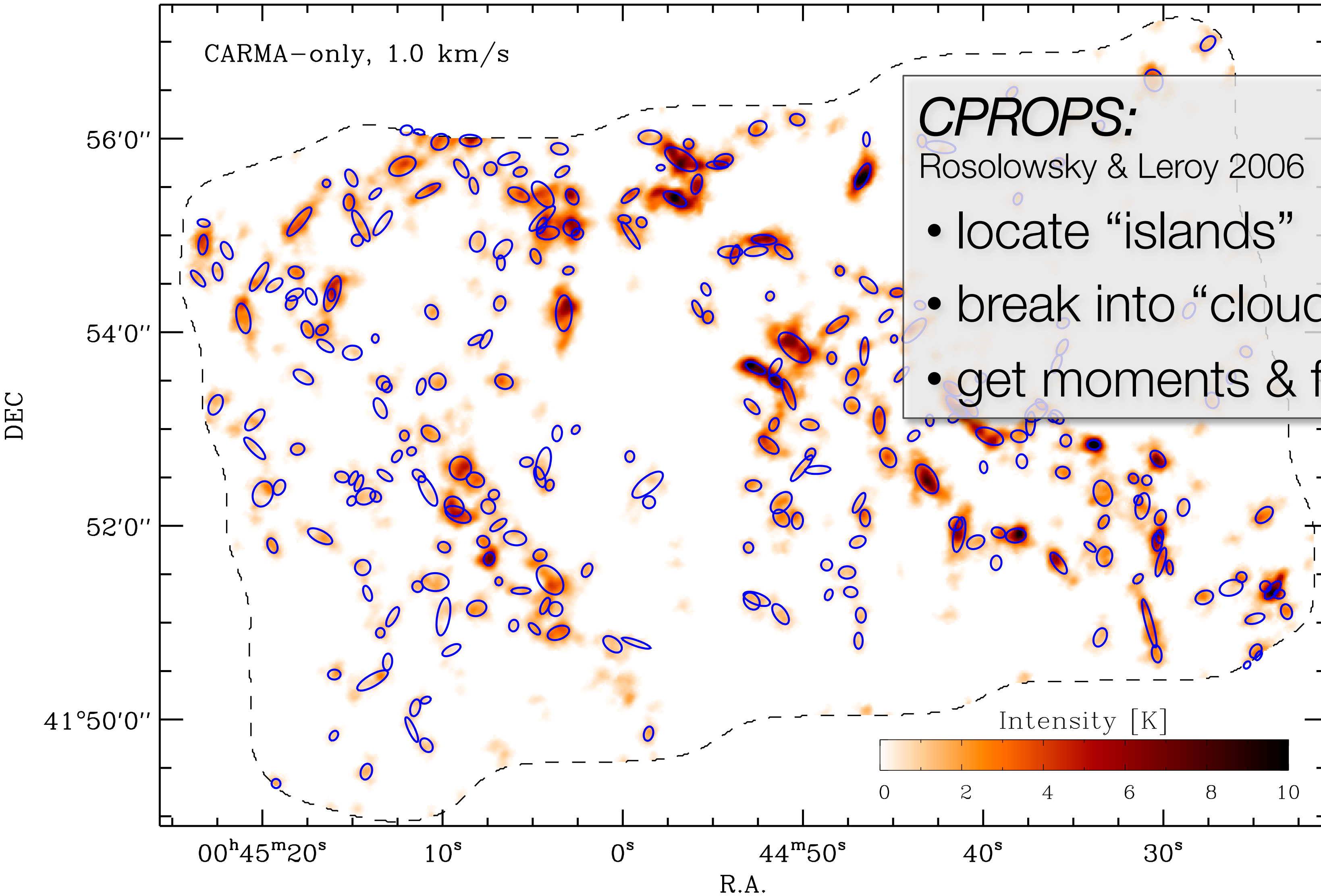
175 hours

335 p mosaic

20 pc x 1 km/s

rms ~ 250 mK

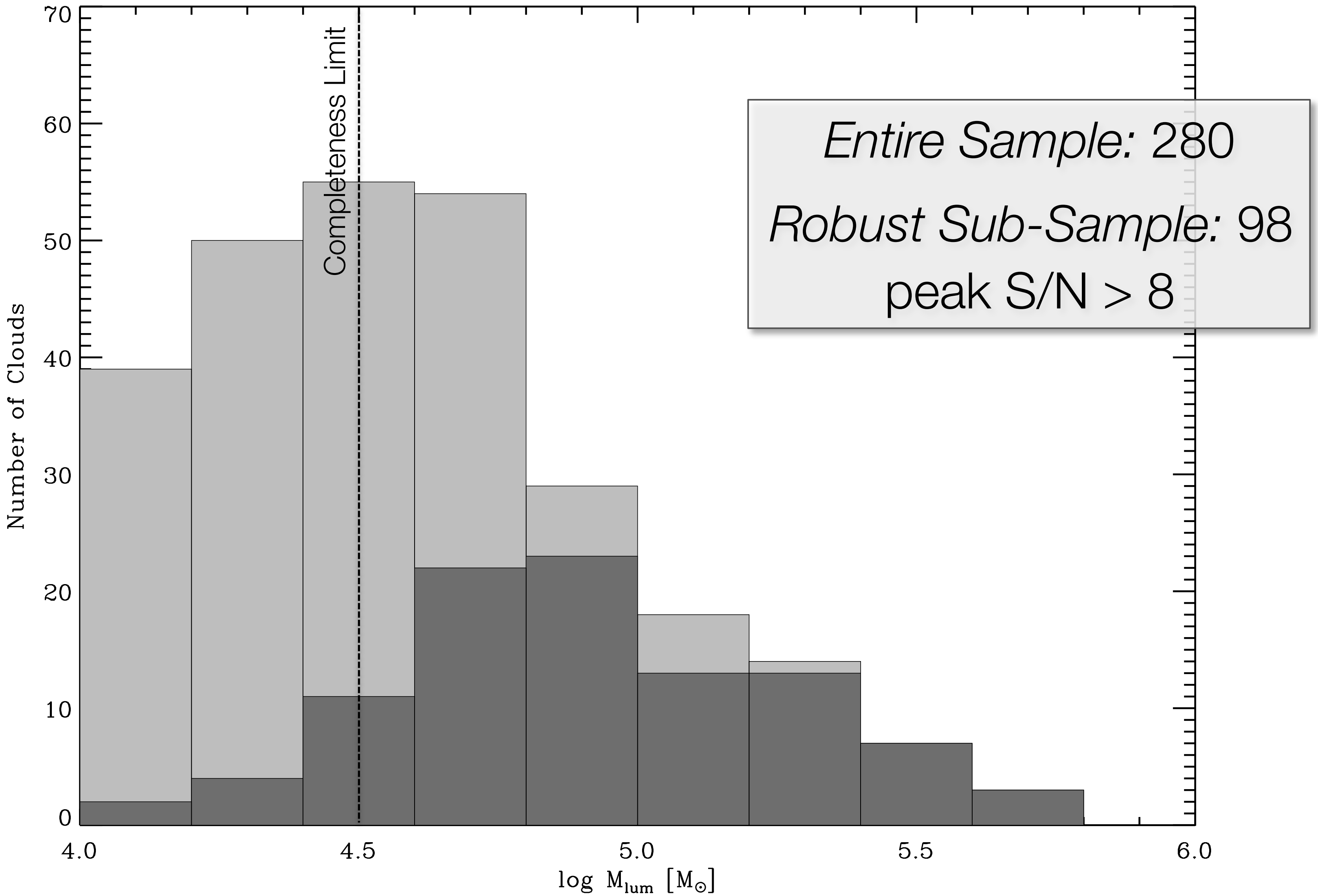
# Cloud Decomposition



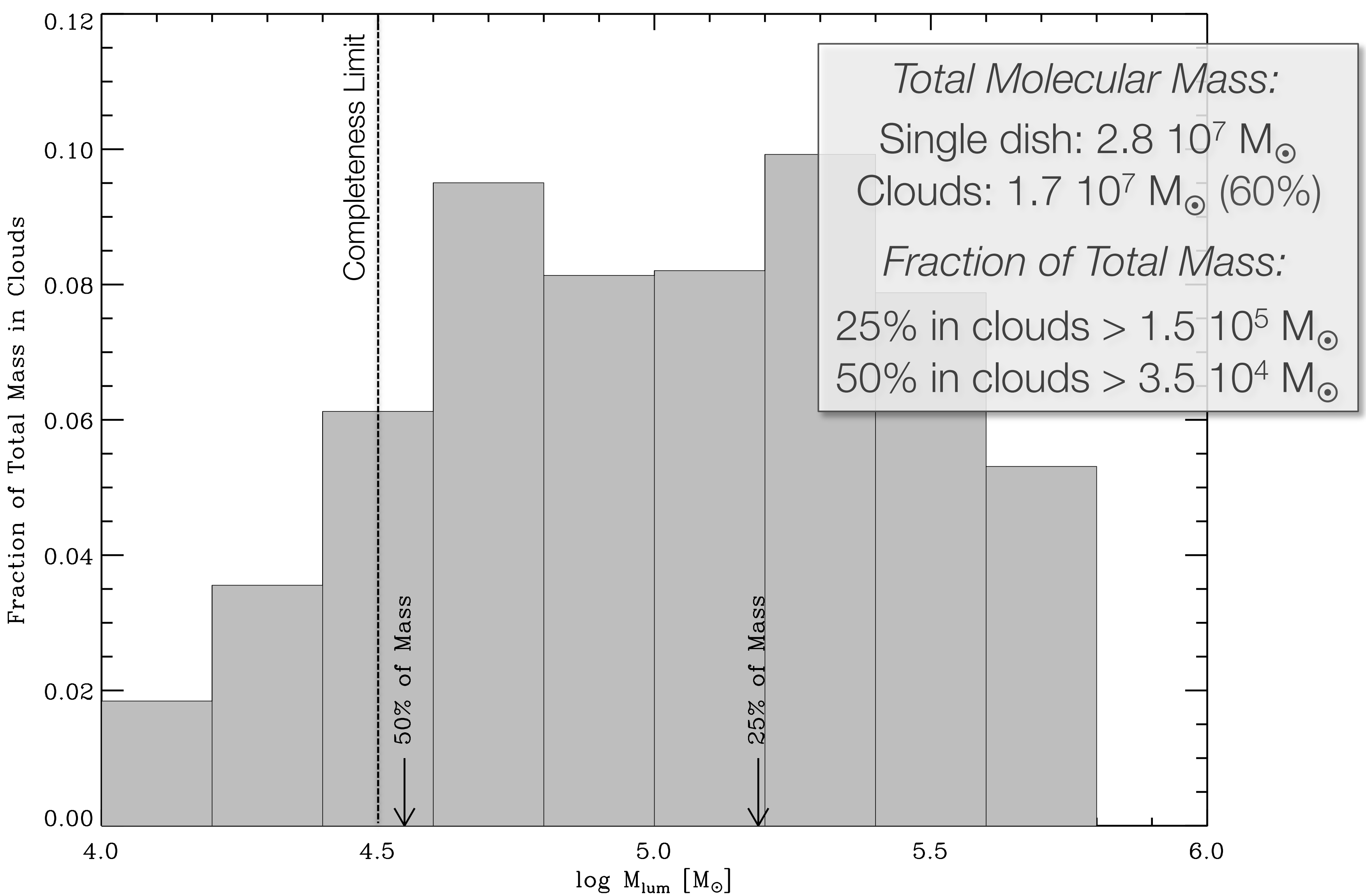

*CPROPS:*
Rosolowsky & Leroy 2006

- locate "islands"
- break into "clouds"
- get moments & flux

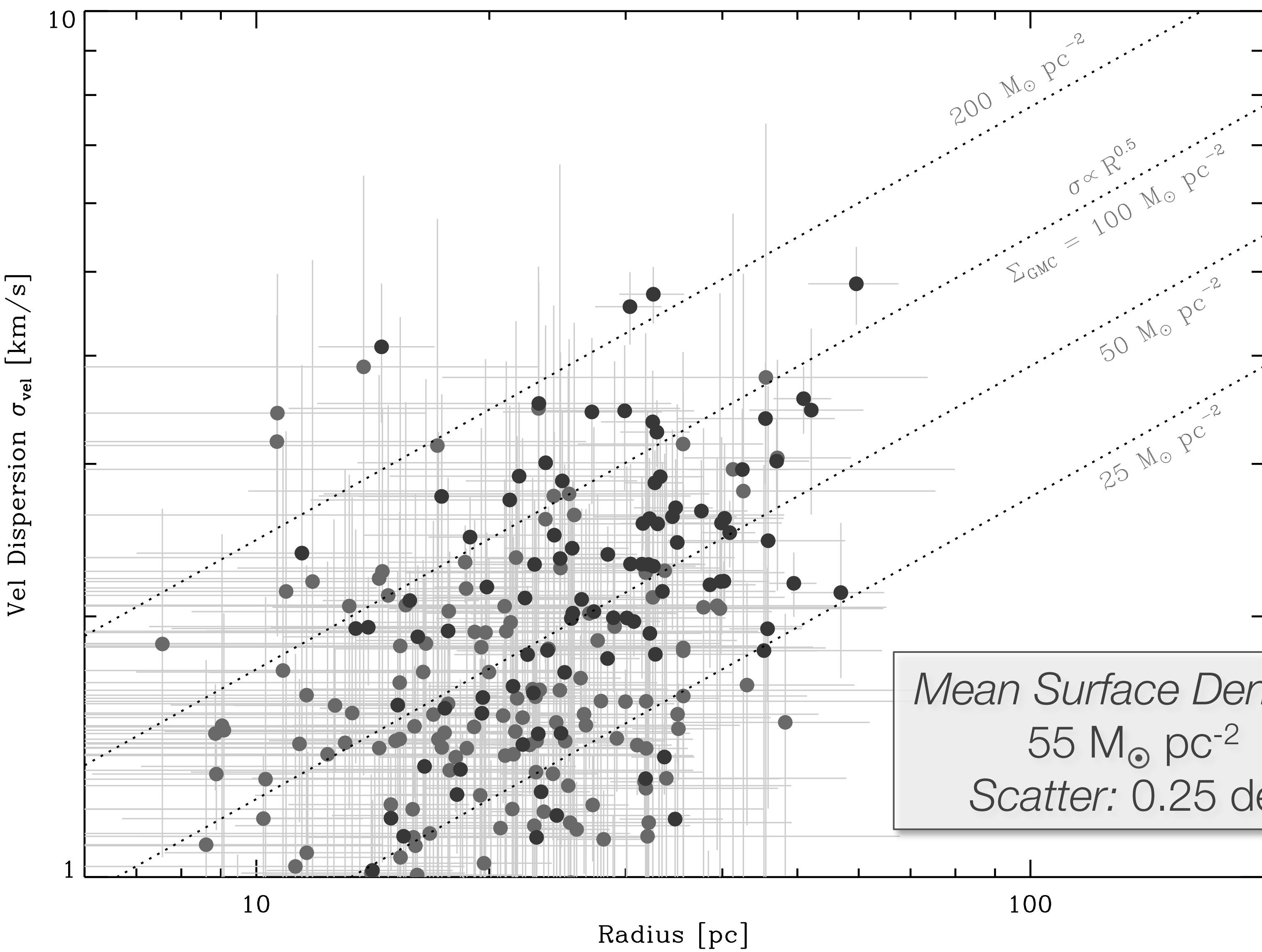
# Number of Clouds



# Masses of Clouds



# Line Width – Size Relation




*Mean Surface Density:*
55 $M_\odot$ pc$^{-2}$
*Scatter:* 0.25 dex

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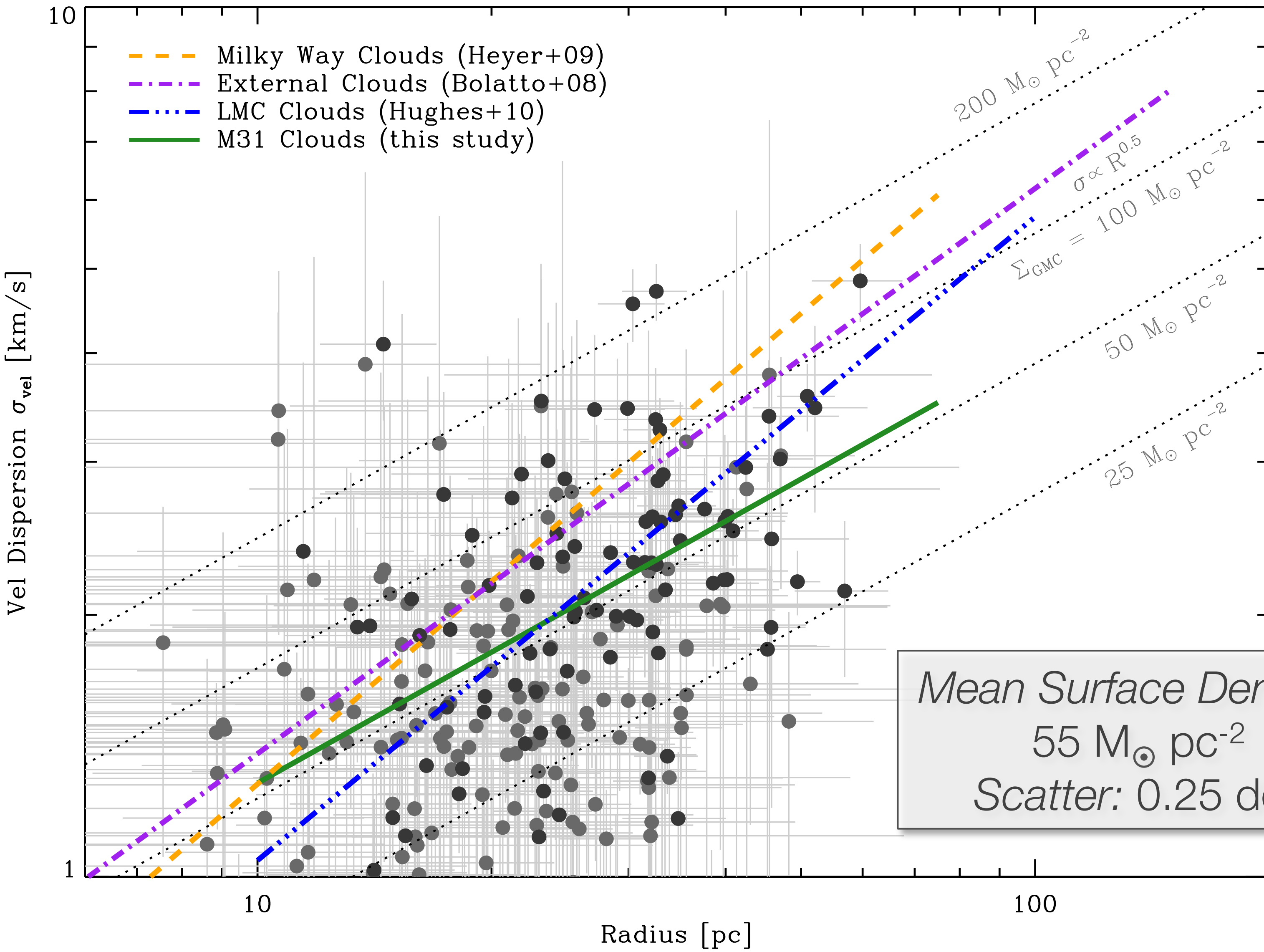


*Mean Surface Density:*
55 $M_\odot$ $pc^{-2}$
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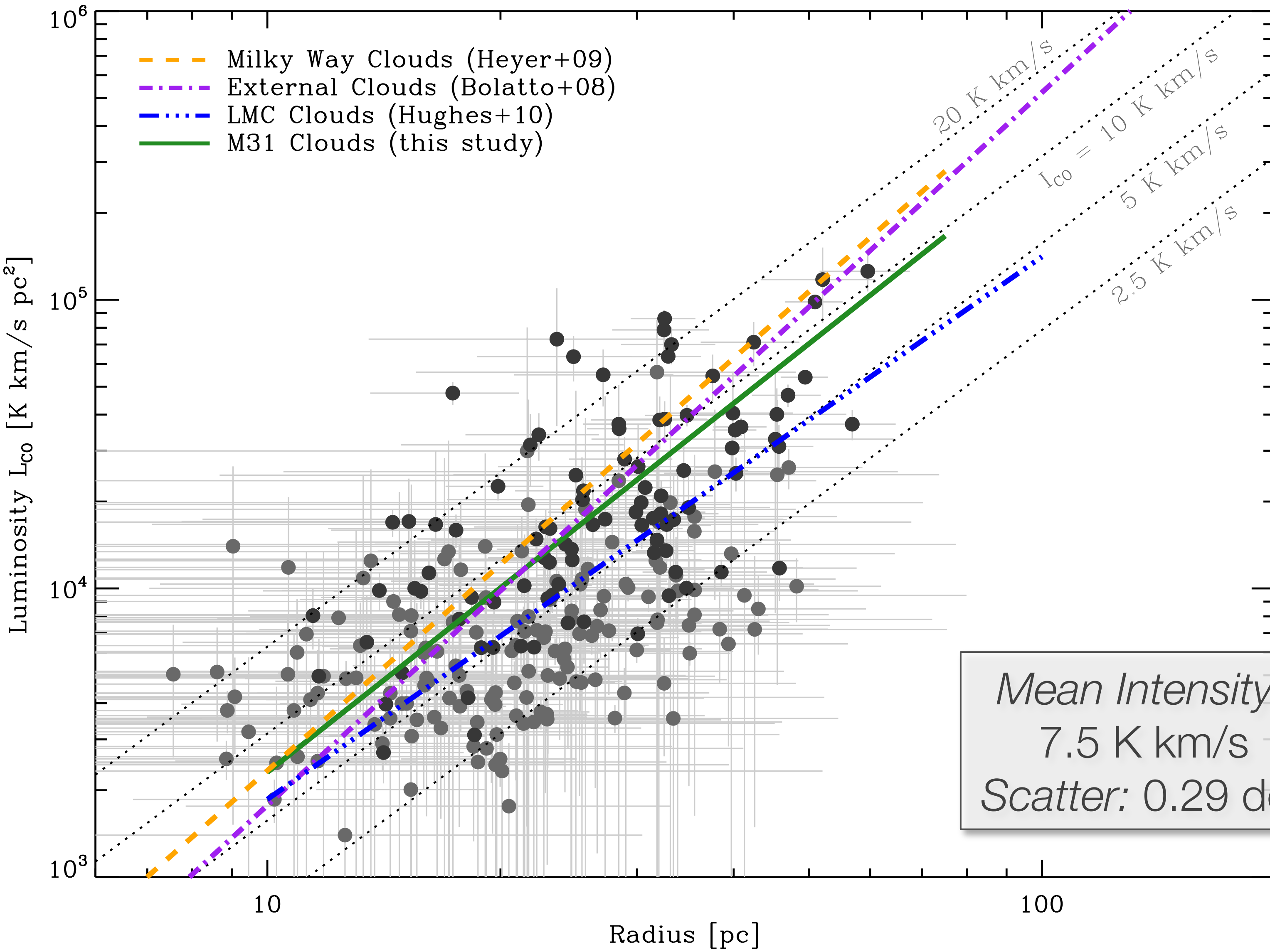
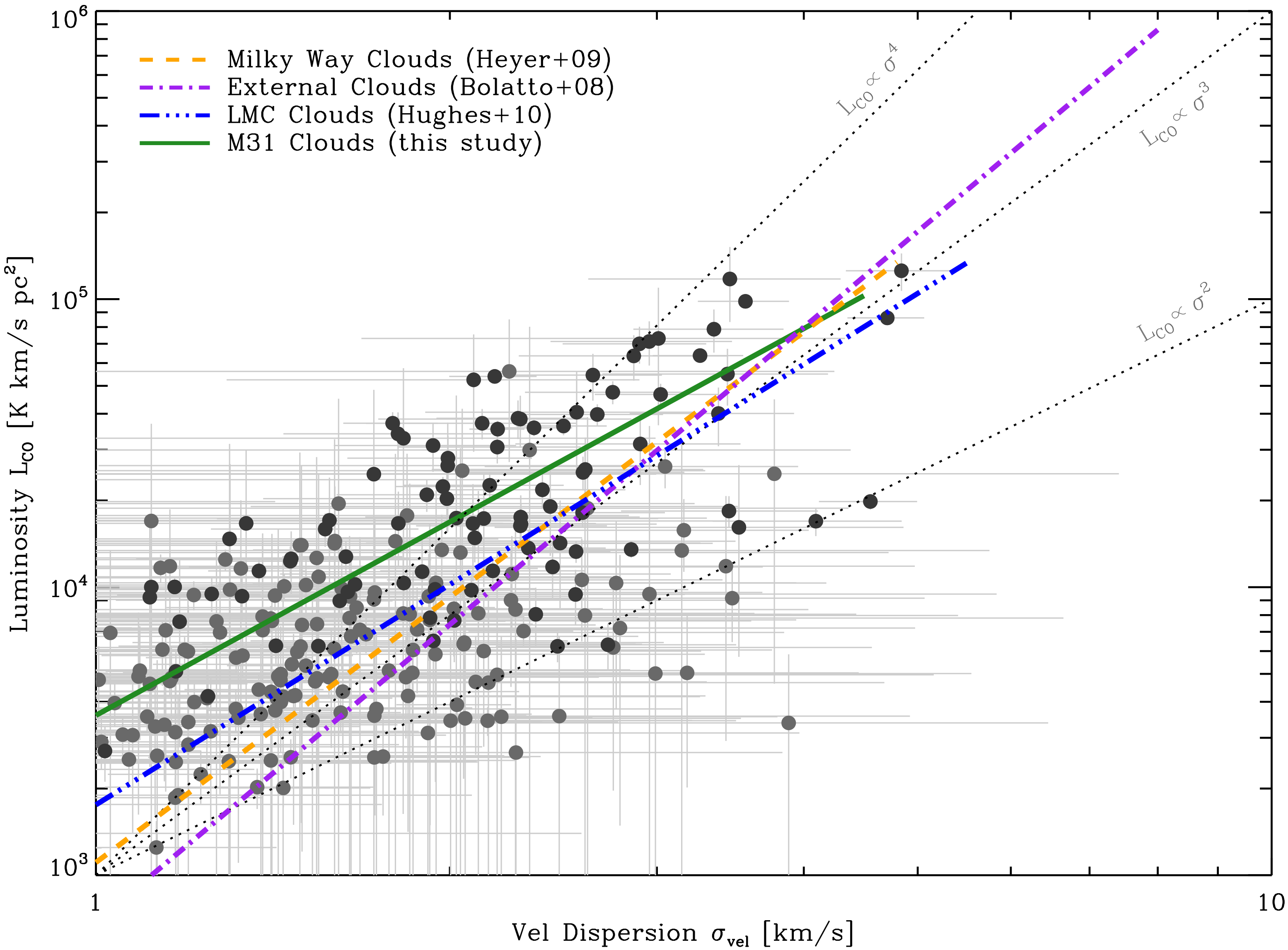
# Luminosity – Size Relation

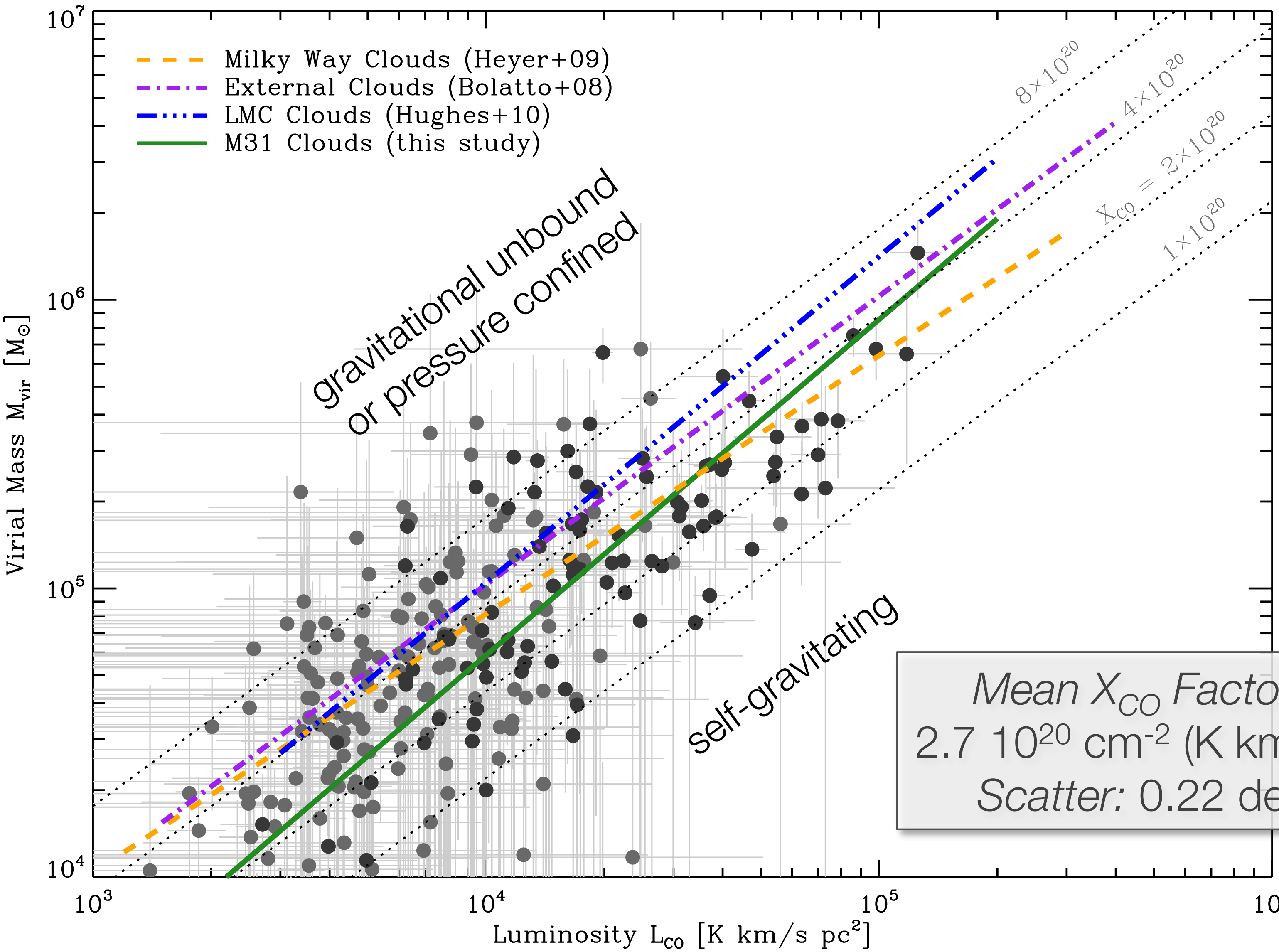



*Mean Intensity:*
7.5 K km/s
*Scatter:* 0.29 dex

# Luminosity – Line Width Relation

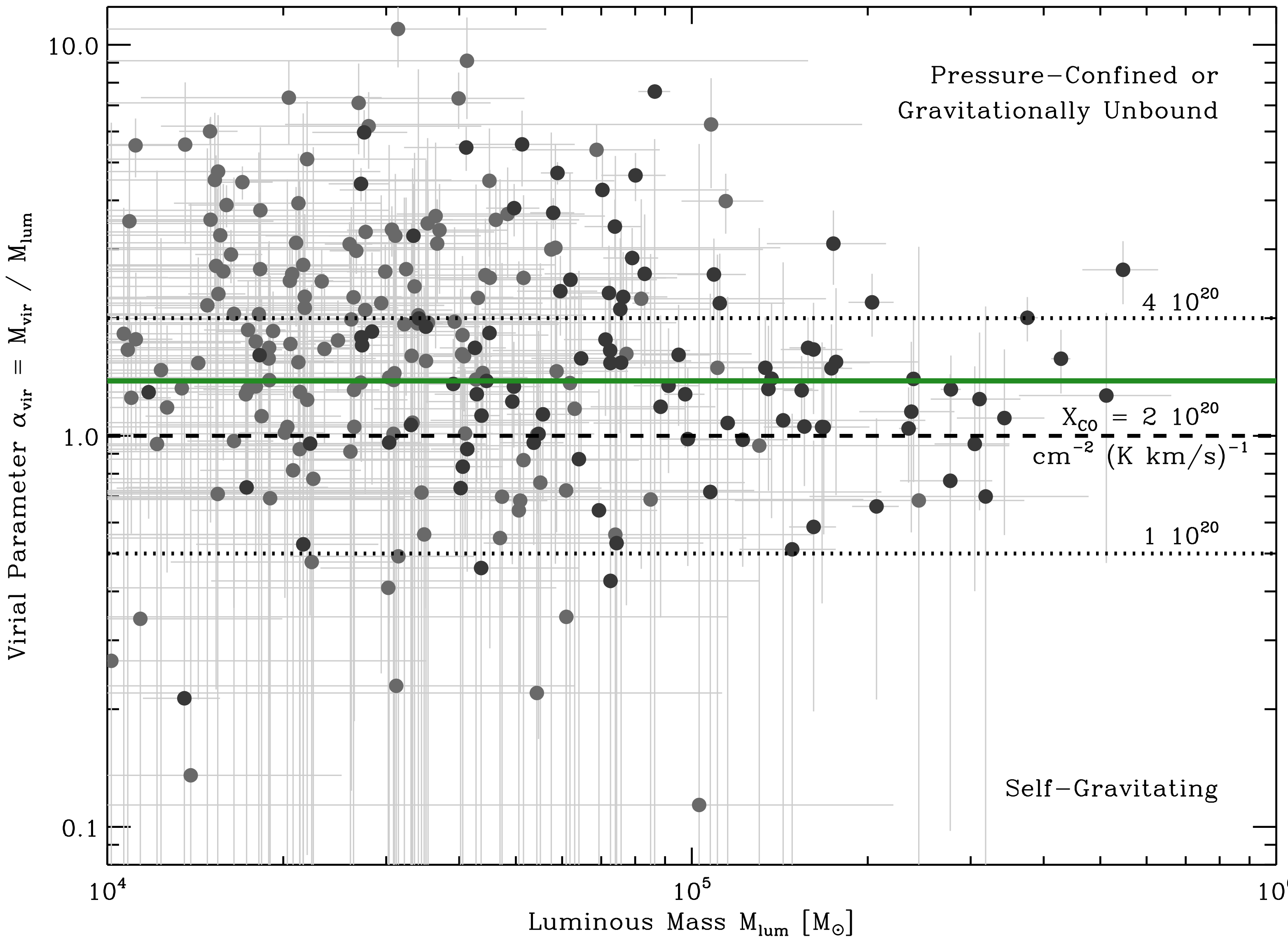


# Virial – Luminous Mass Relation

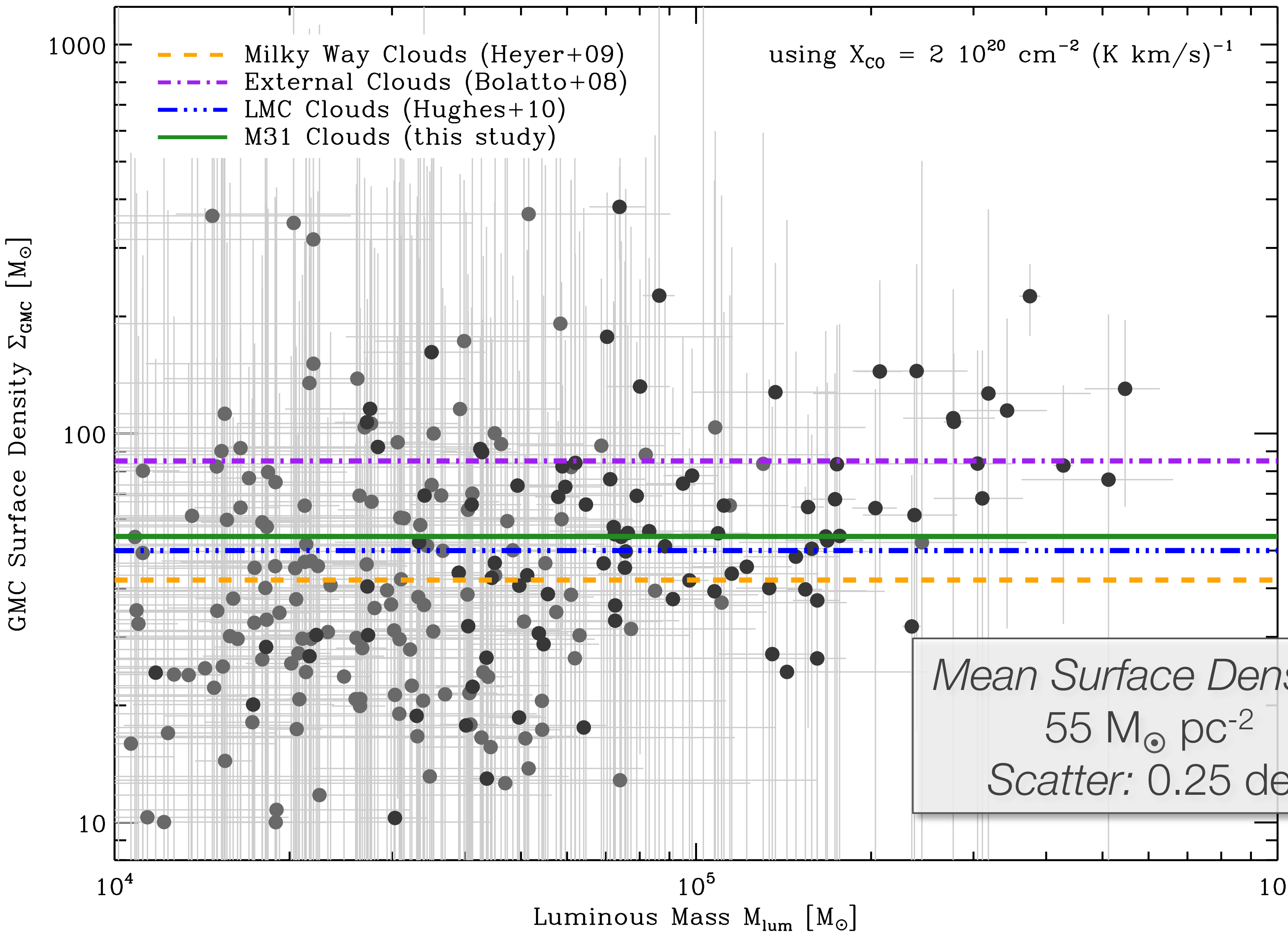



*Mean $X_{CO}$ Factor:*
2.7 $10^{20}$ $cm^{-2}$ $(K\ km/s)^{-1}$
*Scatter:* 0.22 dex

# Virial Parameter



# Cloud Surface Density

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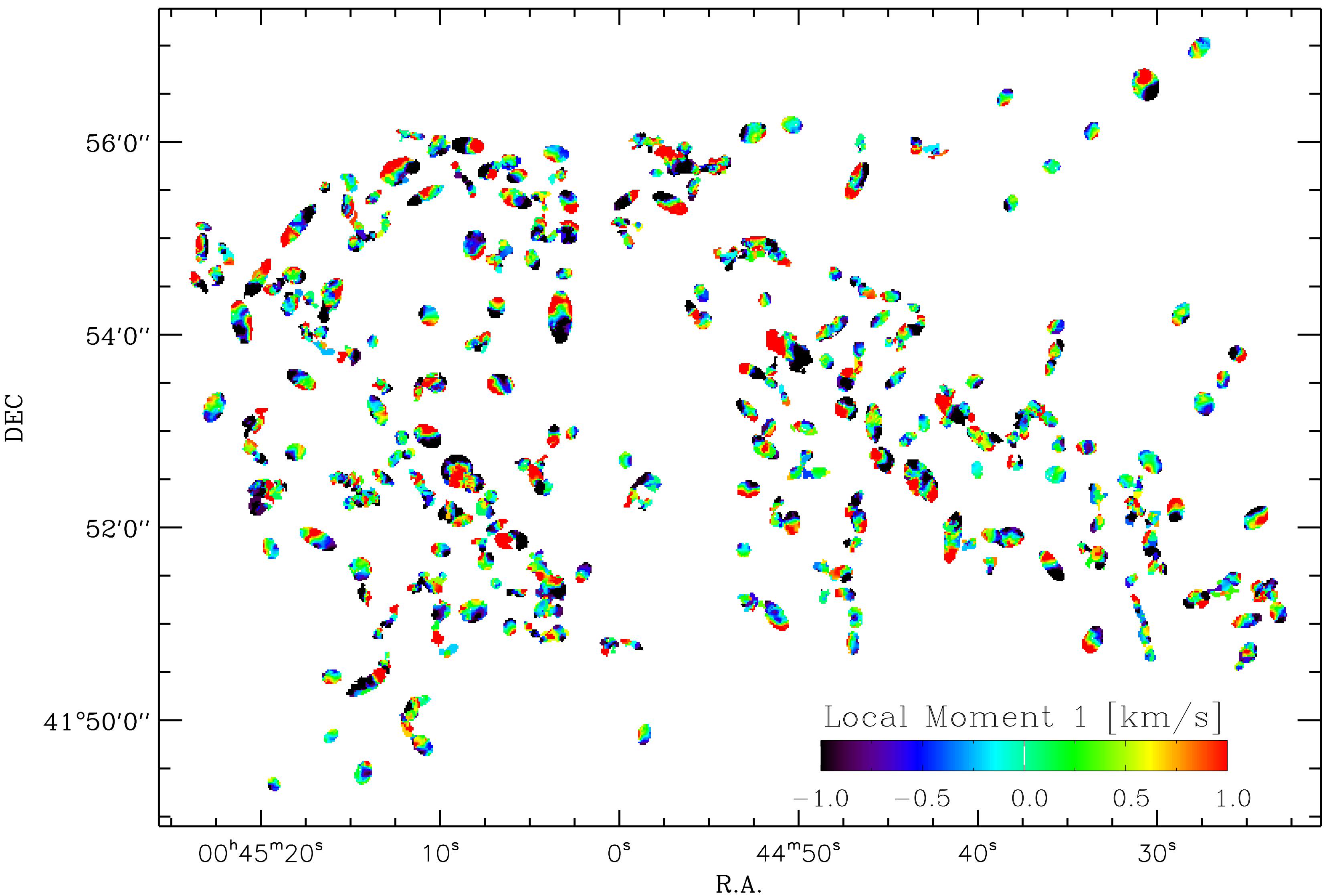
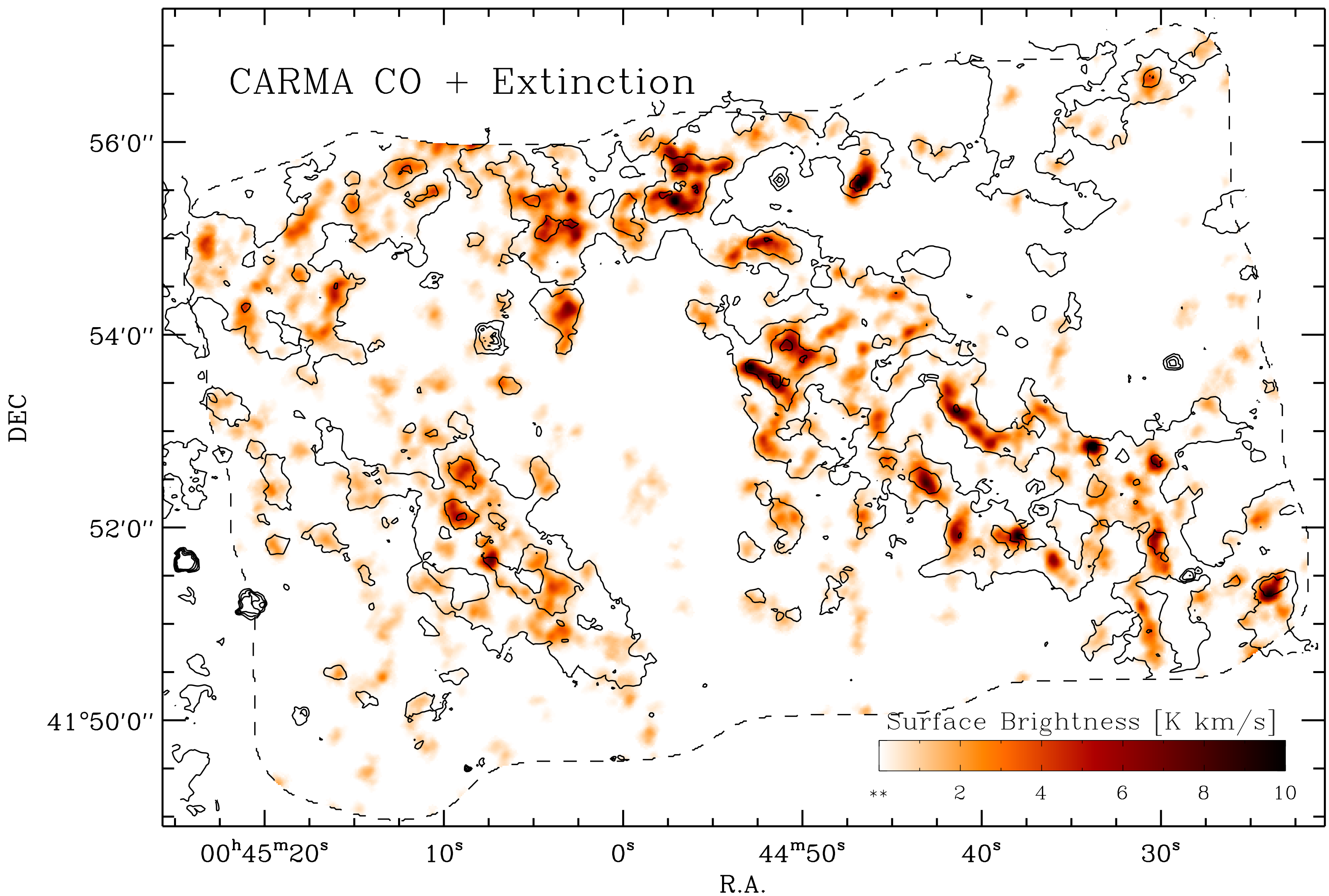
# Summary: Cloud Properties of M31

- "flat" cloud mass distribution
  - 50% of *all* mass in clouds with $M \geq 3.5\ 10^4\ M_\odot$
- Overall "similarity" of scaling relations
  - lower vel. dispersion and lower surface density
  - low dispersion clearly in data but "typical"?
- Factor 2 scatter in most scaling relations
  - measurement uncertainties or cloud evolution?
  - environmental dependence?

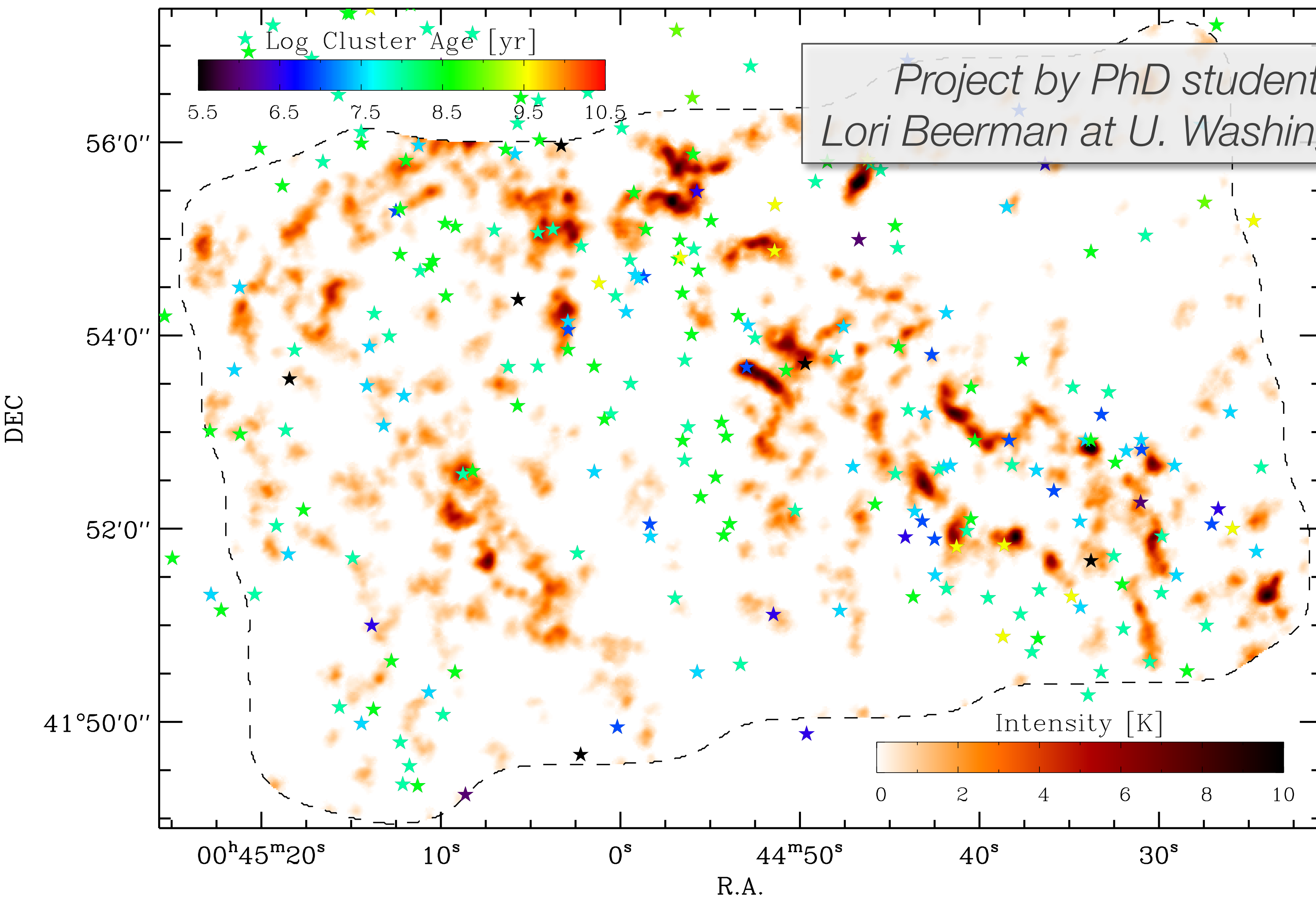
# Prospects: Cloud Dynamics



# Prospects: PHAT Extinction Map



# Prospects: PHAT Cluster Catalog




*Project by PhD student*
*Lori Beerman at U. Washington*

# Prospects: Even More …

- Further CARMA CO maps
- High density tracer observations
- Cloud dynamics: How do cloud form/grow?
- Cloud formation/chemistry: CO, extinction
- Star formation efficiency
- Feedback & cloud life time: stellar catalogs
- ISM Heating & Cooling: stellar catalogs and IR & [CII] cooling

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