Molecular Gas and GMCs in M51 vs M33 and the LMC

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PAWS
PdBI Arcsecond Whirlpool Survey

Max-Planck-Institut für Astronomie Heidelberg
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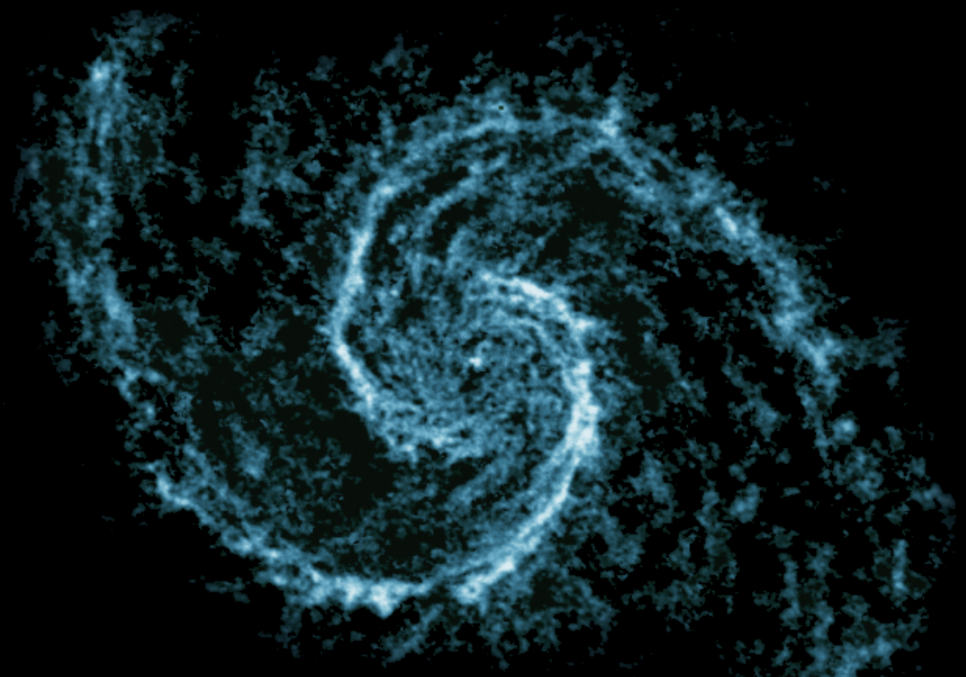
Talk Outline

I. Overview of PAWS data set

II. Properties of GMCs in different galaxies and M51 environments

III. Distribution of CO emission (PDFs) in different M51 environments

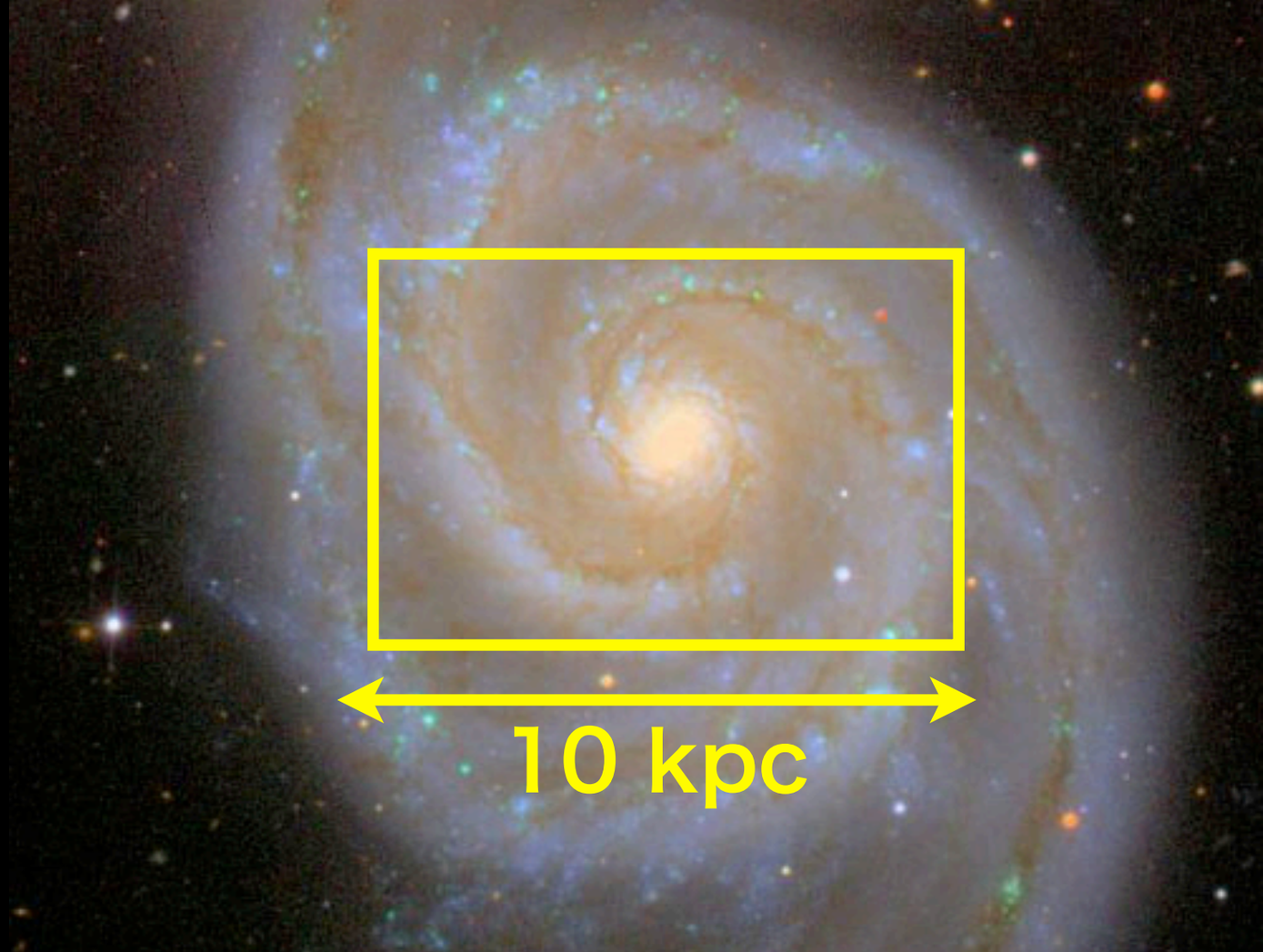
PAWS



PdBI Arcsecond Whirlpool Survey

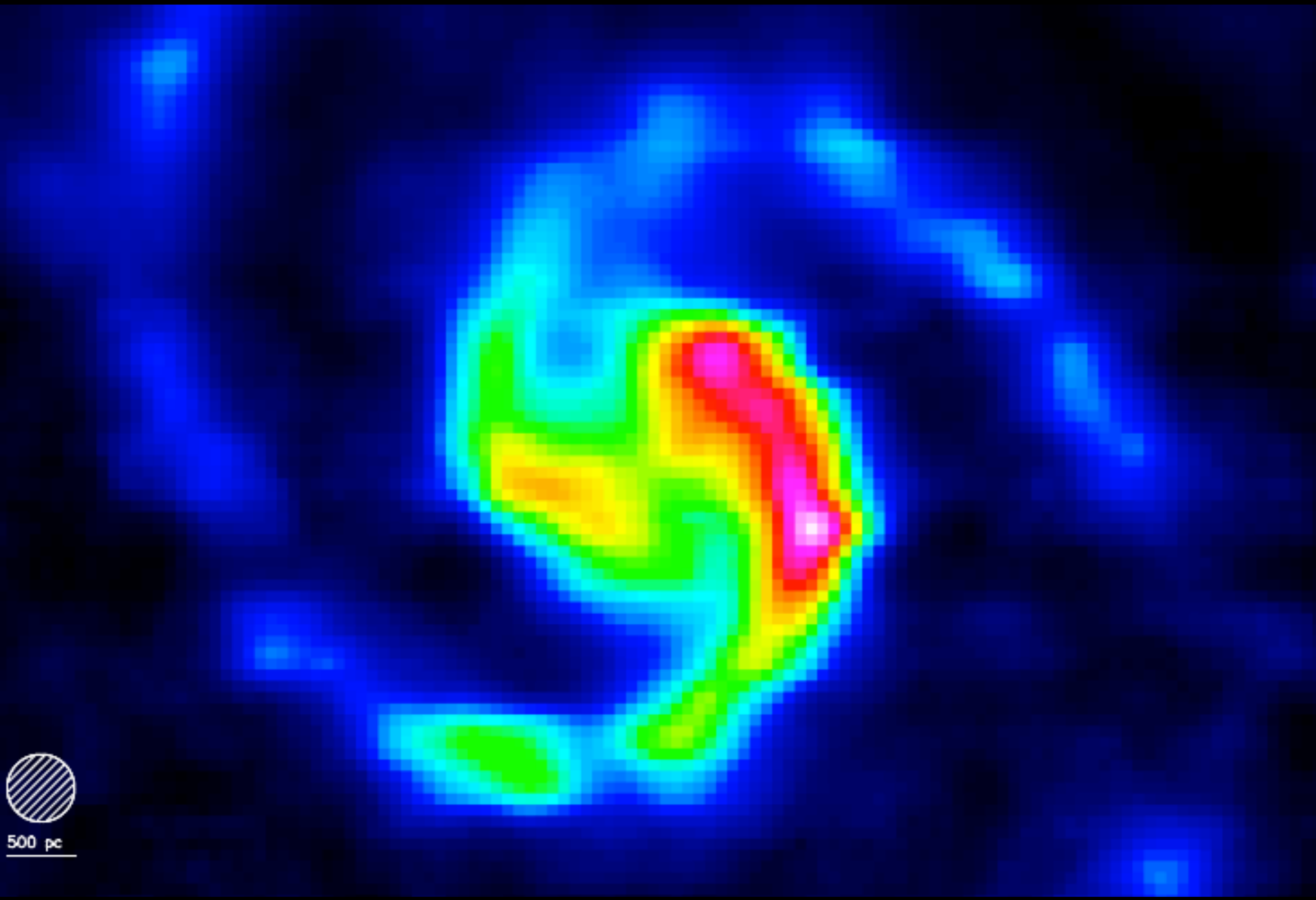
see posters by Eva and Dario

IRAM 30m: 40 hr
PdBI: 170 hr

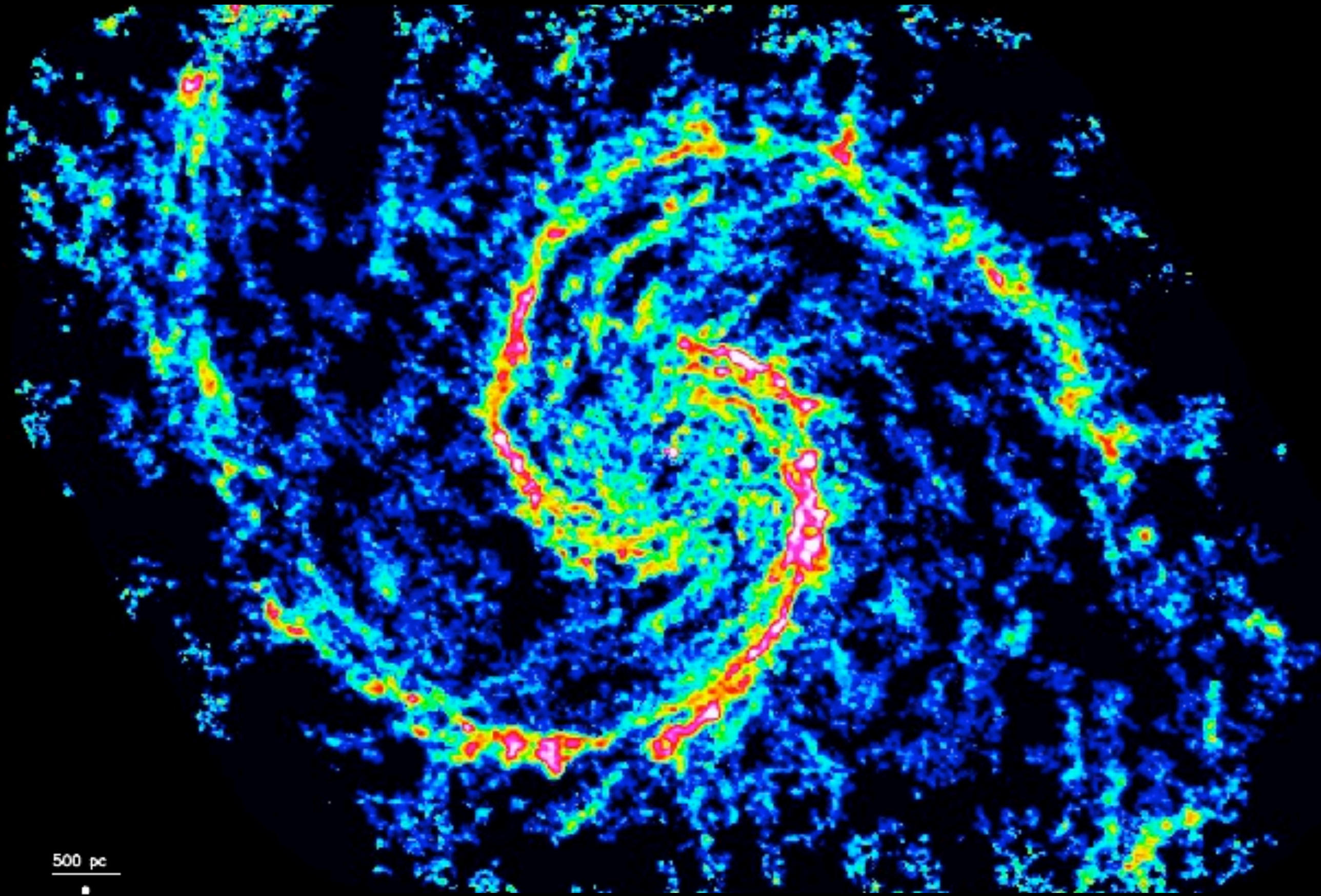


- IRAM Large Programme
- largest PdBI mosaic to date
- public data release: now!
- FoV ~ 60kpc^2
- resolution ~40pc, 5km/s
- RMS T_{mb} ~ 0.4 K per channel

$\Rightarrow 5\sigma$ detection of 1.2e5 $M_\odot$ GMC

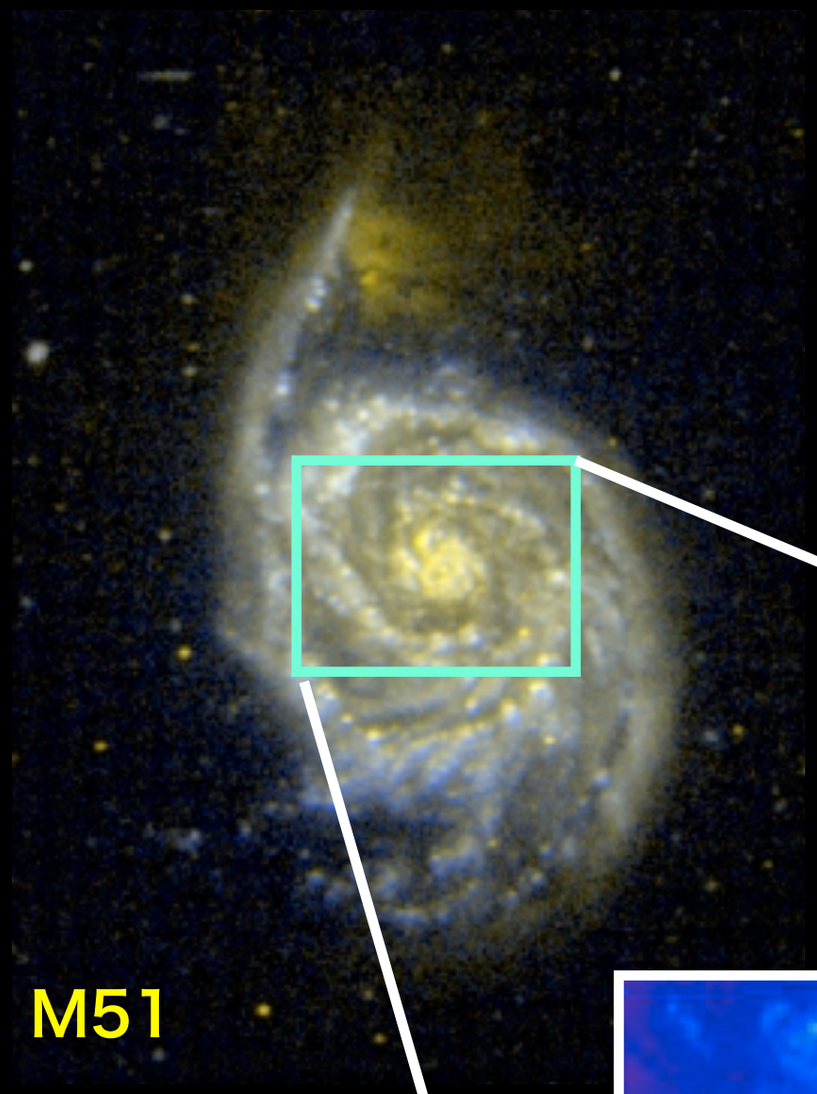


Schuster et al. (2007)

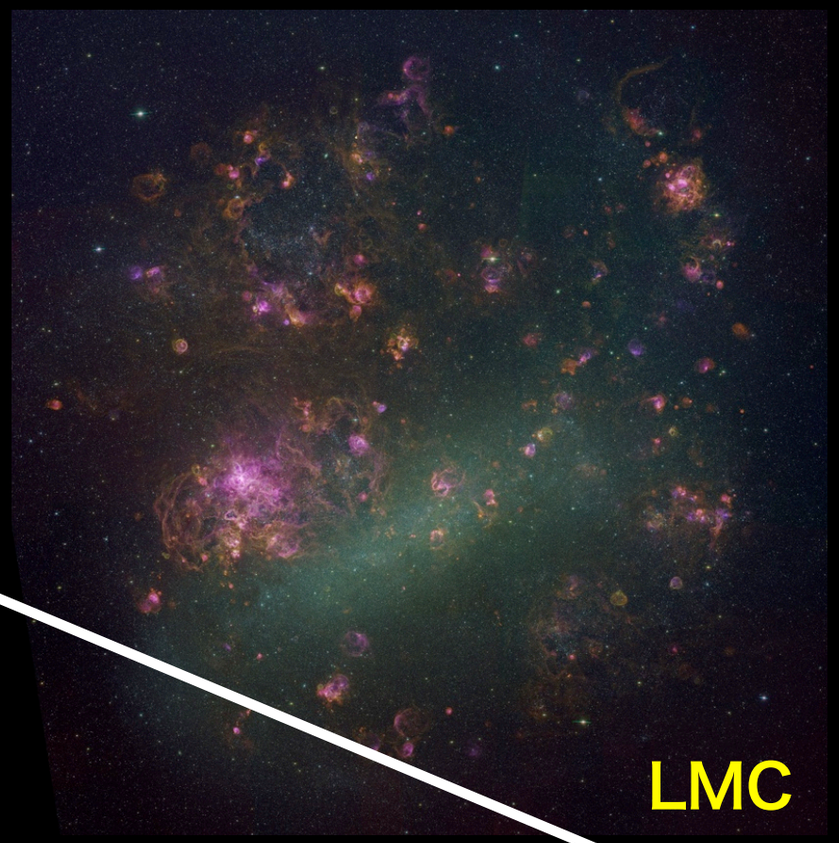


Pety et al. (ApJ, accepted)

GALEX, Gil de Paz et al 2006



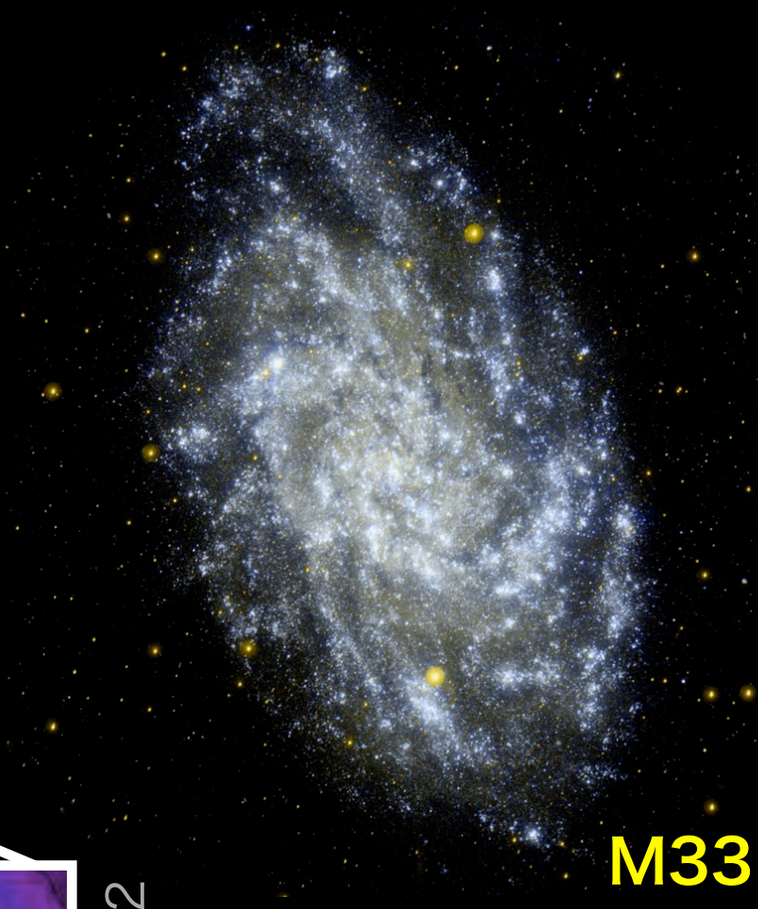
M51



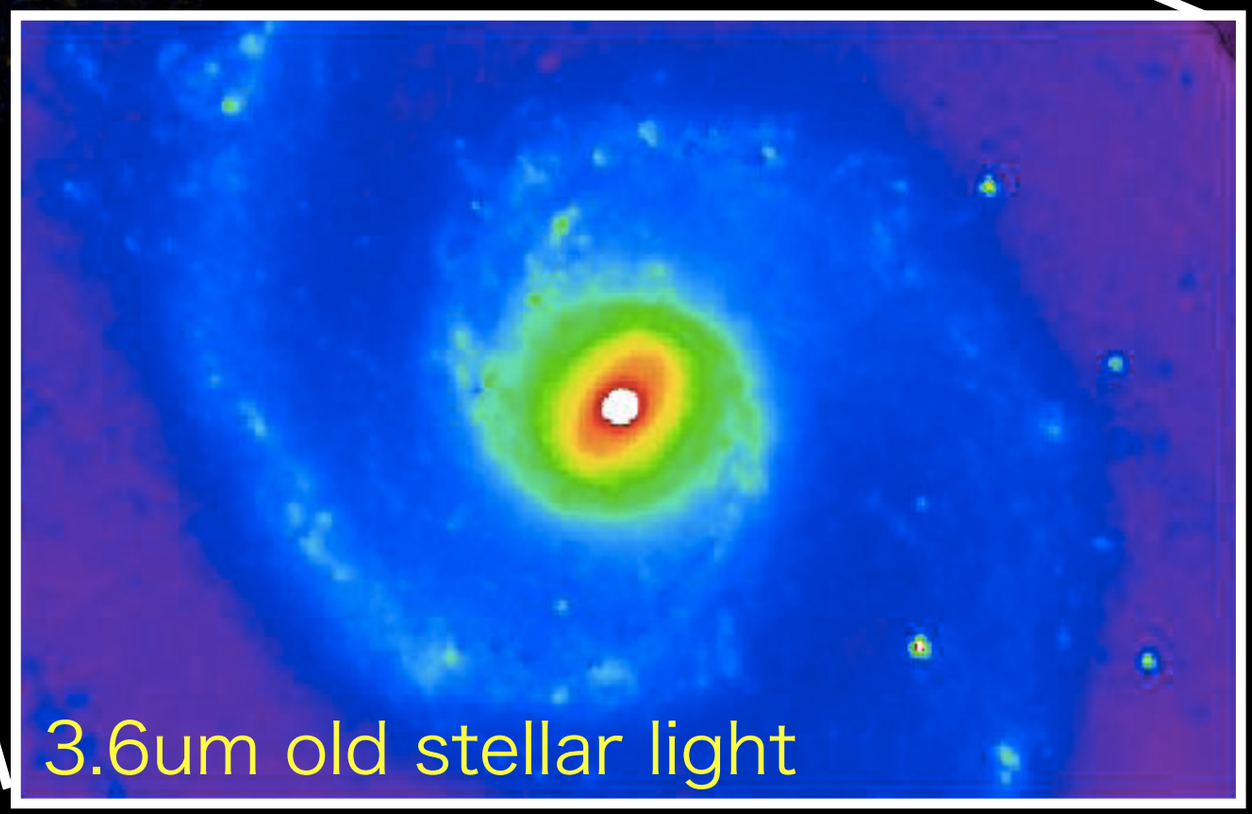
LMC

MCELS, Smith et al 1999

GALEX, Gil de Paz et al 2006

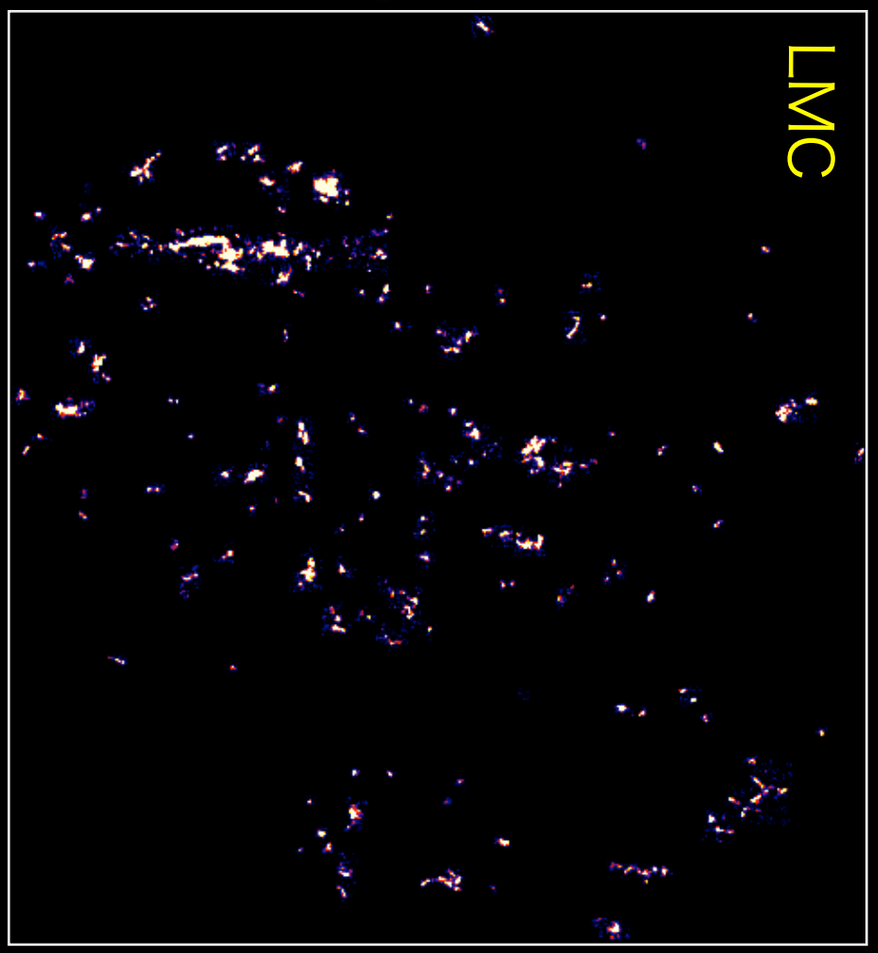


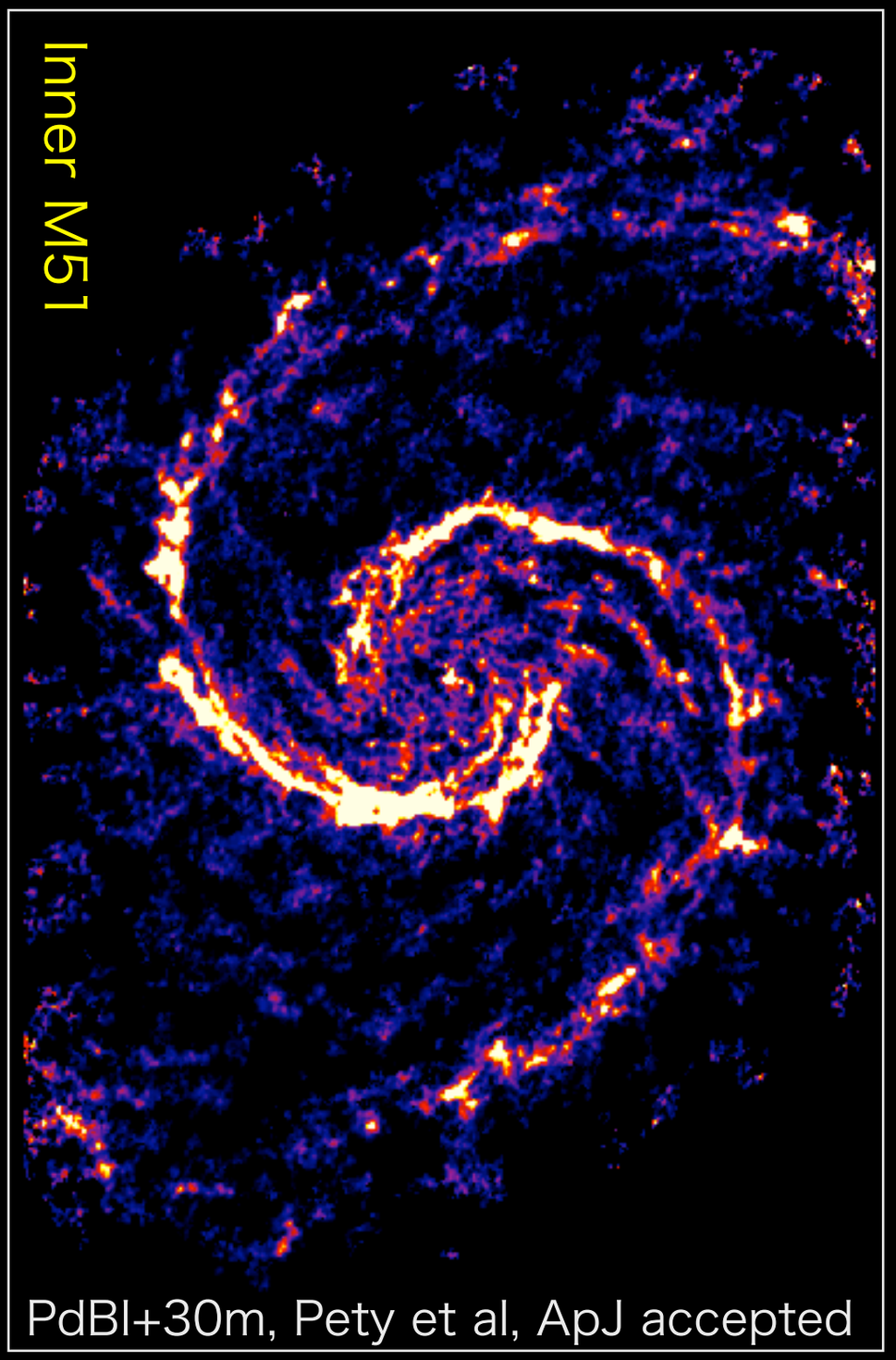
M33



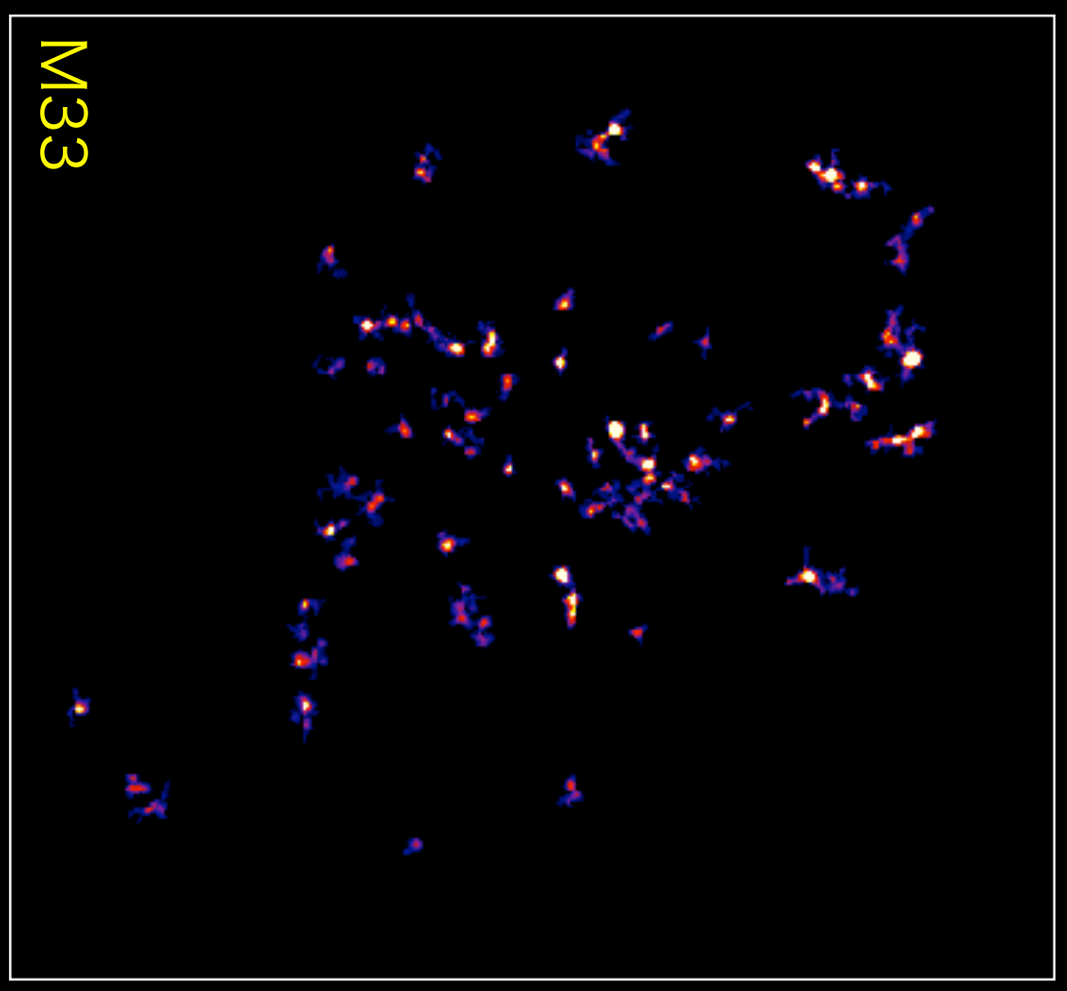
Meidt et al 2012

MAGMA, Wong et al 2011





PdBI+30m, Pety et al, ApJ accepted



FCRAO+BIMA, Rosolowsky et al 2007

M51

5 kpc

M33

LMC

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GMC Properties

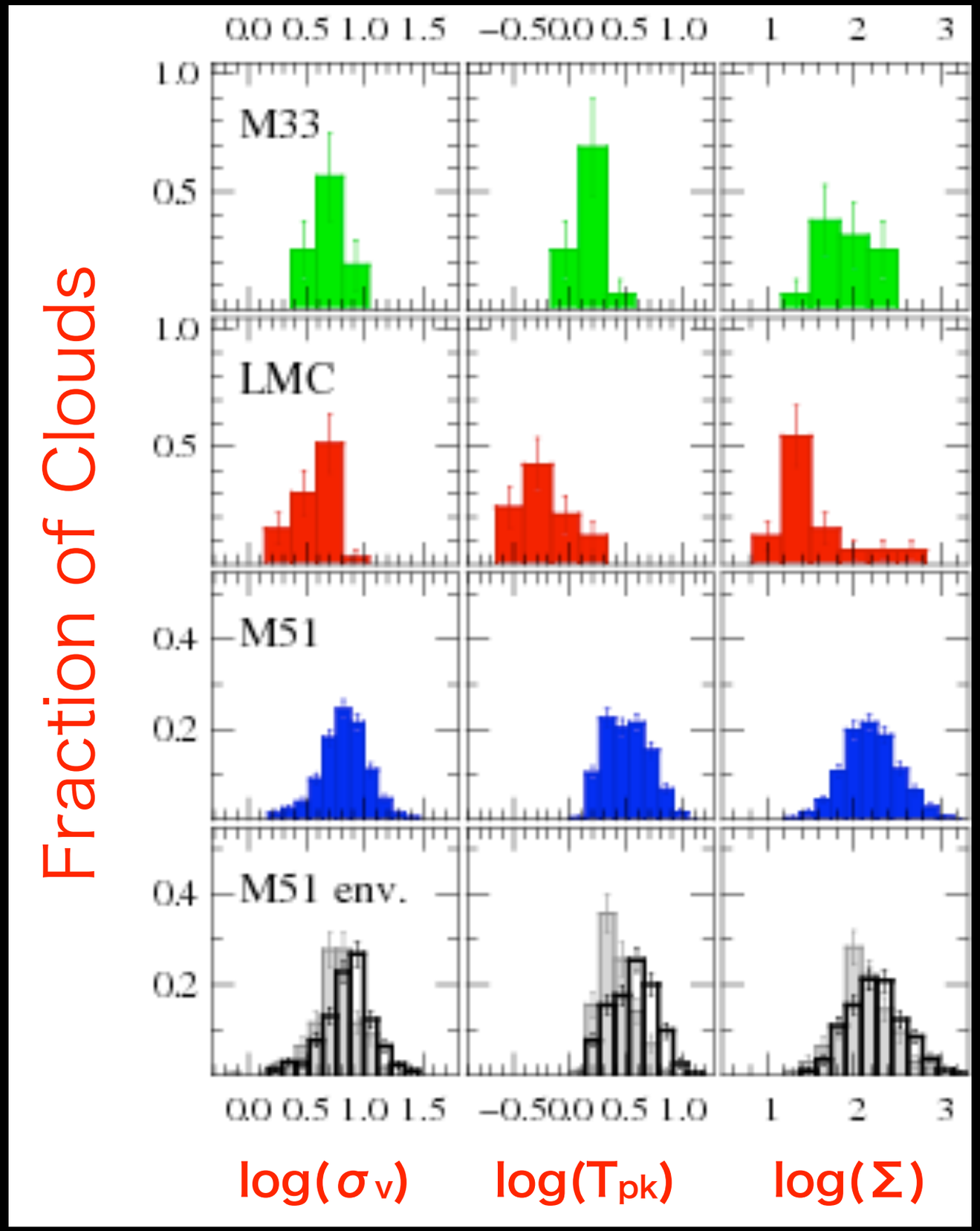
After homogenizing the datasets, M51 GMCs:

➡ are larger

➡ are brighter (peak T and CO surface brightness)

➡ have larger linewidths (especially relative to size) than GMCs in M33 and LMC

Hughes et al. (submitted)



GMC Properties

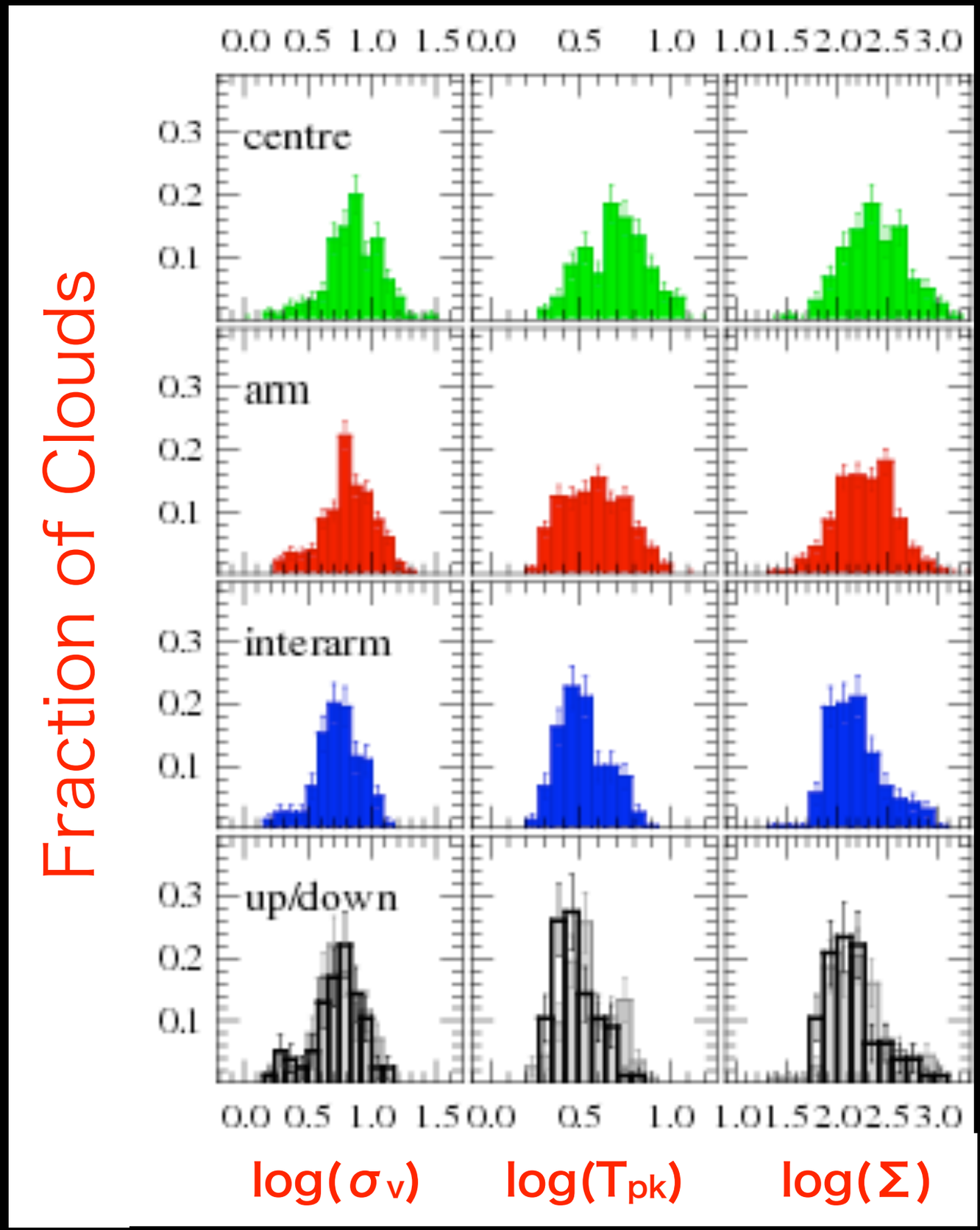
Within M51, GMCs in the arms and centre:

➡ have larger linewidths; and

➡ are brighter than interarm clouds.

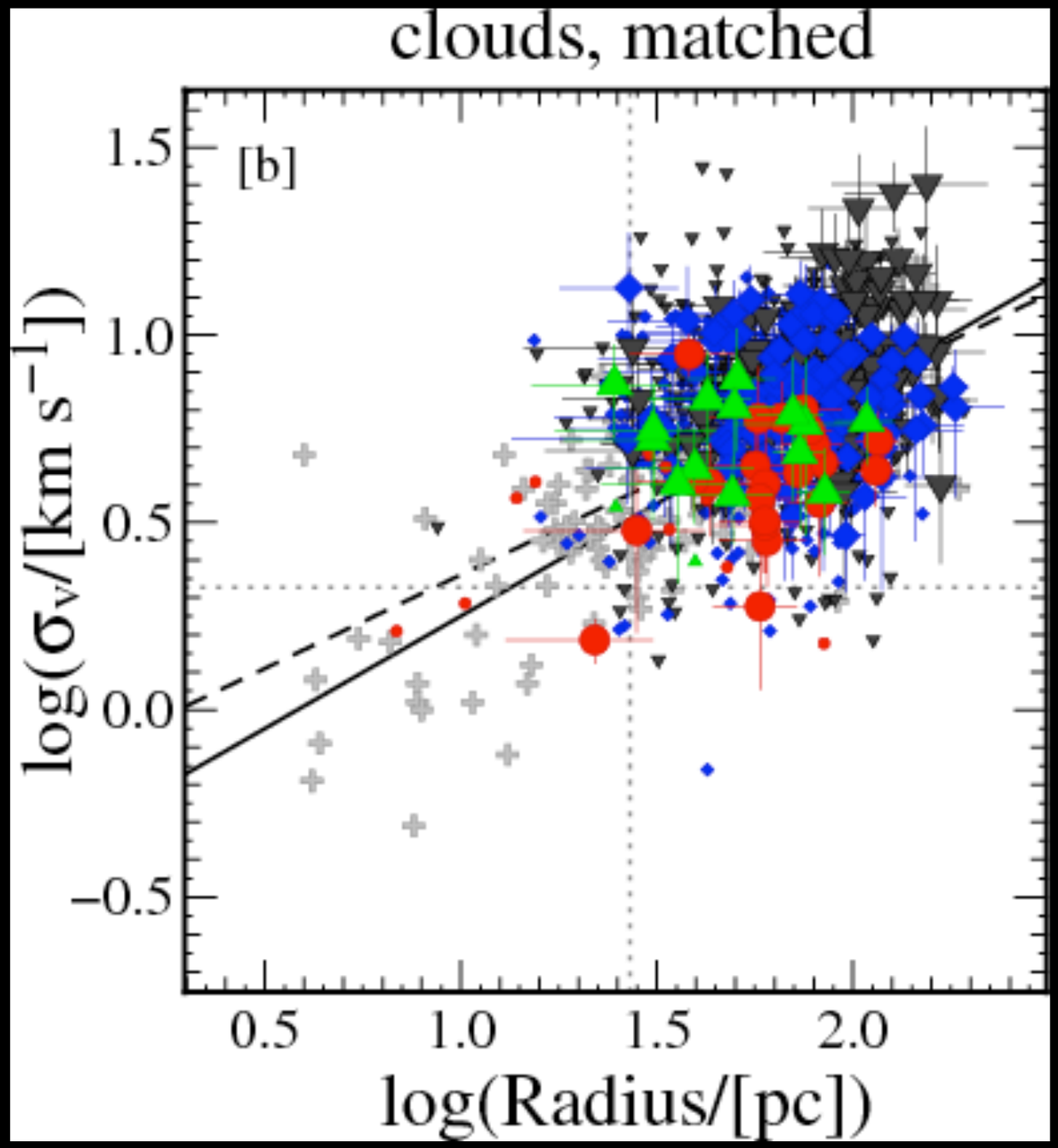
Also detect small variations between T_{pk} and σ_v of up- and downstream GMCs.

Colombo et al. (submitted)



Size-linewidth relation

Hughes et al. (submitted)



Larson Laws

1. GMCs follow $\sigma_v \propto R^{0.5}$

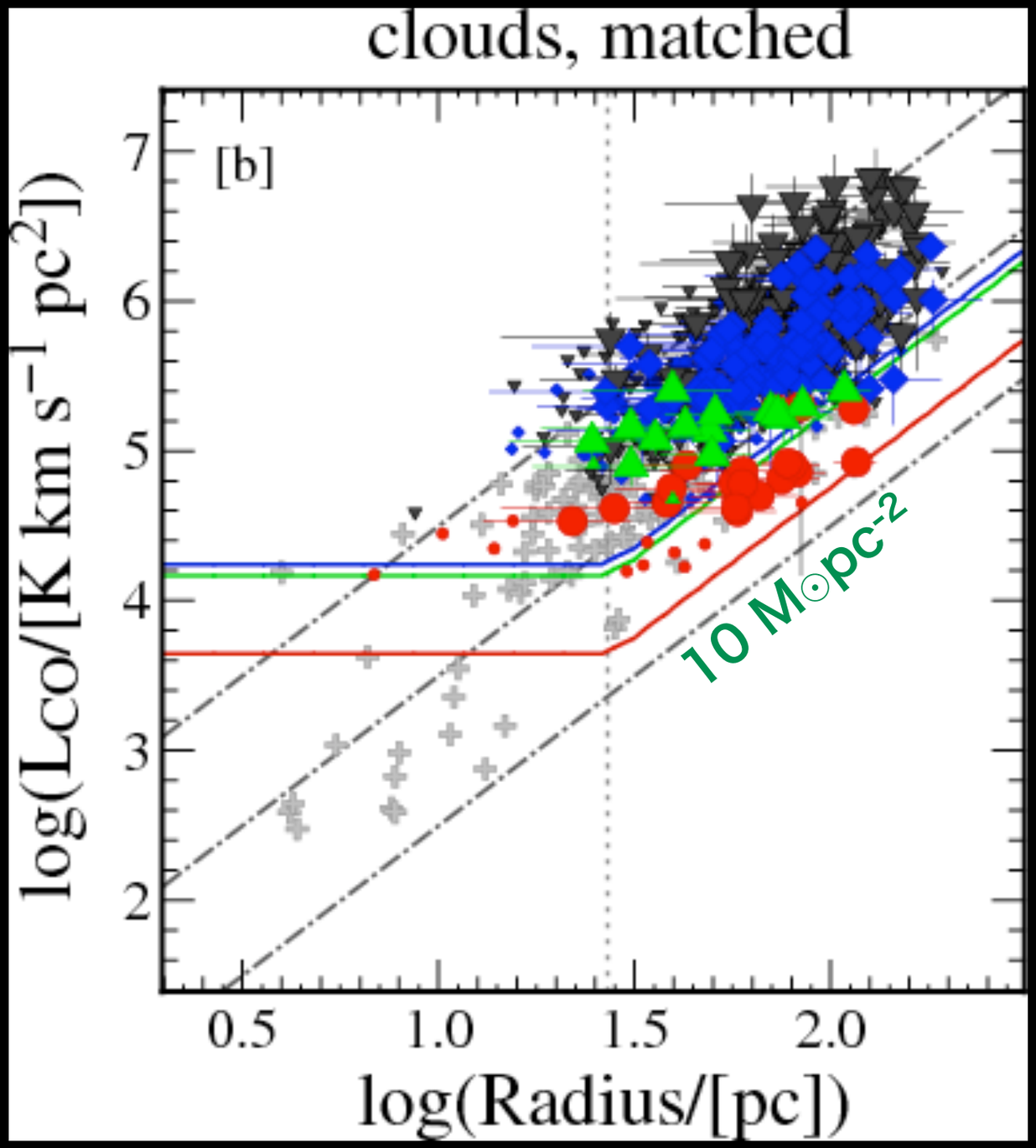
2. GMCs achieve virial equilibrium ($M \propto \sigma_v^2 R$)

3. GMCs have constant mass surface density (~100 $M_\odot$ pc^{-2})

▼ M51 arm + centre ◆ M51 i-arm ▲ M33 ● LMC

Size-luminosity relation

Hughes et al. (submitted)



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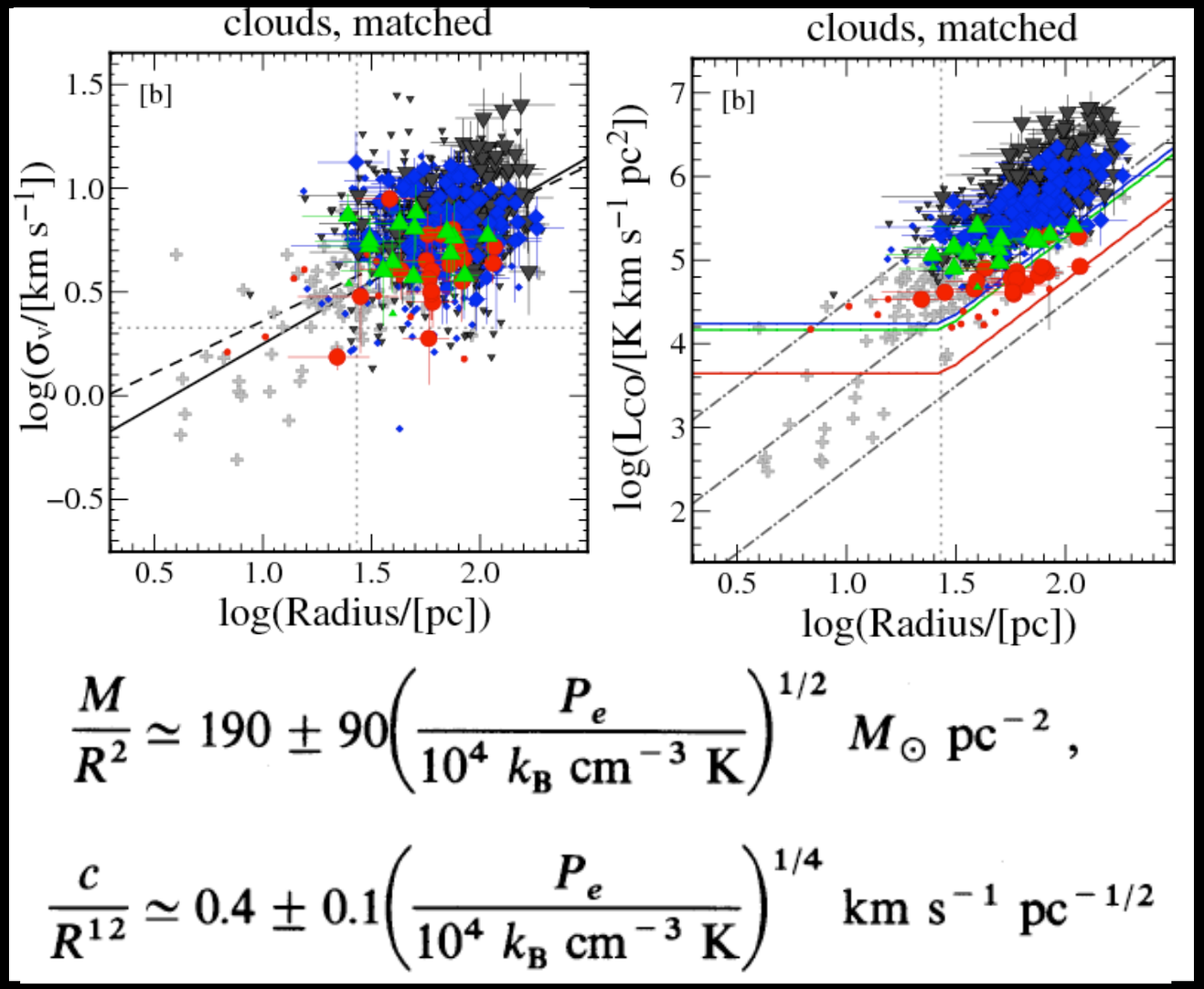
A consequence of P_{ext}?

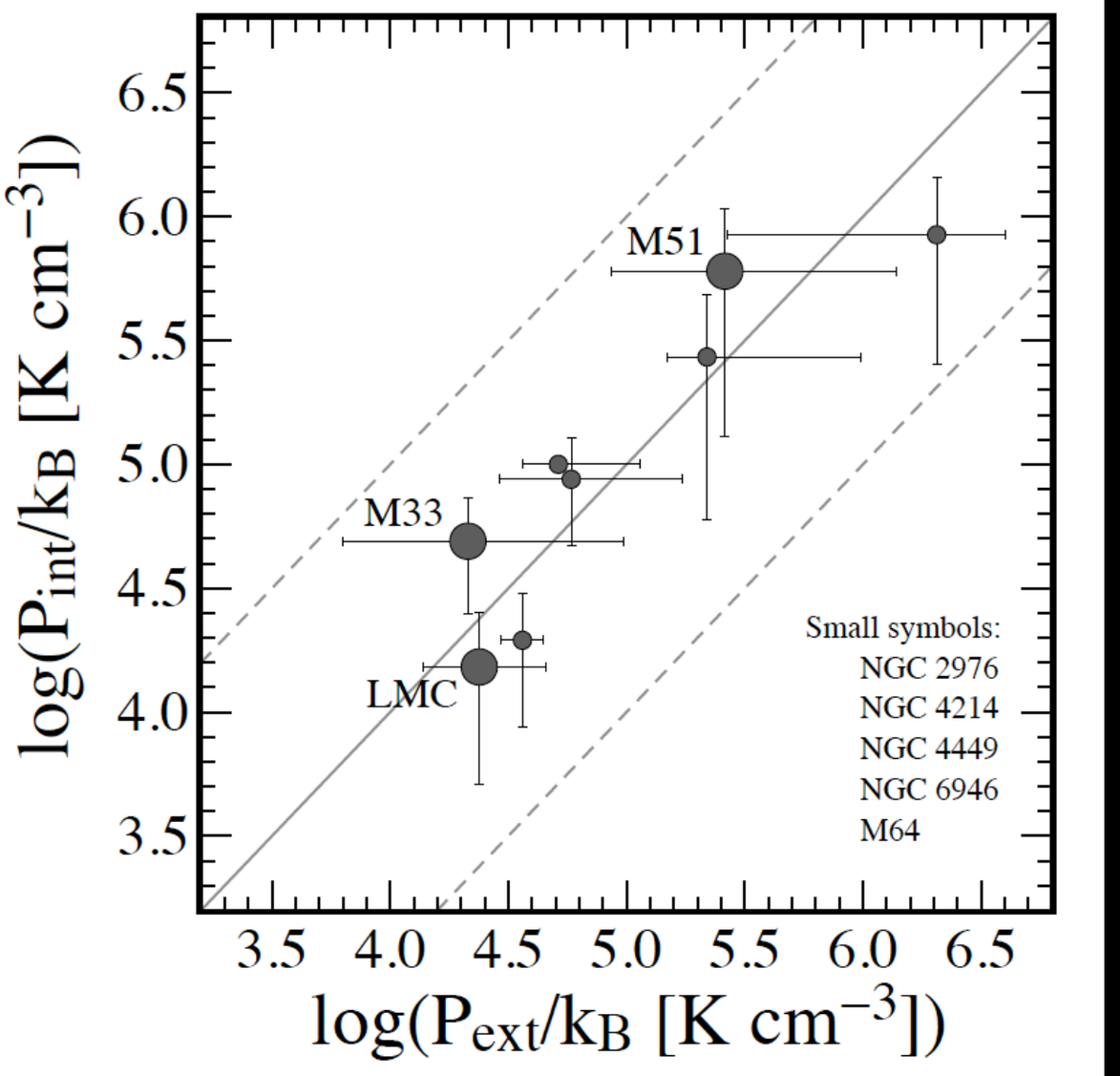
Hughes et al, submitted



$$\frac{M}{R^2} \simeq 190 \pm 90 \left(\frac{P_e}{10^4\ k_B\ \mathrm{cm}^{-3}\ \mathrm{K}} \right)^{1/2} M_\odot\ \mathrm{pc}^{-2},$$

$$\frac{c}{R^{12}} \simeq 0.4 \pm 0.1 \left(\frac{P_e}{10^4\ k_B\ \mathrm{cm}^{-3}\ \mathrm{K}} \right)^{1/4} \mathrm{km\ s}^{-1}\ \mathrm{pc}^{-1/2}$$

e.g. Elmegreen (1989)



▼M51 arm + centre ◆M51 i-arm ▲M33 ●LMC

Part II: Summary

• Basic physical properties of GMCs (e.g. T_{pk}, R, σ_v) vary with galactic environment

• Constant Σ_{H2} of GMCs reported by previous extragalactic CO studies may be observational artifact

• No compelling evidence of size-linewidth relationship, but M51 clouds have larger linewidths at a fixed size scale than clouds in the dwarf galaxies

• σ_v and Σ_{H2} of GMCs regulated -- or at least influenced -- by external pressure?

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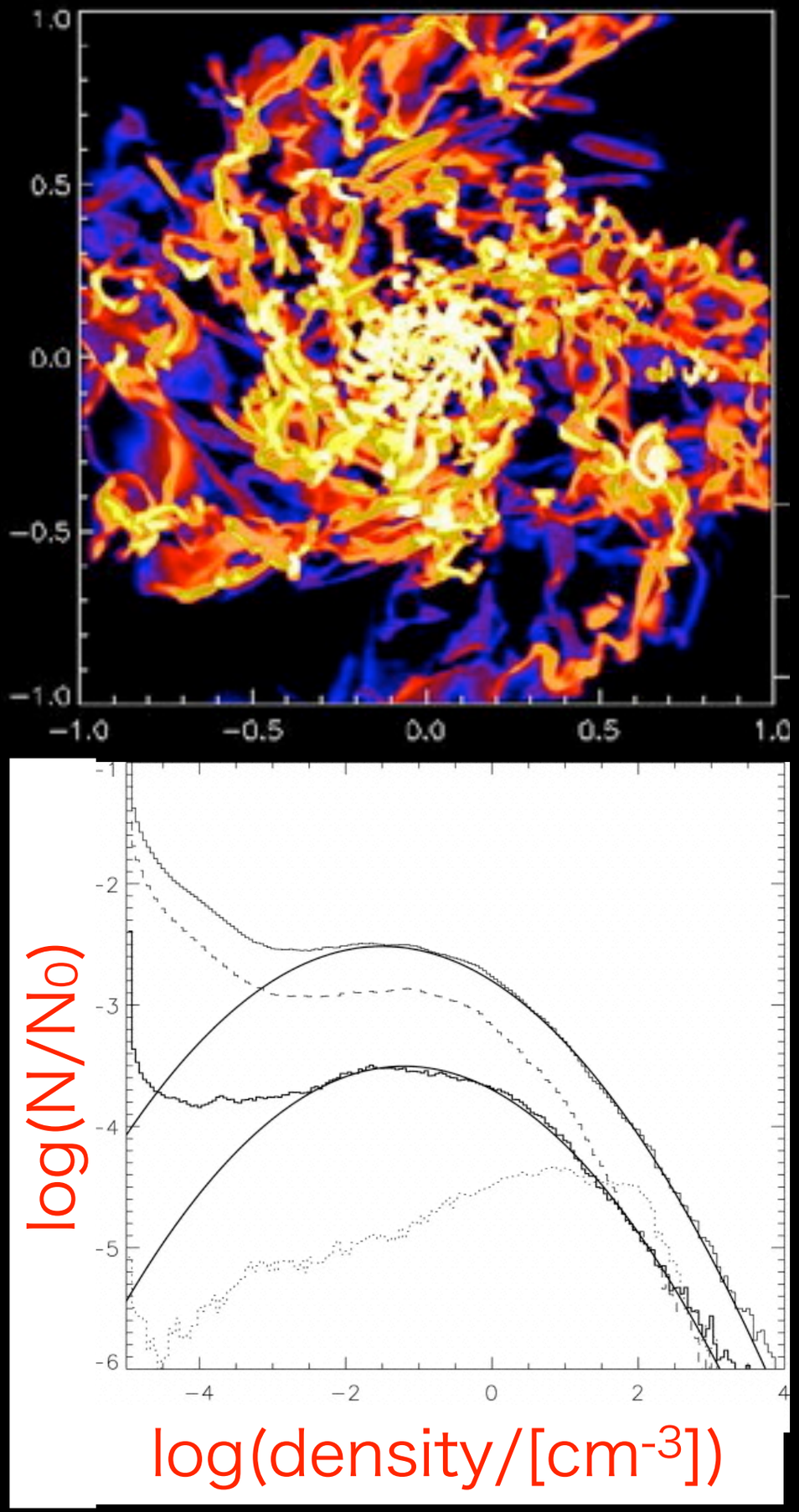
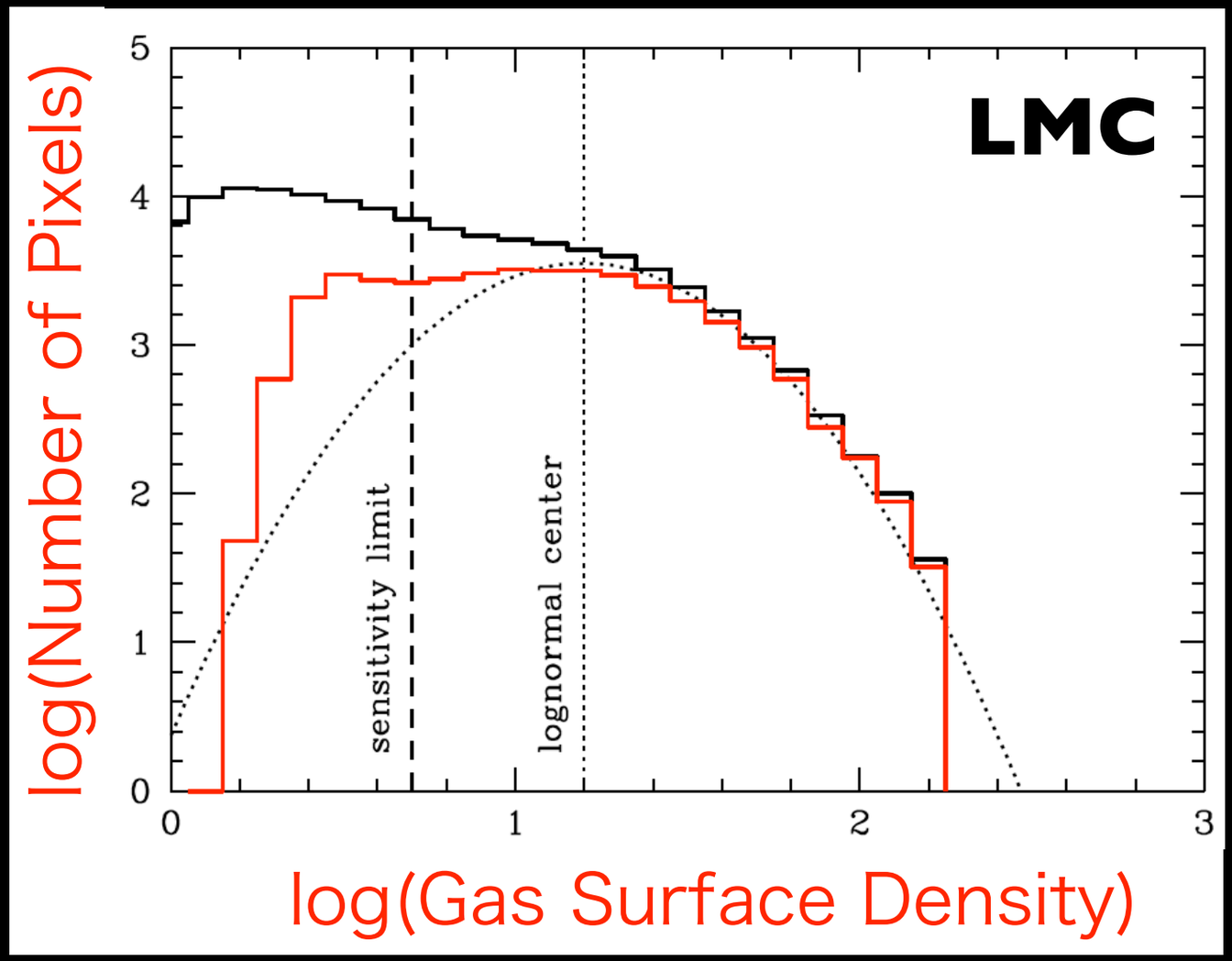
Wada & Norman (2007)



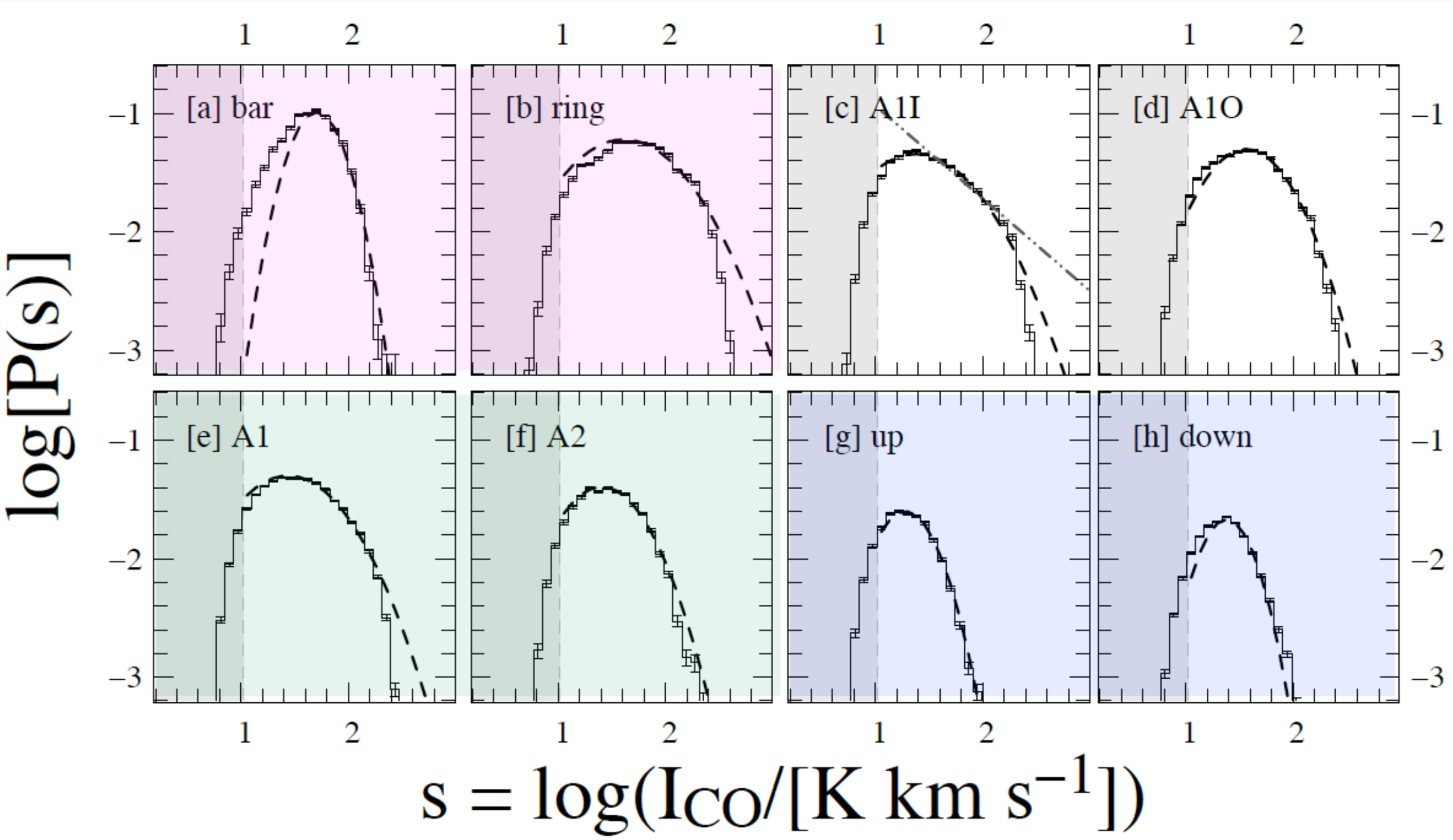
Wong et al. (2011)



But: universal lognormal PDF for galactic disks not observationally established

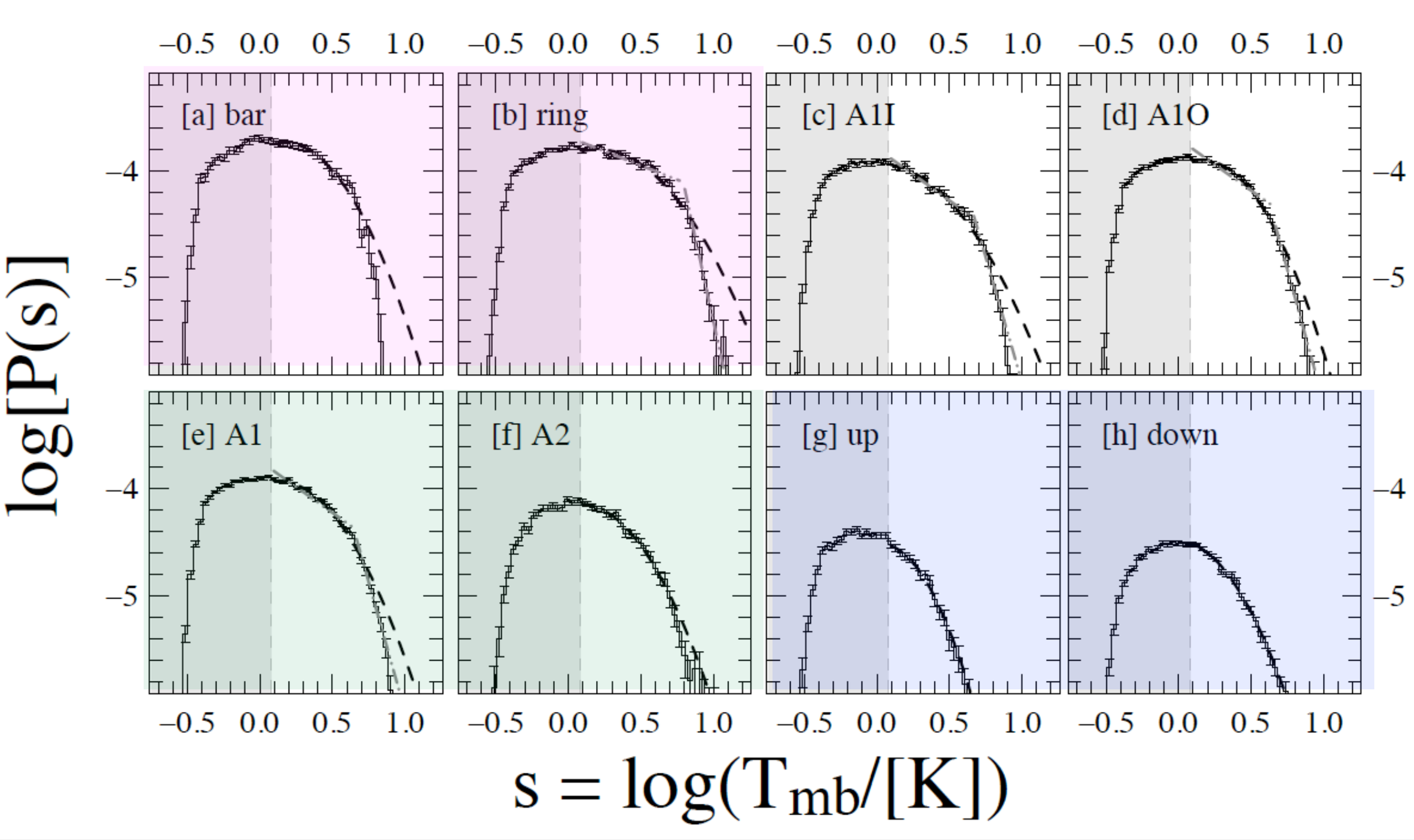
Integrated Intensity PDF

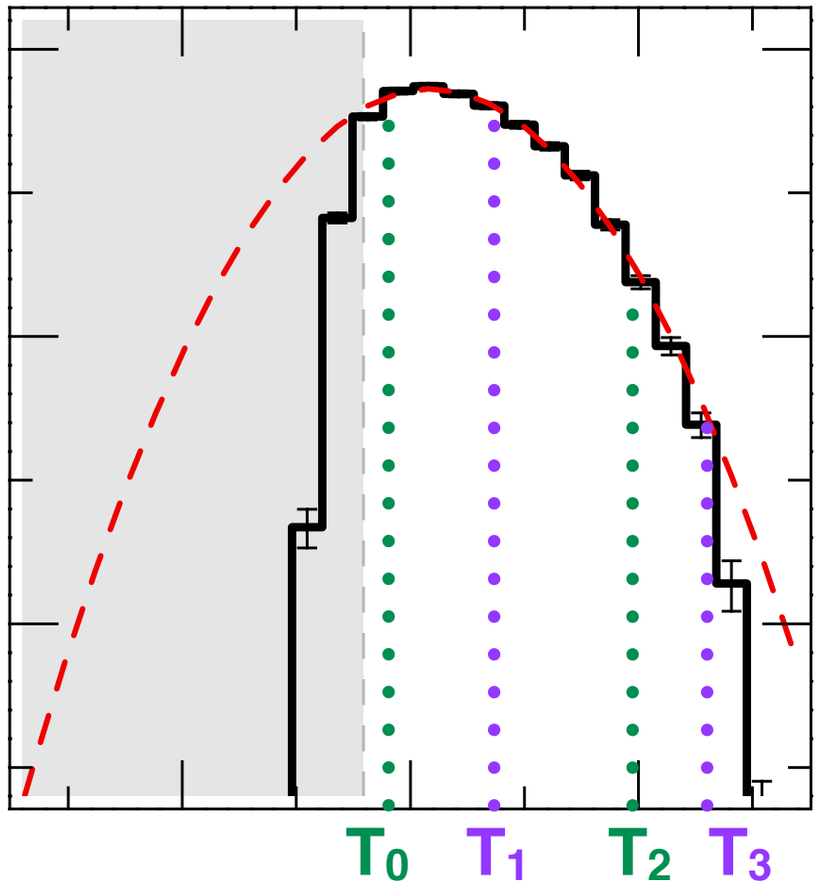
Hughes et al. (accepted)



CO Brightness PDF

Hughes et al. (accepted)



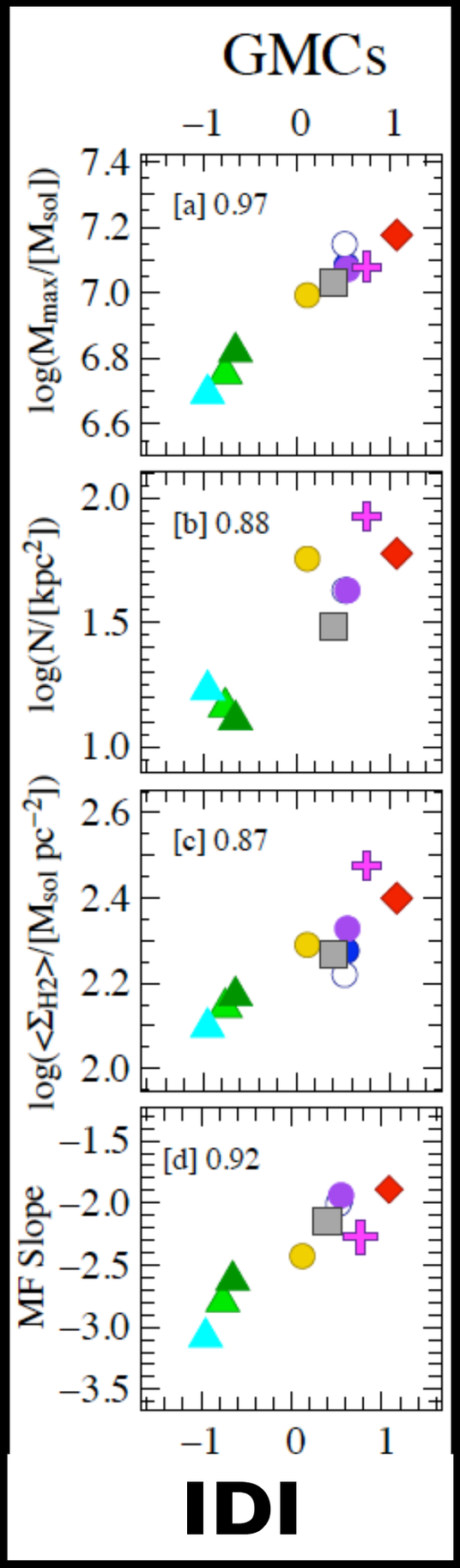


Characterise the shape of a PDF using the BDI, which expresses a ratio between bright and faint CO emission (Sawada et al 2012).

$$BDI = \log \frac{\Sigma T_i \,,\ T_2 < T < T_3}{\Sigma T_i \,,\ T_0 < T < T_1}$$

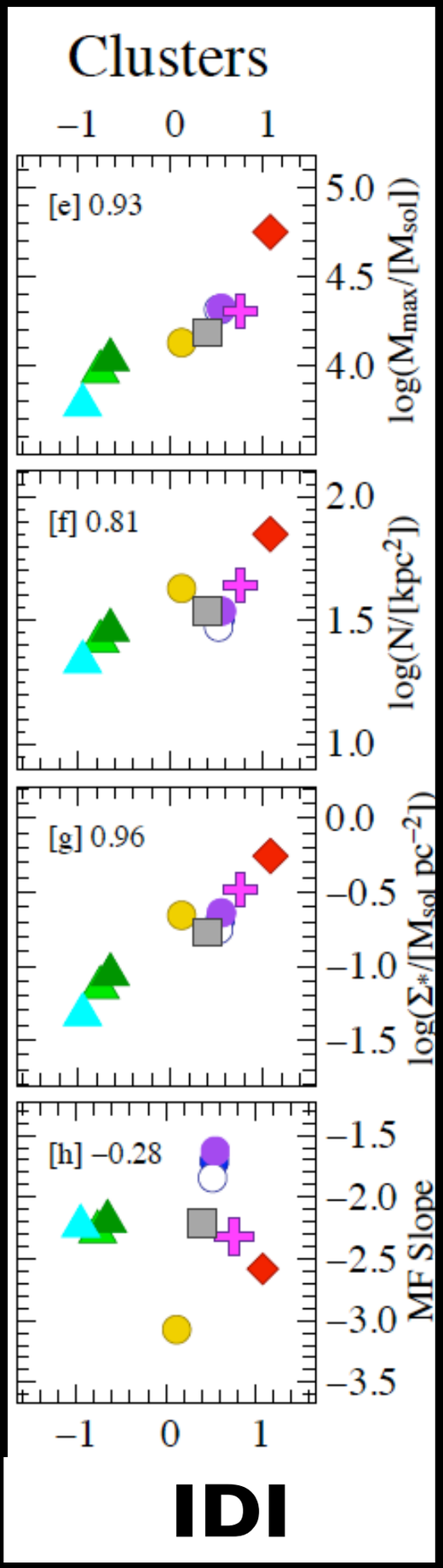
Region	L_{CO} [10^7 K km s^{-1} pc^2]	BDI	IDI
Global	70.4	-0.66	0.40
Nuclear Bar	6.6	-0.85	0.76
Molecular Ring	16.6	-0.13	1.08
Arm 1 inside corotation (A1I)	11.9	-0.59	0.52
Arm 1 outside corotation (A1O)	17.6	-0.83	0.55
Arm 1 (A1)	29.6	-0.72	0.54
Arm 2 (A2)	6.7	-0.76	0.12
Upstream	4.7	-1.73	-0.95
Downstream	6.2	-1.50	-0.65

PDFs & GMC Properties



High BDI and IDI values associated with:

- higher number density of GMCs
- higher maximum GMC mass
- higher average GMC surface density
- shallower GMC mass spectrum



PDFs & Young Clusters

High BDI and IDI values associated with:

- higher number density of clusters
- higher surface density of clusters
- more massive clusters
- higher maximum cluster mass

But:

- no relationship to shape of cluster mass function

Part III: Summary

• Width of CO PDFs increases with increasing average gas surface density, as predicted by simulations

• Observed shapes of CO PDFs are diverse ➡ spiral arm phenomena (shocks/streaming motions/stellar feedback) produce observable departures from lognormal gas density distribution on 50 pc to kiloparsec scales

• Shape of CO PDF is connected to properties of both the GMC and young stellar cluster populations.

Conclusions

- Are GMC properties universal? **No.**
- Are lognormal (column) density PDFs ubiquitous? **No.**
- Do gas dynamics and spiral structure matter? **Yes.**