Topics of Discussion

- **GMC Lifecycle?**
  - Lifetime of GMCs?
  - Environmental dependence?

- **Paradigm of GMCs?**
  - GMC identification in obs. and in sim.
  - Diffuse CO emitting gas?
  - Paradigm of GMCs? – bound? Just part of continuous power-spec?

- **ALMA perspective**
  - What can we do with ALMA?
  - Sensitivity, resolution, and *uv-coverage*

TOPIC 1: GMC LIFECYCLE?

GMC LIFETIME?

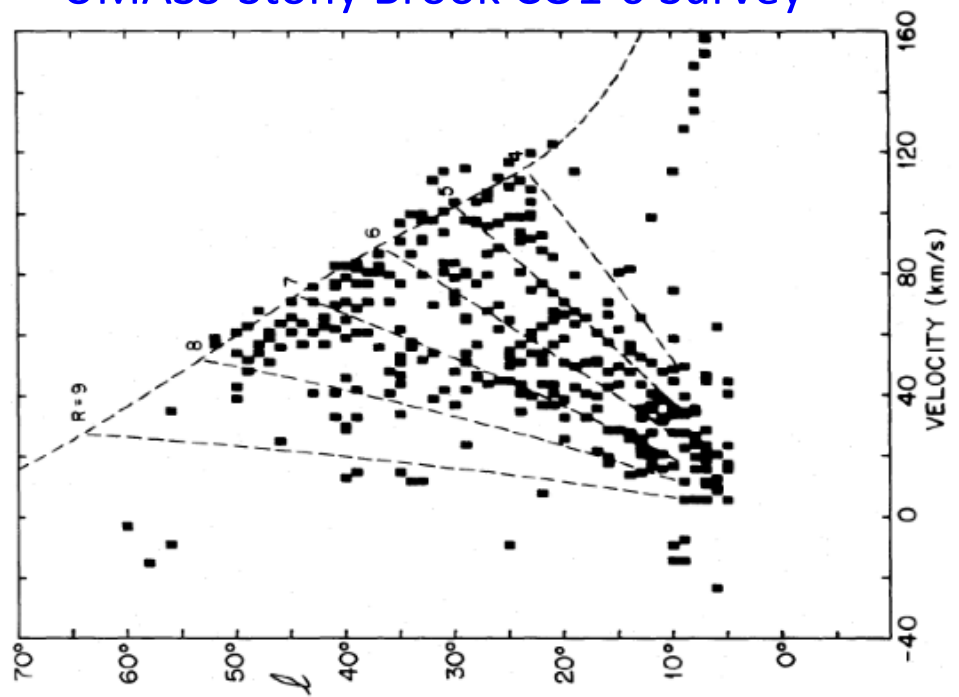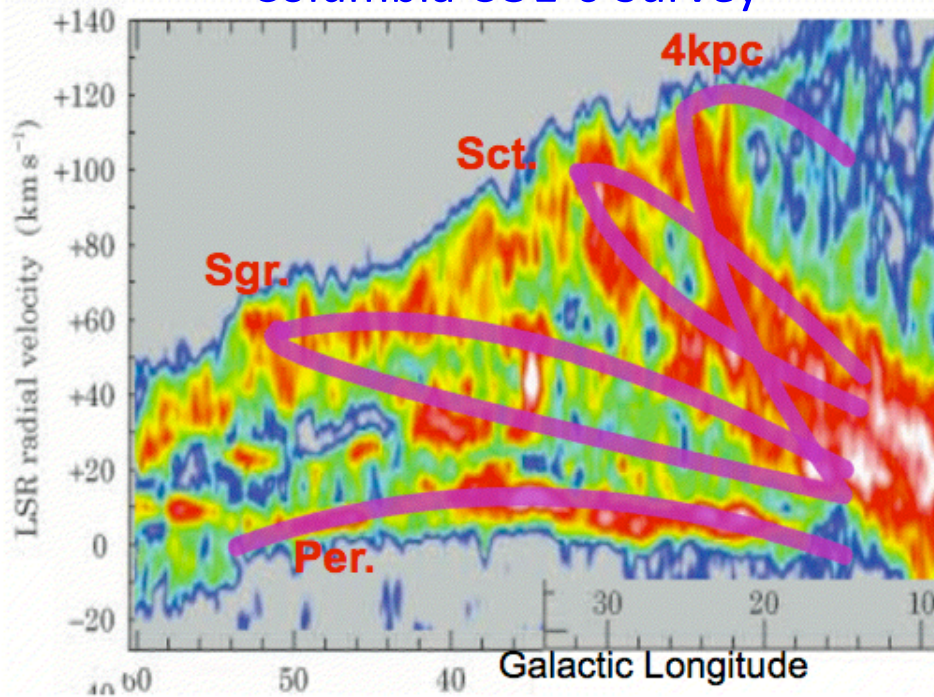## ENVIRONMENTAL EFFECTS?

GMC Lifetime: Long? or Short?

Galactic rotation timescale ~200-300 Myr – very long compared to timescales within GMCs (e.g., star formation, turbulence decay)

Columbia CO1-0 Survey

UMASS-Stony Brook CO1-0 Survey

No GMCs in interarm regions

GMC lifetime
~ Arm crossing time
~20-30Myr?

Cohen et al. 1980; Dame et al. 2001

GMCs exist in interarm regions

GMC lifetime
~ Galactic rotation time
~200-300Myr?

Sanders, Scoville & Solomon 1985; Solomon & Rivolo 1989

GMC Distribution

Molecule-rich

M51

Koda et al. 2009

MW

Koda et al. 2006

M33 - GMC on HI

Atom-rich

CO on HI

Engargiola et al. 2003
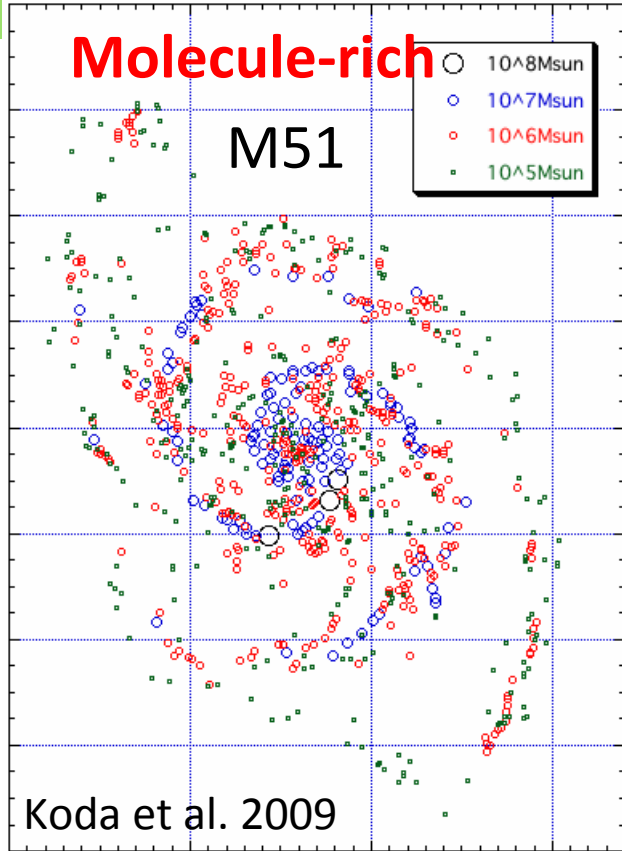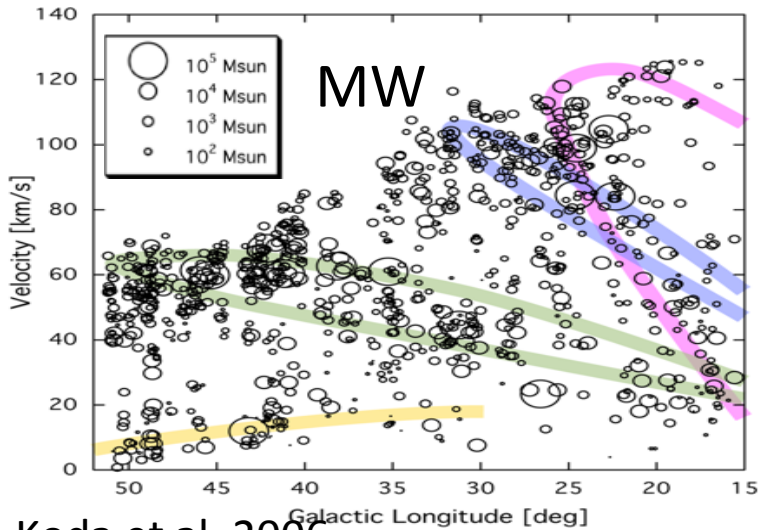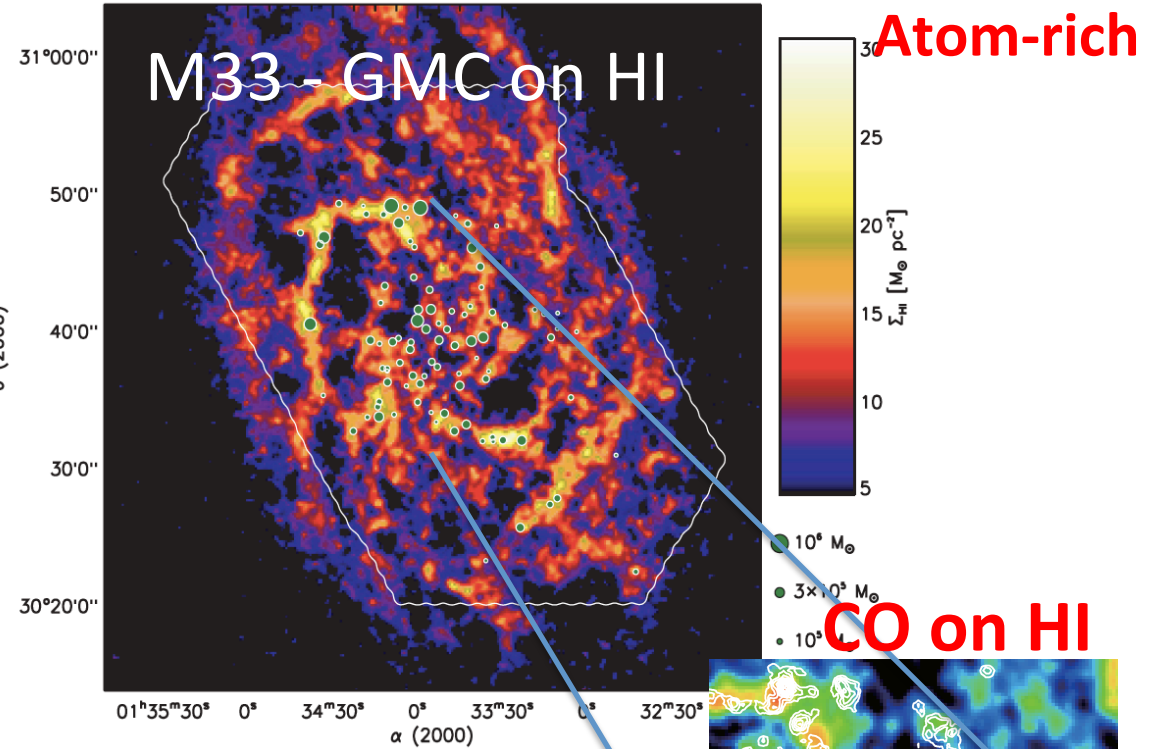
Center more like
M51 & MW.

Tosaki et al. 2011

Environmental Dependences?

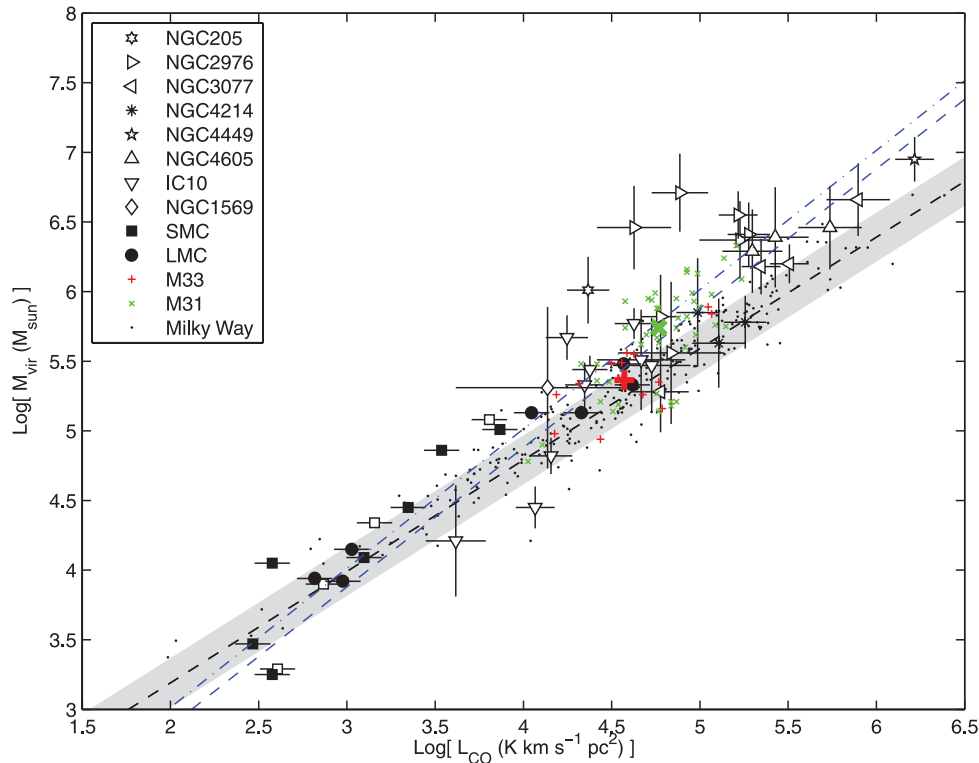Comparison in size

Molecule-rich

Atom-rich

MW

M51

M33

LMC
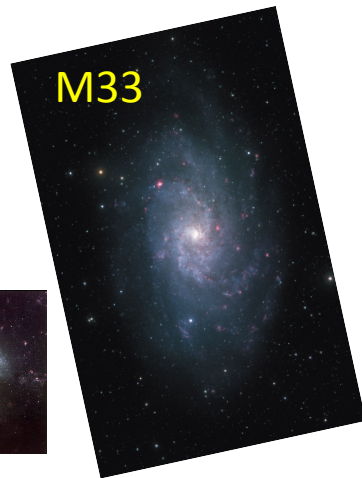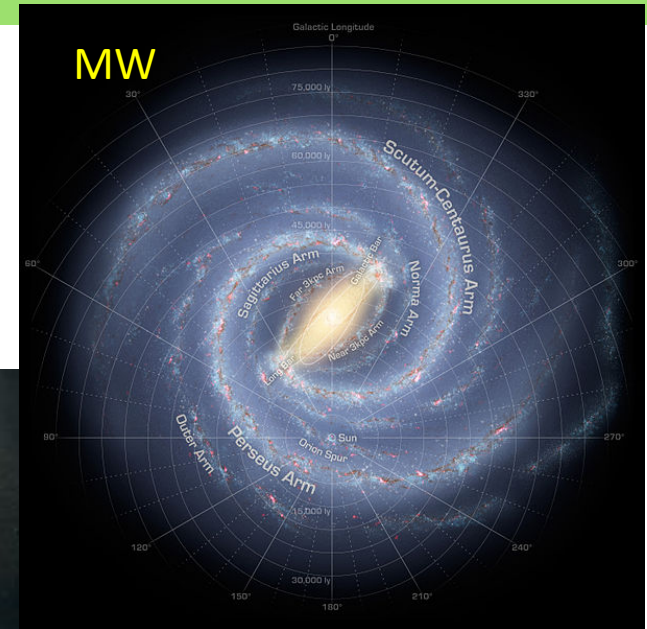
Almost any parameter
e.g., gas phase & density, metallicity, stellar component, radiation field ...
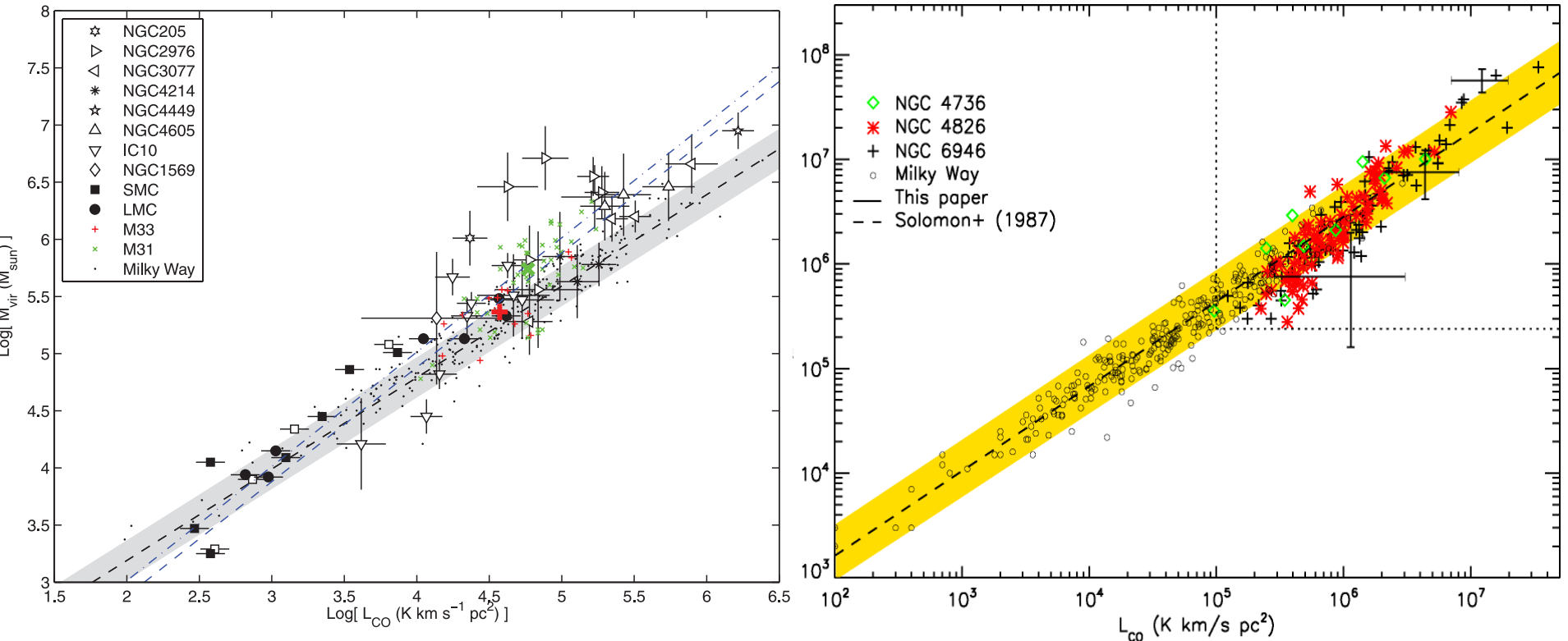
What's most important?

Similar GMC Properties

Dwarfs (atom-rich)

Bolatto et al. 2008
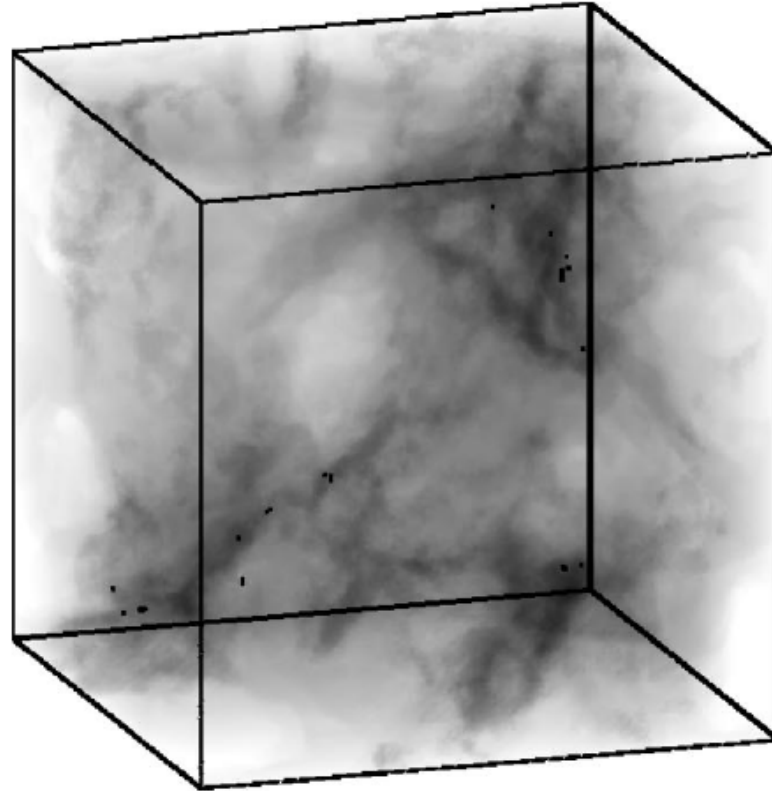
Disks (molecule-rich)

Donovan Meyer et al. (2013)

Current limitation: resolution ~ GMC size.

Similar in very different environments – how can they be?

Difference between arm and interarm GMCs in M51?

Supersonic Turbulence

Mac Low & Klessen 2004

Rapid decay within crossing time (~2-3Myr)

Supersonic turbulence drive/regulate SF
Difficult to maintain turbulence without continuous E input.

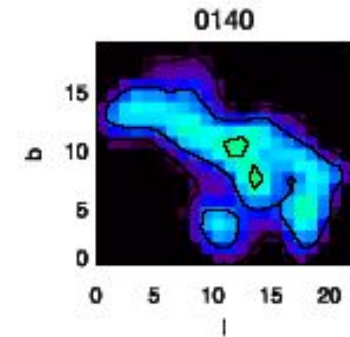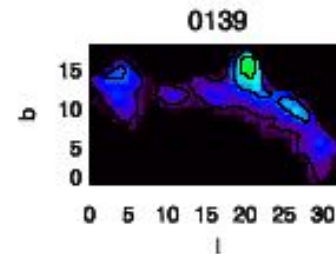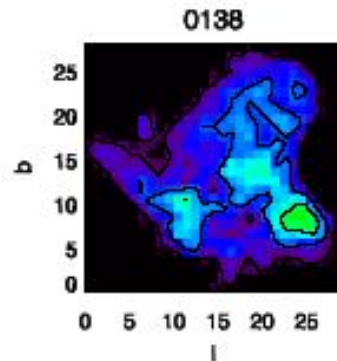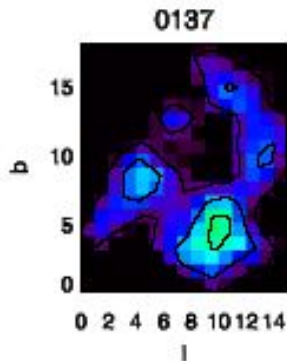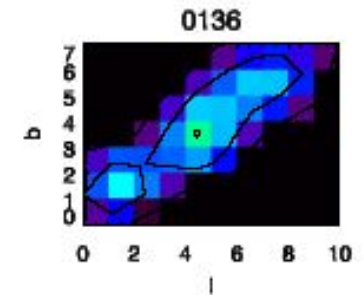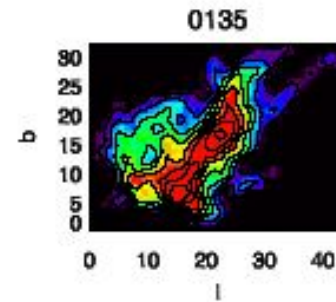# TOPIC 2: GMC PARADIGM?

GMC PARADIGM?

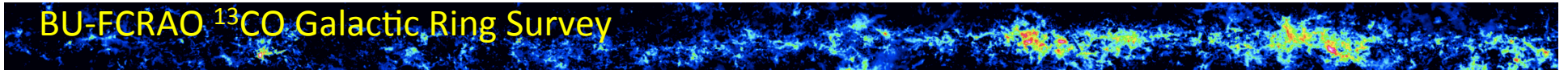## DIFFUSE CO EMISSION?

Paradigm of GMC?

- 13CO GMC Examples
  – Emission peak down to closed surface above $T_{mb}=2K$
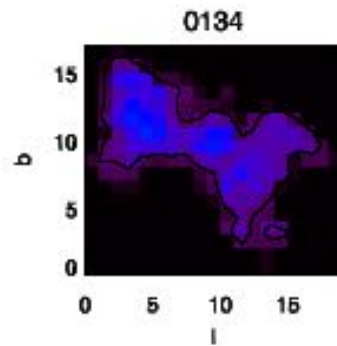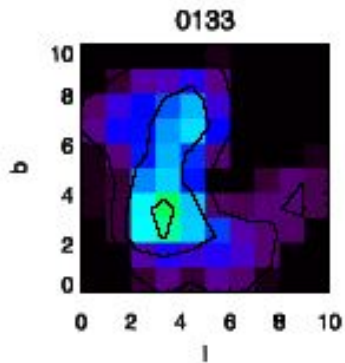
Koda et al. 2006

Paradigm of GMC?

Nobeyama 45m CO(1-0) Channel maps of MW (l~38 deg)
50 arcmin x 50 arcmin, 15" resolution (<0.7pc)

Interarm   Spiral arm   Interarm

40pc or 130pc   90pc
Clumpy in spiral arms   Sawada et al. 2012
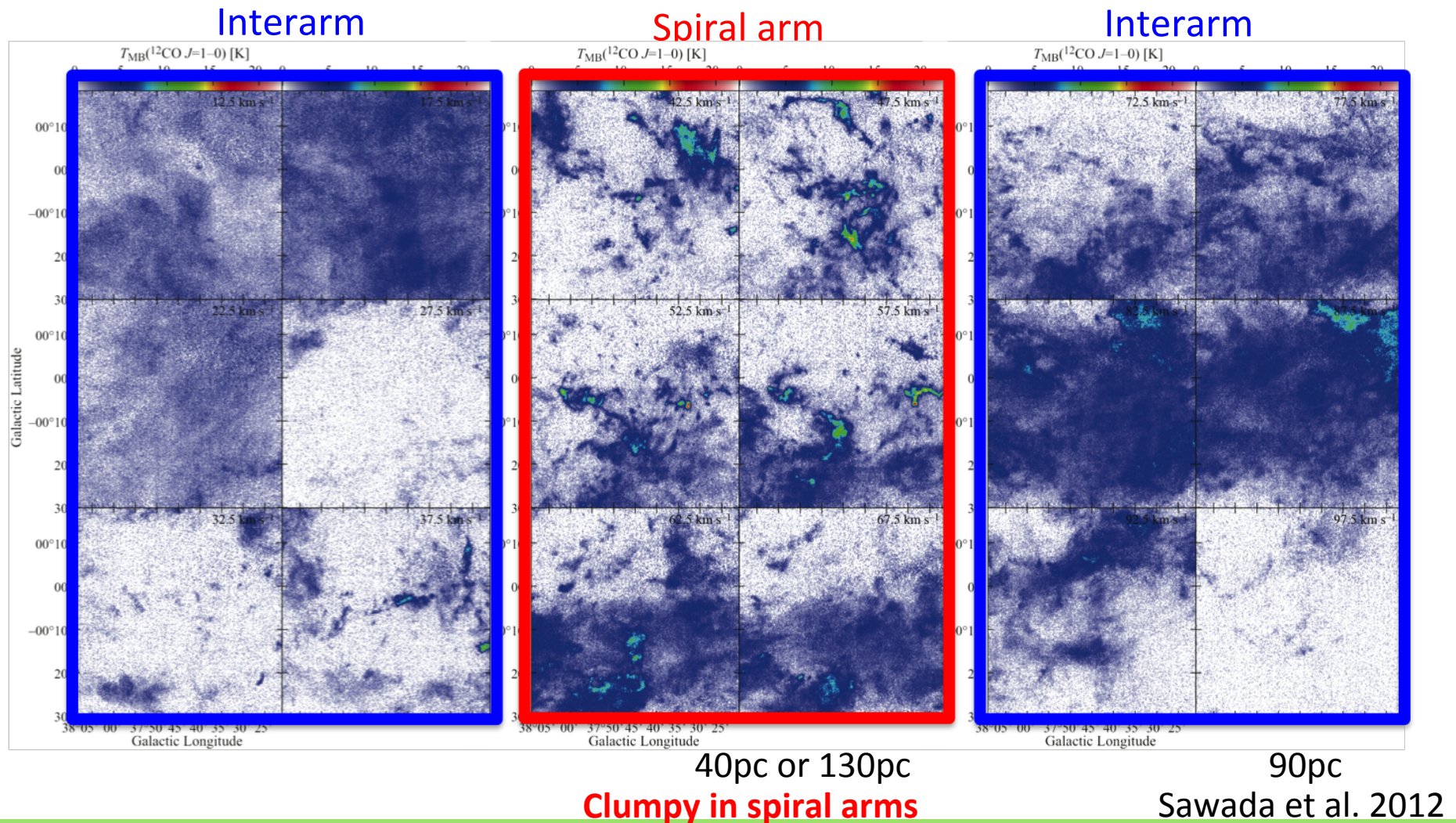
Structural Evolution Across Spiral Arms

Brightness Distribution Index
~ bright/ faint 13CO emission

$$BDI = \log_{10}\left(\frac{\int_{T_2}^{T_3} T \cdot B(T)dT}{\int_{T_0}^{T_1} T \cdot B(T)dT}\right)$$
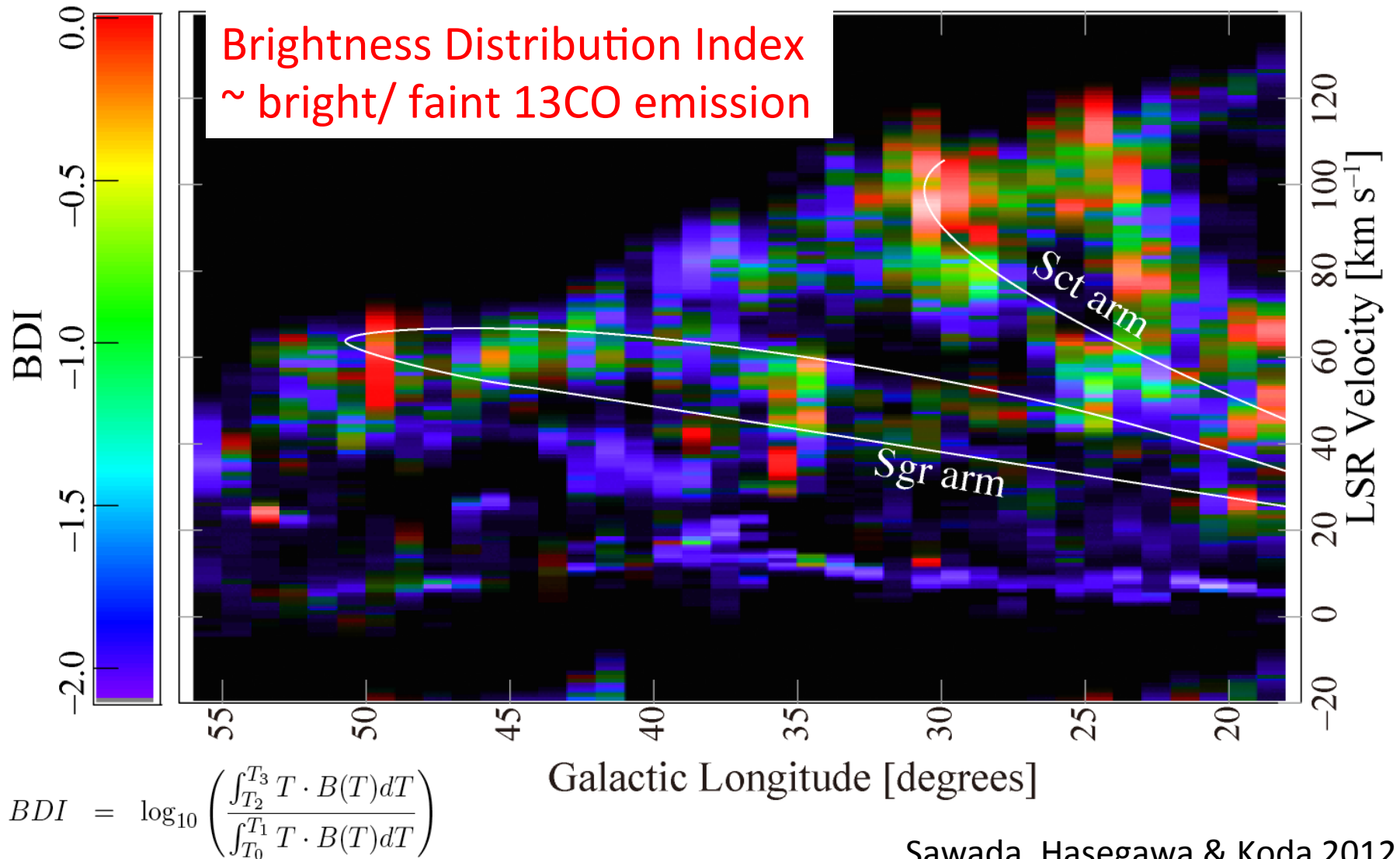
Sawada, Hasegawa & Koda 2012
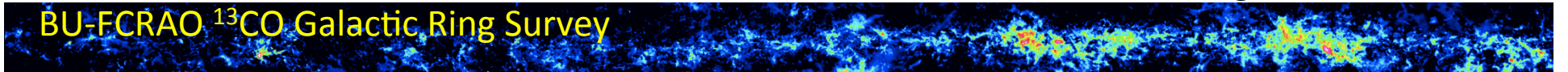
Diffuse CO? – Outside GMCs?

- New PdBI CO(1-0) map of M51
  - Resolution ~40pc
  - Sensitivity ~10^5 M$_{sun}$

Unresolved emission ~50%
  - Dynamically-hot extra-planar gas
  - Diffuse CO emitting gas?

mm-interferometer (~ 40pc)

500 pc
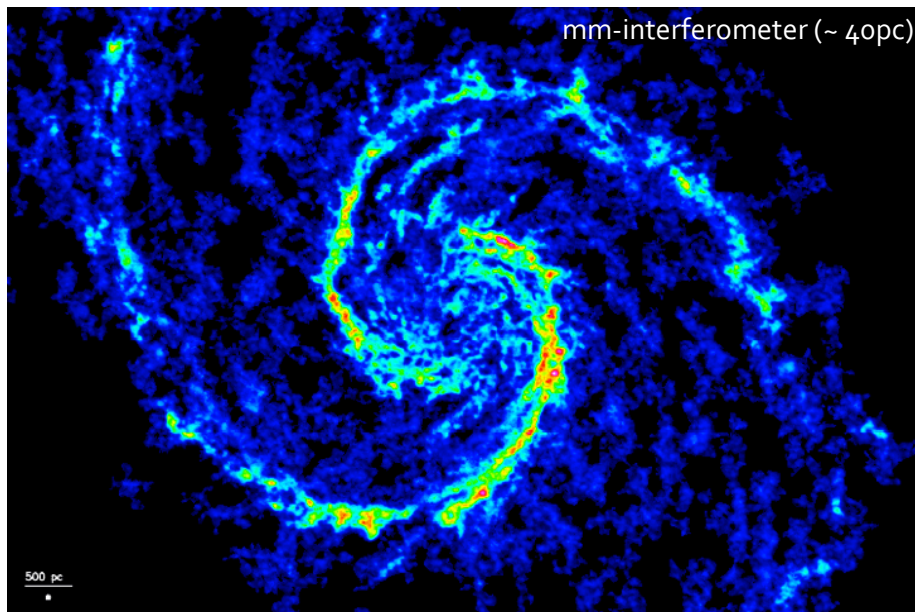
Schinnerer et al. 2013

Rest Frequency (MHz)

Stacked 30m spectrum

Brightness (K[T$_{mb}$])

Residuals (K[T$_{mb}$])

Velocity (km/s)
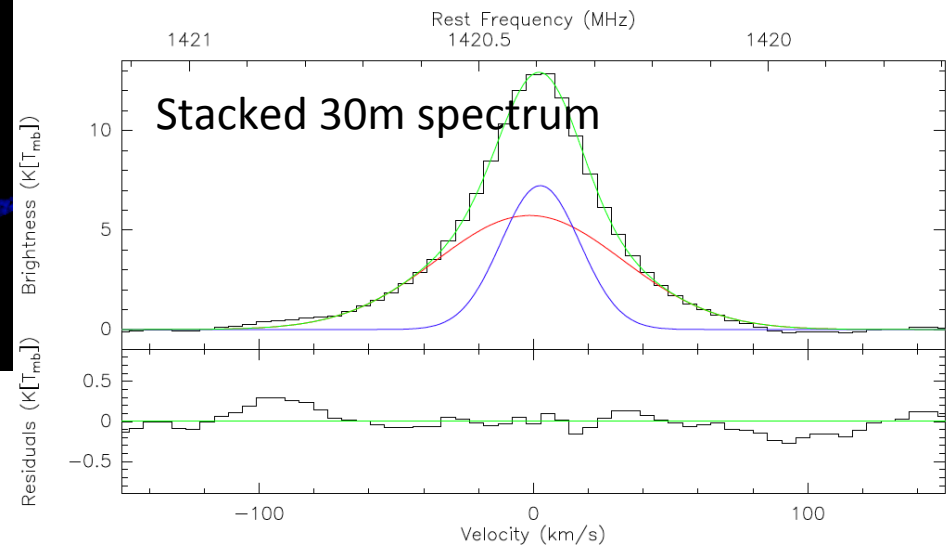
Pety et al. 2013

Basics

- ## Survival of CO

  - ### Balance between

    - CO formation rate $\propto n^2$
    - CO destruction rate (by UV) $\propto n$

  - ### Self-shielding needs Av~0.5-1.0 mag @ $n_H=10^3 cm^{-3}$

    van Dishoek & Black 1988

- ## Critical density for collisional excitation

$$n_{crit} = \frac{A}{C}\beta \approx \frac{A}{C}\left[\frac{1-e^{-\tau}}{\tau}\right]$$

Escape probability (photon trapping)

Optically-thin: $n_{crit} \approx \frac{A}{C} \approx 2000 \text{ cm}^{-3}$

Optically-thick: $n_{crit} \approx \frac{A/\tau}{C} \approx 300 \text{ cm}^{-3}$
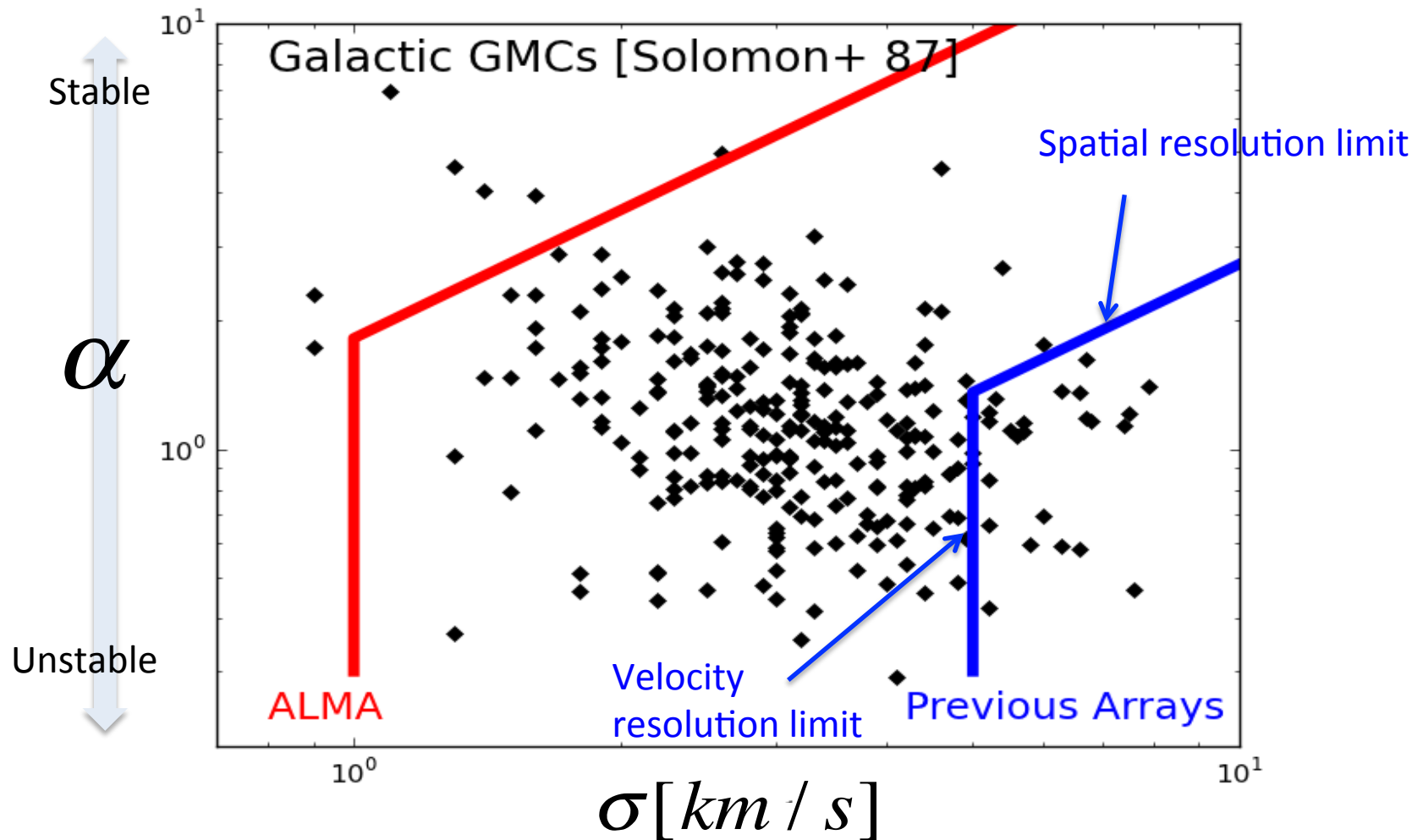
Average GMC density

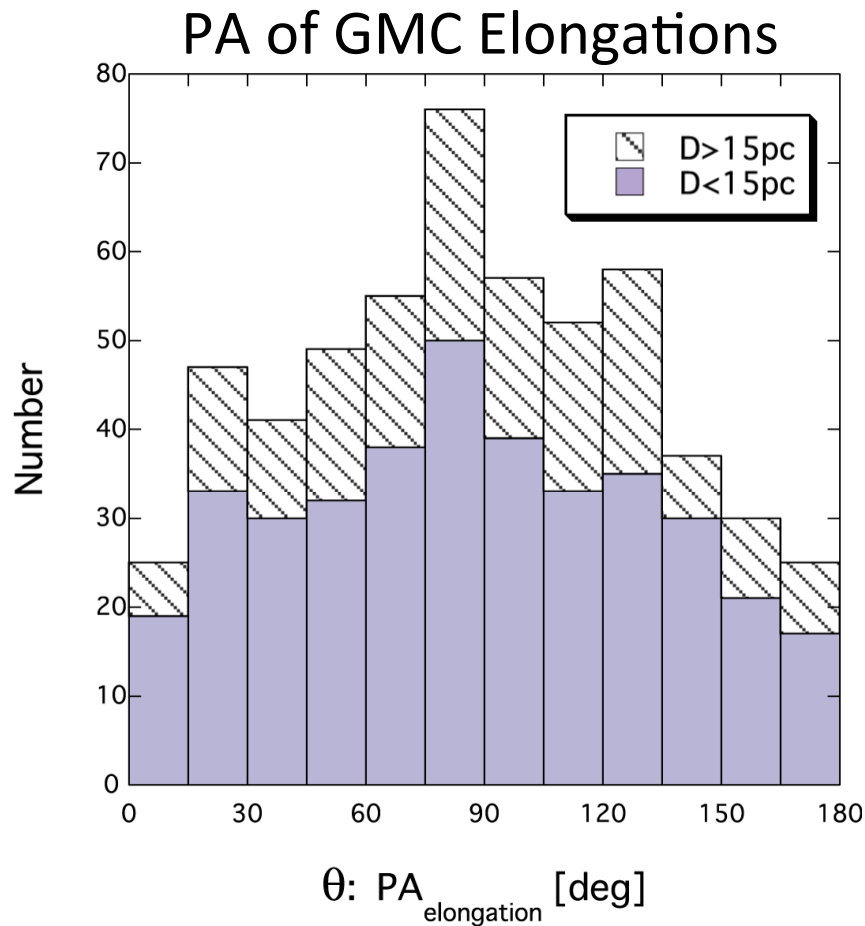# TOPIC 3: ALMA PERSPECTIVE

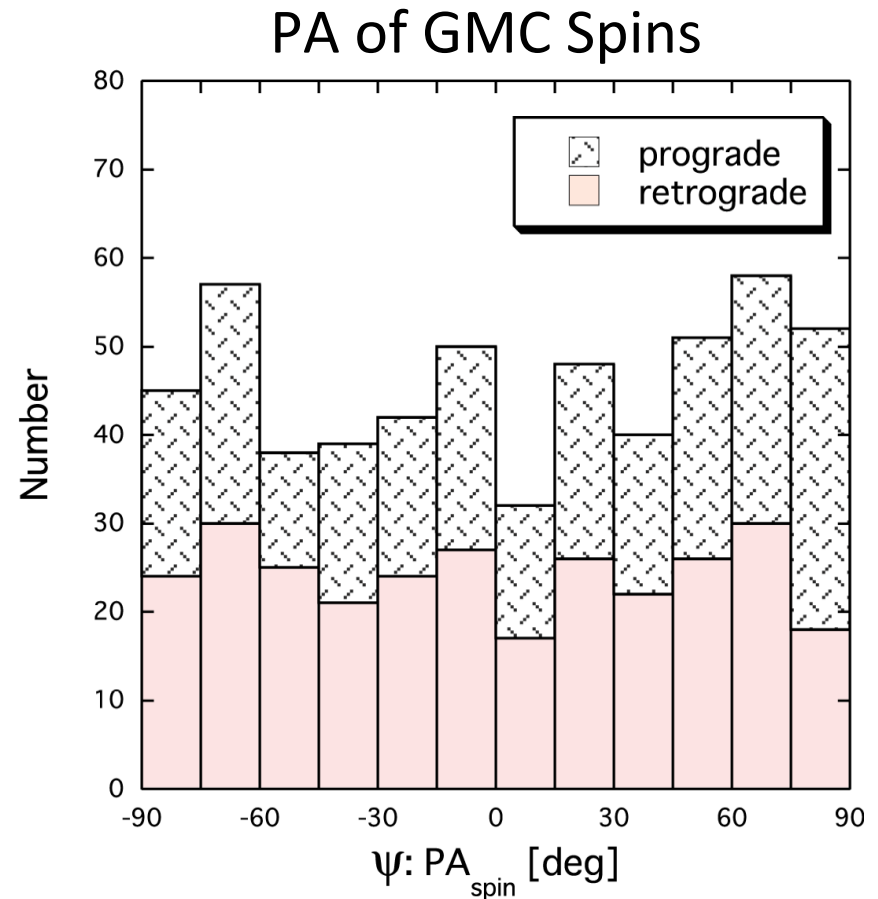## WHAT CAN WE DO WITH ALMA?

UV-COVERAGE

Current Limitations

Virial parameter: $\alpha \propto M_{vir} / M_{GMC} \propto M_{vir} / L_{CO} \propto \sigma / TR$

GMC Elongations and Spins in MW

PA of GMC Elongations

θ: PA$_{elongation}$ [deg]

GMCs elongated preferentially along G.P.

PA of GMC Spins

ψ: PA$_{spin}$ [deg]

Spin no preferred orientation
Prograde and retrograde equally populated

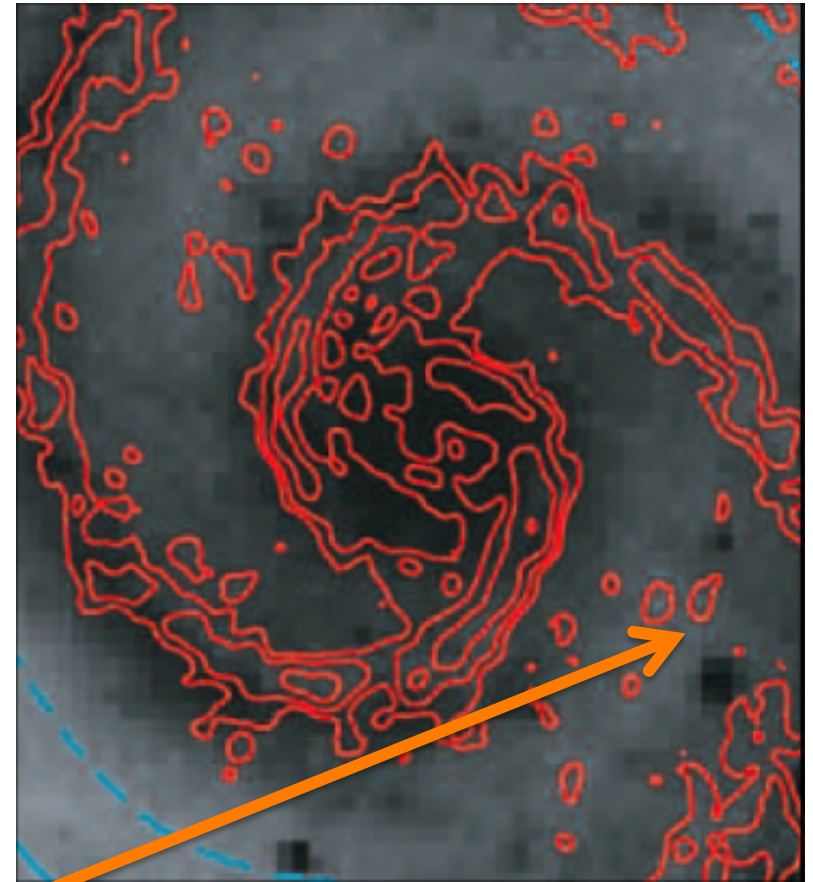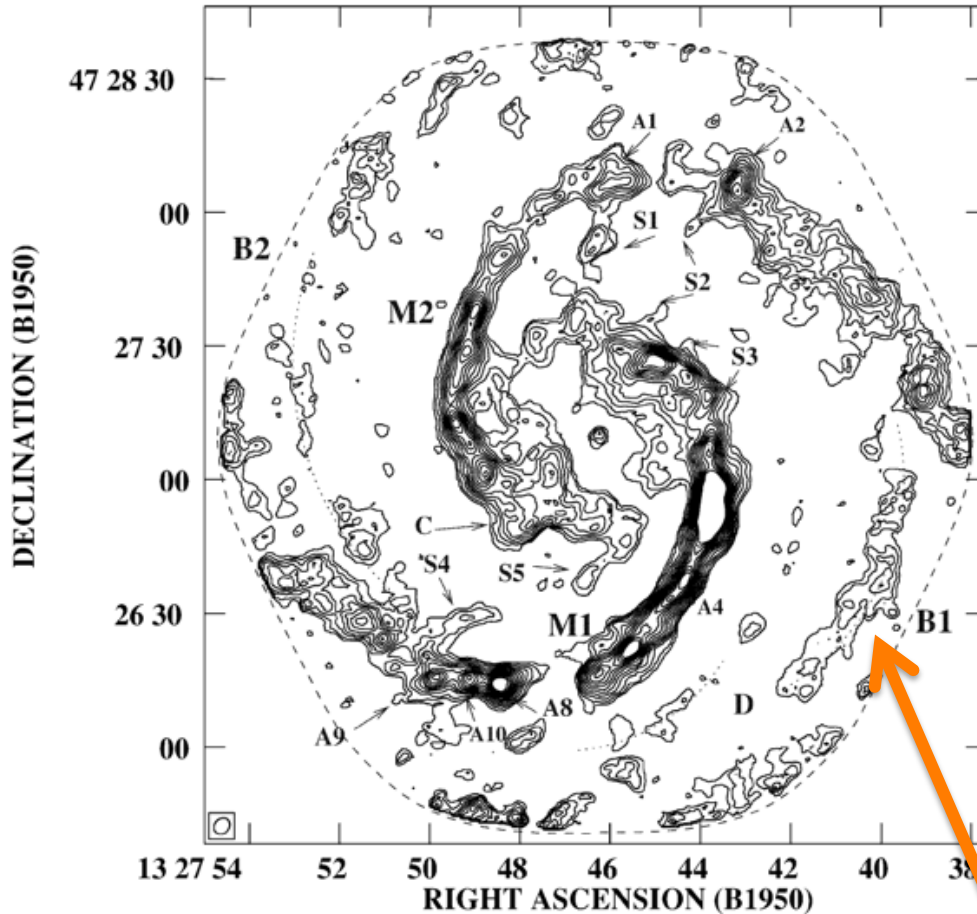Koda et al. 2006

Jackson et al. 2006

Struggle with Small Number of Antennas

OVRO map (Aalto et al. 1999)
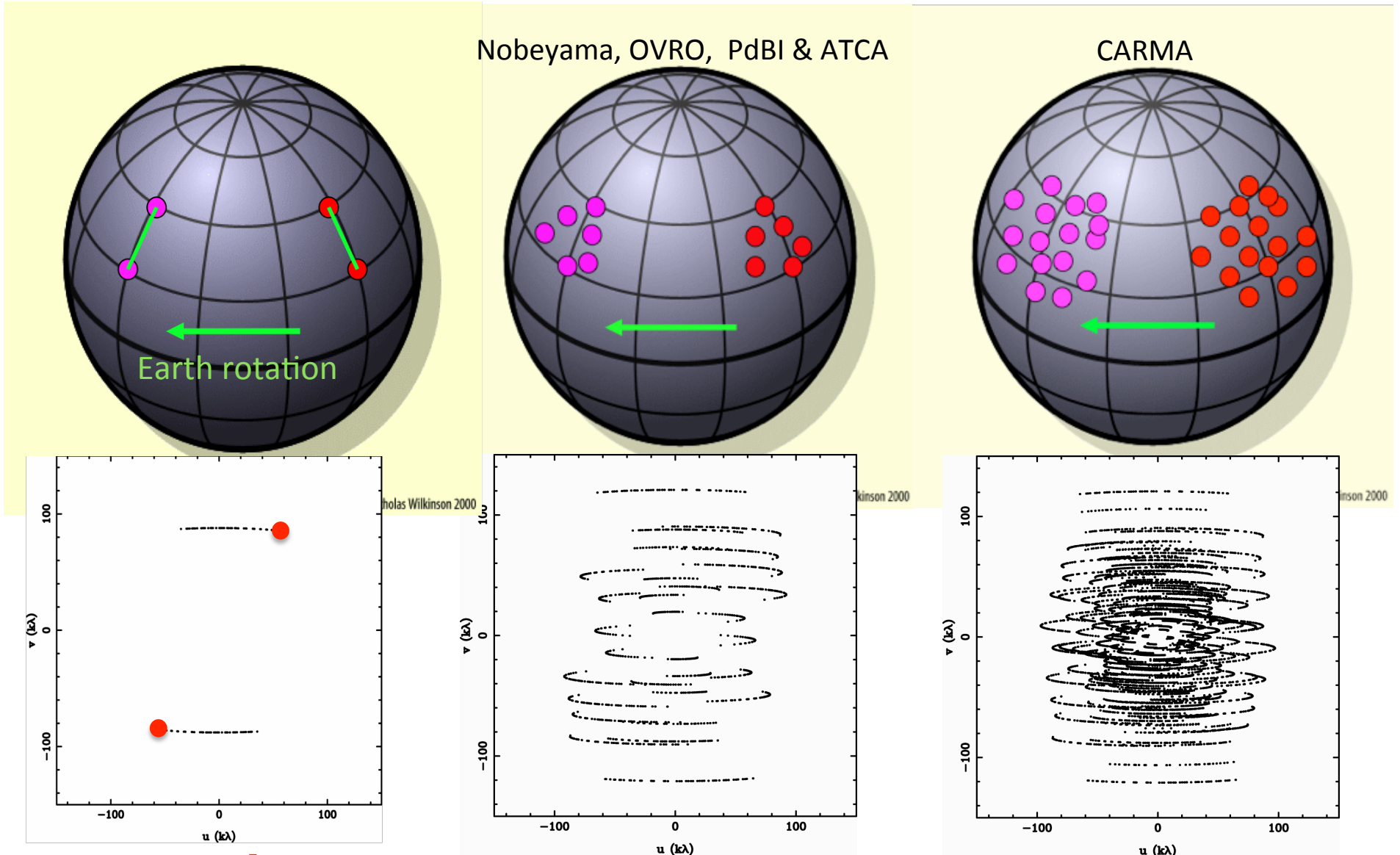
6 antennas

BIMA map (Helfer et al. 2003)

10 antennas

3rd spiral arm??

Synthesis Imaging

2 antennas

6 antennas

15 antennas

Nobeyama, OVRO, PdBI & ATCA

CARMA

Earth rotation

N=6 → 15 pairs

UV-coverage

# of Antennas (A)	# of Baselines (B)	Obs time (T)	Uv-coverage (B*T)
6	15	~100h	1500
15 (CARMA)	105	~100h	**10500**
36 (ALMA Cycle 1)	630	~5h	**3150**
50 (ALMA full)	1225	~5h	6125

In addition to sensitivity and resolution,
Full synthesis (rise to set) is important!