Observations of giant molecular clouds in Nearby Galaxies with ALMA

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Star formation processes: currently open questions

Nearby galaxies

The galactic GMC W49

Simulations of ALMA observations

Star formation processes: currently open questions

Some still open questions about star formation in galaxies:

- Importance of local (disk or cloud instability)
versus global effects (spiral density waves, tidal forces, magnetic fields)
in triggering SF.

- How the properties of SF depend on various environmental parameters

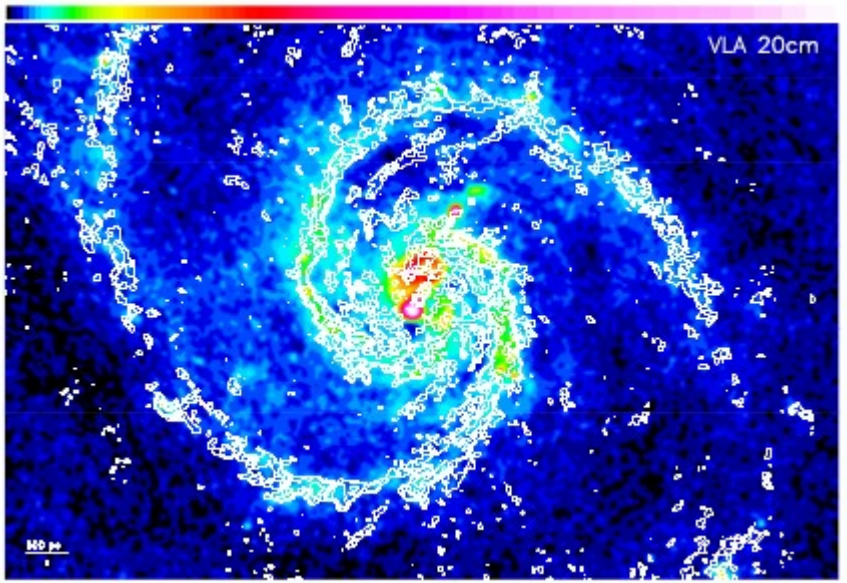
- How SF might differ in nuclear regions or in burst and quiescent modes

- Which is the role of the relativistic phase (cosmic rays and magnetic field)
in SF processes

- **Do giant molecular clouds care about the galactic structure?**

Nearby galaxies

M51 @ 7.6 Mpc

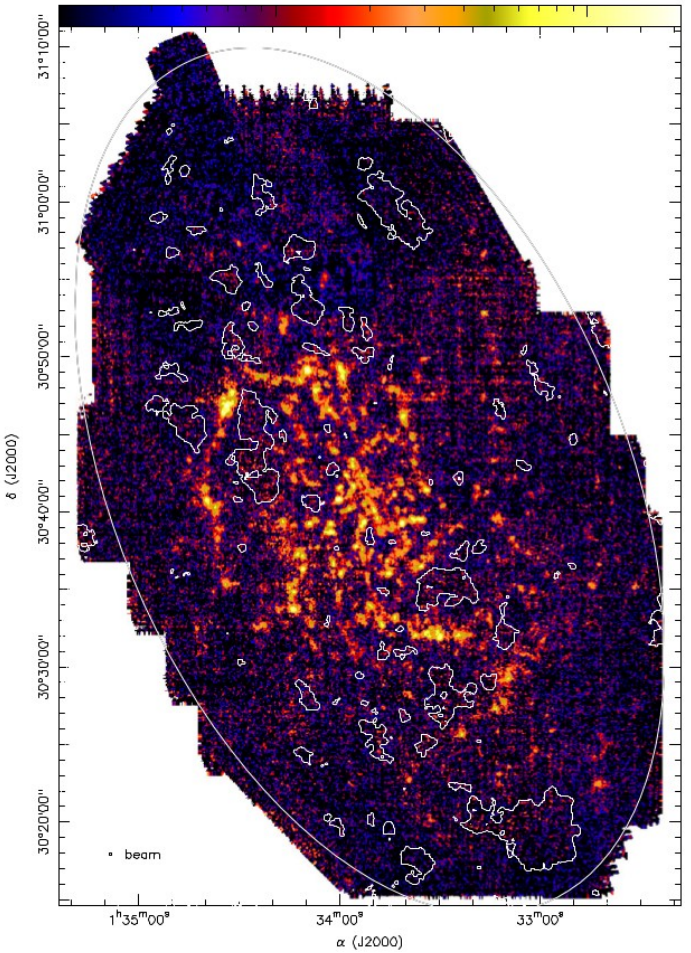


1.4 GHz image (VLA)
CO(1-0) contours (IRAM)
Resolution ~ 1 arcsec ~ 40 pc

Schinnerer et al., 2013
Colombo et al., 2014

Evidence of GMCs sensitive to their galactic environments
In very nearby galaxies:
M51, M33, SMC

(Hughes et al. 2013)



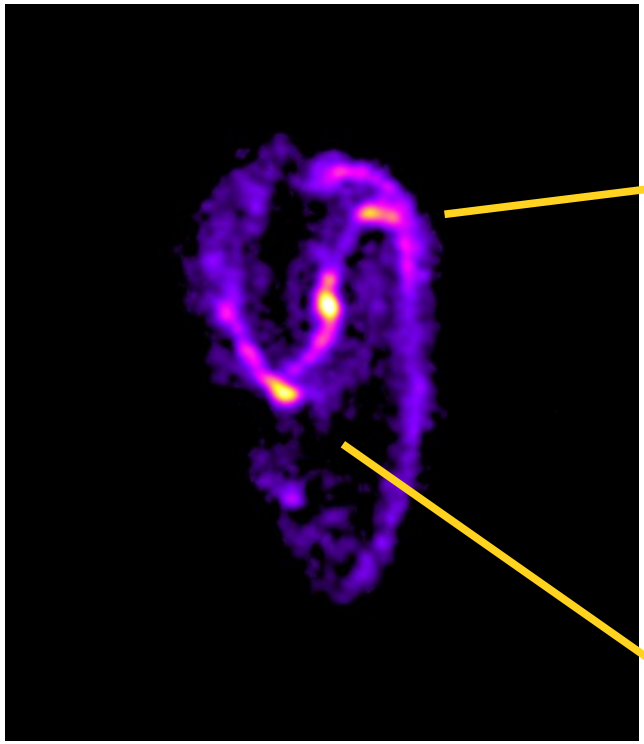
M33 @ 840 kpc

CO(2-1) (IRAM – 30m)
Resolution ~ 12 arcsec ~ 49 pc

Druard et al., 2014

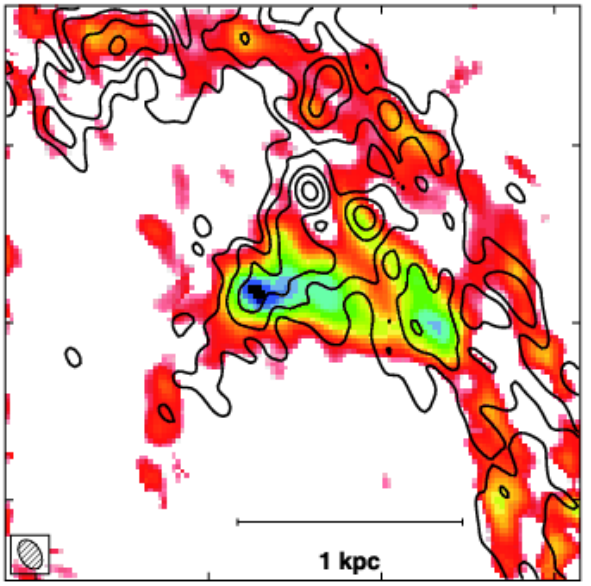
Nearby galaxies

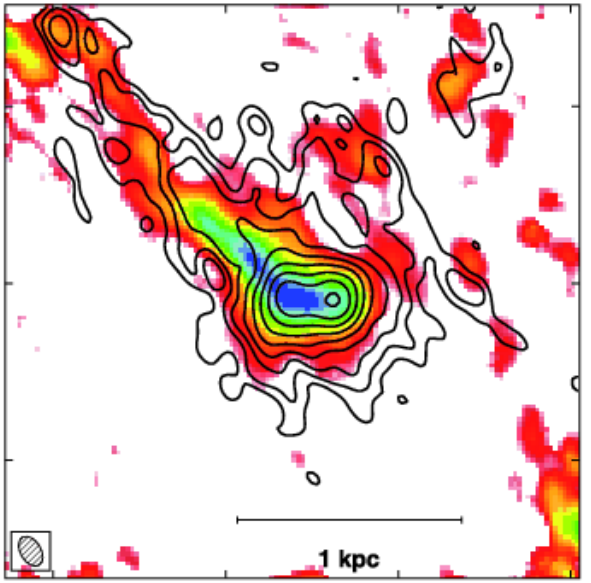
NGC3627 @ 11 Mpc



CO(1-0) image (BIMA)
Resolution ~ 6 arcsec ~ 320 pc

Helfer et al., 2003



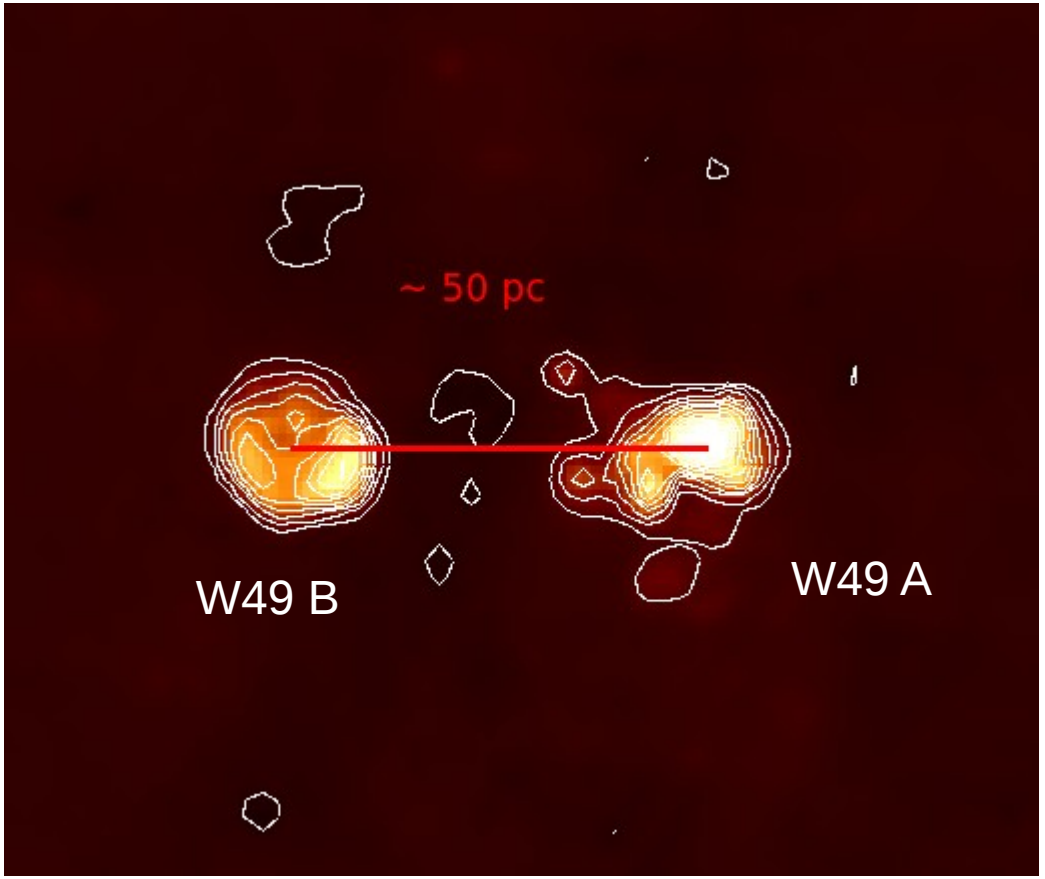


CO(1-0) image (IRAM)
1.4 GHz contours (VLA)
Resolution ~ 2 arcsec
~ 100 pc

Paladino et al., 2008

Typical size of a GMC in the Milky Way is 40 pc...

Nearby galaxies



NVSS 1.4 GHz image
of the W49 complex

We need:

high spatial resolution to resolve different components

high spectral resolution to avoid blendings of regions with different velocities

Nearby galaxies

ALMA resolution

Band	Freq GHz	FoV arcsec	min res arcsec	max res arcsec
1	31.3 - 45	145 - 135	13 - 9	0.14 - 0.1
2	67 - 90	91 - 68	6 - 4.5	0.07 - 0.05
3	84 - 116	72 - 52	44.9 - 3.6	0.05 - 0.038
4	125 - 163	49 - 37	3.3 - 2.5	0.035 - 0.027
6	211-275	29-22	2.0 - 11.1	0.021 - 0.016

Scale @ 10 Mpc (pc)	50 Mpc (pc)
5	24
2.5	12
2	9
1.3	7
0.77	5

Not yet available

In Band 2 DCO^+ (1-0) ; DCN and NH_2D predicted from simulations in starburst or CR enhanced regions (Bayet 2010)

CO(1-0) ; HCN(1-0) ; HCO^+ (1-0)

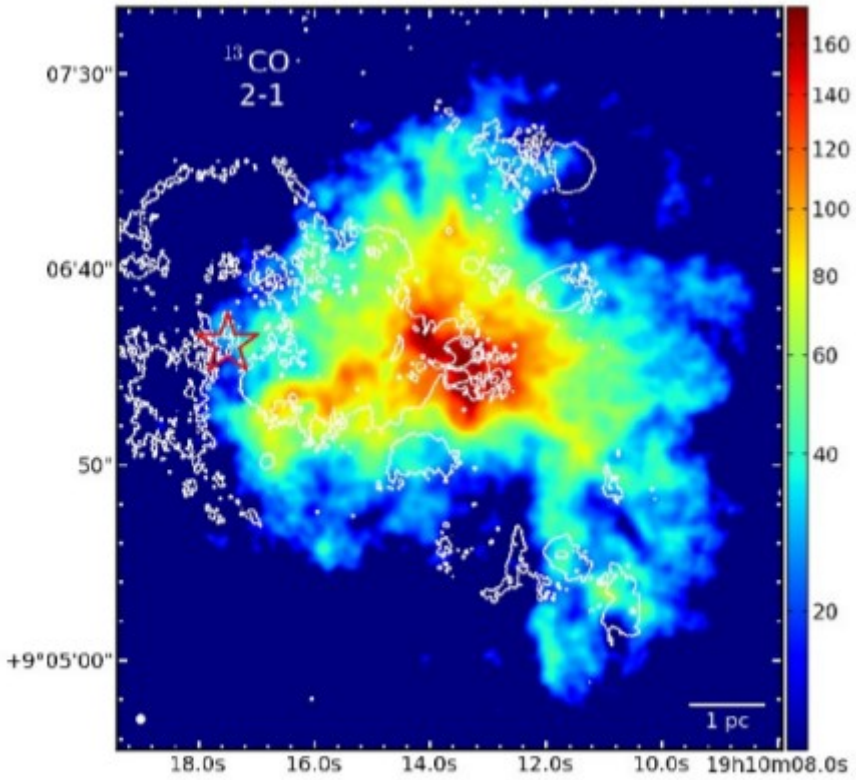
DCO+ (2-1)

CO (2-1) ; HCN (3-2) ; HCO+ (3-2) ; SO_2

The galactic GMC W49

One of the most luminous star forming regions in the MW @ ~11 kpc

$L \sim 10^{7.2} L_{\odot}$ (Sievers et al. 1991) $M_{gas} \sim 10^{6} M_{\odot}$ (Miyawaki et al., 2009)



MUSCLE W49

Lines and continuum observations
in 4 GHz bands
@ 220 and 230 GHz
resolution: 2 arcsec to 0.8 arcsec
More than 50 molecules (isotopologues)
Have been identified.

CO(2-1) integrated flux
1.23553×10^{5} Jy km s^{-1}
rms = 4.8 Jy beam^{-1} km s^{-1}

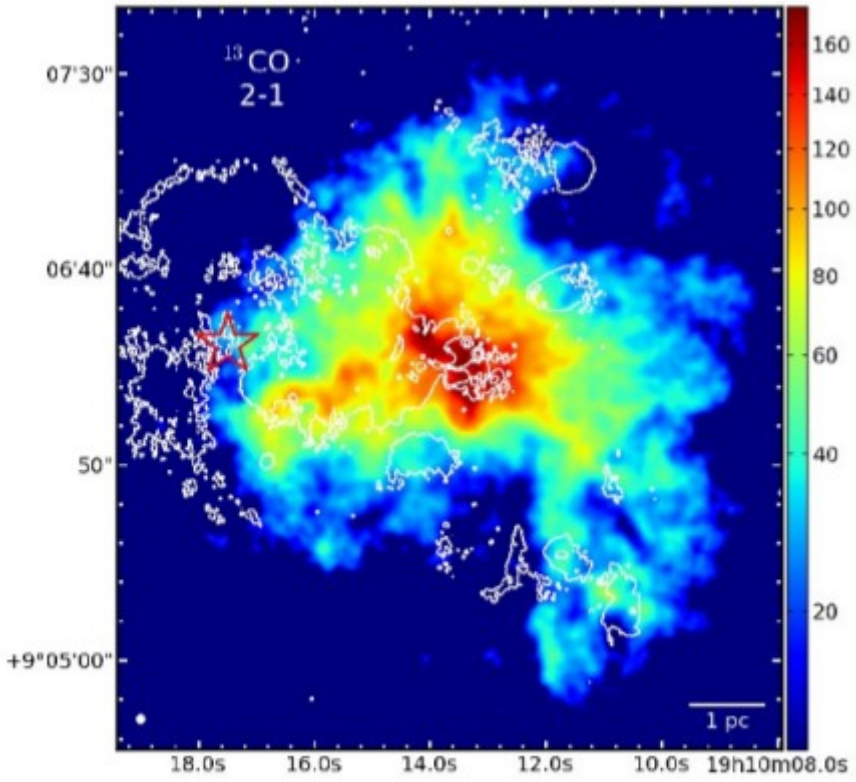
W49A

CO(2-1) SMA image
Contours 3.6 cm free free emission

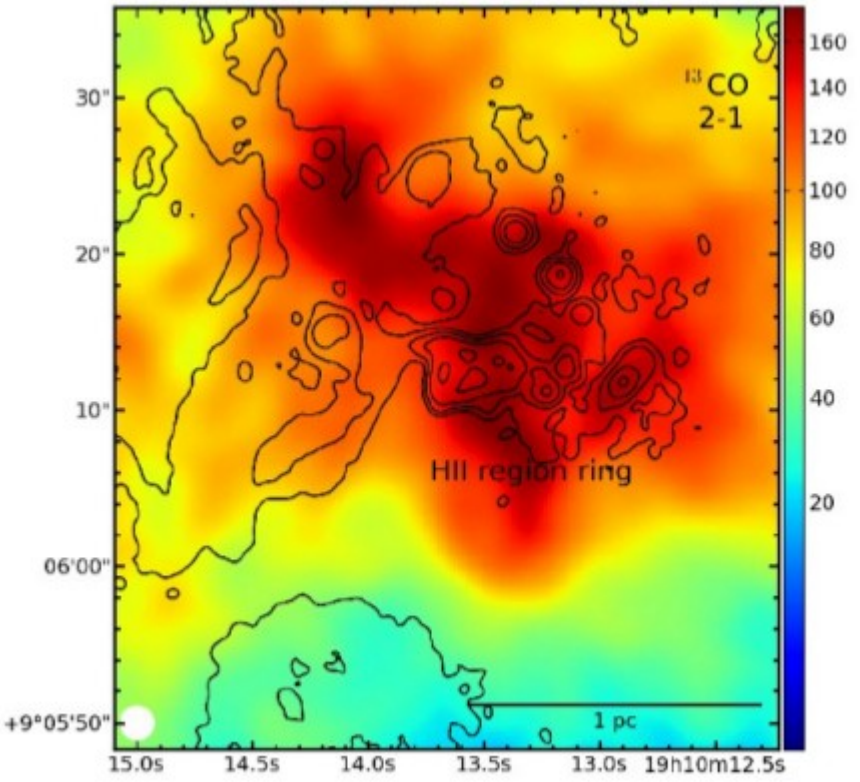
Galvàn-Madrid et al., 2014

The galactic GMC W49

Comparison between thermal free-free and molecular emission



W49A
CO(2-1) SMA image
Contours 3.6 cm free free emission

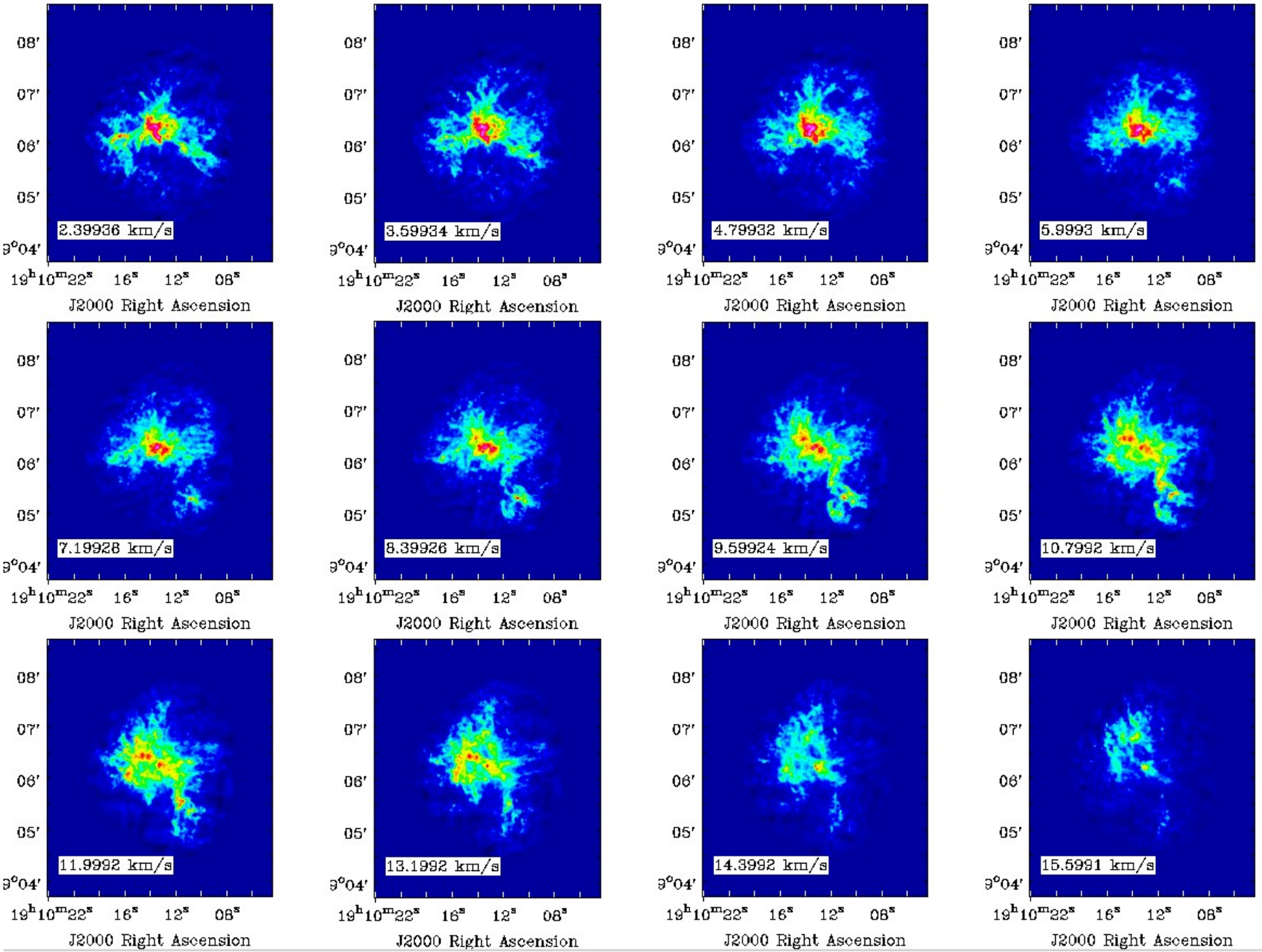


W49A zoomed-in
CO(2-1) SMA image
Contours 3.6 cm free free emission

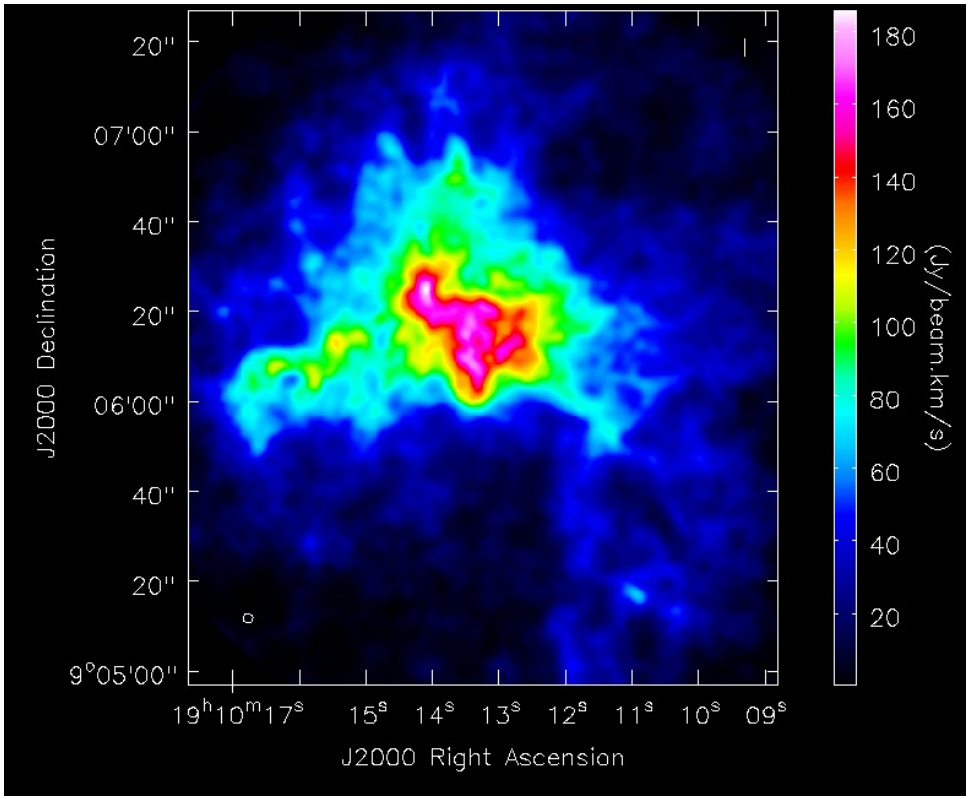
Galvàn-Madrid et al., 2014

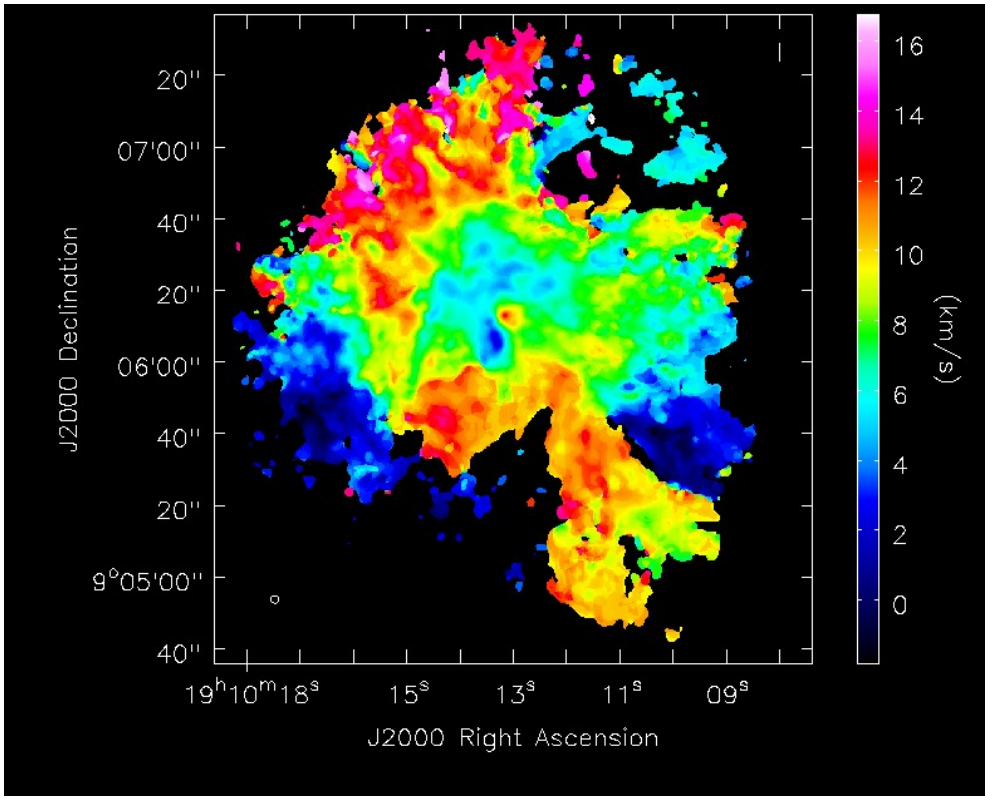
The galactic GMC W49

Channel map



The galactic GMC W49





Integrated intensity map

Velocity intensity map

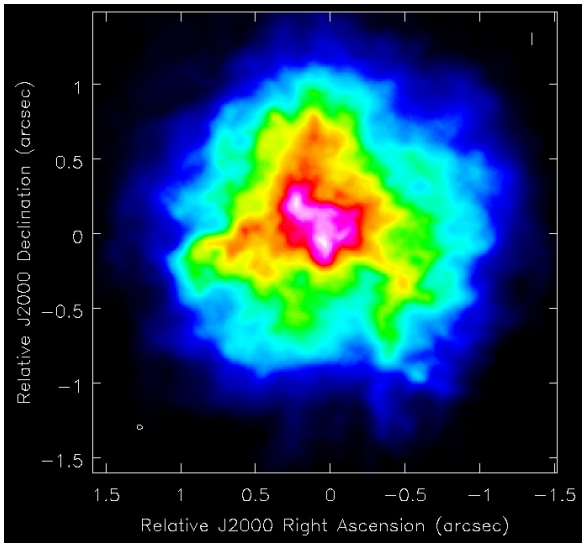
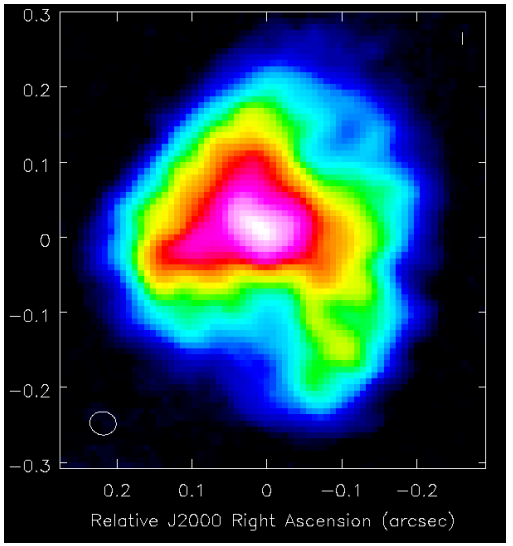
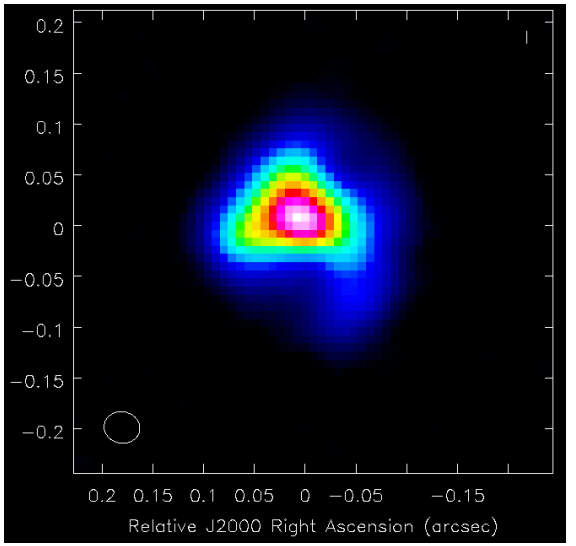
Region size ~ 2.5' → ~ 8 pc

Peak = 12.85 Jy
Freq resolution = 1.2 km/s

Simulations of ALMA observations

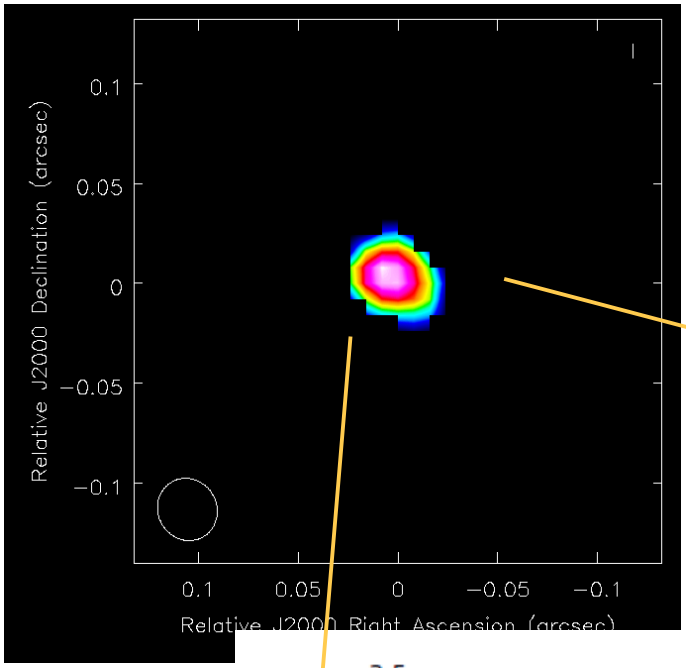
Integrated intensity maps

Scaling the peak brightness, the observing frequency, and the channel width of W49A at various distances, observations with ALMA in Band 6 at resolution of 0.03'', 5 min on source (rms ~ 3 mJy/beam) have been simulated

	800 kpc	5 Mpc	10 Mpc
			
Size	**~2.5''**	**~0.5''**	**~0.25''**
Spatial res (pc)	**0.11**	**0.72**	**1.45**
Peak (Jy km/s)	**1.2**	**0.6**	**0.45**

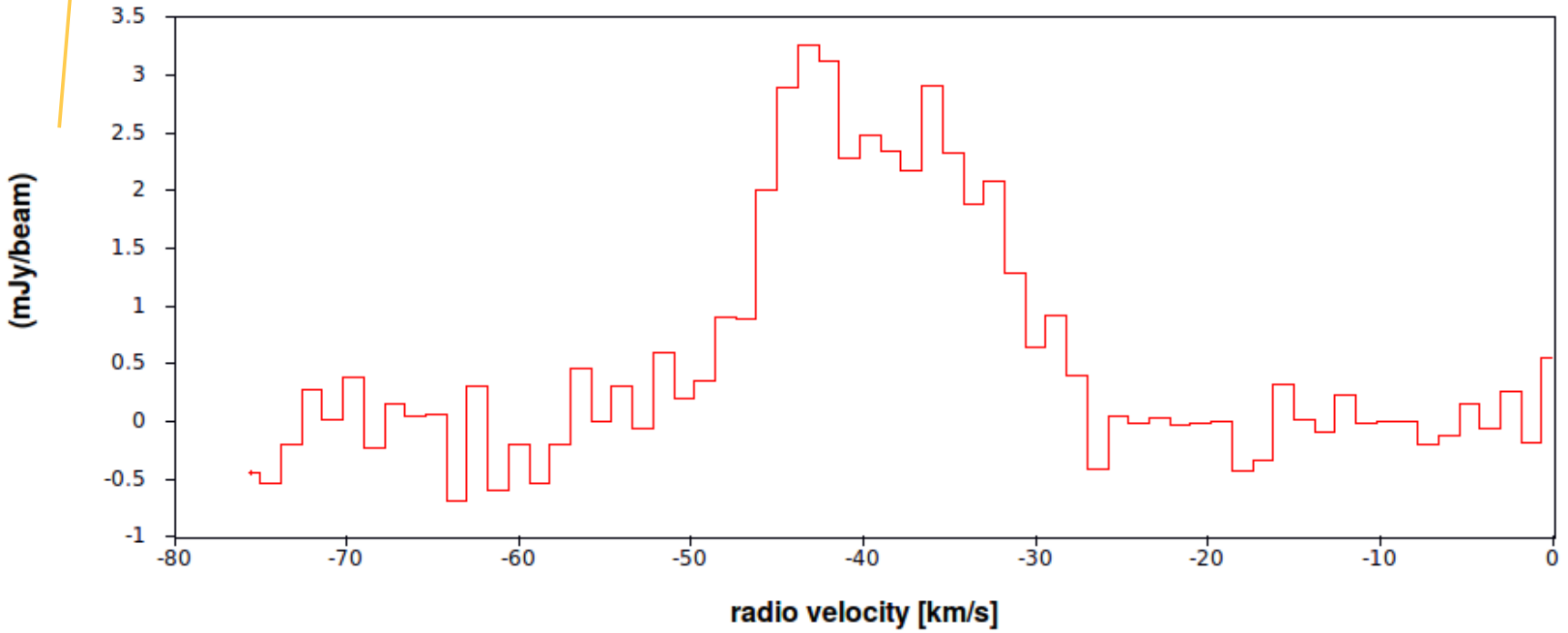
Simulations of ALMA observations

W49 @ 30 Mpc



Observation 30min on source (rms ~ 1mJy/beam)
Spatial res ~ 4 pc

The CO line profile of the cloud is well visible even when the structure is unresolved.



Simulations of observations with ALMA

show how a GMC like the galactic W49A

can be seen in galaxies up to 30 Mpc.

The study of a large sample of GMCs in nearby galaxies can

help in understanding star formation processes.

Grazie