Gas temperature structures of Galactic center clouds

Katharina Immer
ESO, Munich, Germany

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Soul of High-Mass Star Formation

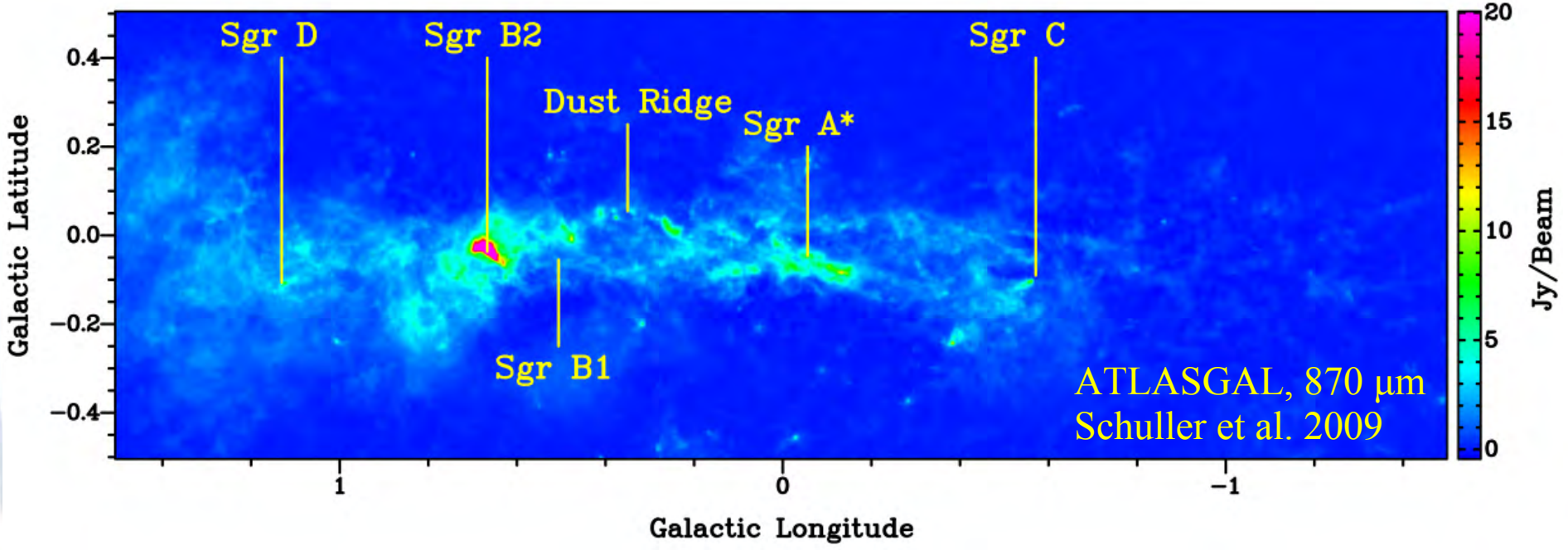
Collaborators: J. Kauffmann (MPIfR)
T. Pillai (MPIfR)
K. M. Menten (MPIfR)

The Central Molecular Zone (CMZ)

Star formation in an exceptional environment

CMZ: central few hundred parsec of the Milky Way, produces 5–10% of the infrared luminosity of the Galaxy and contains ca. 10% of its neutral gas (5–$10 \cdot 10^7$ $M_\odot$) (e.g. Güsten 1989; Rodríguez-Fernández et al. 2004)

Extreme conditions: temperature, velocity dispersion, pressure, … much higher than in the Galactic disk (Morris & Serabyn 1996)

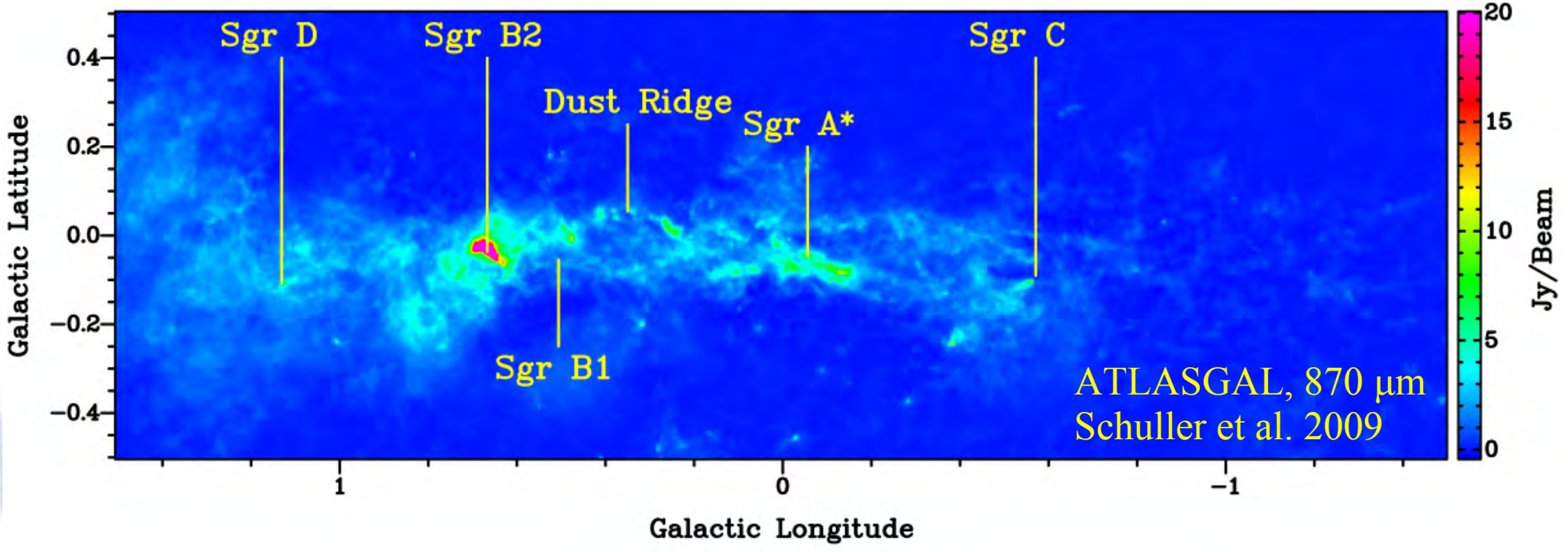


The Central Molecular Zone (CMZ)

Star formation in an exceptional environment

High gas temperatures vs. cold dust temperatures in many CMZ clouds

„Warm“ clouds show low star formation rate, although they are massive and dense



H_2CO Thermometry

H_2CO = slightly asymmetric rotor molecule => rotational levels split into two energy levels: $J_{K_{+1}K_{-1}}$

Mangum & Wootten 1993:
The integrated intensities ratio of two K-components of the same $\Delta J=1$ transition probe the kinetic temperature of molecular gas.

Used intensity ratios: $\frac{H_2CO(3_{2,1}-2_{2,0})}{H_2CO(3_{0,3}-2_{0,2})}$

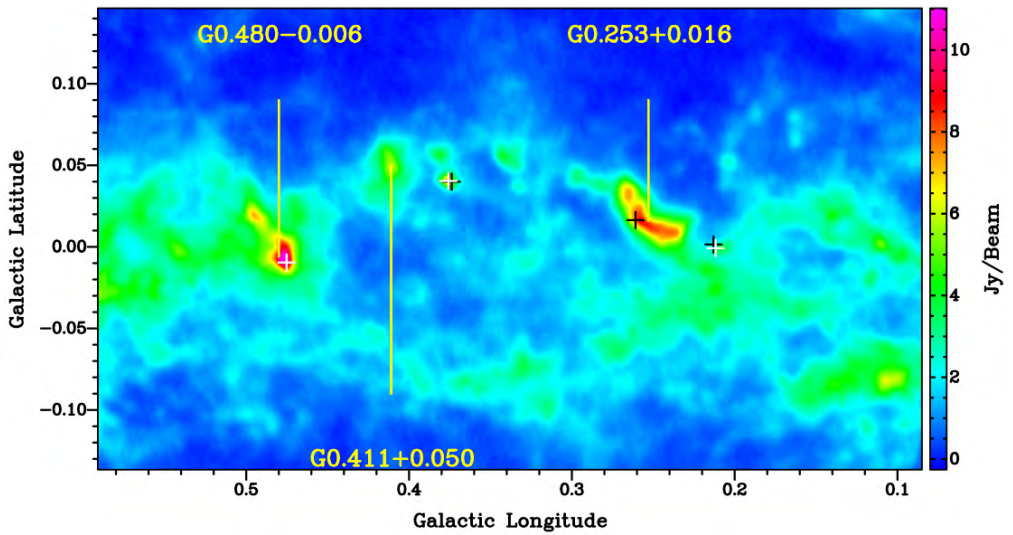
p-H_2CO thermometry successfully applied to CMZ gas (Ao et al. 2012, Ginsburg et al., subm., Poster 18)

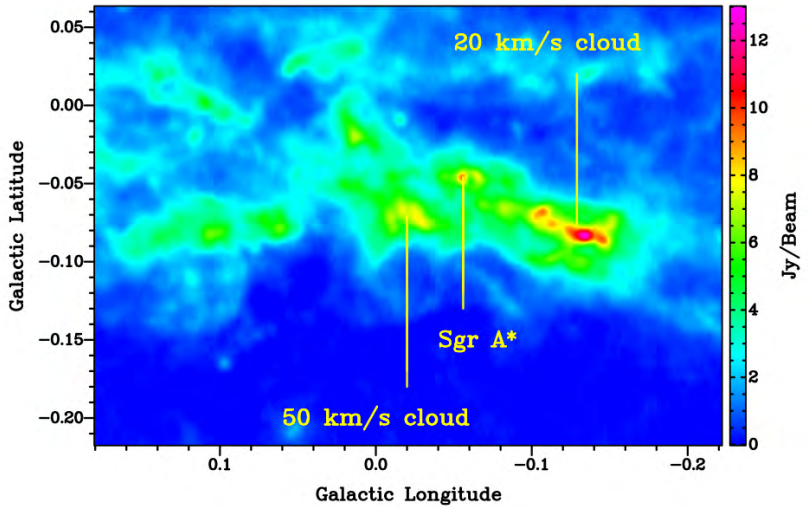
Goals

- Detailed gas temperature maps of five molecular clouds in the Central Molecular Zone (CMZ), using the H_2CO thermometer
- Is the warm gas associated with the cold dust?
- Is para-H_2CO a trustworthy temperature probe?
- What is the origin of the warm gas?
  Are gas temperatures driven by shocks traced by SiO?

Project part of a coordinated survey of dense CMZ clouds with single-dish telescopes and interferometers

Targets





Background: ATLASGAL (Schuller et al. 2009) 870 μm emission; white crosses: 6.7 GHz methanol masers; black crosses: 22 GHz water masers

Source	T_{Dust} (K)	T_{Gas} (K)	M_{Cloud} (10^3 $M_\odot$)	
G0.253+0.016	18	~80	141	No signs of ongoing star formation
G0.411+0.050	17		72	No signs of ongoing star formation
G0.480-0.006	17	>50	153	Ongoing star formation in early stage
20 km/s cloud	~20	64	~150	Ongoing star formation
50 km/s cloud	~20	65	~80	Ongoing star formation

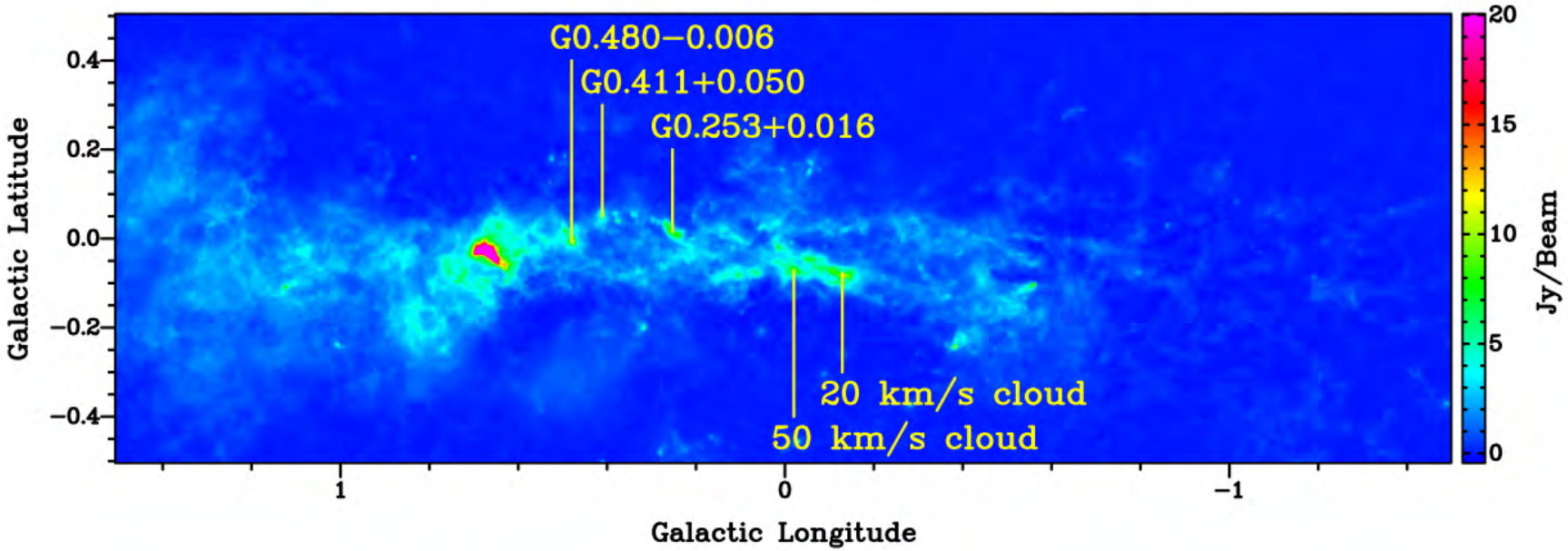
Pierce-Price et al. 2000, Lis et al. 2001, Nagayama et al. 2007, Immer et al. 2012

Observations

On-the-fly maps of five clouds in the CMZ

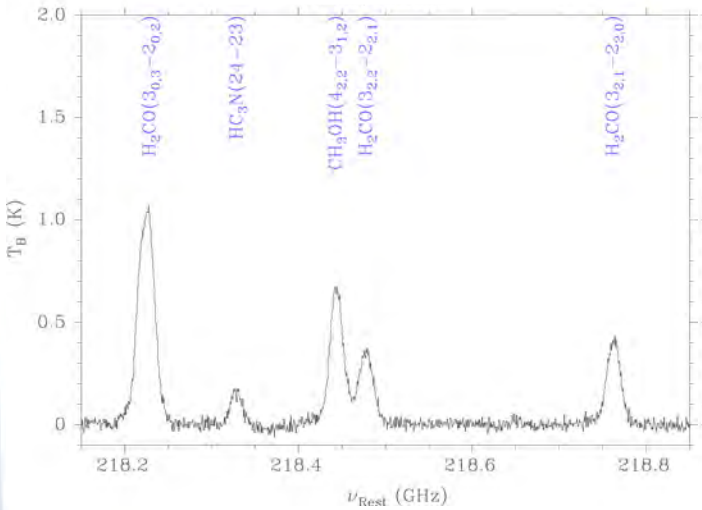
p-H_2CO(3-2) at 218 GHz

Smoothed velocity resolution: 1 km/s
Beam size: ~30"



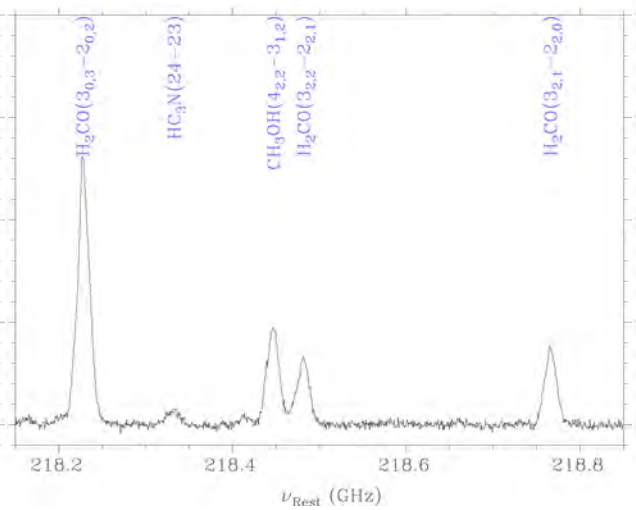
H_2CO Spectra

50 km/s cloud



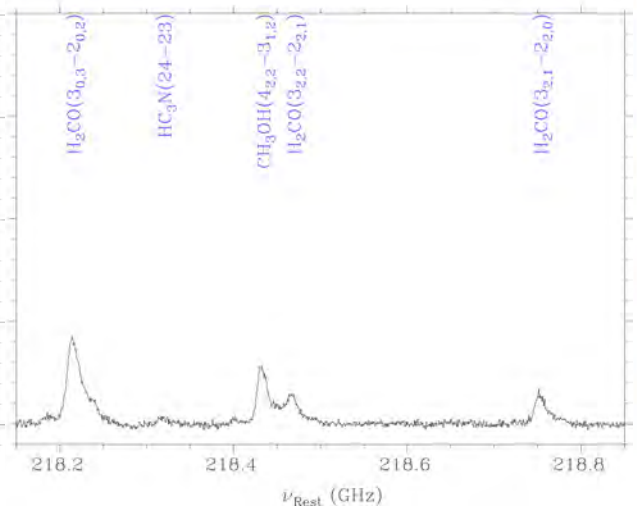
ΔV_{avg} = 20 km/s; σ_{base} = 18 mK

20 km/s cloud



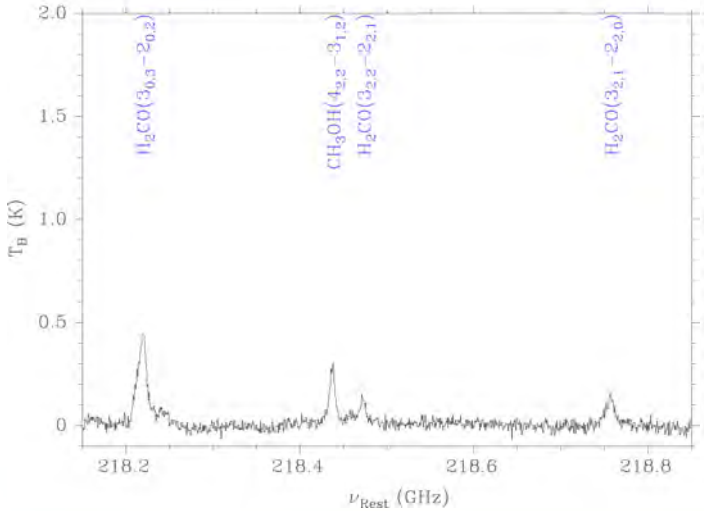
ΔV_{avg} = 16 km/s; σ_{base} = 12 mK

G0.253+0.016



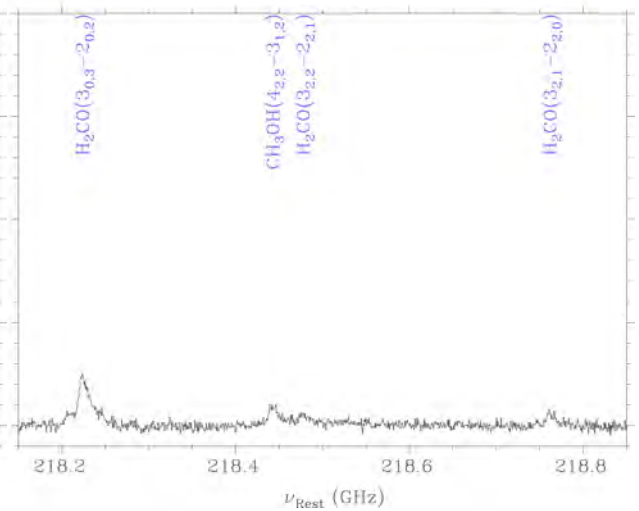
ΔV_{avg} = 26 km/s; σ_{base} = 10 mK

G0.480+0.006



ΔV_{avg} = 14 km/s; σ_{base} = 20 mK

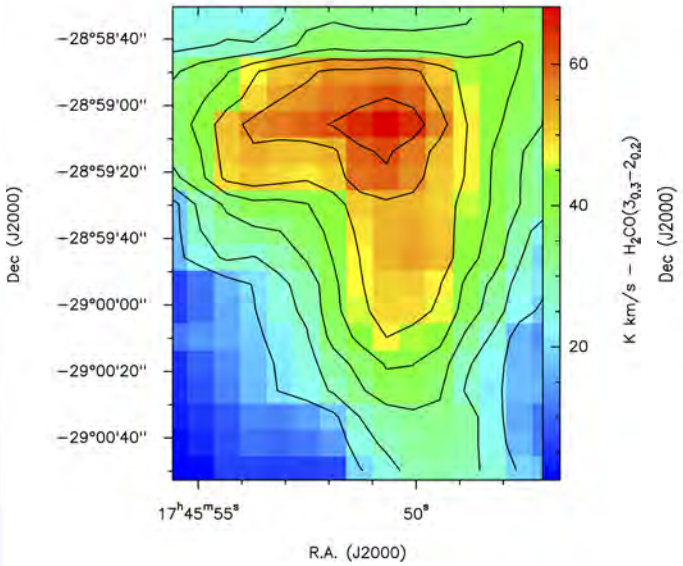
G0.411+0.050



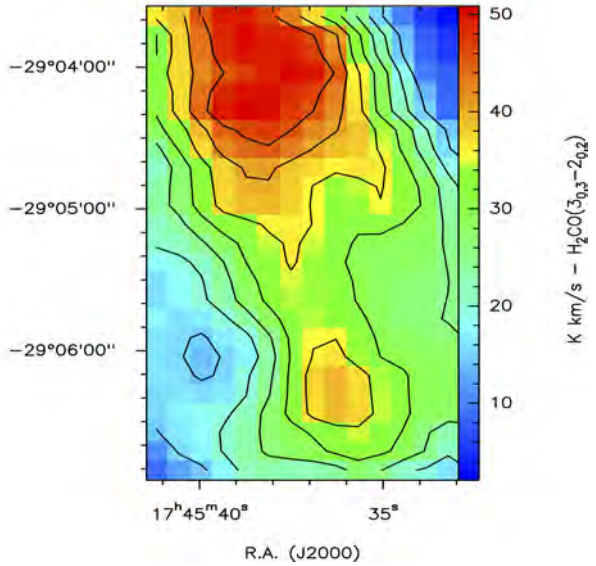
ΔV_{avg} = 15 km/s; σ_{base} = 15 mK

$H_2CO(3_{03}\text{-}2_{02})$ maps

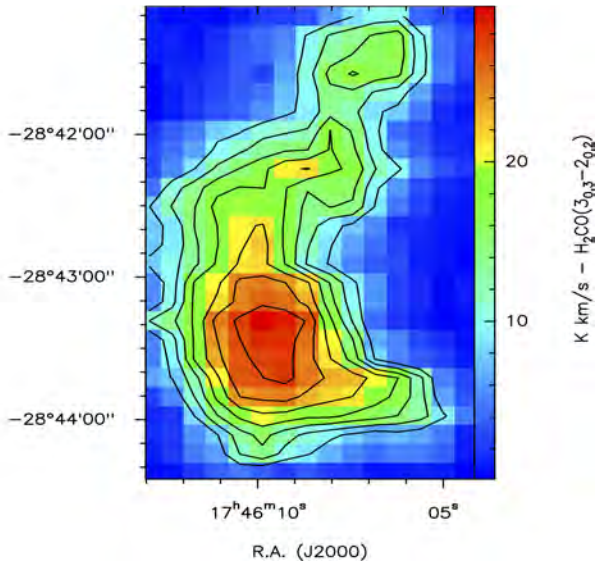
50 km/s cloud 16 – 80 km/s



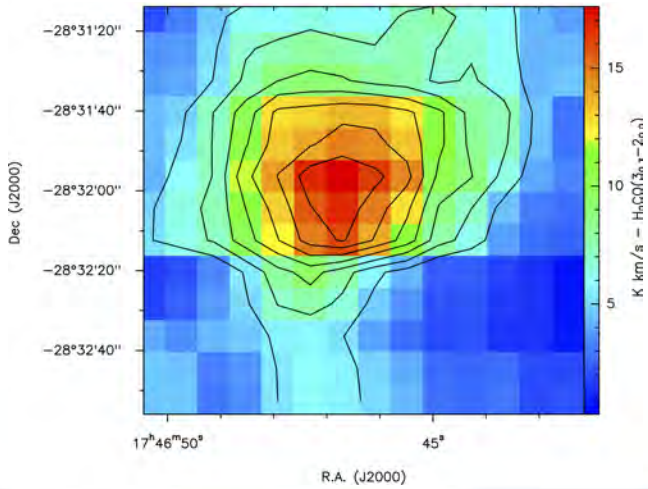
20 km/s cloud –15 – 36 km/s



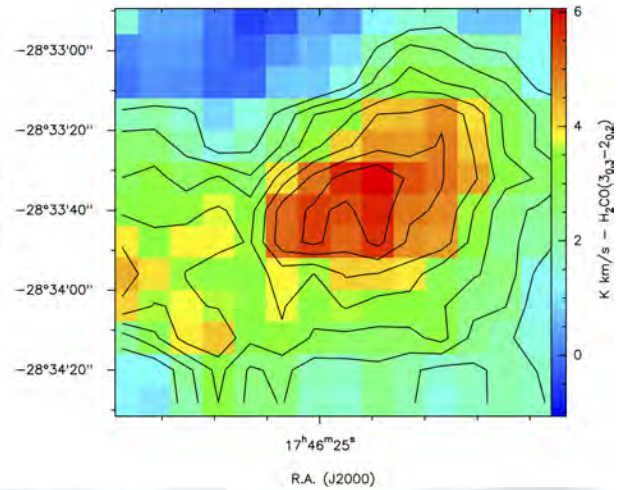
G0.253+0.016 –6 – 54 km/s



G0.480+0.006 19 – 44 km/s

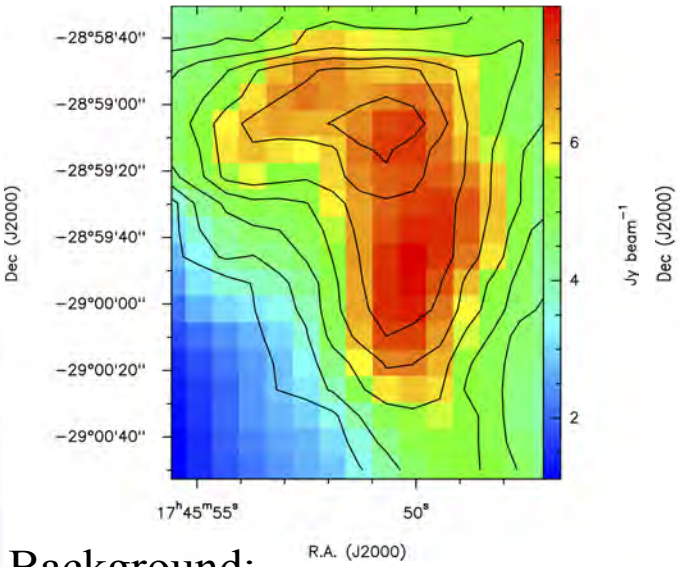


G0.411+0.050 10 – 30 km/s

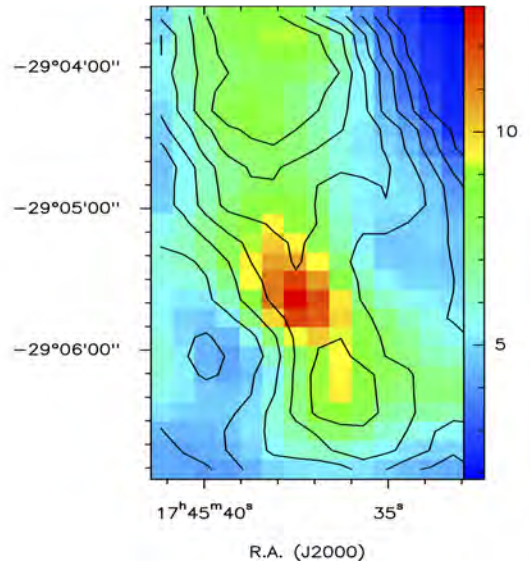


Correlation warm gas – cold dust?

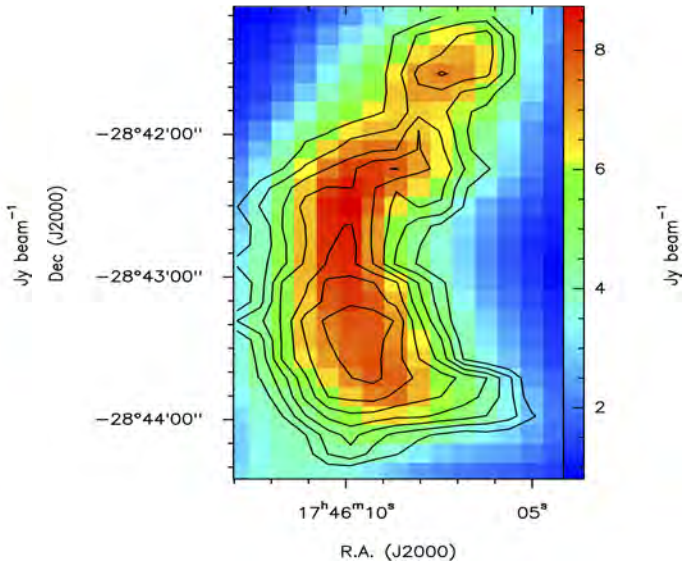
50 km/s cloud 16 – 80 km/s



20 km/s cloud –15 – 36 km/s

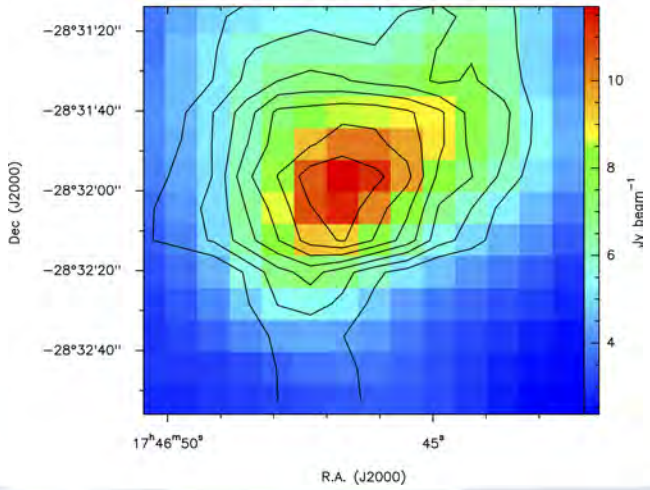


G0.253+0.016 –6 – 54 km/s

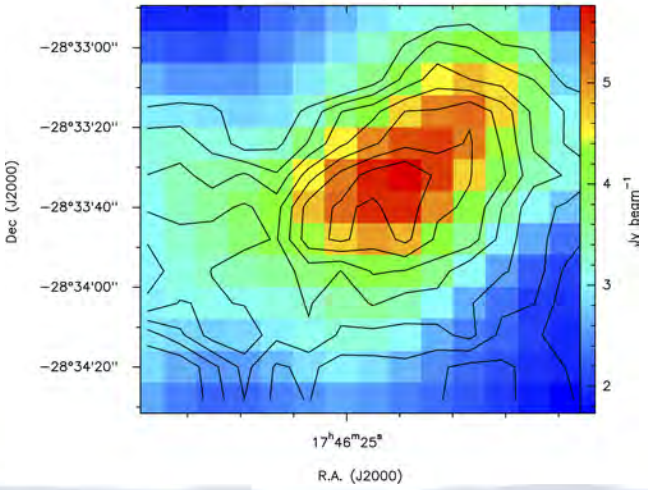


Background: ATLASGAL 870 μm Schuller et al. 2009
Contours: H_2CO integrated intensity maps

G0.480+0.006 19 – 44 km/s

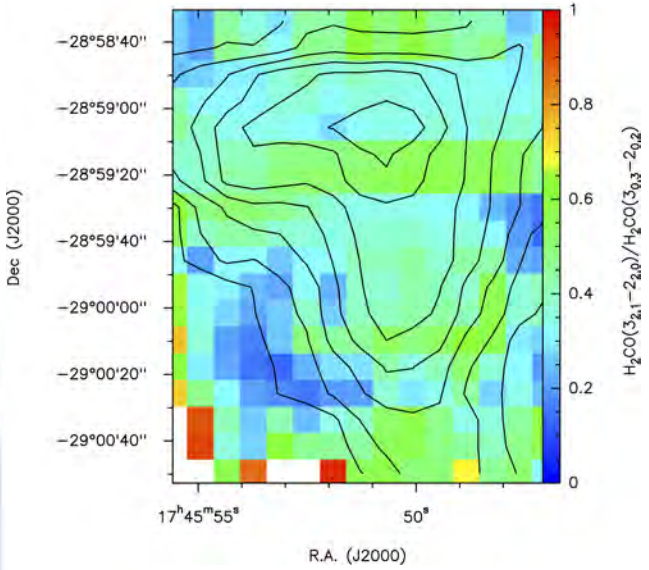


G0.411+0.050 10 – 30 km/s

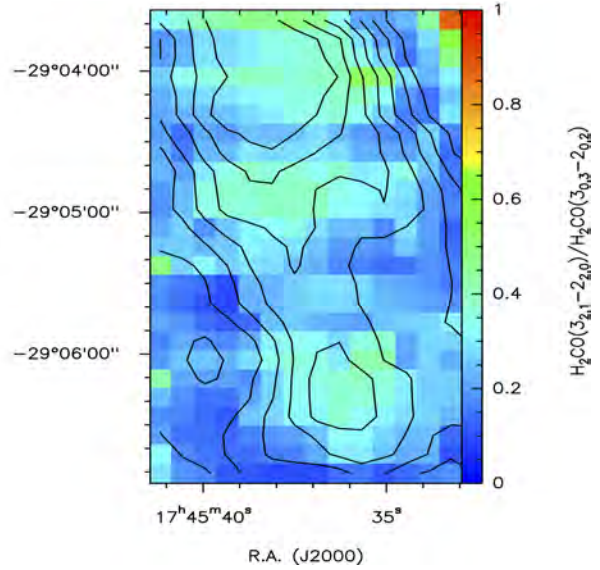


Ratio maps

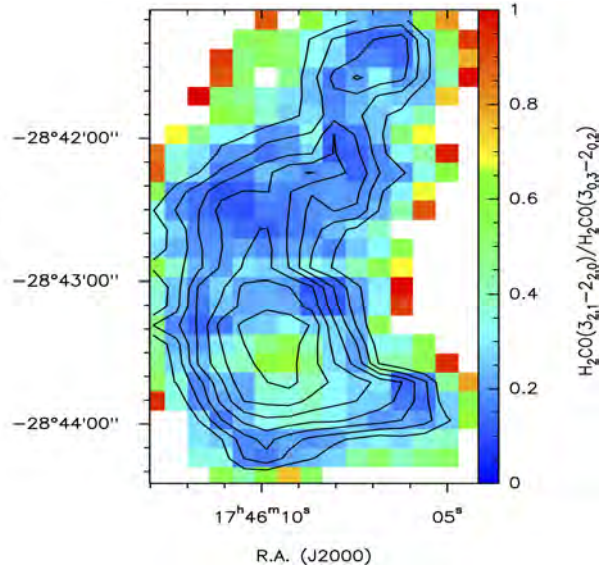
50 km/s cloud 16 – 80 km/s



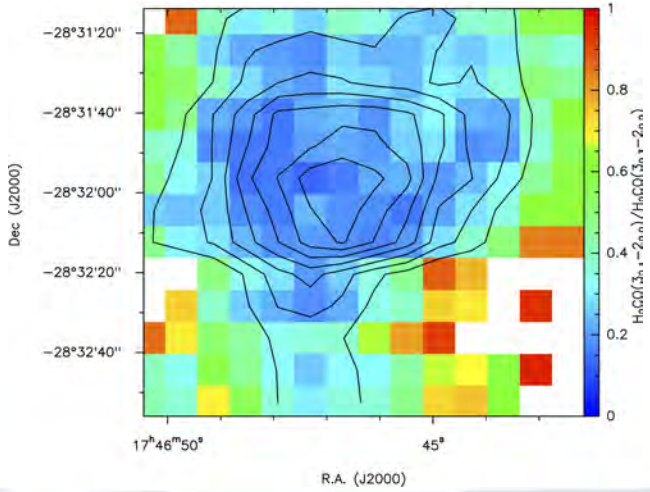
20 km/s cloud –15 – 36 km/s



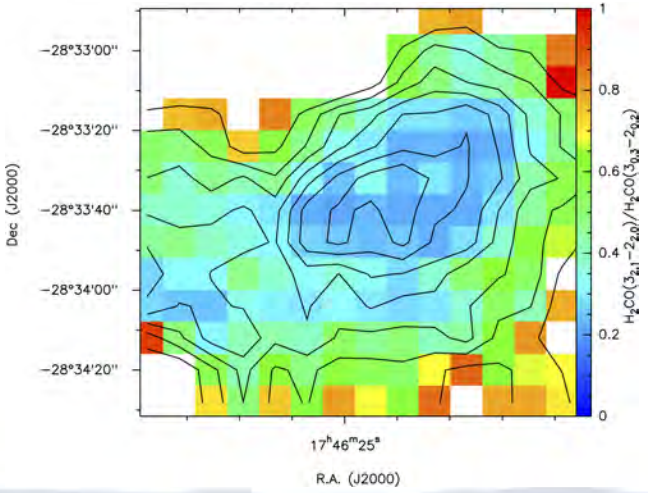
G0.253+0.016 –6 – 54 km/s



G0.480+0.006 19 – 44 km/s

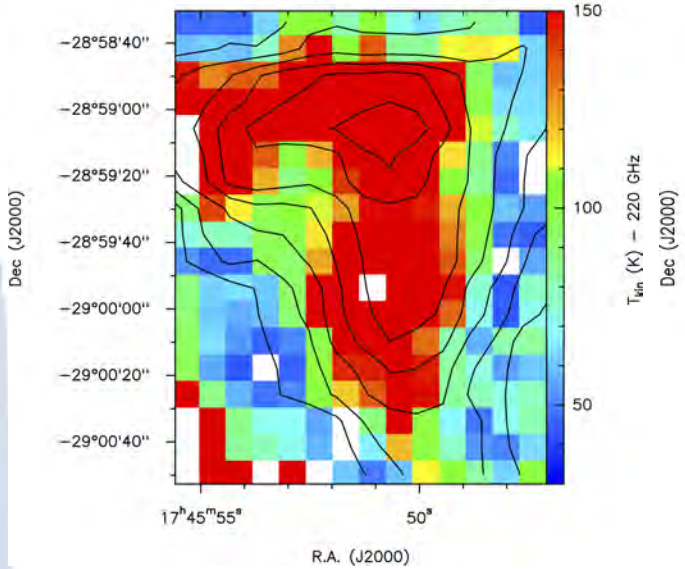


G0.411+0.050 10 – 30 km/s

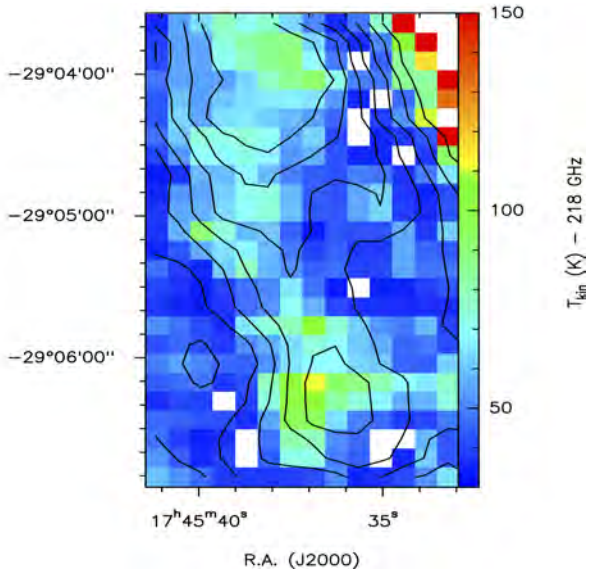


Temperature maps

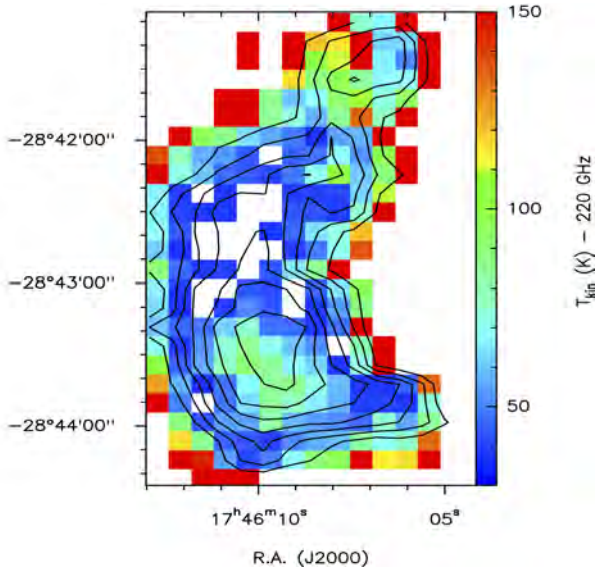
50 km/s cloud 16 – 80 km/s



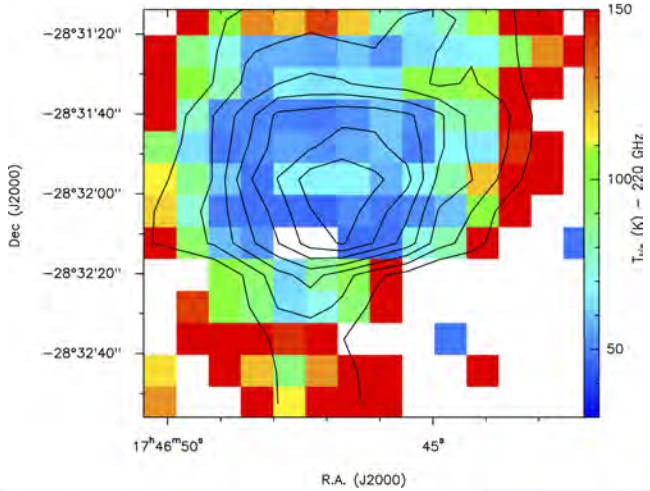
20 km/s cloud –15 – 36 km/s



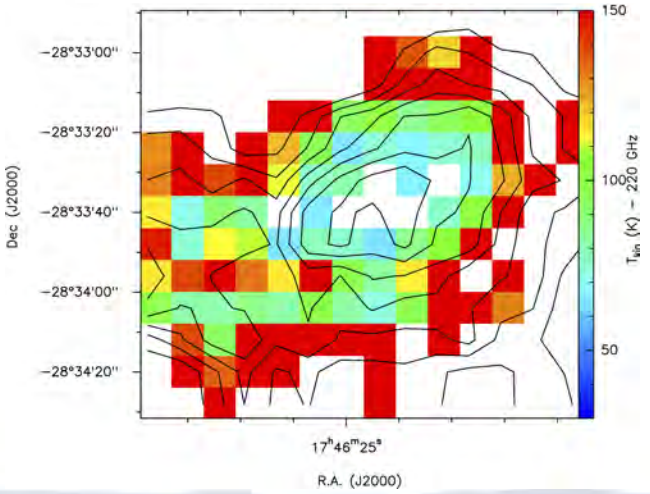
G0.253+0.016 –6 – 54 km/s



G0.480+0.006 19 – 44 km/s

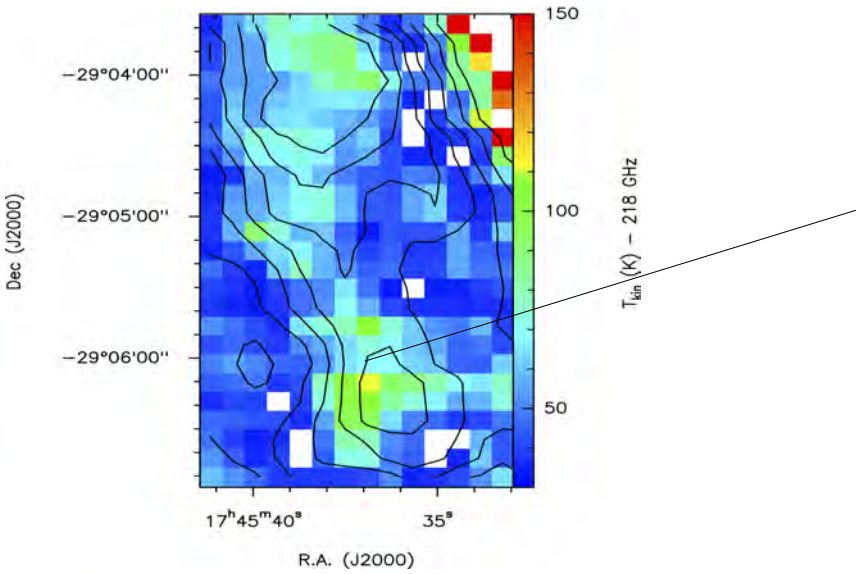


G0.411+0.050 10 – 30 km/s

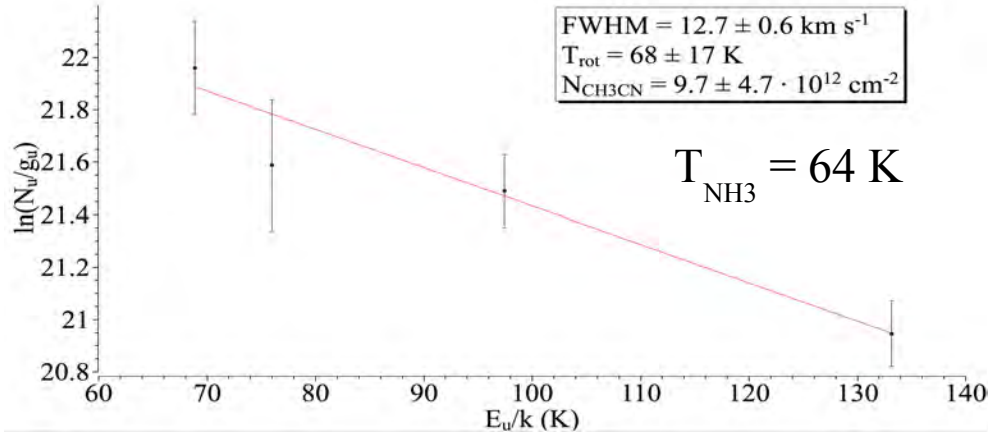


CH_3CN Temperatures

20 km/s cloud –15 – 36 km/s

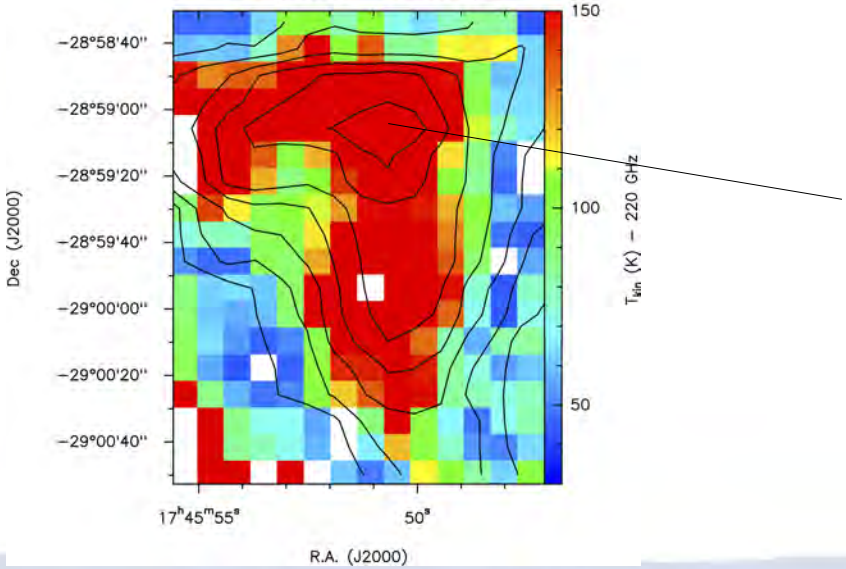


T_{H2CO} = 60-75 K

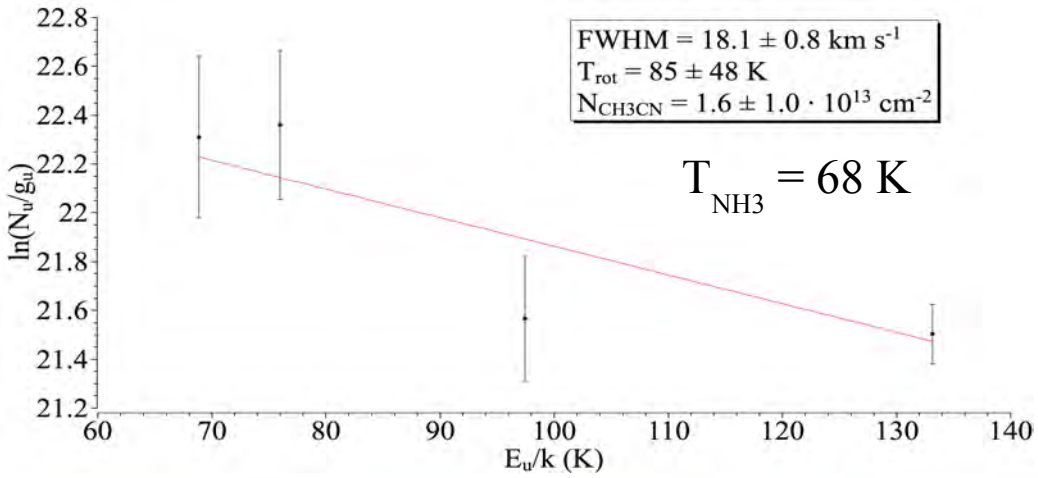


T_{NH3} = 64 K

50 km/s cloud 16 – 80 km/s



T_{H2CO} > 150 K



T_{NH3} = 68 K

Conclusion

Detailed gas temperature maps of five clouds in the CMZ with high gas and low dust temperatures

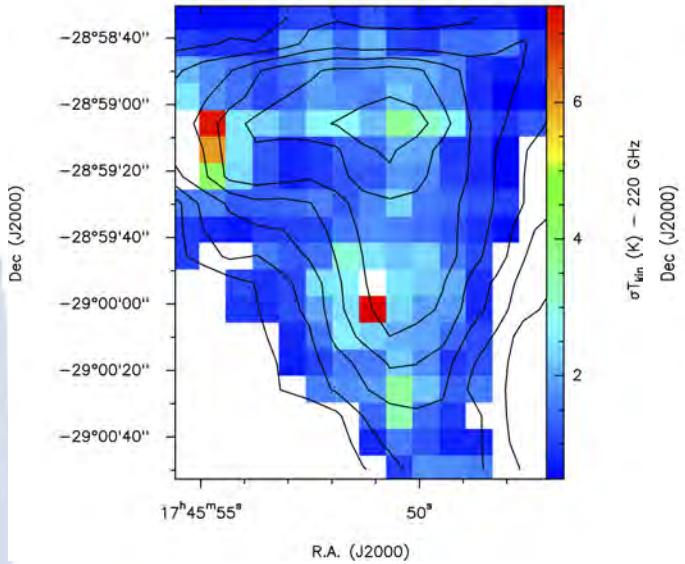
1.) Association of warm gas with cold dust?
=> Warm gas follows same distribution as cold dust but peaks at different positions for warmer clouds

2.) Is para-H_2CO a trustworthy temperature probe?

H_2CO gas temperatures much higher than dust temperatures in all clouds, also tend to be higher than NH_3 or CH_3CN gas temperatures

Temperature uncertainty maps

50 km/s cloud 16 – 80 km/s



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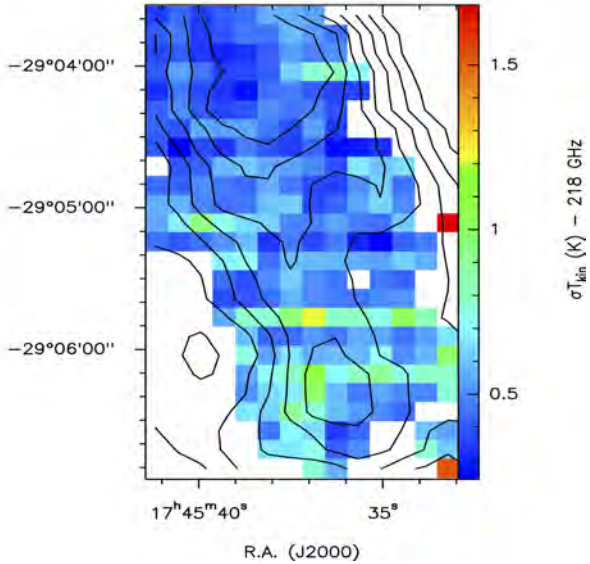

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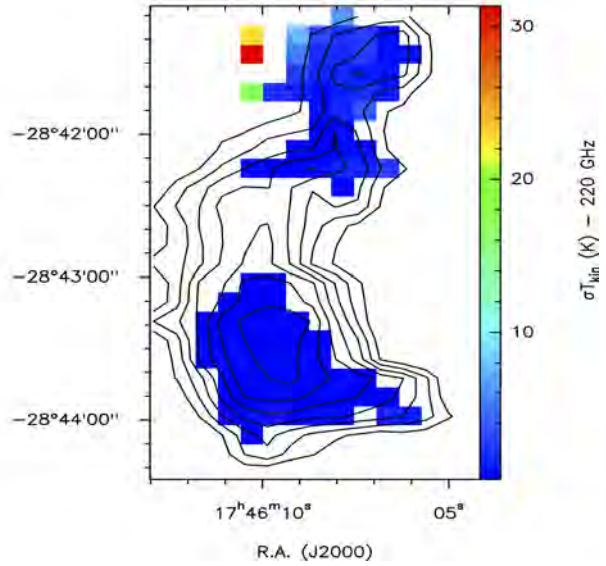
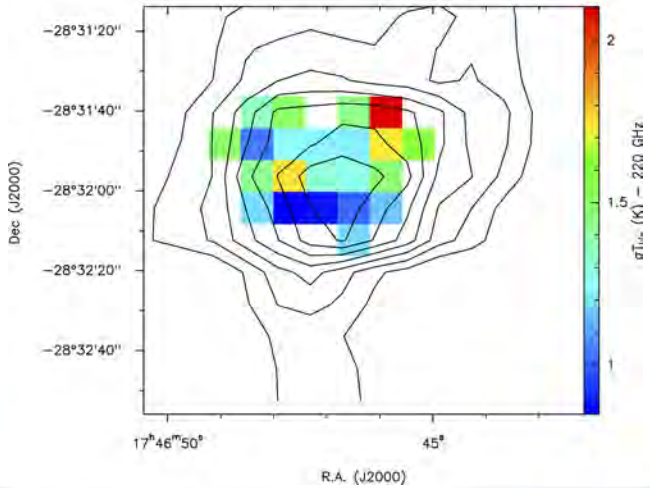


G0.480+0.006 19 – 44 km/s



G0.411+0.050 10 – 30 km/s