DeGaS – MC

A Dense Gas Survey of the Magellanic Clouds

http://irfu.cea.fr/Pisp/maud.galametz/DeGaS-MC/DeGaS.html

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Content

Introduction on gas content and elemental abundances in the LMC

Previous studies on the dense gas in the LMC

The DeGaS-MC single-pointing campaign

Previous attempts to resolve the dense gas

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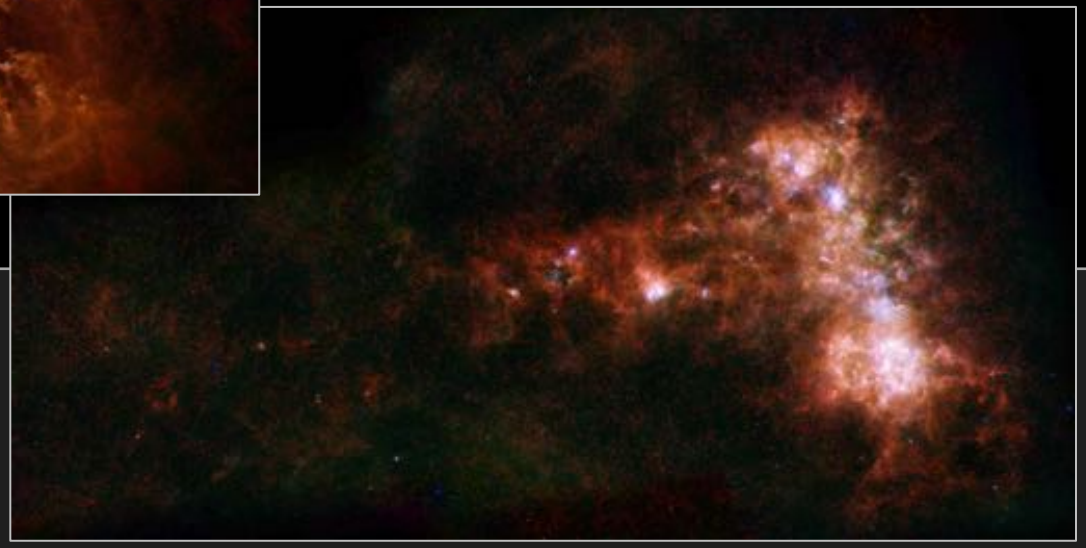
The Large and Small Magellanic Clouds

LMC

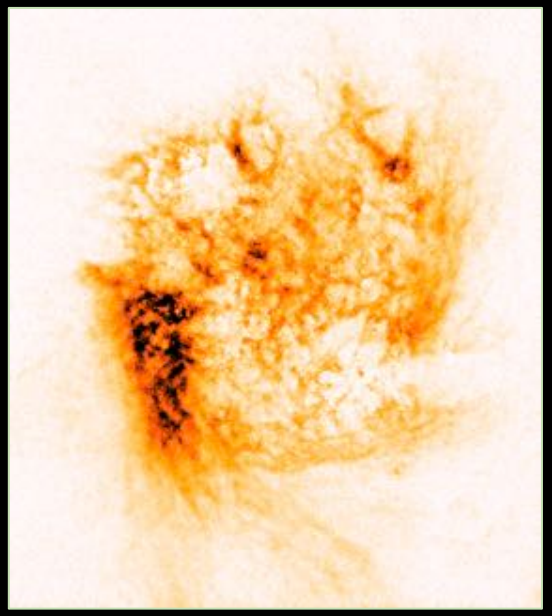
- **Distance: 50 kpc**
- **Metallicity: 1/2 solar**
- **Mass: 10^9 $M_\odot$**

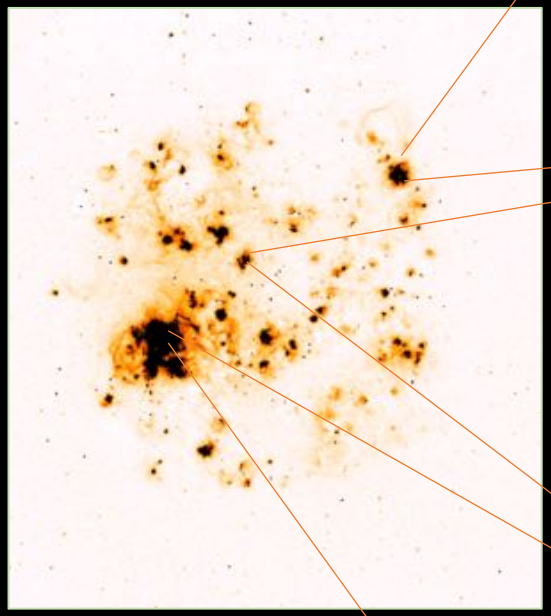


SMC

- **Distance: 61kpc**
- **Metallicity: 1/5 solar**
- **Mass: LMC / 5**

Atomic and ionized gas in the LMC





Atomic gas
HI

Ionized gas
Hα

Kim et al 2003

MCELS, Smith et al. 2005

Molecular gas in the LMC traced via CO

CO, MAGMA survey

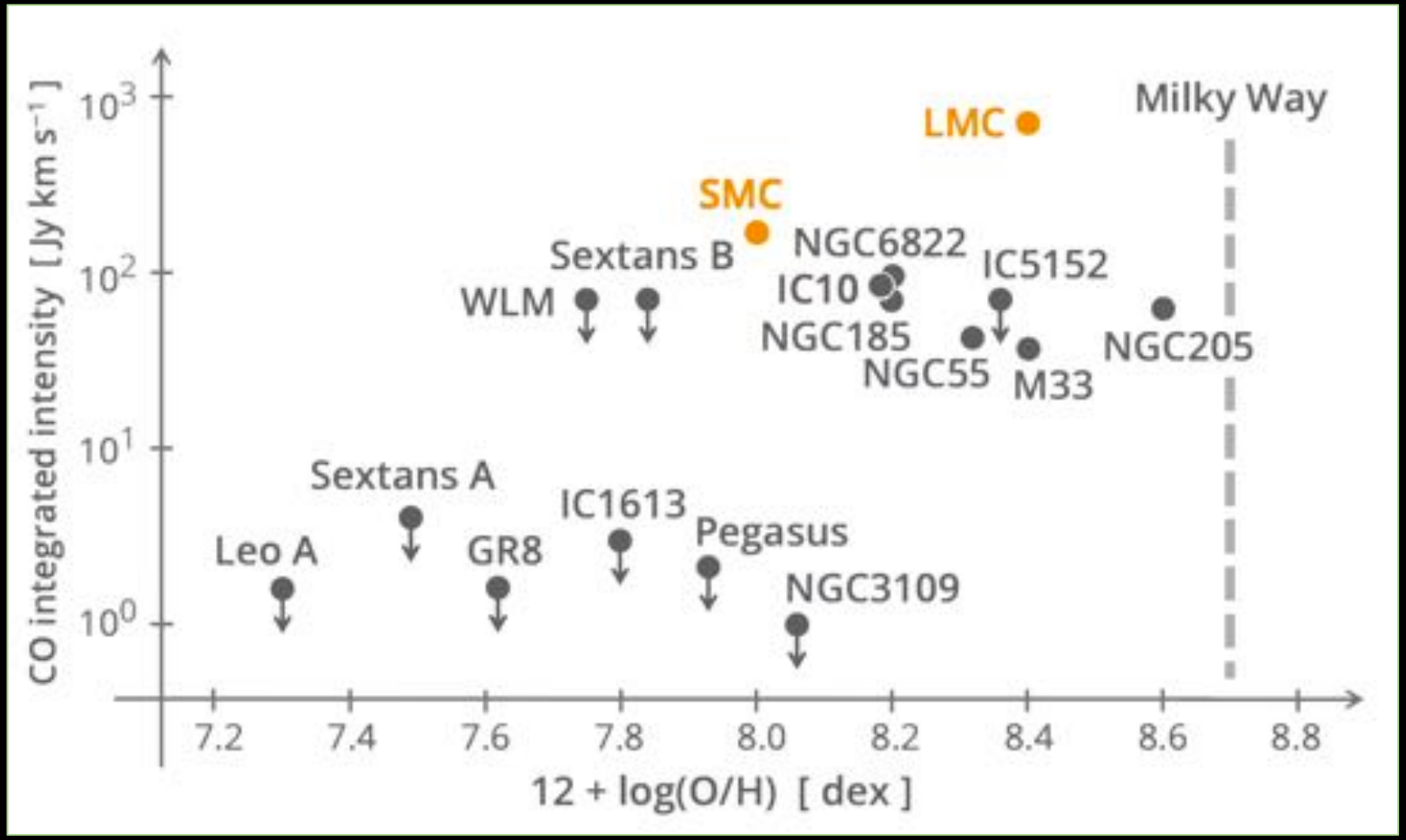
(Wong et al 2011)

See also Fukui et al. 2008
with NANTEN

For the SMC:

APEX / COSSA (Van Kempen et al in prep)

The MG clouds among the dwarf population …



Adapted from Y. Nishimura

Elemental abundances

Major differences in the elemental abundances of C, N, O

Galaxy	$Z / Z_{\odot}$	O / H	C / H	N / H	S / H
Milky Way	1	7.41×10^{-4}	4.47×10^{-4}	9.12×10^{-4}	1.70×10^{-4}
LMC	1/3-1/2	2.4×10^{-4}	0.79×10^{-4}	0.87×10^{-4}	1.02×10^{-4}
	Thus:	*1/3*	*1/5*	*1/10*	*1/2*

Dufour et al. 1982

Why studying dense gas in the Magellanic Clouds

How do molecular clouds fragment ?

How is the star formation efficiency affected by the ISM conditions ?

CO does not provide the whole picture at low-metallicity

Dense gas:
where star formation is taking place

LMC and SMC : ideal laboratories

- Proximity
- low metal content
- Range of SF activity

Previous surveys with MOPRA

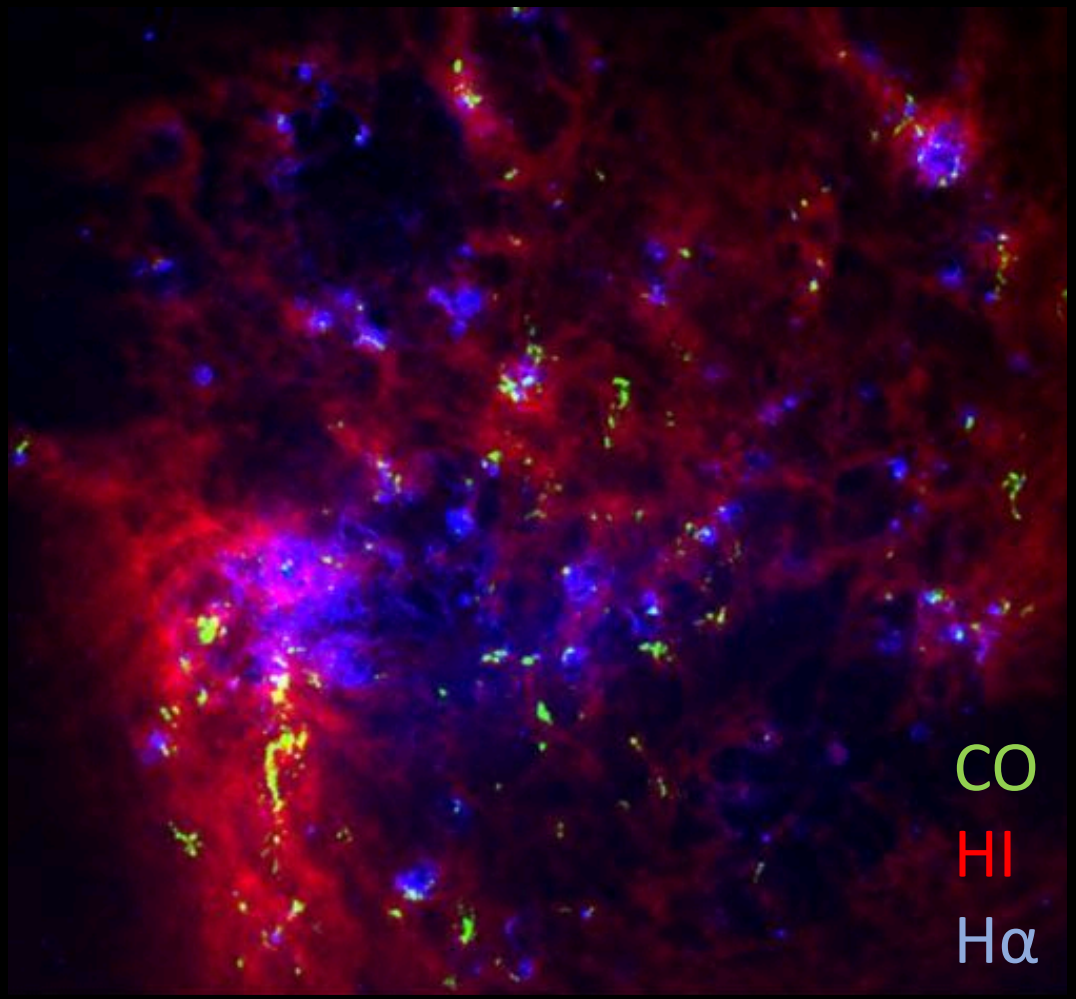
MAGMA :

MOPRA (22m) survey of LMC
@11pc resolution
Wong et al 2011

^{12,13}CO(1-0) already released

HCO^+(1-0), HCN(1-0), HNC(1-0) toward 48 GMCs

Levy et al in prep



Previous surveys with MOPRA

Nishimura et al 2016

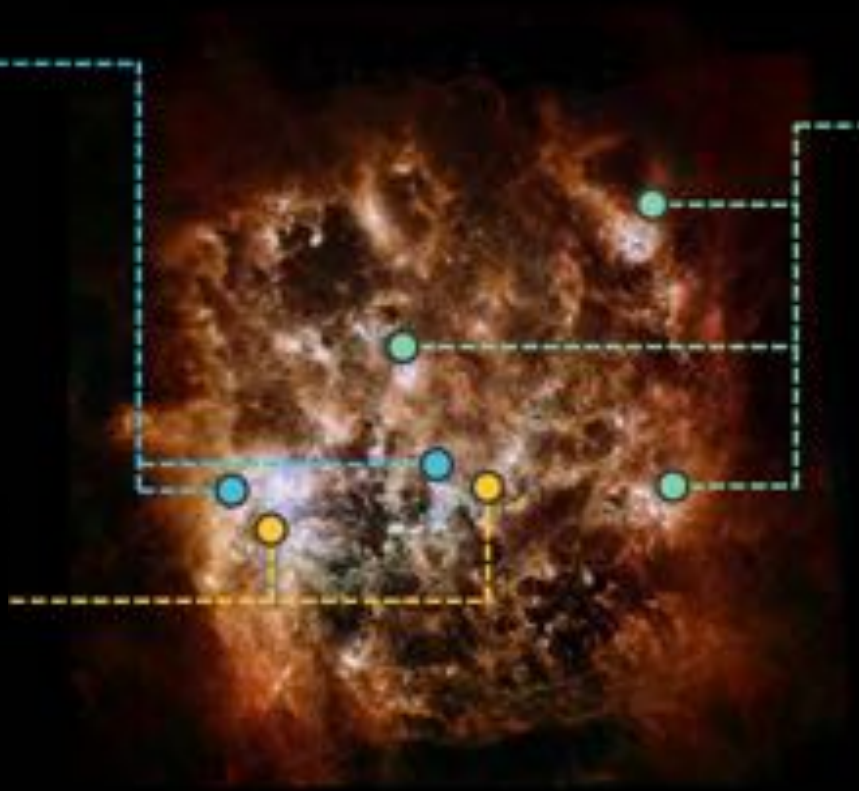
Survey towards 7 clouds with MOPRA

Quiescent Clouds

CO Peak 1
NQC2

Star-forming clouds

N79
N44C
N11B

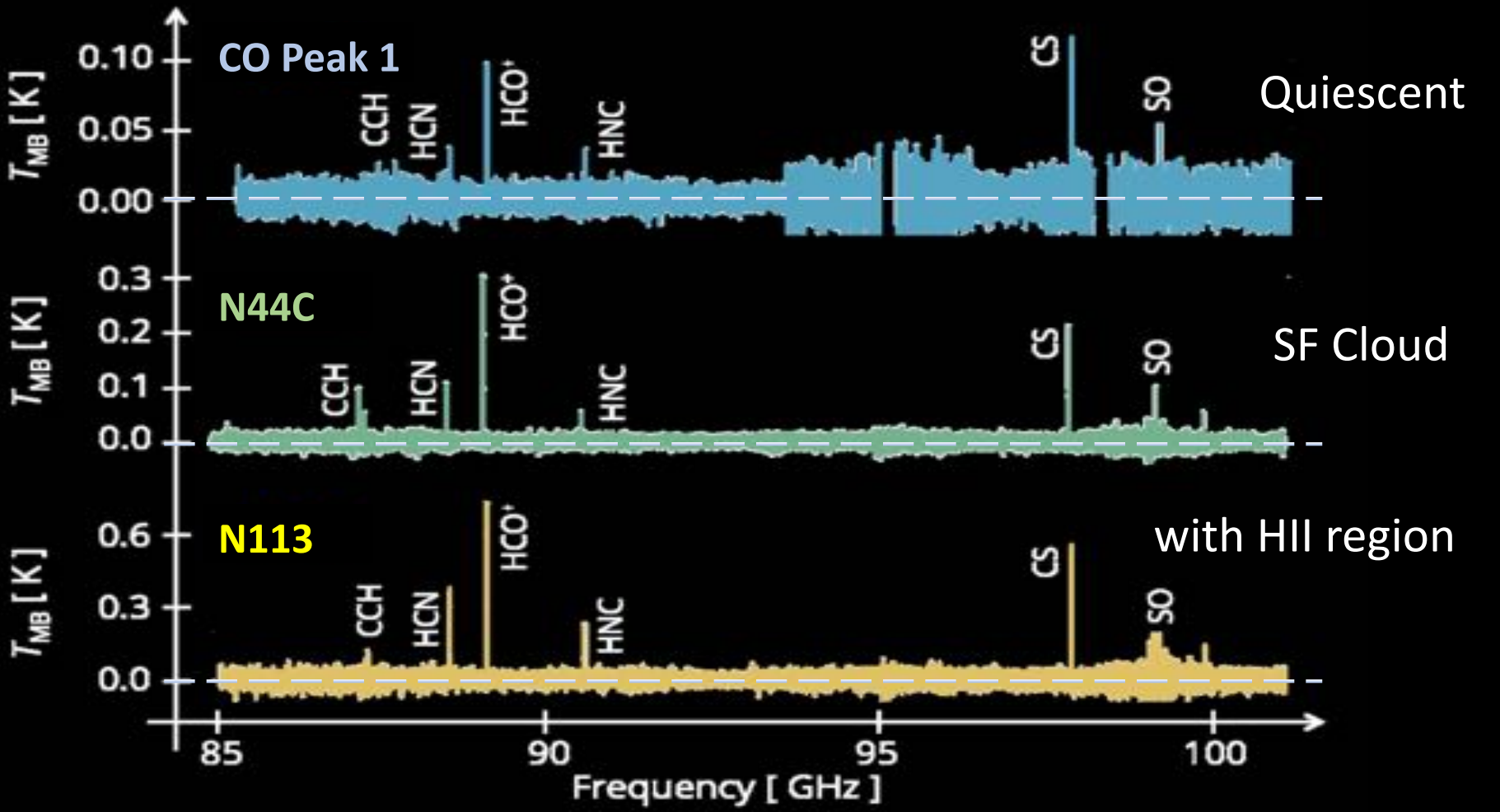


Star-forming clouds with HII region

N113
N159W

Previous surveys with MOPRA

Very few differences with the star formation activity of the cloud



Nishimura et al. 2016

Previous surveys with MOPRA

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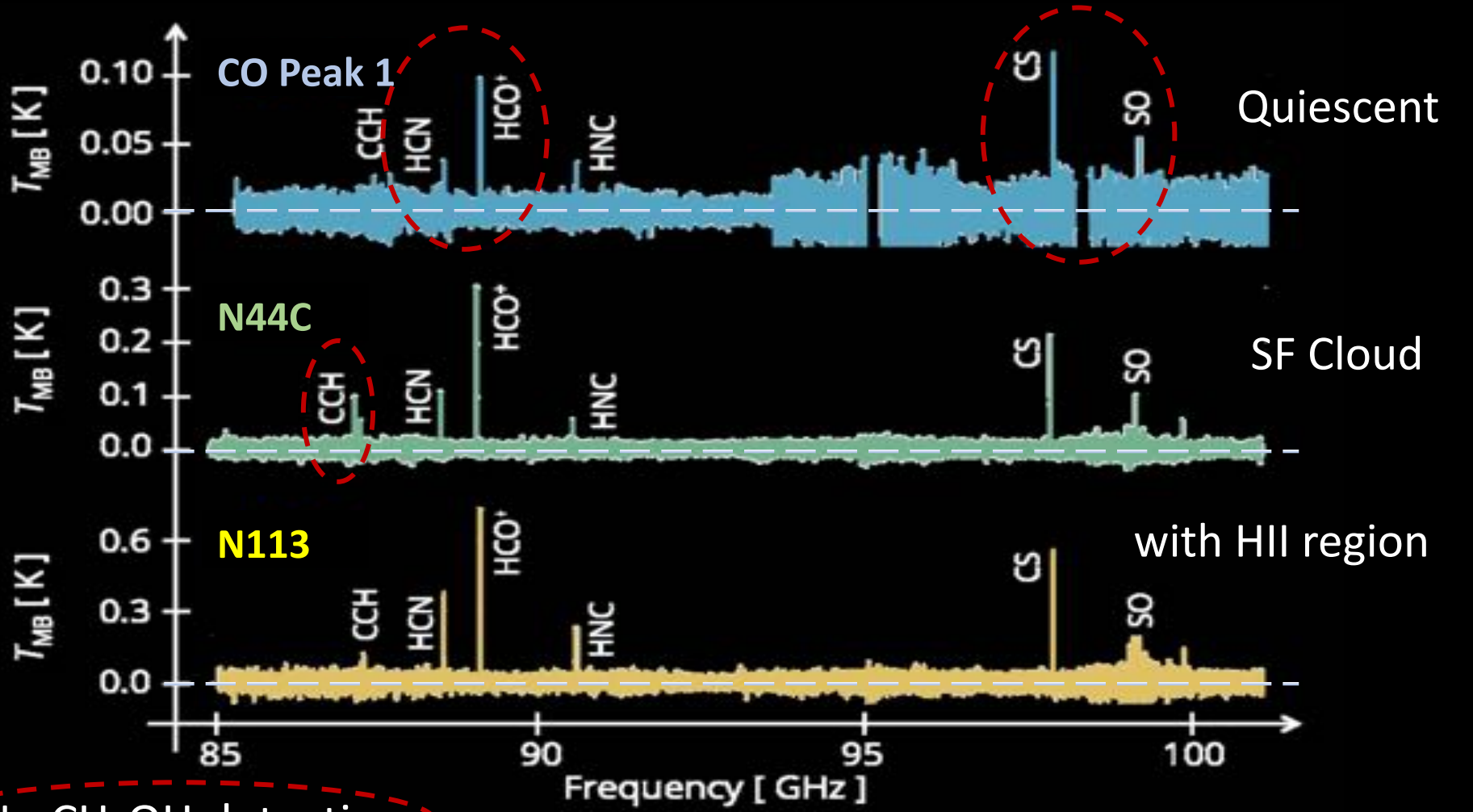


No CH_3OH detection

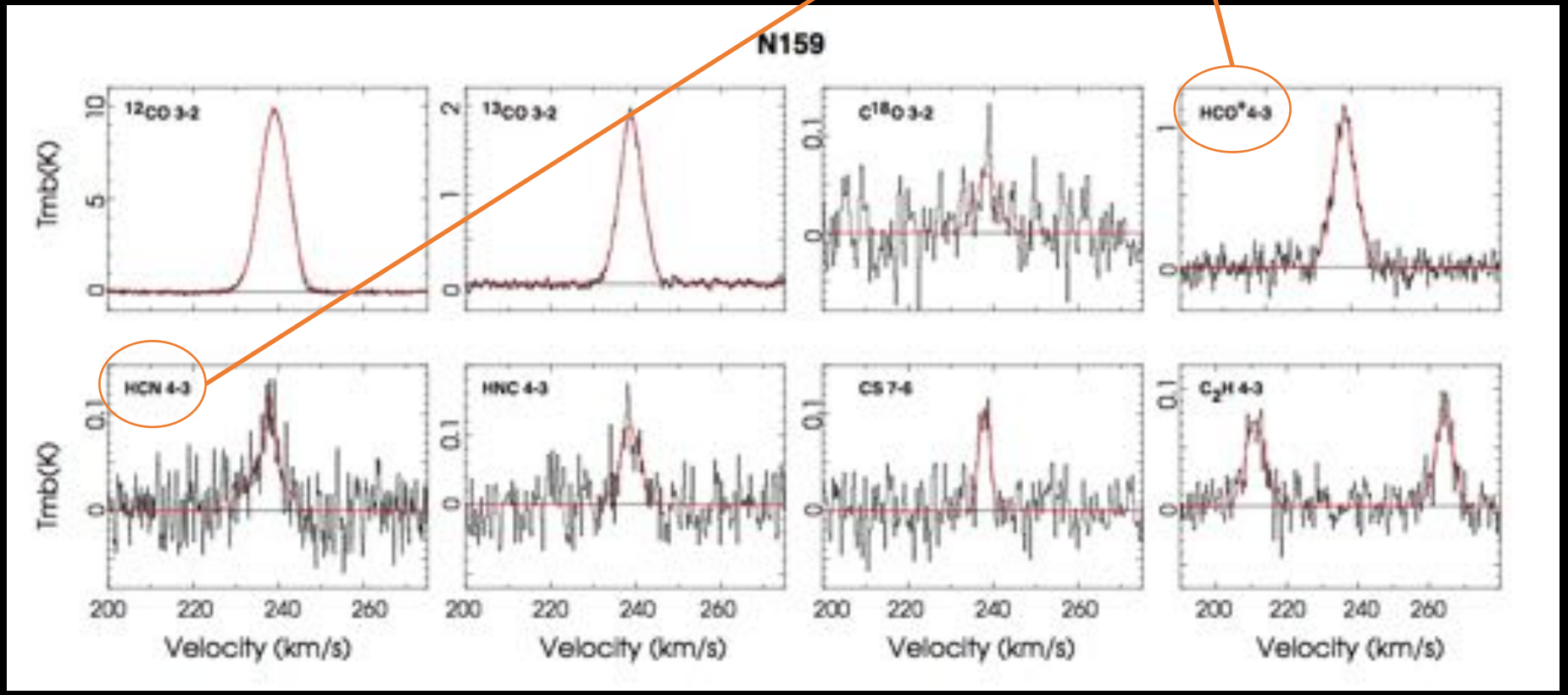
Nishimura et al. 2016

Previous surveys with ASTE

Paron et al 2015

Survey towards 3 HII regions

345GHz window



Dense Gas Survey in the Magellanic Cloud

APEX Band 5 survey of the HCO^+ and HCN 2-1 lines

Motivations

- Selection bias in the LMC – barely any analysis in the SMC

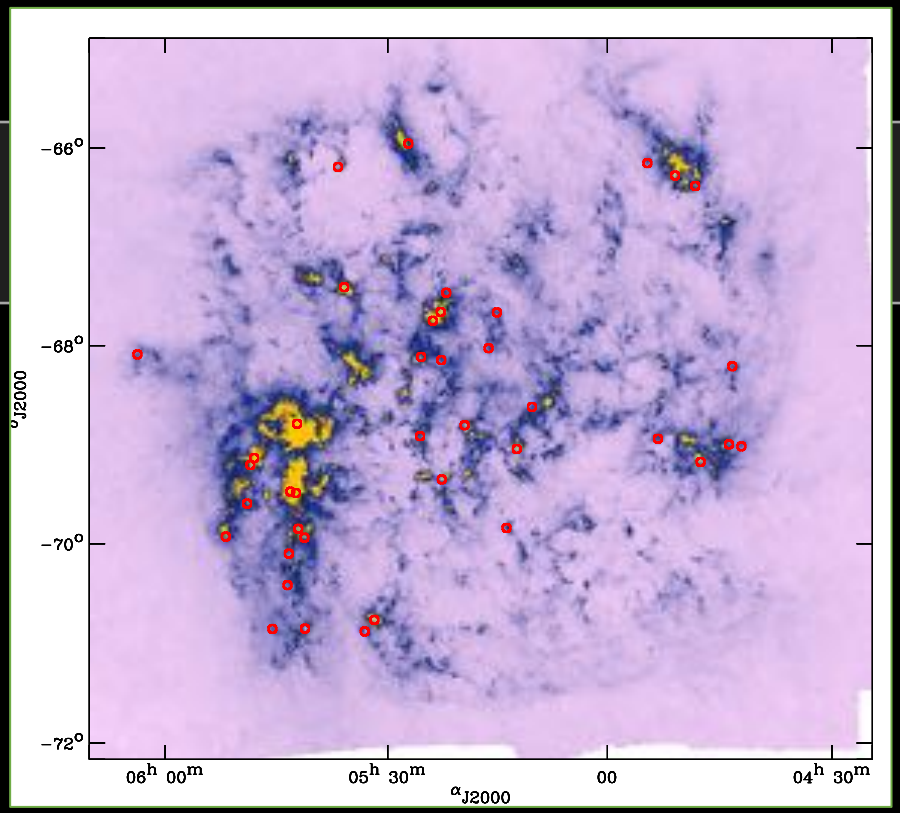
- Second transition of HCO^+ and HCN to derive cloud properties:
  Density
  Excitation temperature

- Probe the variations of the SFE with the dense gas fraction

Characteristics of the sample

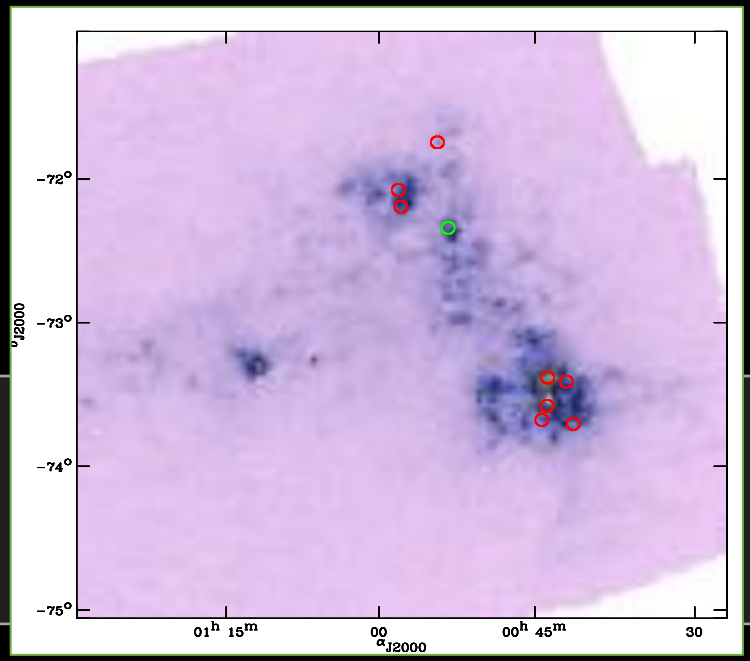
- from massive OB complexes to lower-mass star-forming clouds
  The $M_{CO,vir}$ range from 2×10^4 to 10^6 $M_\odot$

DeGaS-MC: the single pointing campaign



LMC

21 regions observed in ESO P97

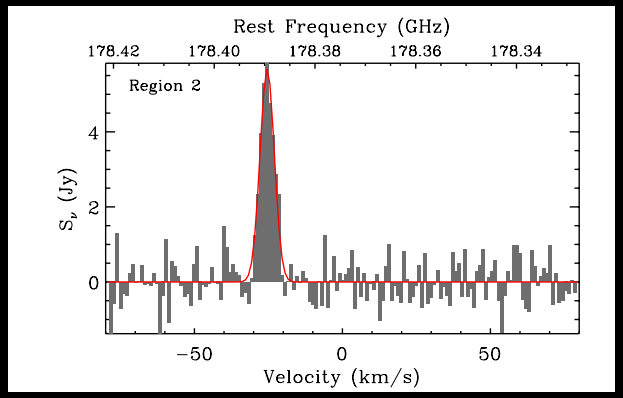


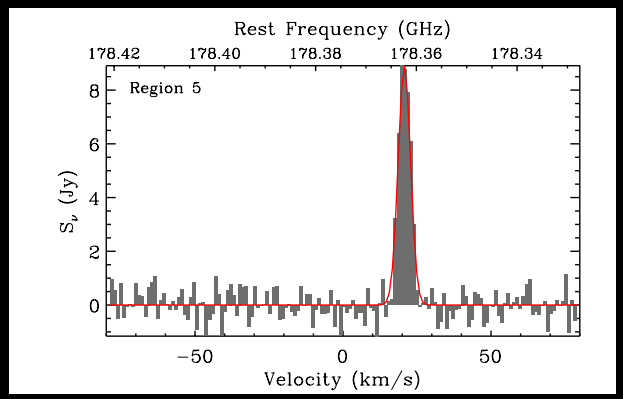
SMC

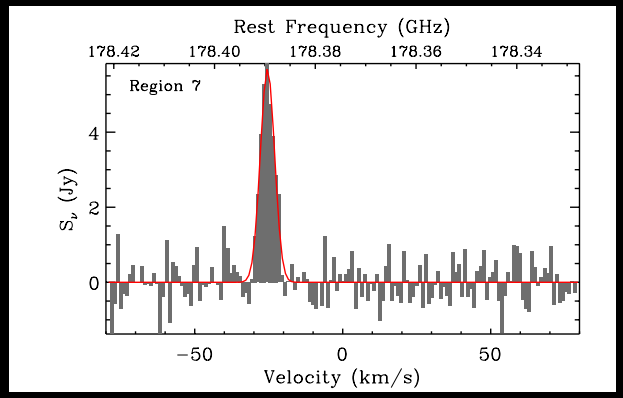
1 region observed in SV phase

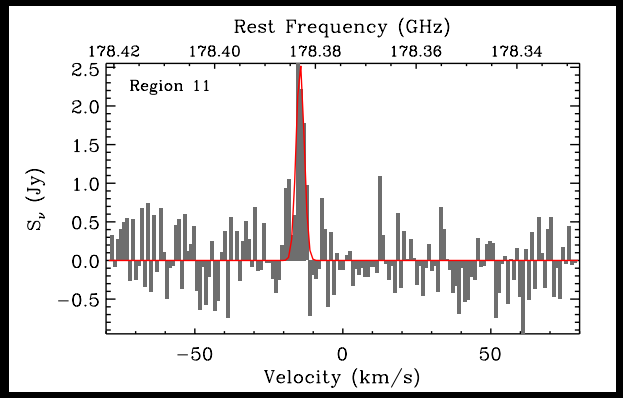
8 regions observed in P97

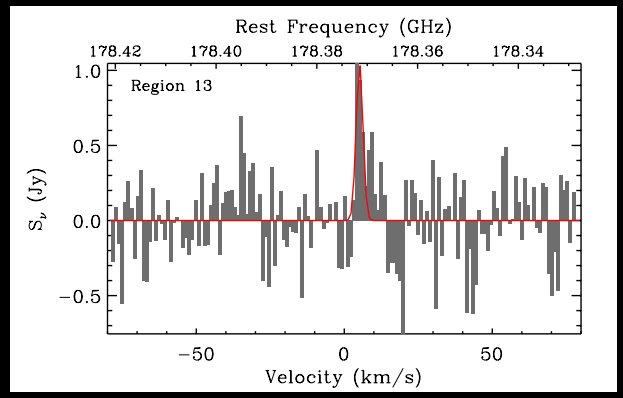
DeGaS-MC: LMC HCO^+ detections

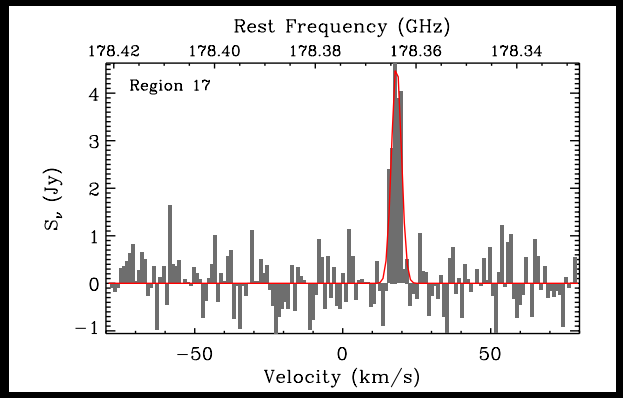


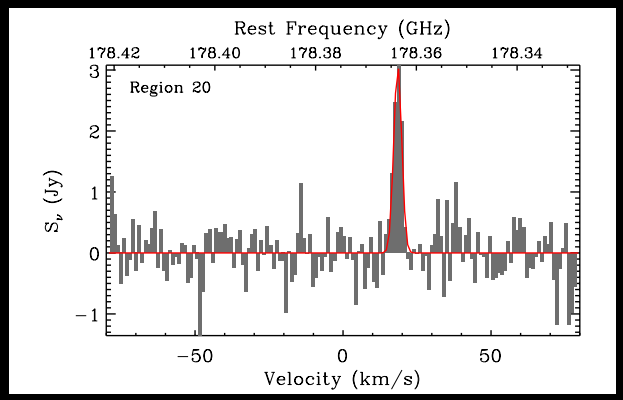


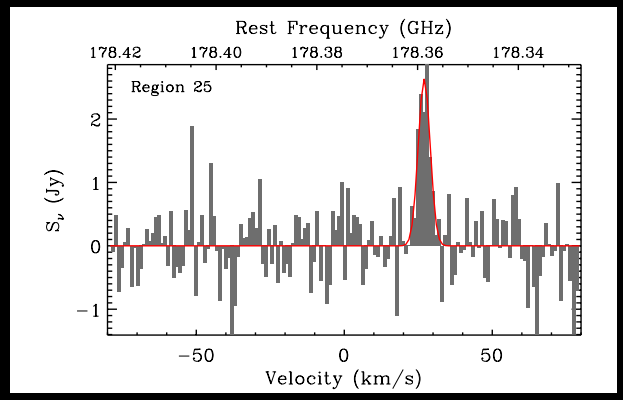


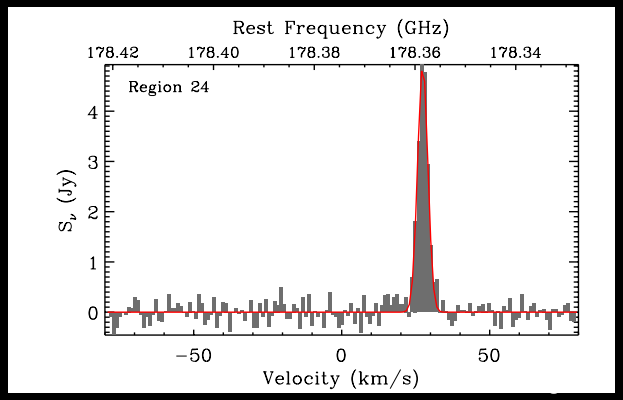












DeGaS-MC: Line characteristics

HCN difficult to detect
mostly detected toward strong HII regions

HCO^+ easily detected

		Observed	Detected	Average Width	T_{peak} (mK)
LMC	HCO^+ (2-1)	21	16	4.1	20 to 270
	HCN (2-1)	21	5	5.1	20 to 80
SMC	HCO^+ (2-1)	9	6	4.7	45 to 100
	HCN (2-1)	9	2	7.2	15

DeGaS-MC: Line characteristics

The lines detected toward the SMC clouds have larger linewidths:

more turbulence?
outflows ?

		Observed	Detected	Average Width	T_{peak} (mK)
LMC	HCO^+ (2-1)	21	16	4.1	20 to 270
	HCN (2-1)	21	5	5.1	20 to 80
SMC	HCO^+ (2-1)	9	6	4.7	45 to 100
	HCN (2-1)	9	2	7.2	15

DeGaS-MC: Line characteristics

When both are detected: HCO^+ / HCN > 2. Inverse ratio in the MW

→ Different N/O abundances

Variations of the ratio throughout the LMC

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LMC	HCO^+ (2-1)	21	16	4.1	20 to 270
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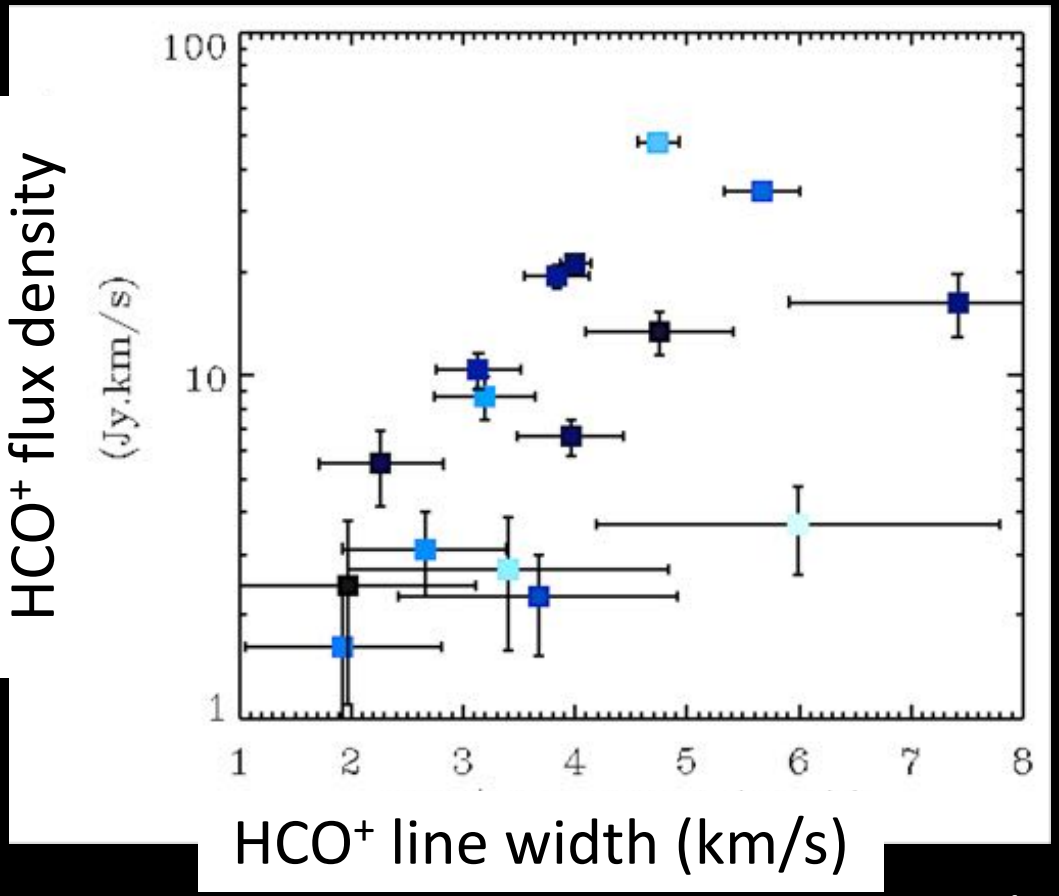
DeGaS-MC: Line characteristics

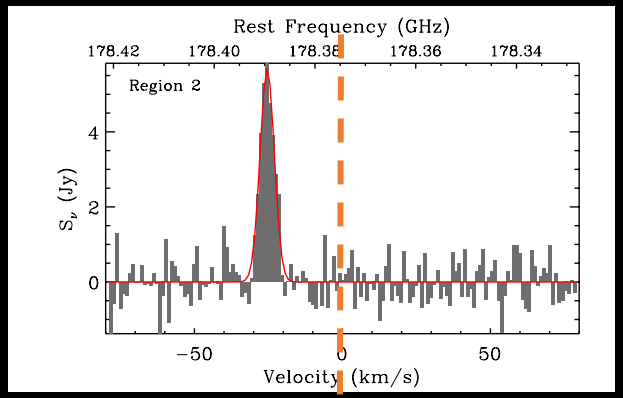


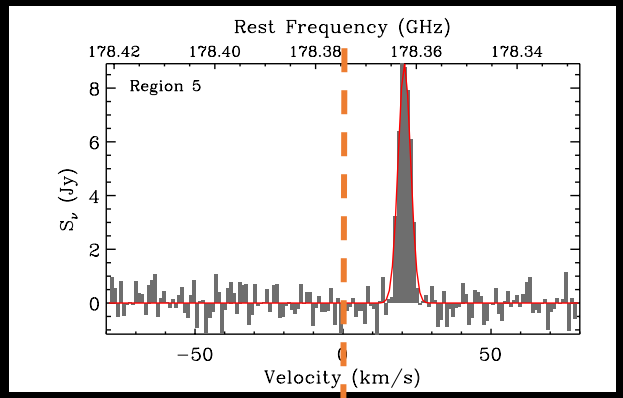
Trend of the linewidth with the flux density

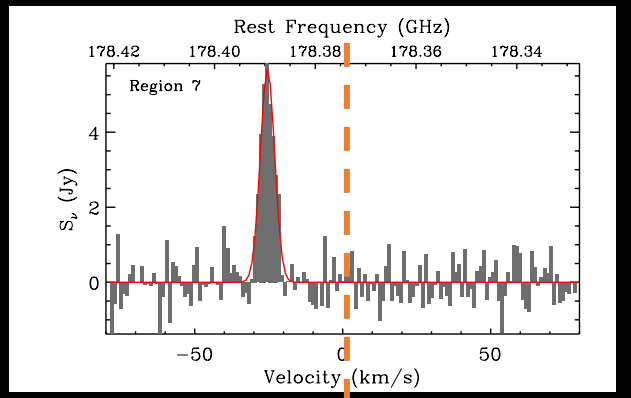
Weak correlation between the CO-based gas masses and the strength of the HCO^+ lines

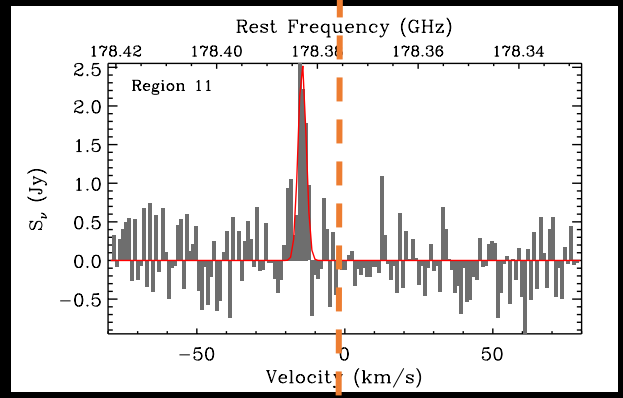
Points are color-coded by increasing $M_{CO,vir}$

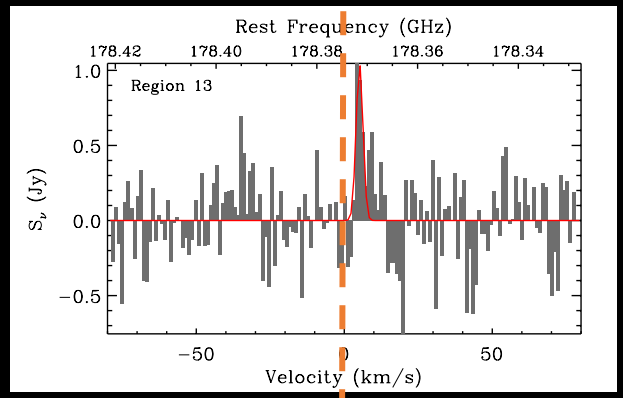
Velocity gradient across the LMC

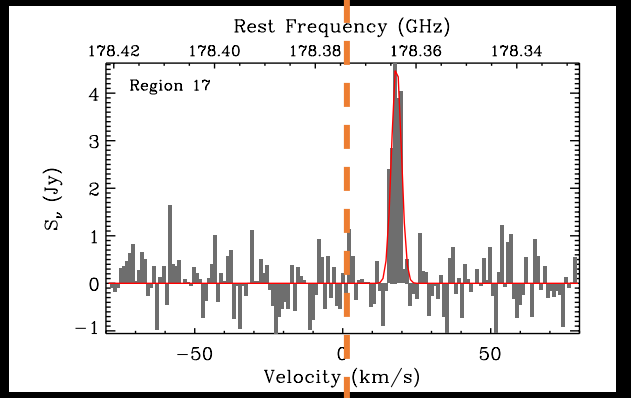


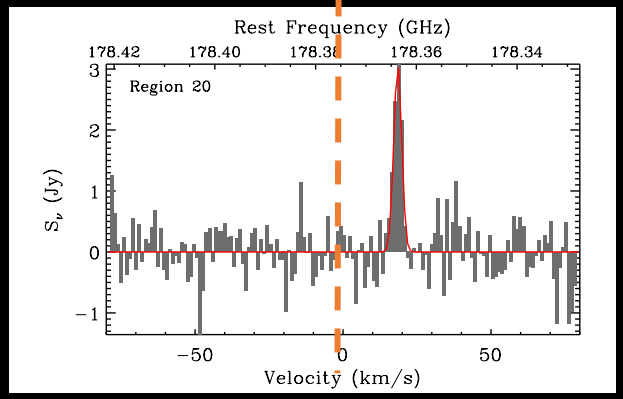


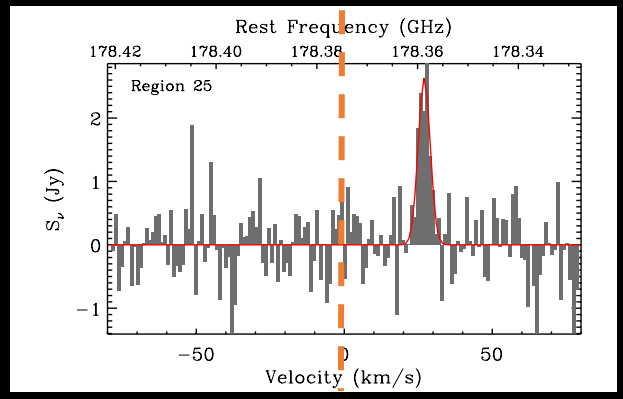


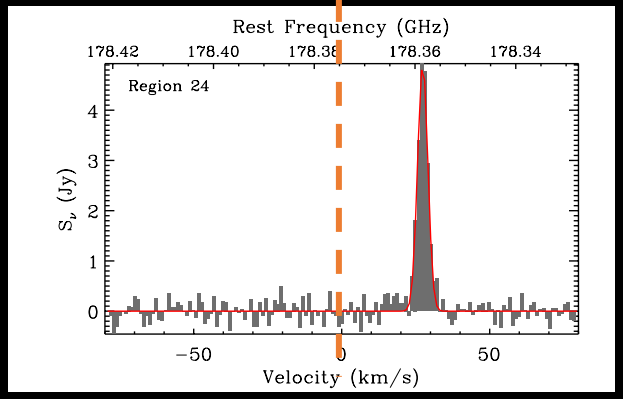




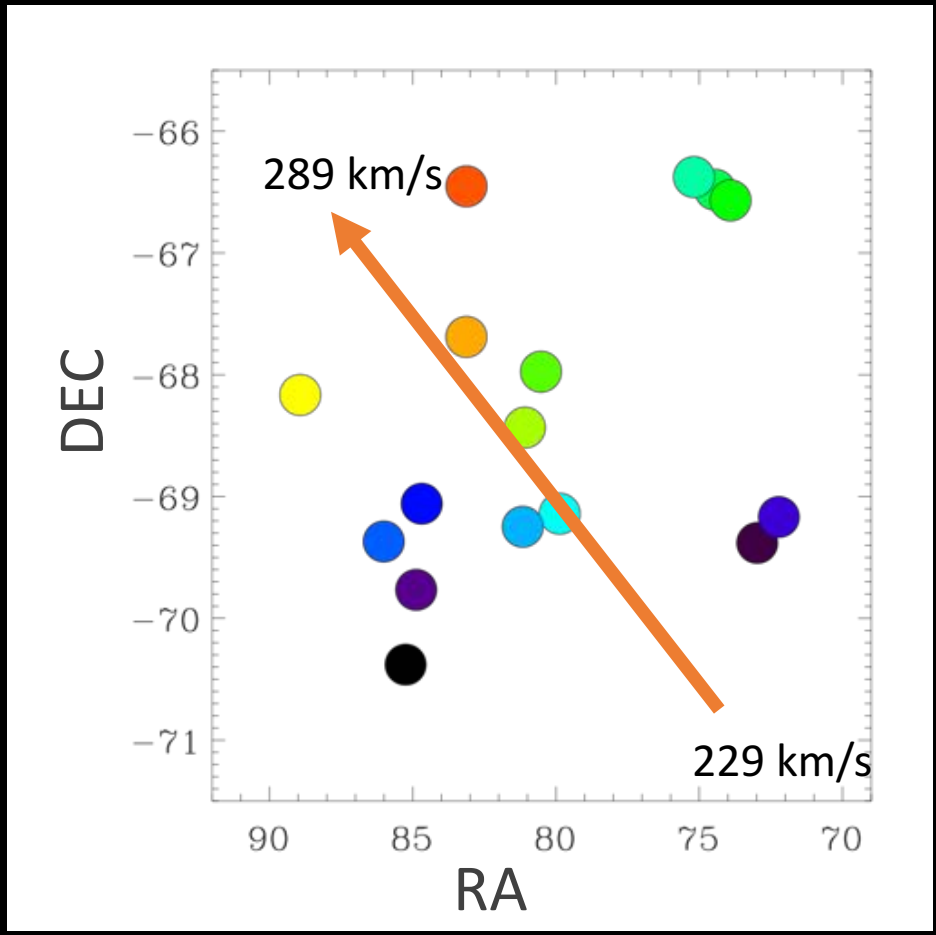




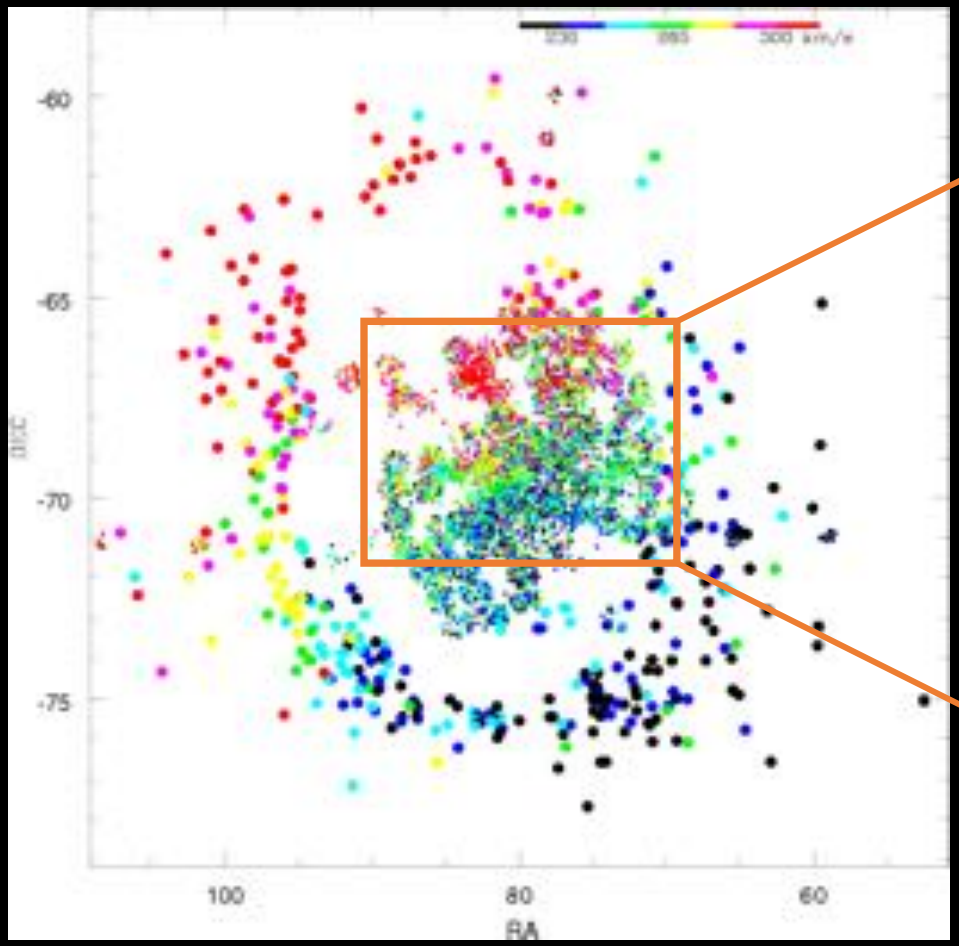


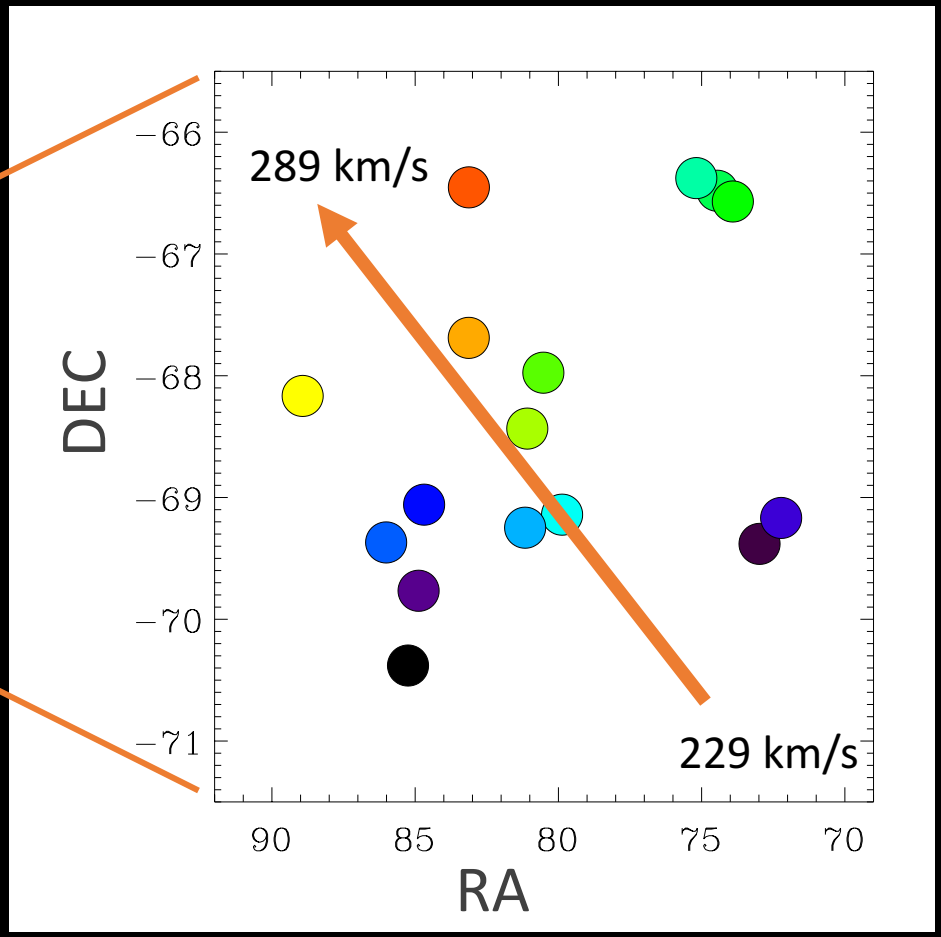


Velocity gradient across the LMC



Velocity gradient across the LMC





van der Marel et al. 2013

velocity field derived from observed stellar velocities

Dense Gas Survey in the Magellanic Cloud

BUT

There are limitations to a single pointing campaign

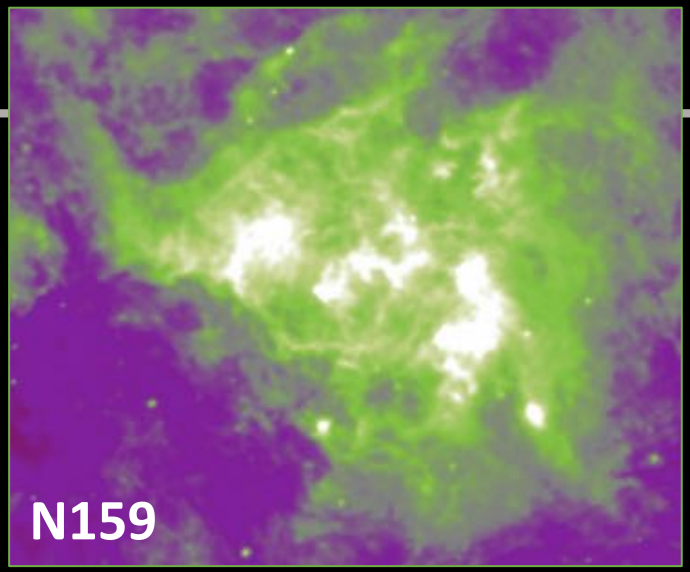
We need to resolve the clouds to:

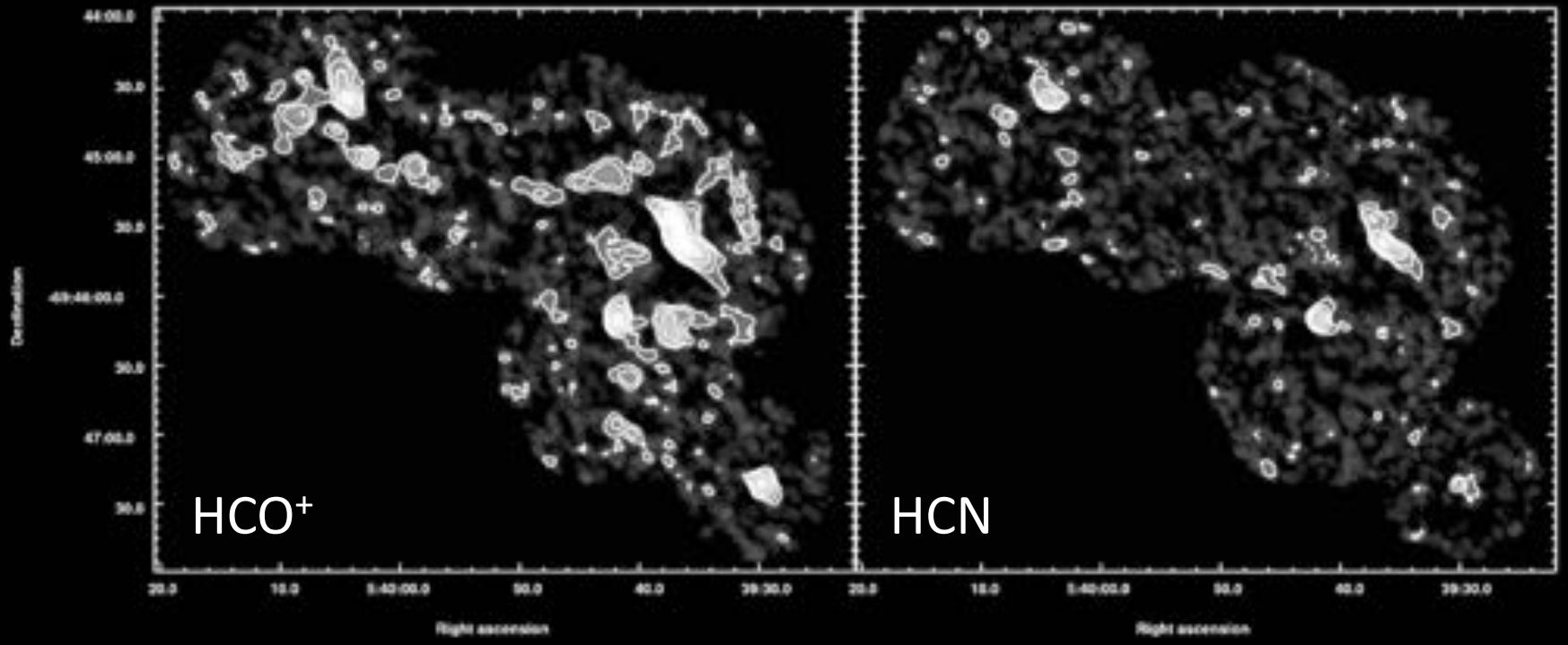
- analyse the cloud morphology and dynamical state
- trace the variation of the density profile
- perform radiative transfer analysis at a per-cloud level

Previous obs. with ATCA

Seale et al 2012

Survey of 4 LMC clouds with ATCA

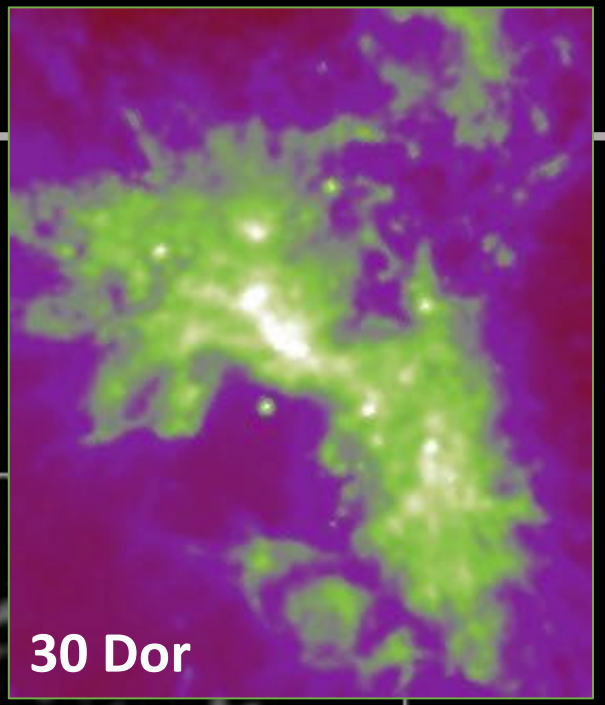


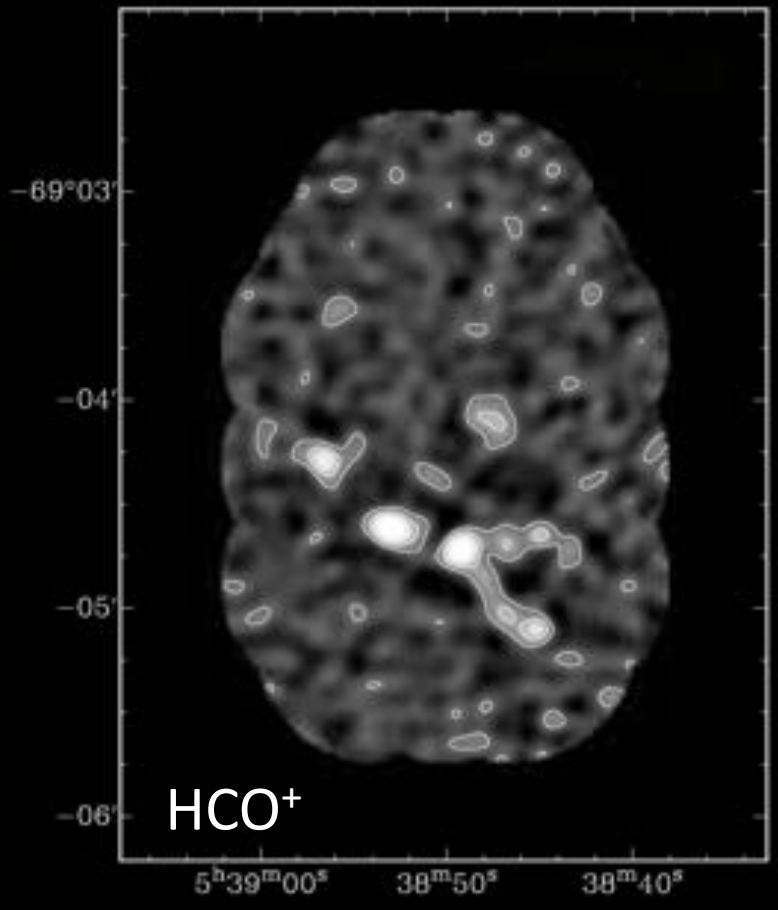


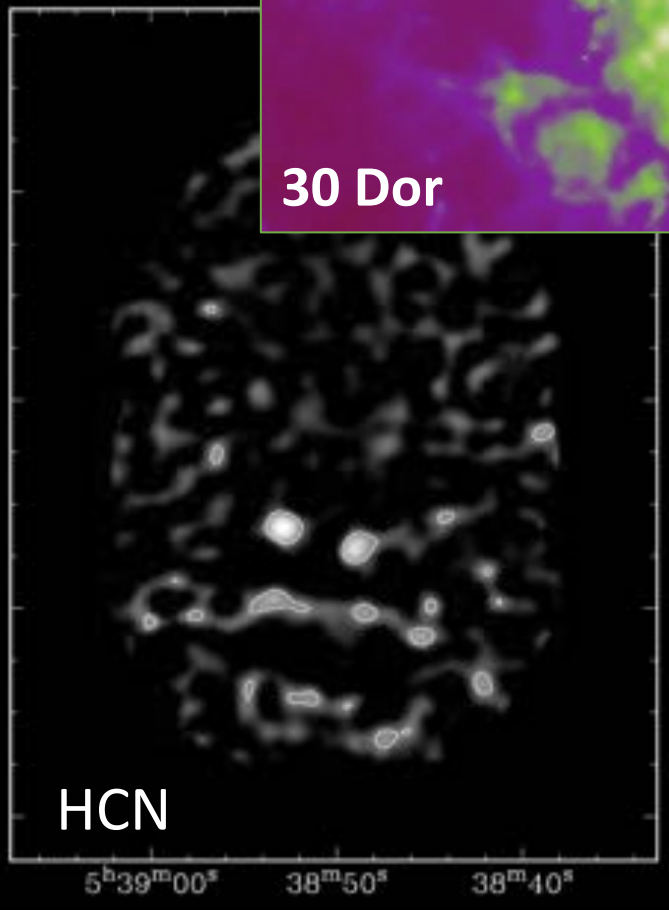
Previous obs. with ATCA

Anderson et al 2014

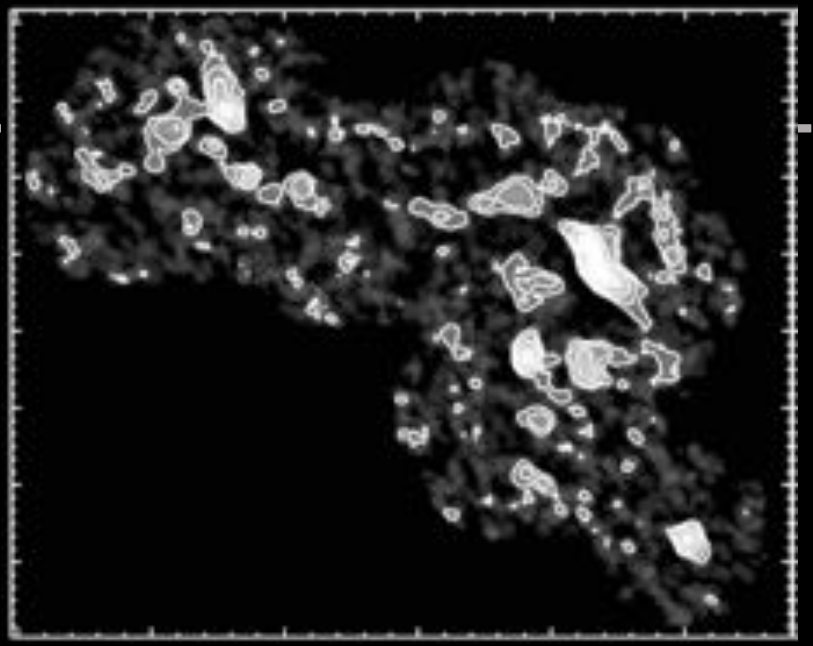
30Dor with ATCA







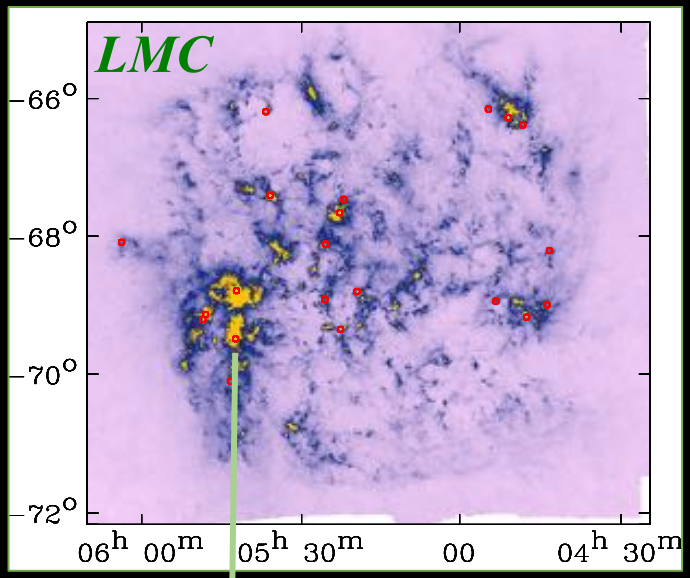
Previous obs. with ATCA

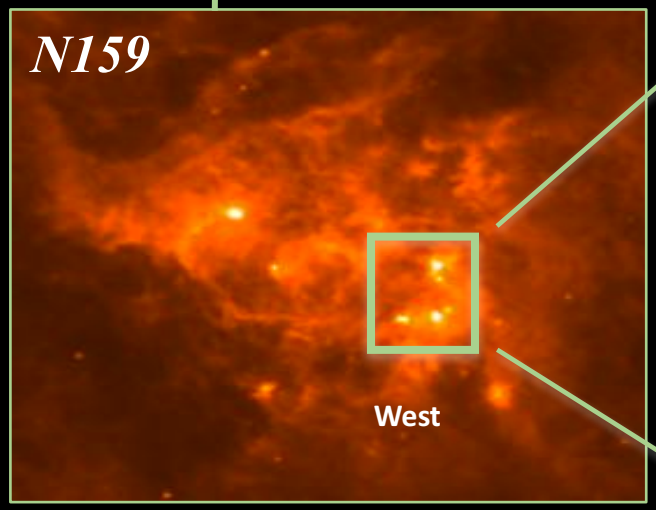


First conclusions

- Low dense gas fraction: 10%
- Clumpy structure of the GMCs
- Clump masses : 10^2 $M_\odot$ to 3×10^4 $M_\odot$
  radii : 1 - 2 pc
- HCN / HCO+ ↘ when mass, column density, and SF activity ↗
- Ability of a clump to form massive stars : determined by clump properties
- Very few massive (>10^3 $M_\odot$) clumps without SF
  → timescale shorter than the clump lifetime.
- Few variations observed with the strength of the UV radiation field

DeGaS-MC: future mapping campaign

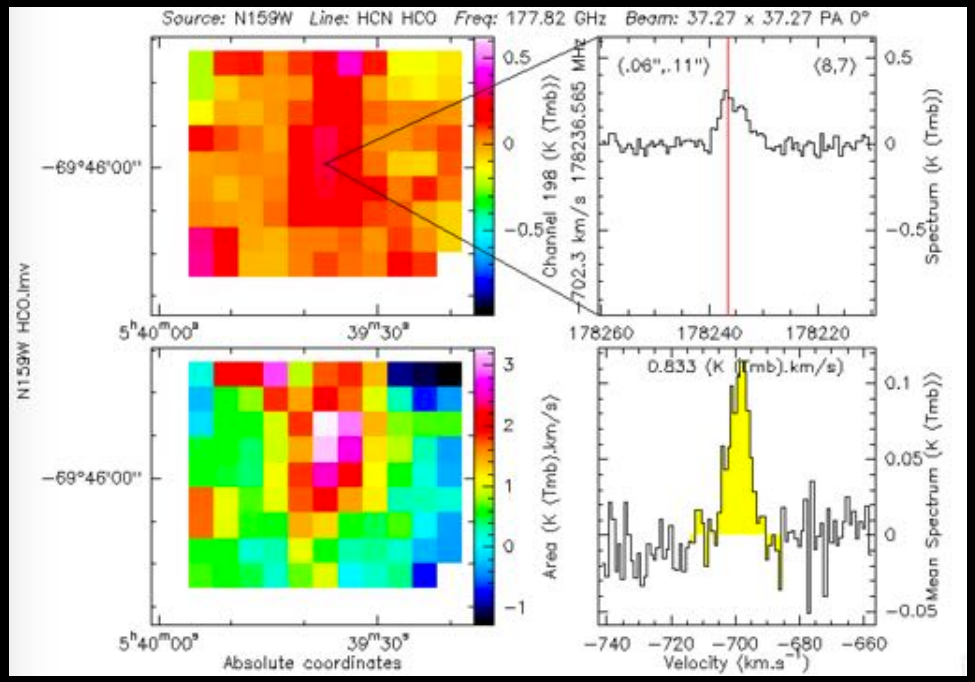




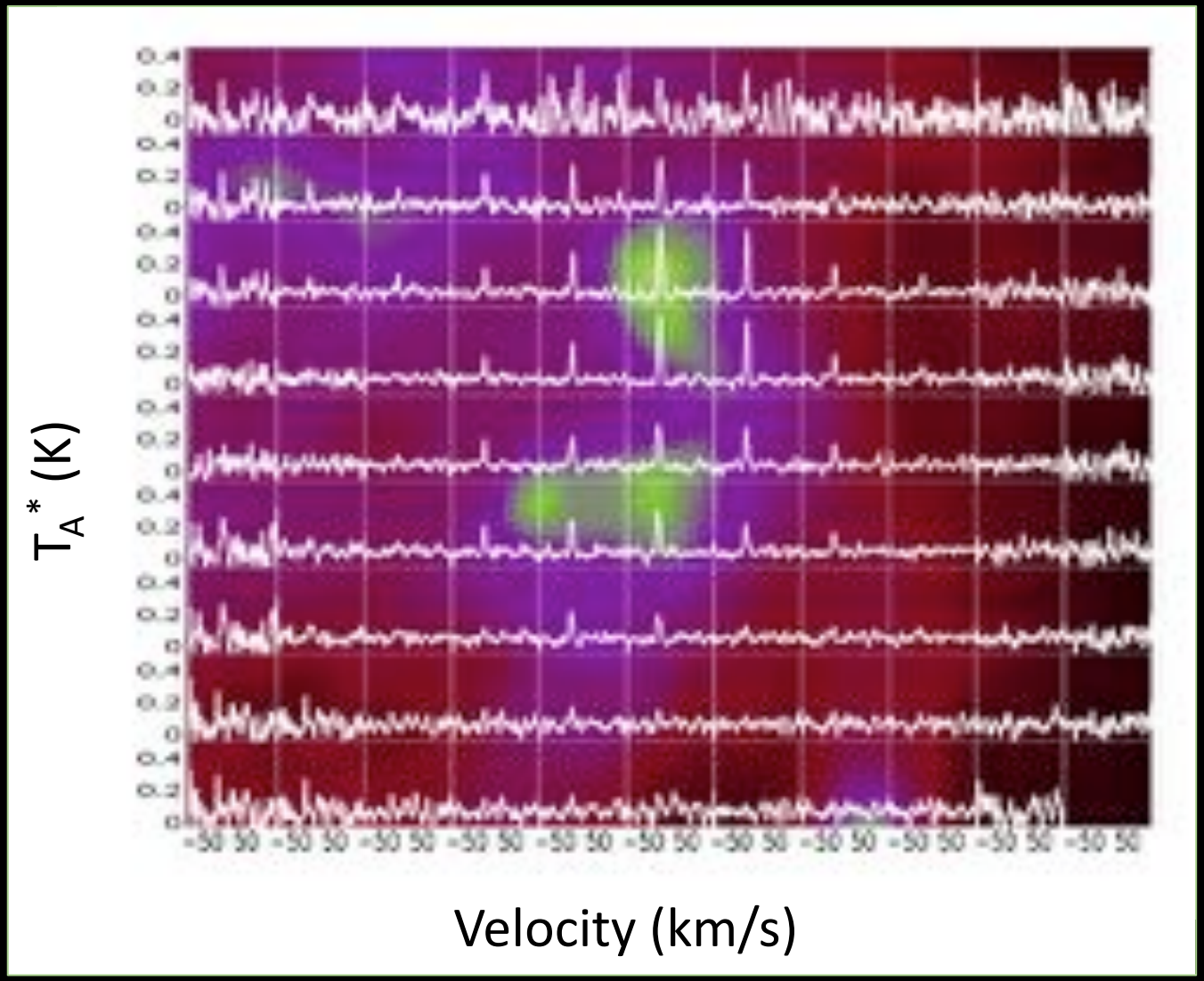
N159W mapped in ESO P98 (DDT)

45 hours of OSO time will be observed in P99

8pc scales:
resolve the molecular gas complexes,
parents of the filaments where stars form



DeGaS-MC: HCO^+ (2-1) observed with SEPIA in N159W



HCO+ detections overlaid on the Herschel SPIRE map

To be studied

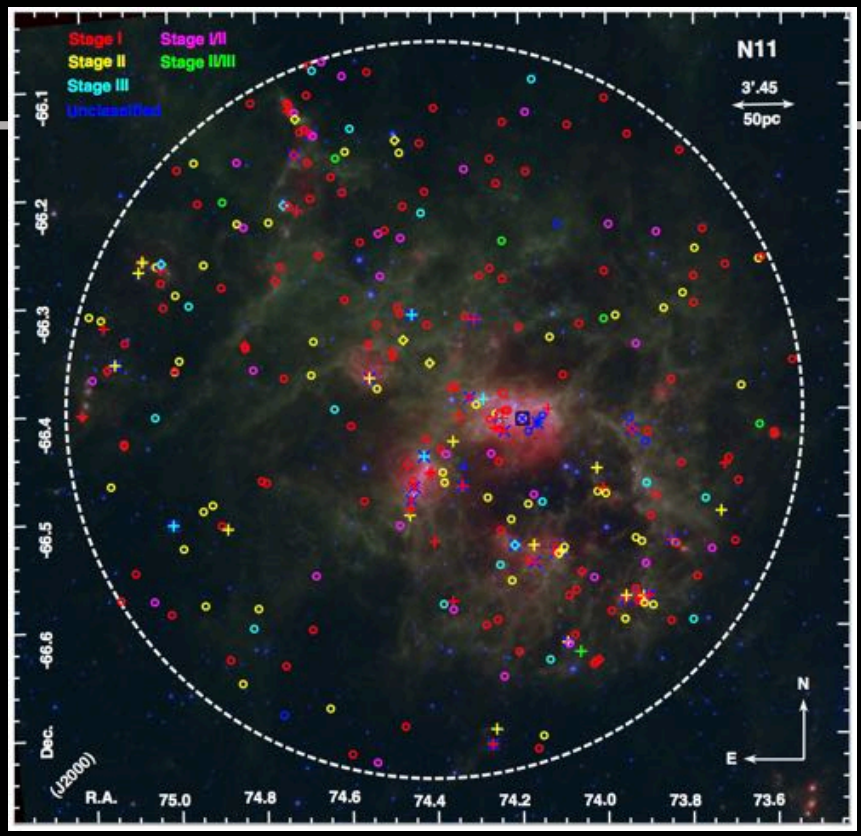
- What drives the local variations in the HCN/HCO^+ ratio ?

- How does the SFE vary with the environment?
  or
  with those derived in other galaxies

- Radiative transfer modelling / gas thermal balance
  - Maps of the kinetic temperature
  - Maps of column densities
  - Constraints for PDR codes or shock models

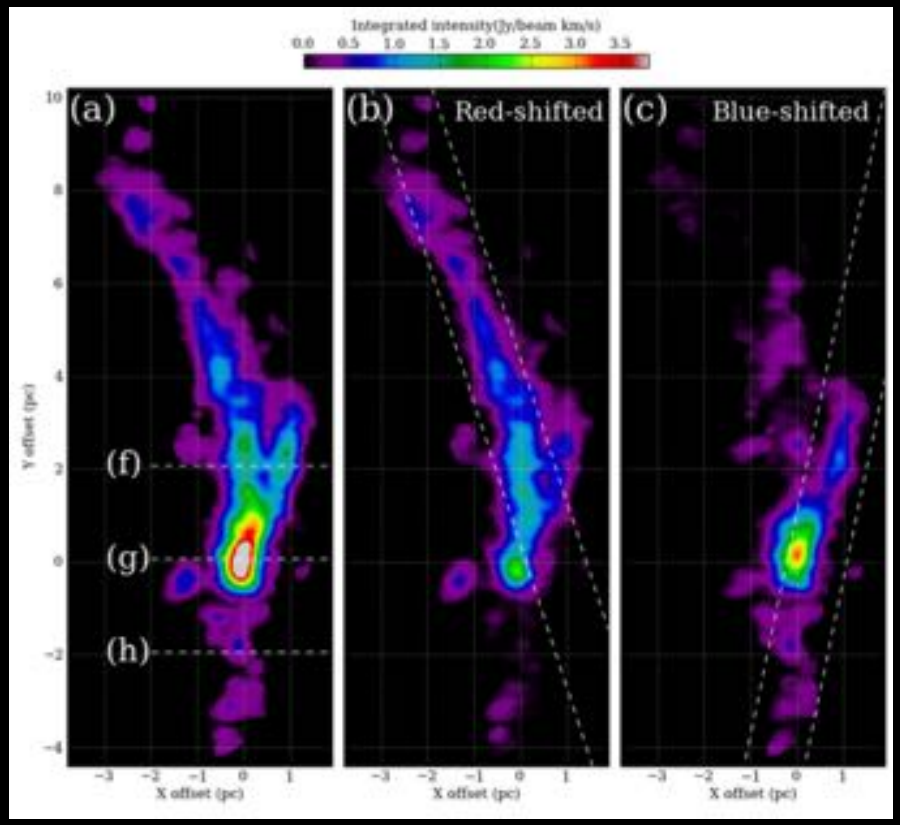
Formation / evolution of YSOs

Carlson et al 2012

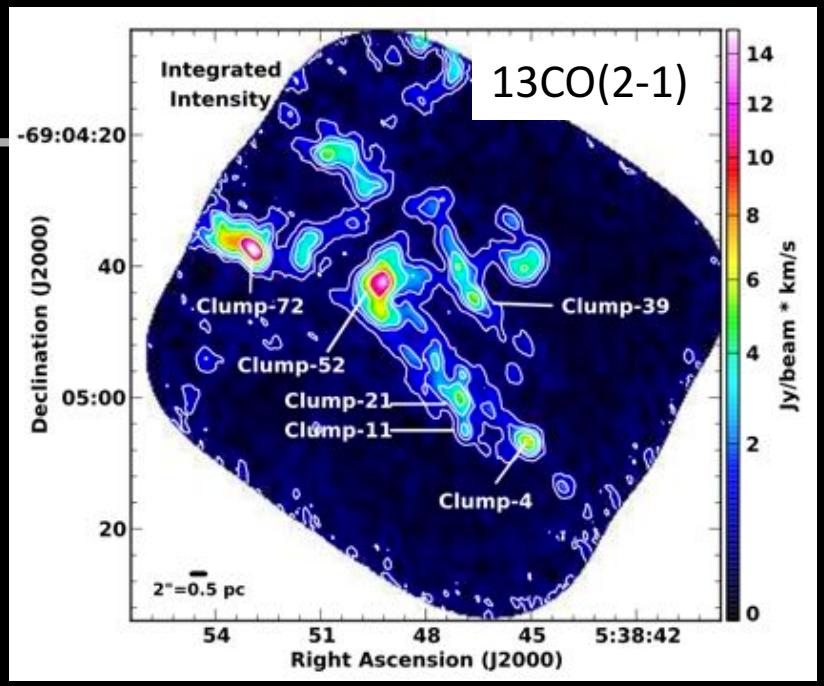


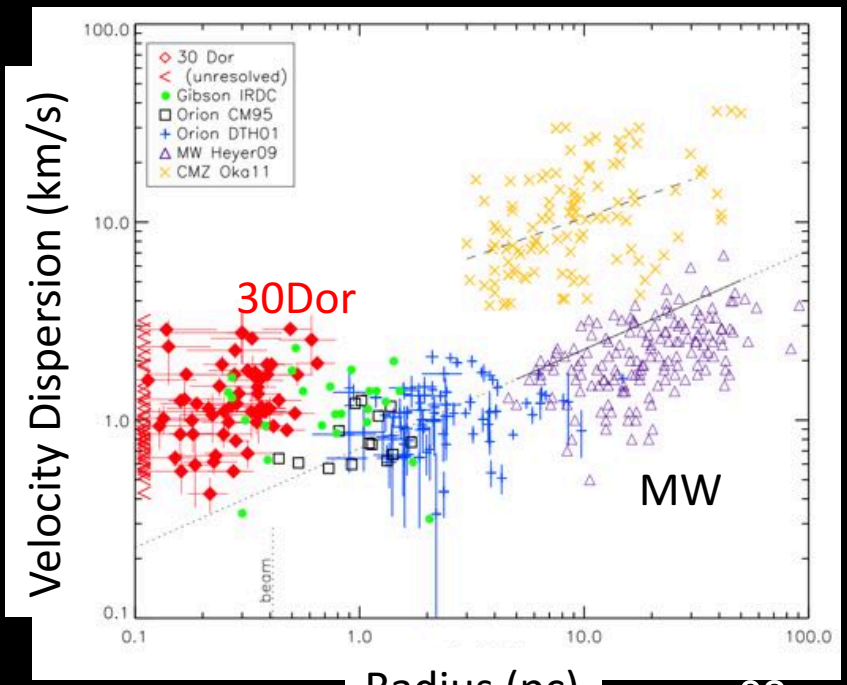
- What is the critical mass for a YSO to form ?
- What are the physical properties (mass, temperature) of their parenting clouds ?
- Where are they found in these clouds: center / edges ?
- How are they affecting / dispersing their host clump ?
- What are the timescales of these different processes ?

A lot to learn from ALMA (<1pc)



Fukui et al. 2015, filament collision in N159W





Indebetouw et al. 2013, 30Dor observed with ALMA

… a lot of on-going work

Stay tuned on our results and releases :
http://irfu.cea.fr/Pisp/maud.galametz/DeGaS-MC/DeGaS.html

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