Cold dense clouds in the Small Magellanic Clouds

CO surveys in the $J = 2 - 1$ and $J = 3 - 2$ transitions

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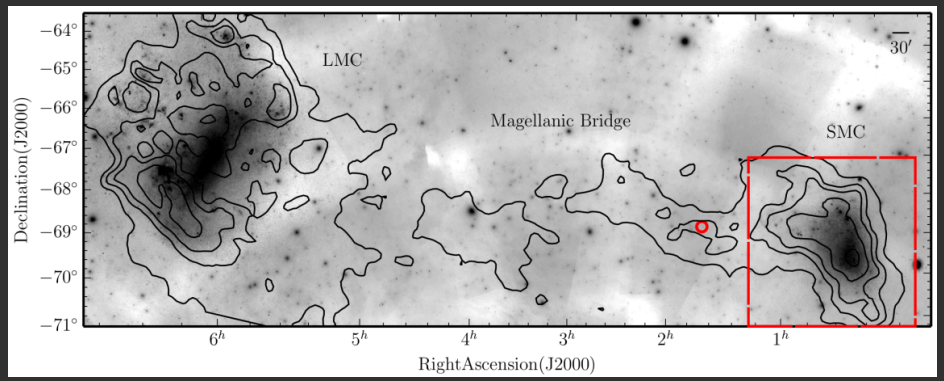
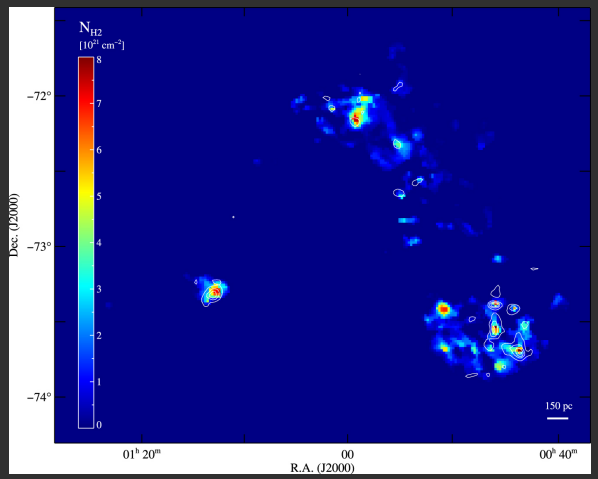
Small Magellanic Cloud (SMC)



V. Kalari et al. (2020)



K. E. Jameson et al. (2016).

Global Properties

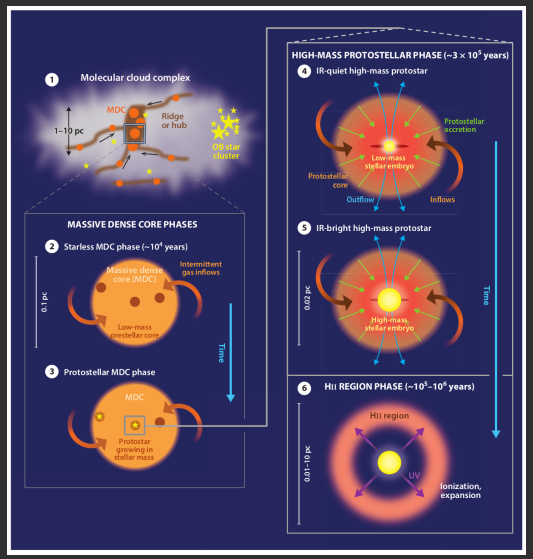
- Distance $\simeq 60.6$ kpc
  (Hilditch et al. 2005)
- $12 + \log(O/H) \simeq 0.8 \quad (20\% Z_{\odot})$
  (Russell & Dopita 1992)
- Molecular gas fraction $\lesssim 6\% M_{\rm HI}$
  (Jameson et al. 2016; Di Teodoro et al. 2019b)
- Gas-to-Dust ratio $\sim 1000 - 2000$
  (Roman-Duval et al. 2014, 2017)

Implications of $Z < Z_\odot$

- Metals (OI, CII): Cooling of the ISM
  (Beirão et al. 2012, Jameson et al. 2018)

$Z < Z_\odot \implies$ gas less susceptible to gravitational collapse.

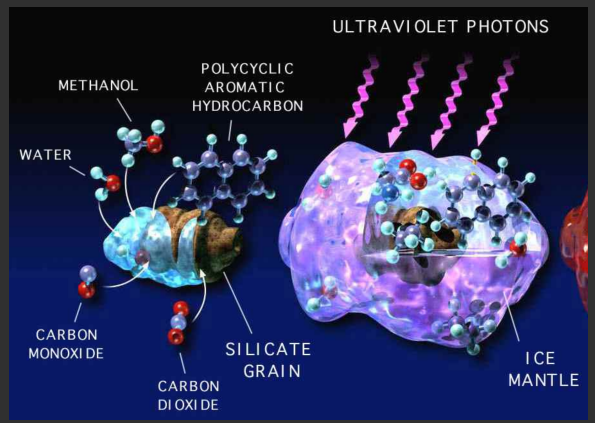
Star formation schemes some different to the standard model.



Motte et al. (2018)

- Metals favors the dust formation.
- Molecules form in dust grain surfaces. (Wakelam et al. 2017)

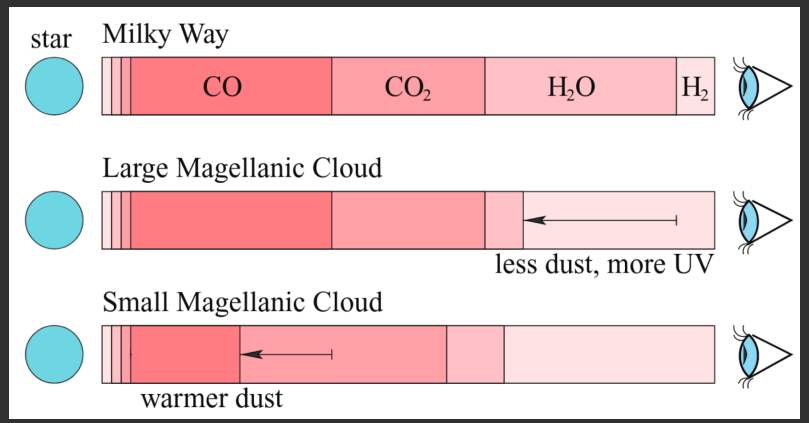
With $Z < Z_\odot \implies$ CO extremely rare.



Implications of $Z < Z_\odot$

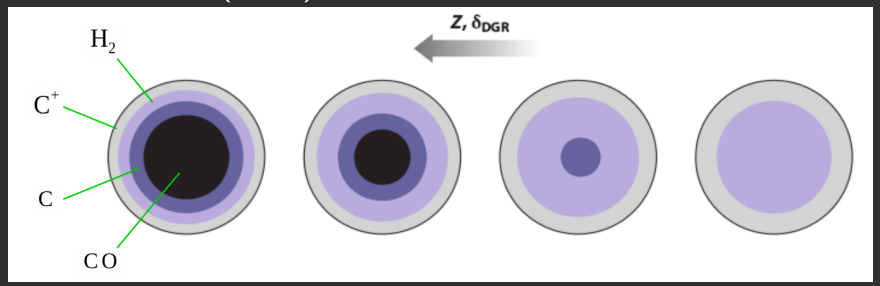
Milky Way:
$50\% - 70\%$ of H_2 gas as "CO-bright".

Low metallicity Galaxies:
$10\% - 20\%$ of H_2 gas as "CO-bright".

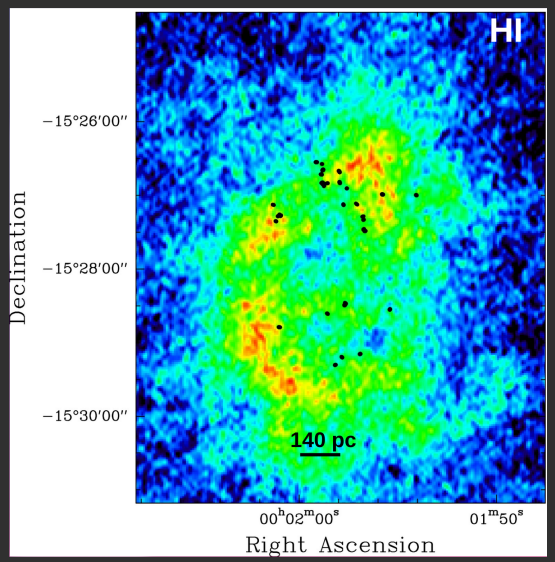


Oliveira et al. (2011)

Bolatto et al. (2013)



- $M_\star \sim 3 \times 10^8$ $M_\odot$
  (Jameson et al. 2016, Licquia and Newman 2015)
- $SFR \simeq 0.033$ $M_\odot$ yr^{-1}
  (Stanimirović et al. 1999, Licquia and Newman 2015)



WLM galaxy ($Z = 13\% Z_\odot$) - Rubio et al. (in preparation)

Atacama Pathfinder EXperiment (APEX)

http://www.apex-telescope.org/ns/the-telescope/#factsheet

- Llano de Chajnantor. Northern Chile.
- Altitude: 5104.47 m
- Diameter: 12 m
- Beam width $= 7''.8 \times \dfrac{800}{\nu(GHz)}$

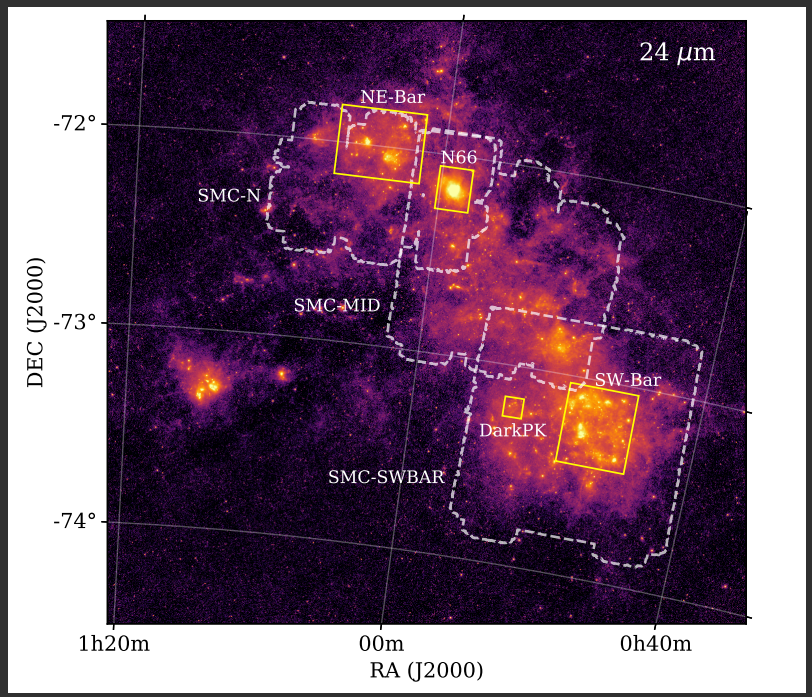
CO$(2-1) \rightarrow 230.538$ GHz $(1.30$ mm$)$
Beam width $\sim 30''$

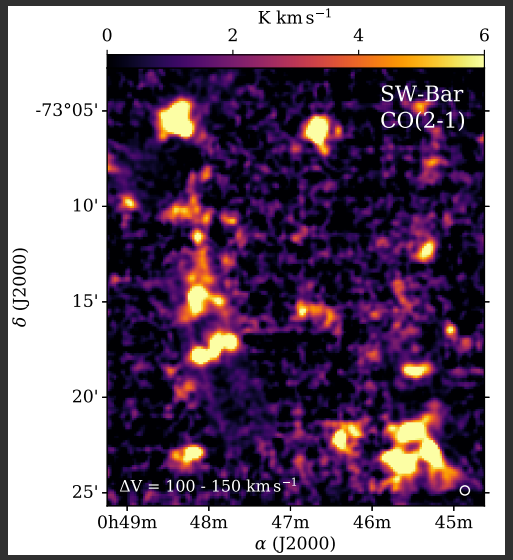
SMC at 60 kpc $\implies$ Beam $\simeq 9$ pc

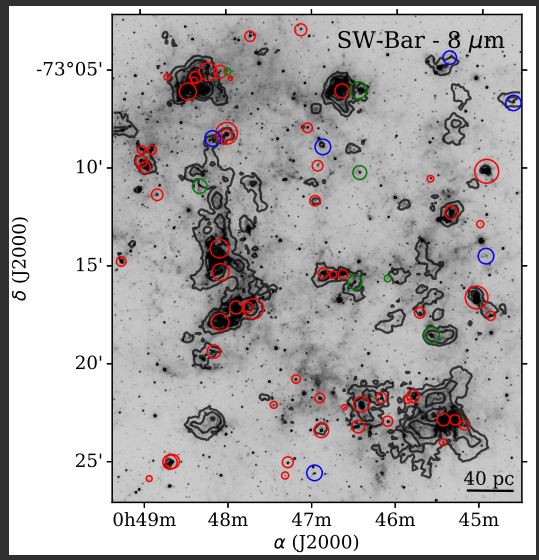
CO$(3-2) \rightarrow 345.795$ GHz $(0.87$ mm$)$
Beam width $\sim 20''$

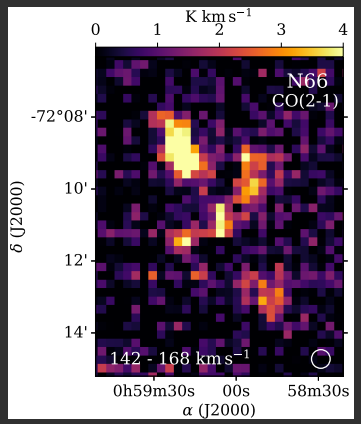
SMC at 60 kpc $\implies$ Beam $\simeq 6$ pc

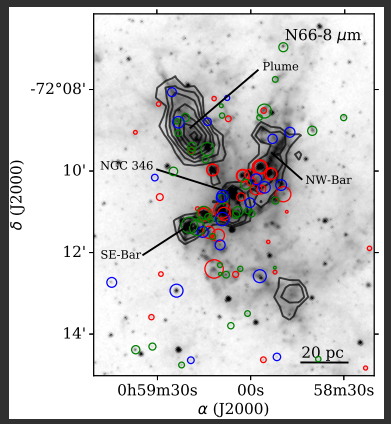
CO(3 – 2) and CO(2 – 1) Observations











CO-YSOs association

55% ⟹ Stage I

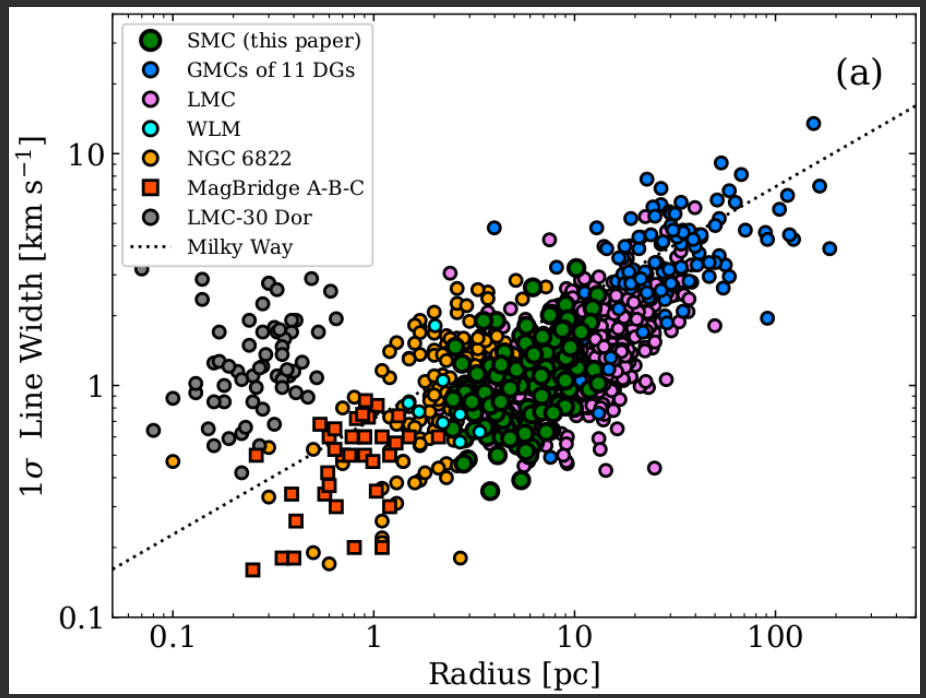
15% ⟹ { Stage II, Stage III }

30% ⟹ Undefined YSOs

CO Clouds in the SMC

CPROPS (Rosolowsky et al. 2006)

More than 150 CO clouds at 6 and 9 pc resolution with S/N > 3



Saldaño et al. (submitted to A&A)

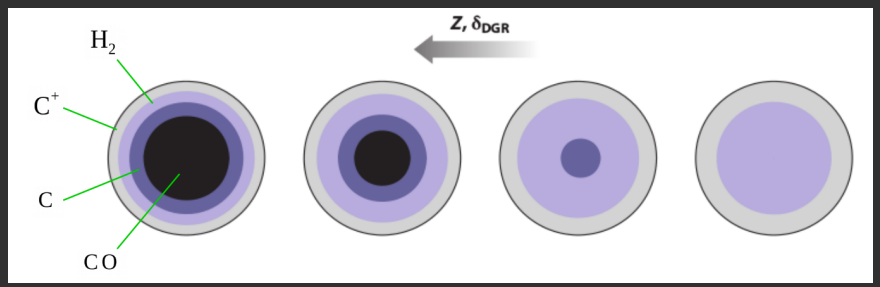
- $R > 1$ pc:

  Departure of R vs. σ_v Relation by a factor of ~ 2.

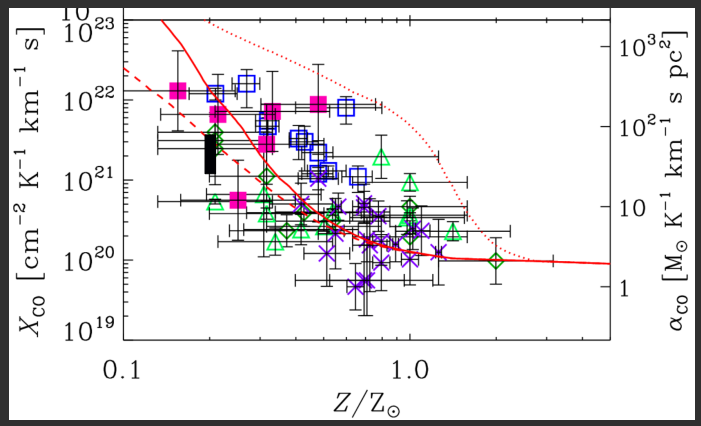
- $R < 1$ pc:

  Departure depending in the star-forming regions.

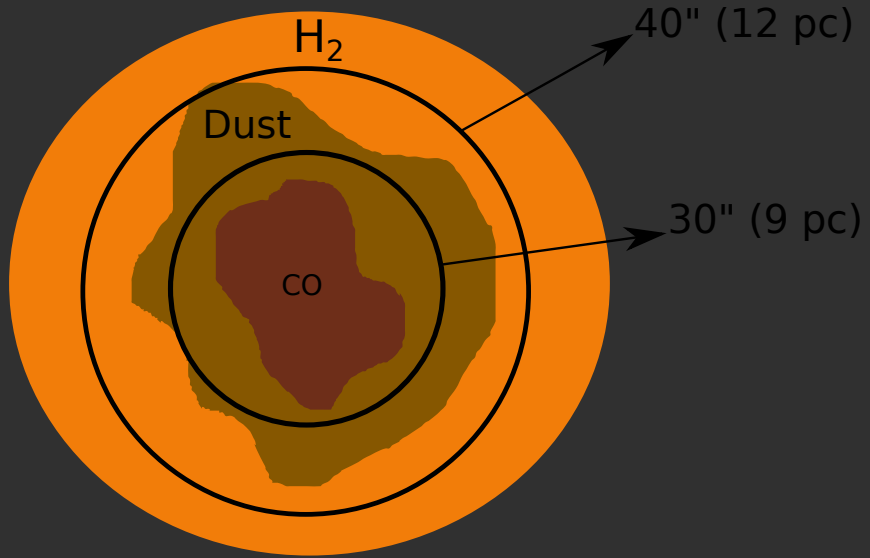
CO-to-H_2 Conversion Factor: $\alpha_{CO} \equiv \frac{M_{H_2}}{L_{CO}}$



(Bolatto et al. 2013)



(Hirashita & Harada 2017)



For the SMC:

$\alpha_{CO} \simeq 10.\ M_\odot\ (K\,km\,s^{-1}\,pc^2)^{-1}$ at 9 pc.

$\alpha_{CO} \simeq 30.\ M_\odot\ (K\,km\,s^{-1}\,pc^2)^{-1}$ at 12 pc.

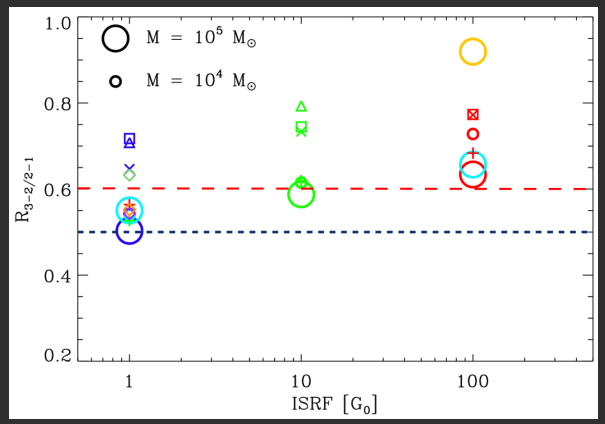
Between $3 - 7 \times \alpha_{CO}(MW)$

Saldaño et al. (submited to A&A)

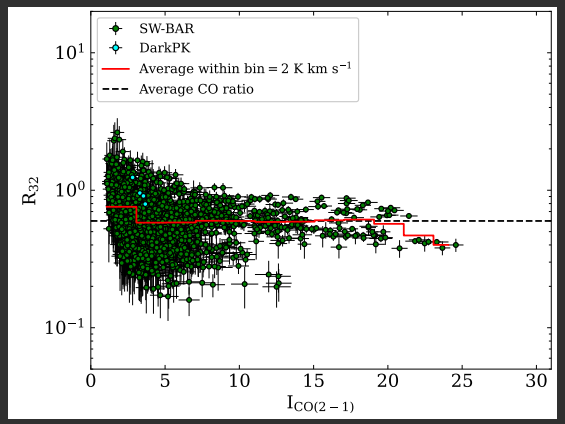
CO(3 – 2) to CO(2 – 1) ratio (R_{32})

$$R_{32} = \frac{I_{CO(3-2)}}{I_{CO(2-1)}}$$

pixel-by-pixel



Peñaloza et al. 2018



Saldaño et al. (in preparation)

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For the SMC: $R_{32} = 0.6 \pm 0.3$.

(Consistent with Bolatto et al. (2005))

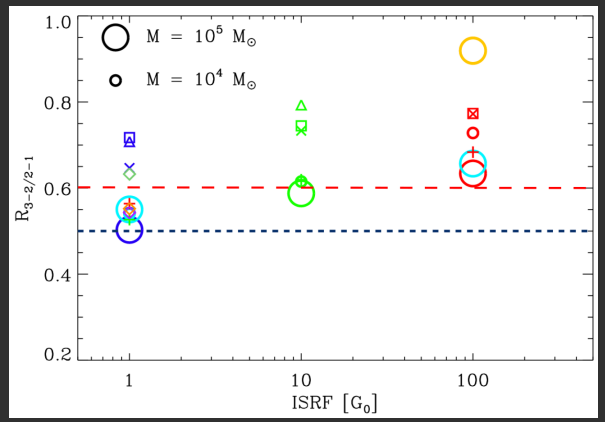
$R_{32} > 0.6 \implies$ High ISRF

$R_{32} < 0.6 \implies$ Low ISRF

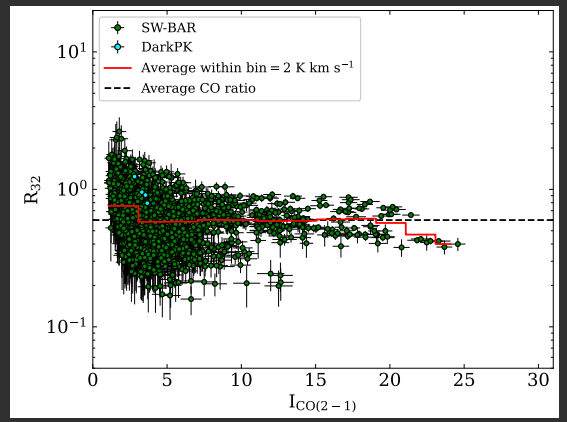
CO(3 – 2) to CO(2 – 1) ratio (R_{32})

$$R_{32} = \frac{I_{CO(3-2)}}{I_{CO(2-1)}}$$

pixel-by-pixel



Peñaloza et al. 2018



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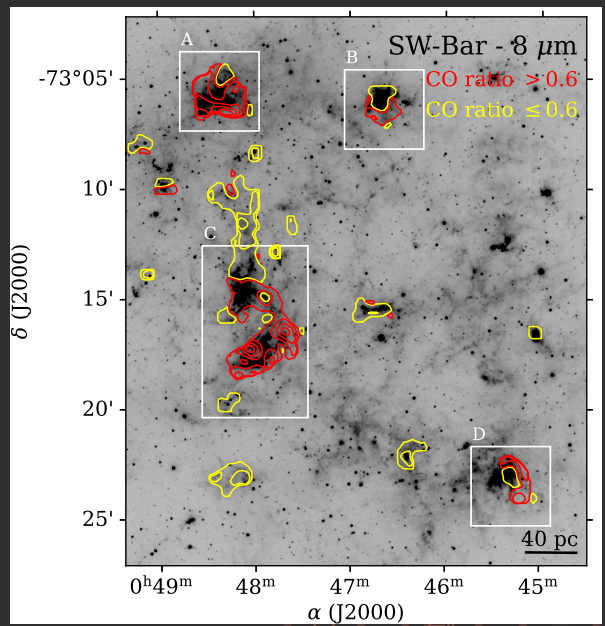
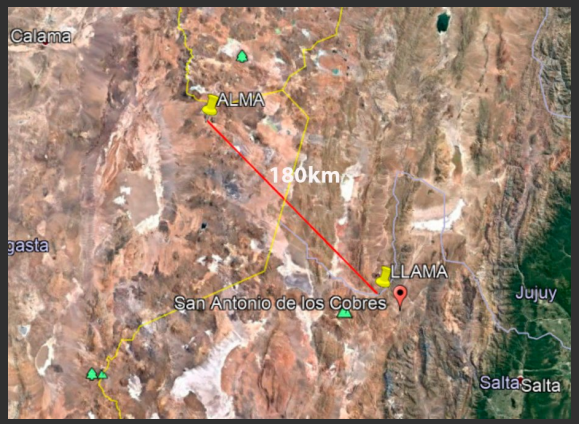


LLAMA (Large Latin American Millimeter Array) - SAC

APEX Telescope

- Antenna: 12 m
- Altitud: 4800 m
- Band 5
  $\Delta\nu = 163 - 211$ GHz
- Band 6
  $\Delta\nu = 211 - 275$ GHz
- Band 9
  $\Delta\nu = 602 - 720$ GHz



Molecular Emission:

- Band 5 and 6:
  Low Transitions of ^{12}CO, ^{13}CO, C^{18}O, CS, HCO^{+}
  Mapping cold and low density regions
- Band 9:
  High Transitions of ^{12}CO, ^{13}CO, C^{18}O, CS, HCO^{+}
  Mapping hot and high density regions

The End