

# The Galactic Center:

Star formation in an extreme environment?

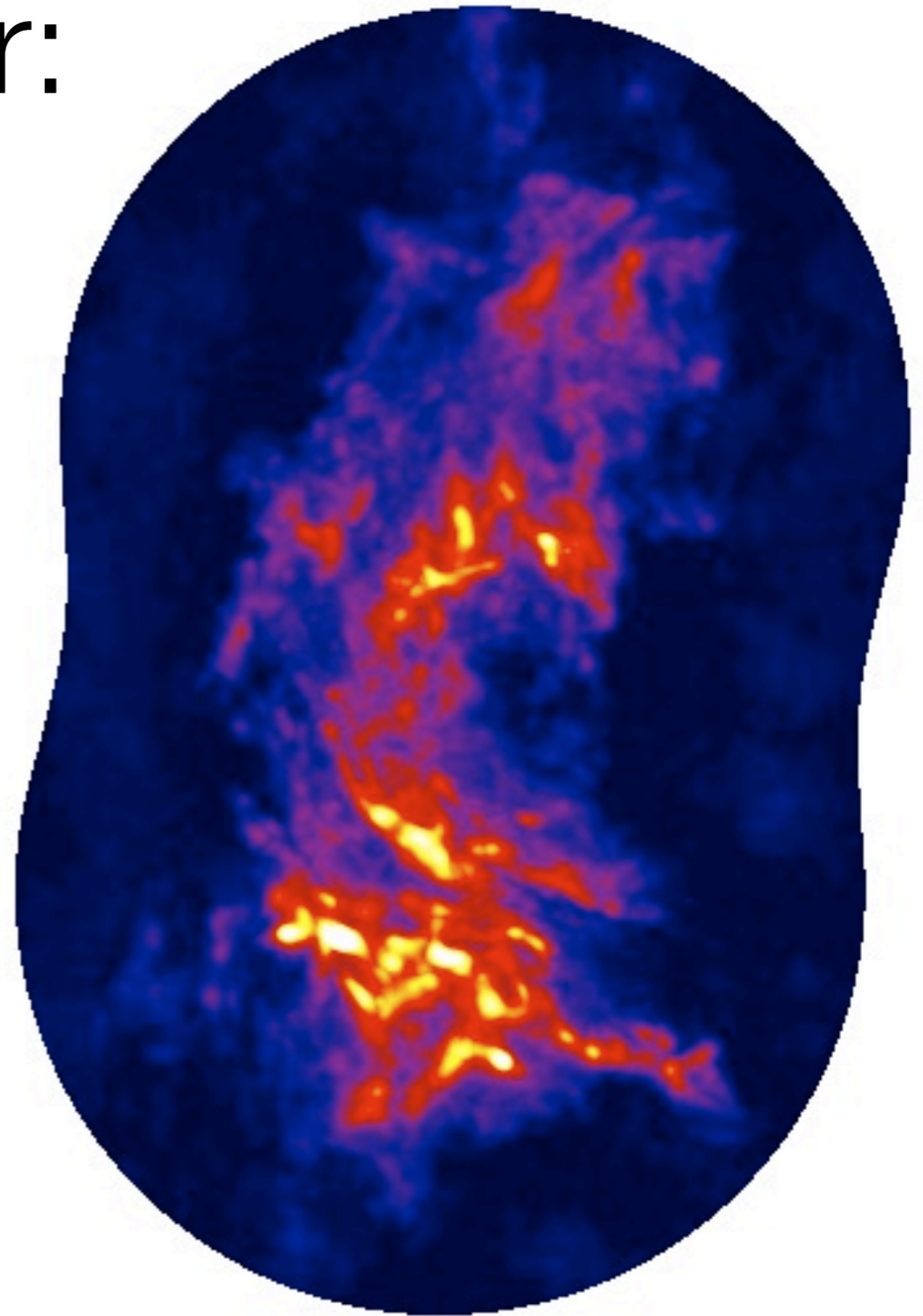
June 14, 2013

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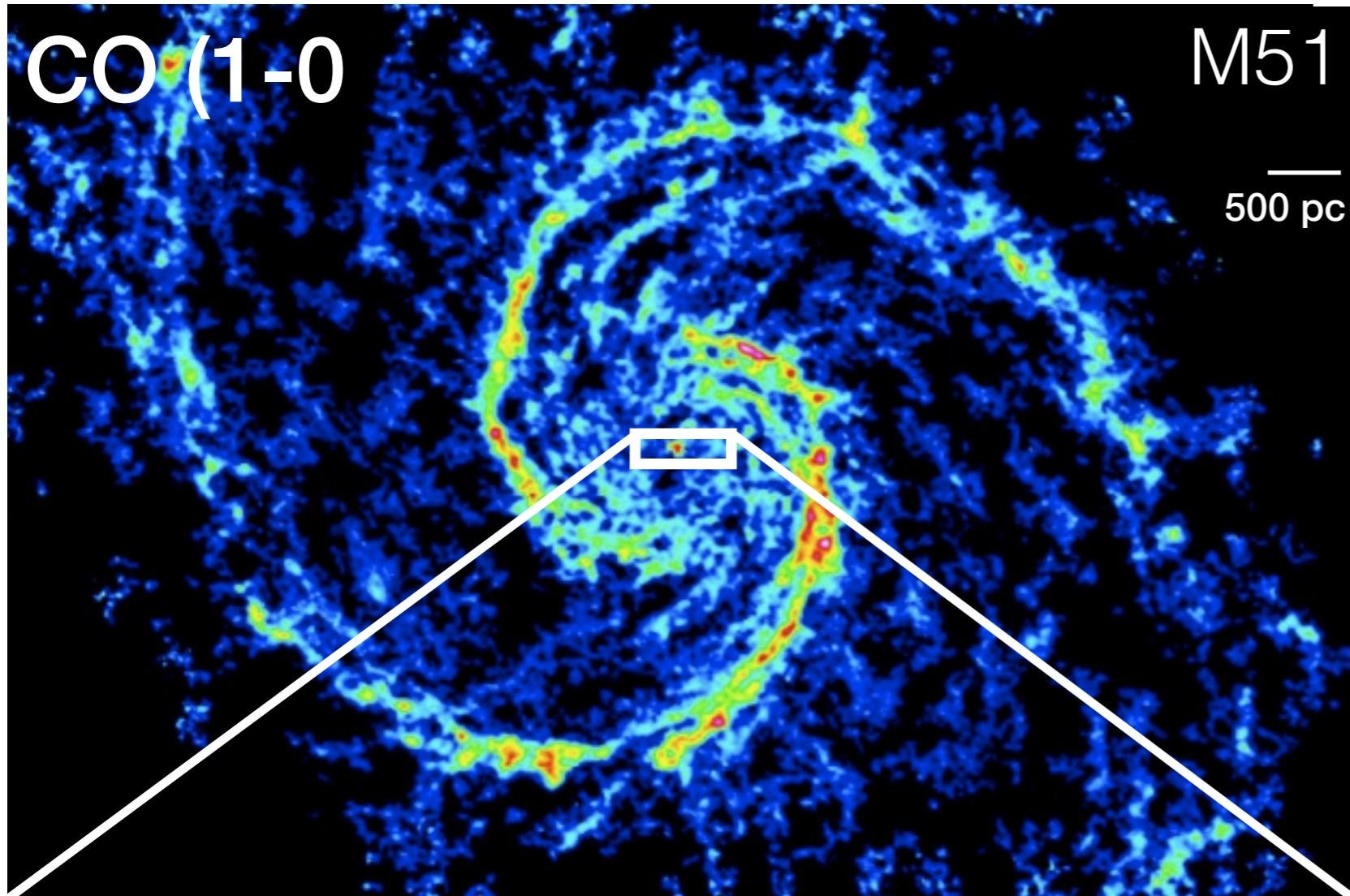
**Betsy Mills**

*Incoming Jansky Fellow @ NRAO-Socorro*

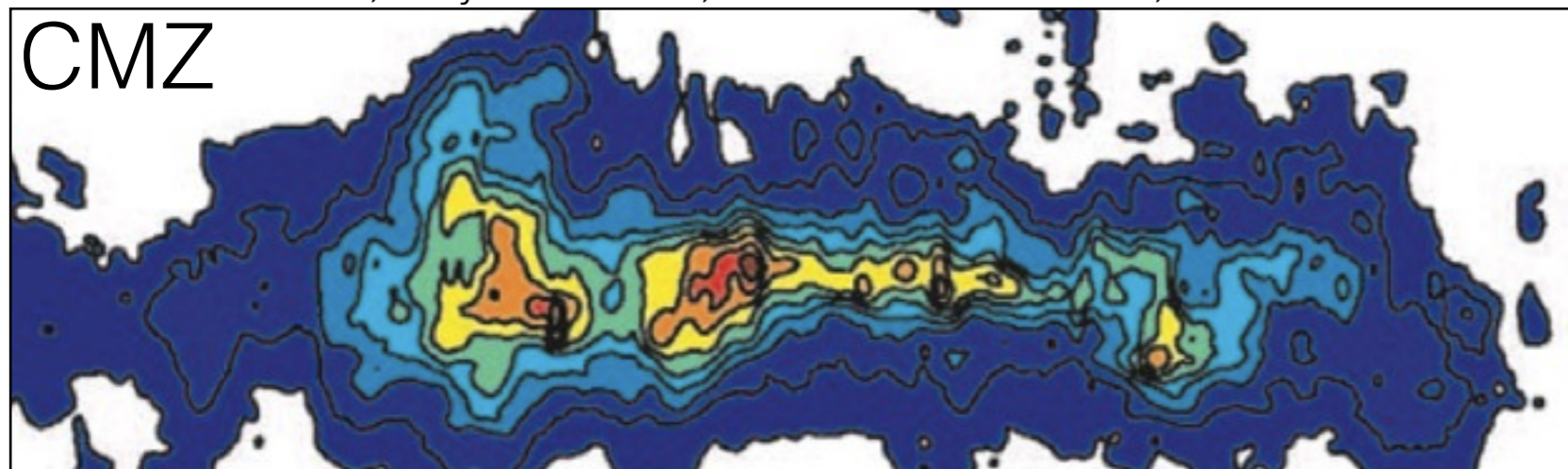
Mark Morris, Cornelia Lang, Juergen Ott,  
Natalie Butterfield, Dominic Ludovici, Jairo  
Armijos, Susie Schmitz



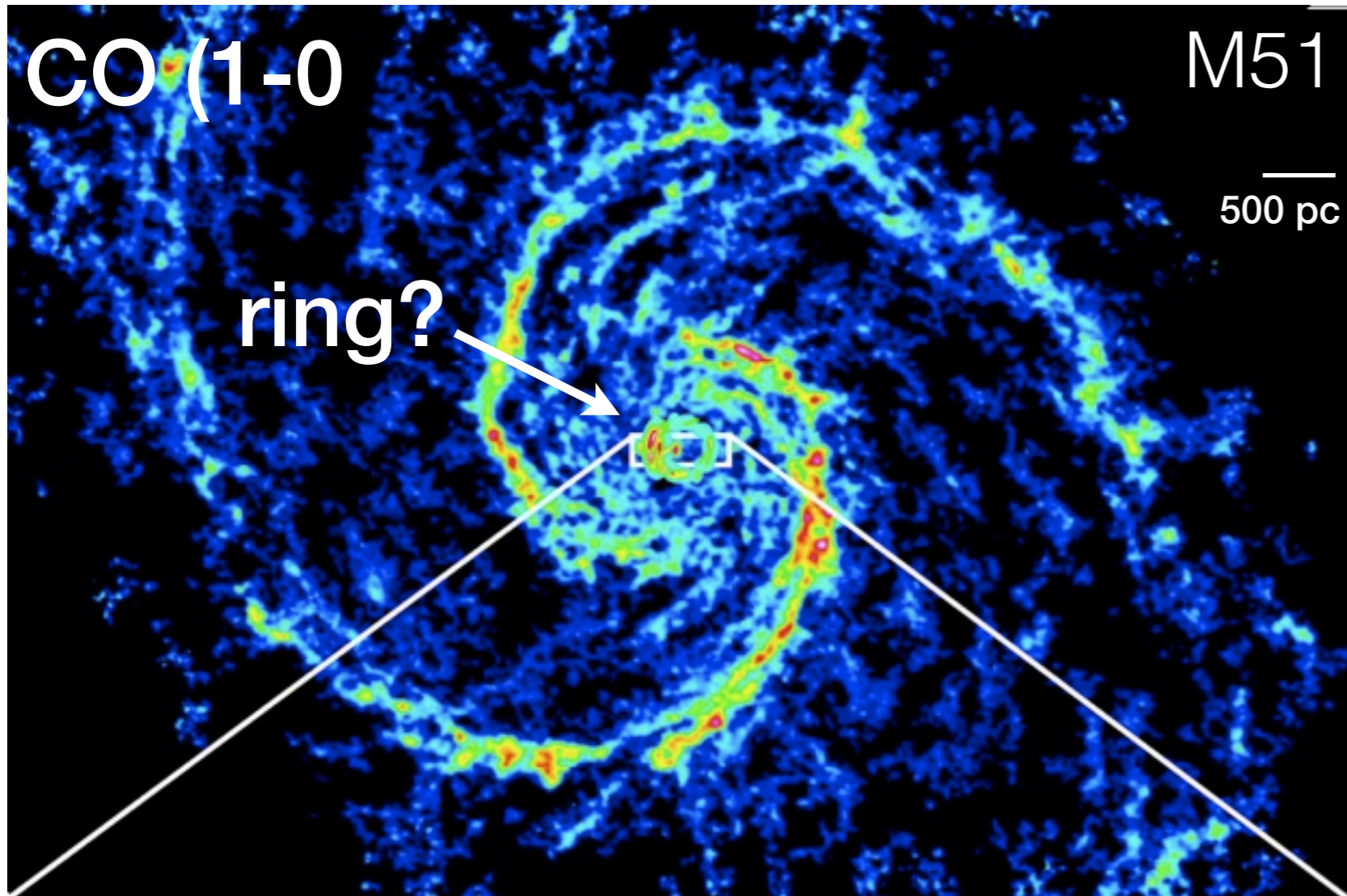
# What does the Galactic center look like?



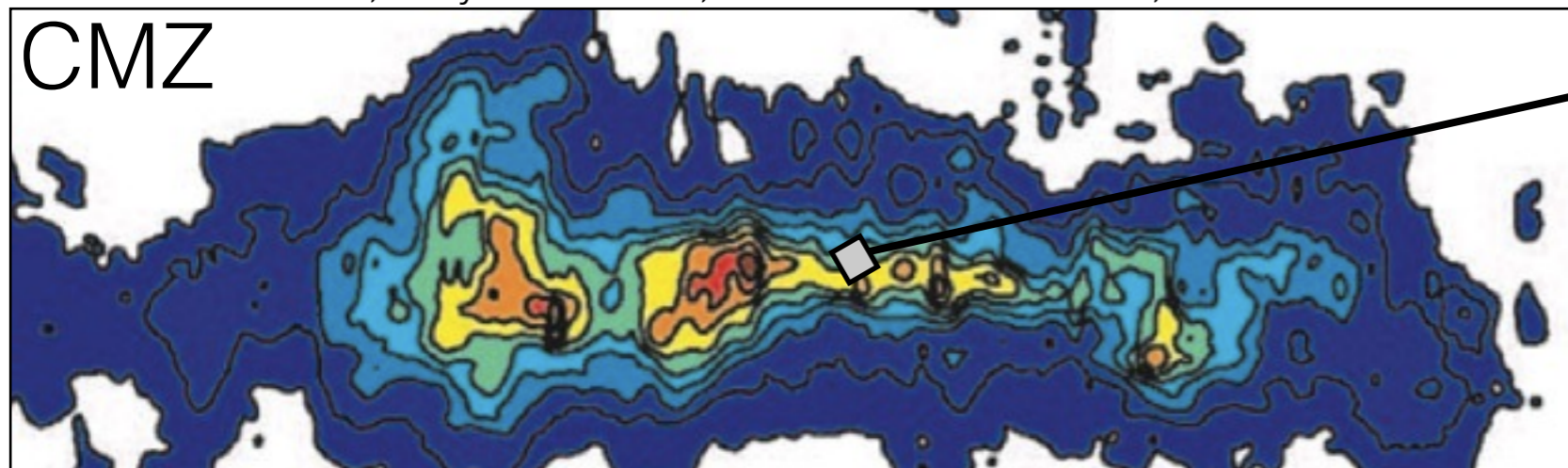
PAWS, Pety et al. 2013, Schinnerer et al. 2013, Colombo et al. 2013



Martin et al. 2004

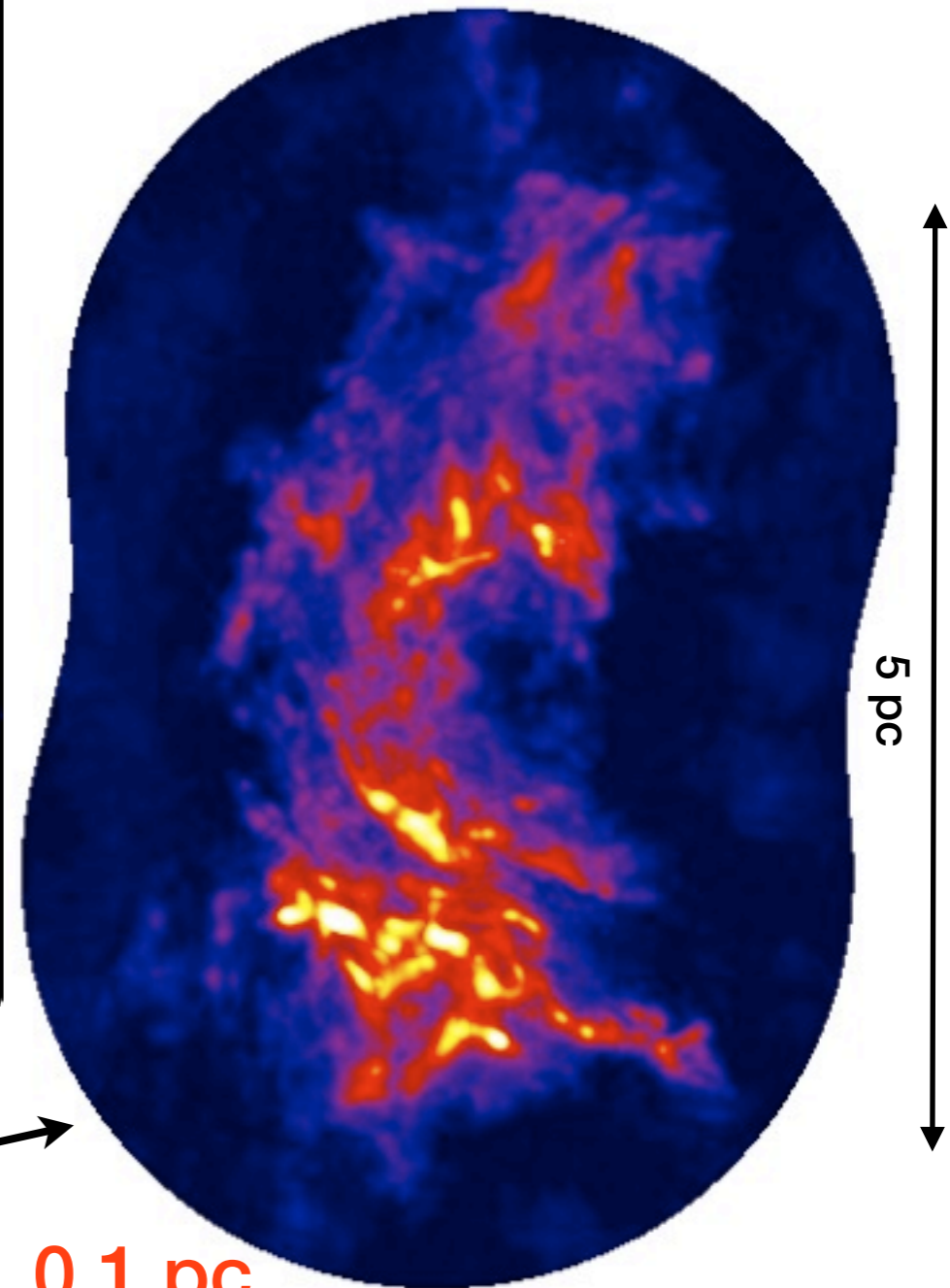


PAWS, Pety et al. 2013, Schinnerer et al. 2013, Colombo et al. 2013



Martin et al. 2004

## VLA - NH<sub>3</sub> (3,3)



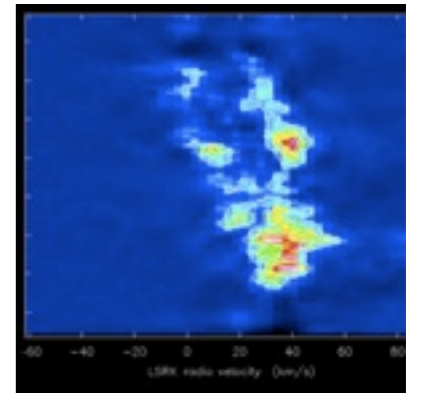
0.1 pc resolution!

Conditions in the central 600 parsecs are much more extreme than the Galactic disk

## Turbulent

$$\Delta v \sim 15-50 \text{ km s}^{-1}$$

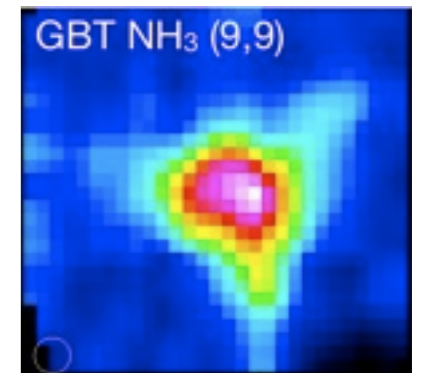
Bally et al. 1987



## Hot

$$T = 50 - 400 \text{ K}$$

Güsten et al. 1981, Morris et al. 1983, Hüttemeister et al. 1993, Ao et al. 2013

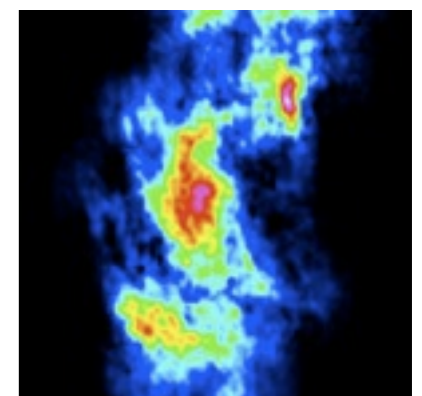


Mills et al. 2013

## Dense

$$n > 10^4 \text{ cm}^{-3}$$

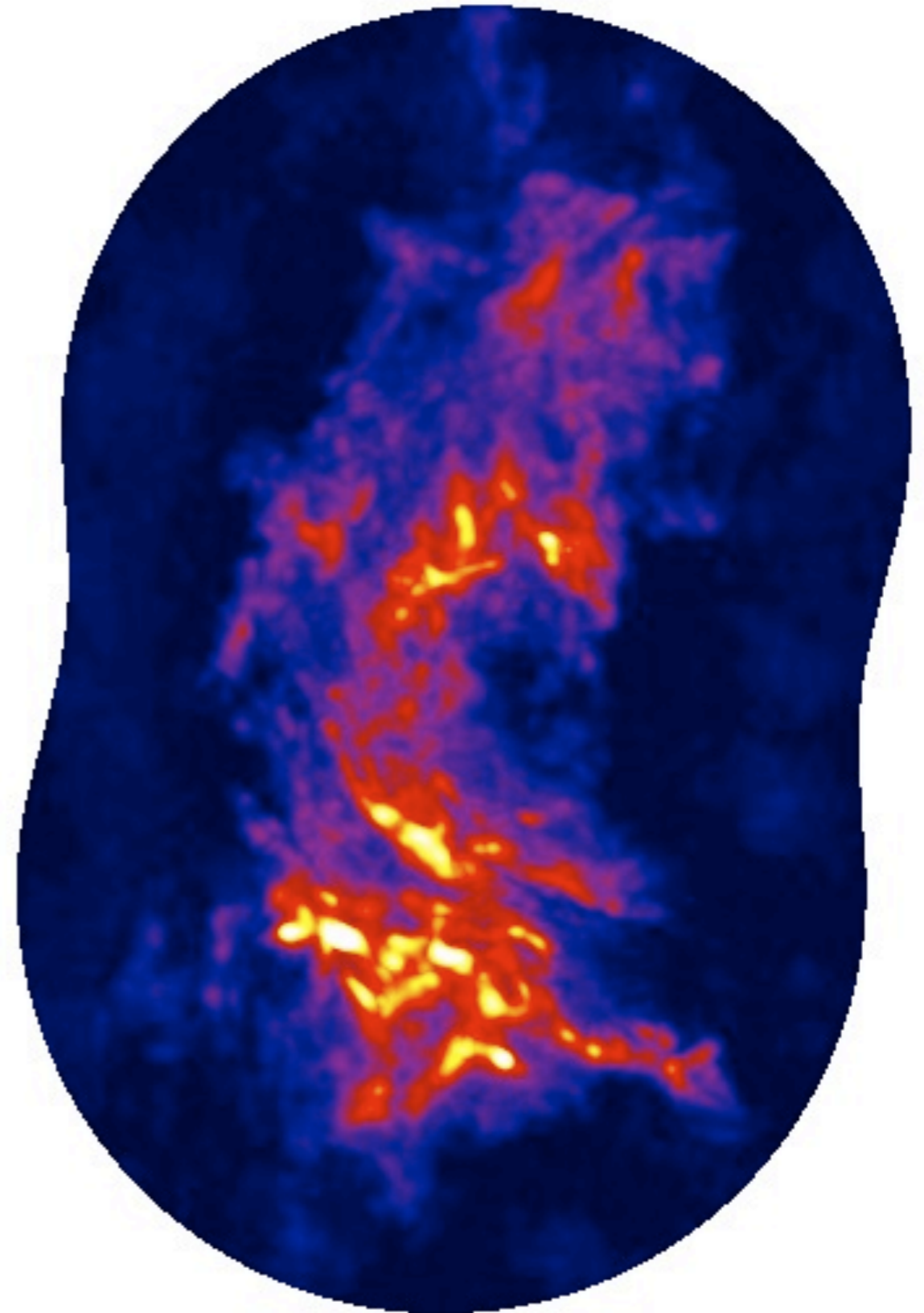
Bally et al. 1987, Serabyn, Lacy & Achtermann 1992

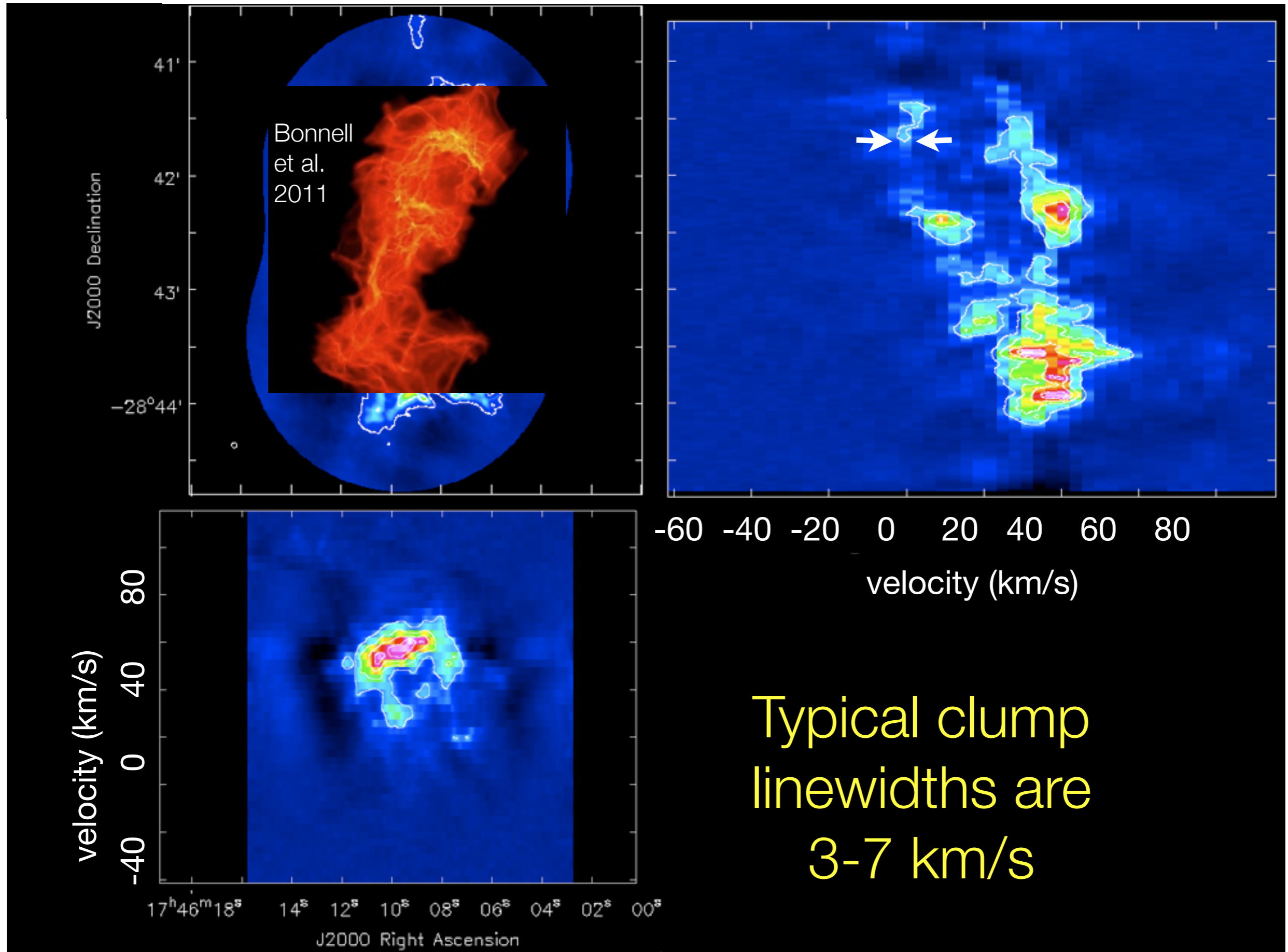


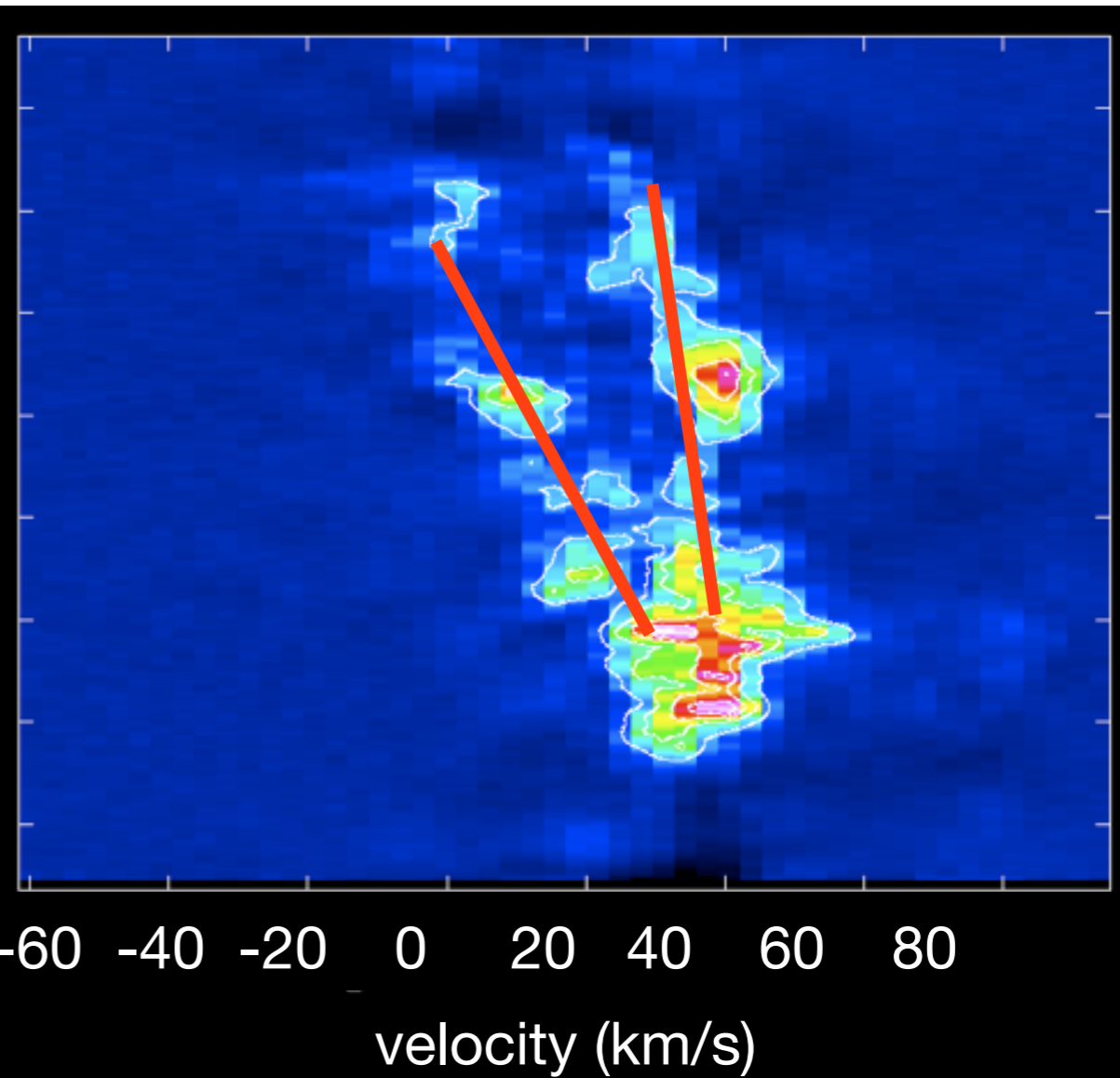
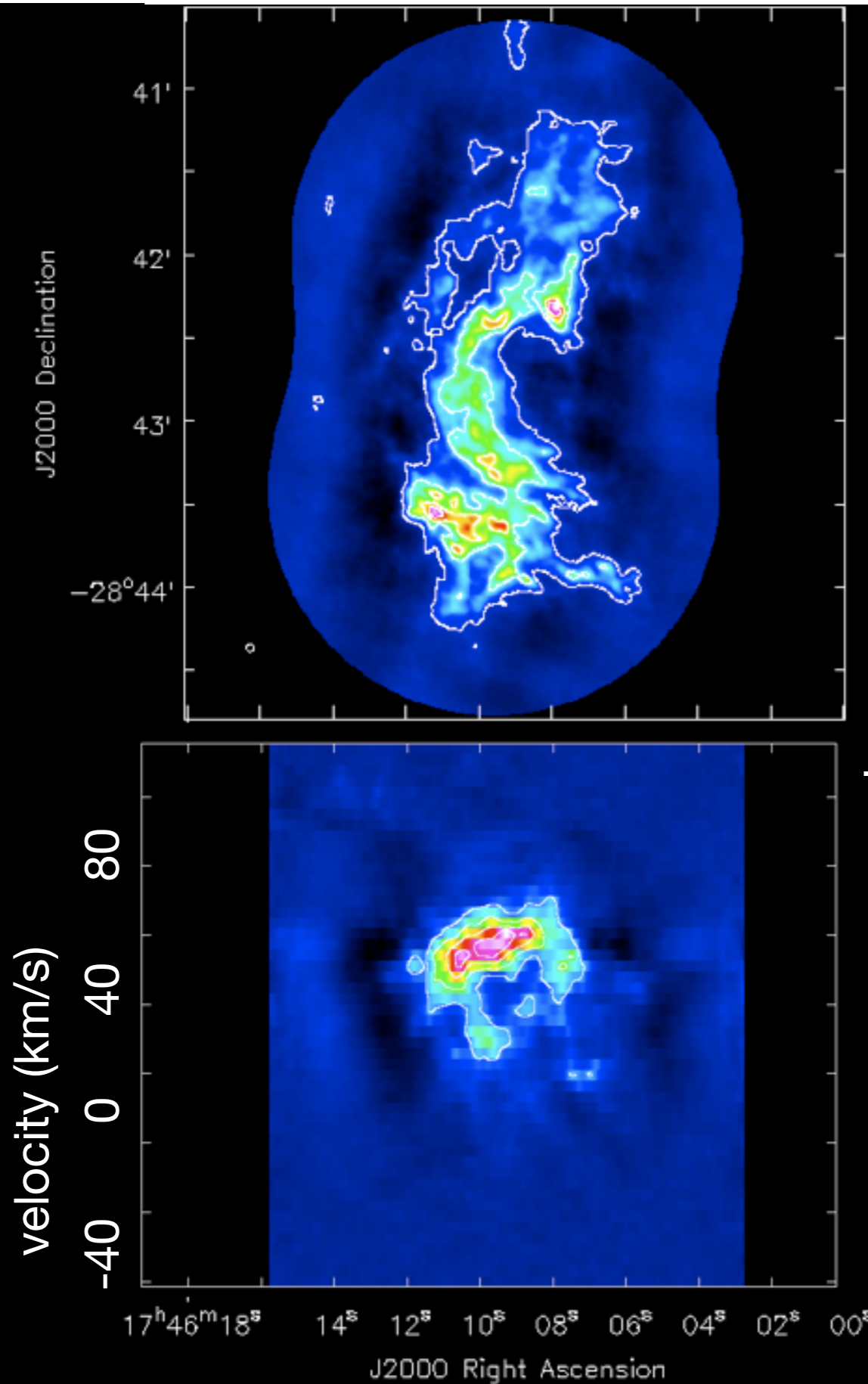
These extreme conditions are just the typical conditions in the CMZ gas, averaged over entire clouds.

How much do conditions inside of the clouds deviate from these typical values?

How  
Turbulent?



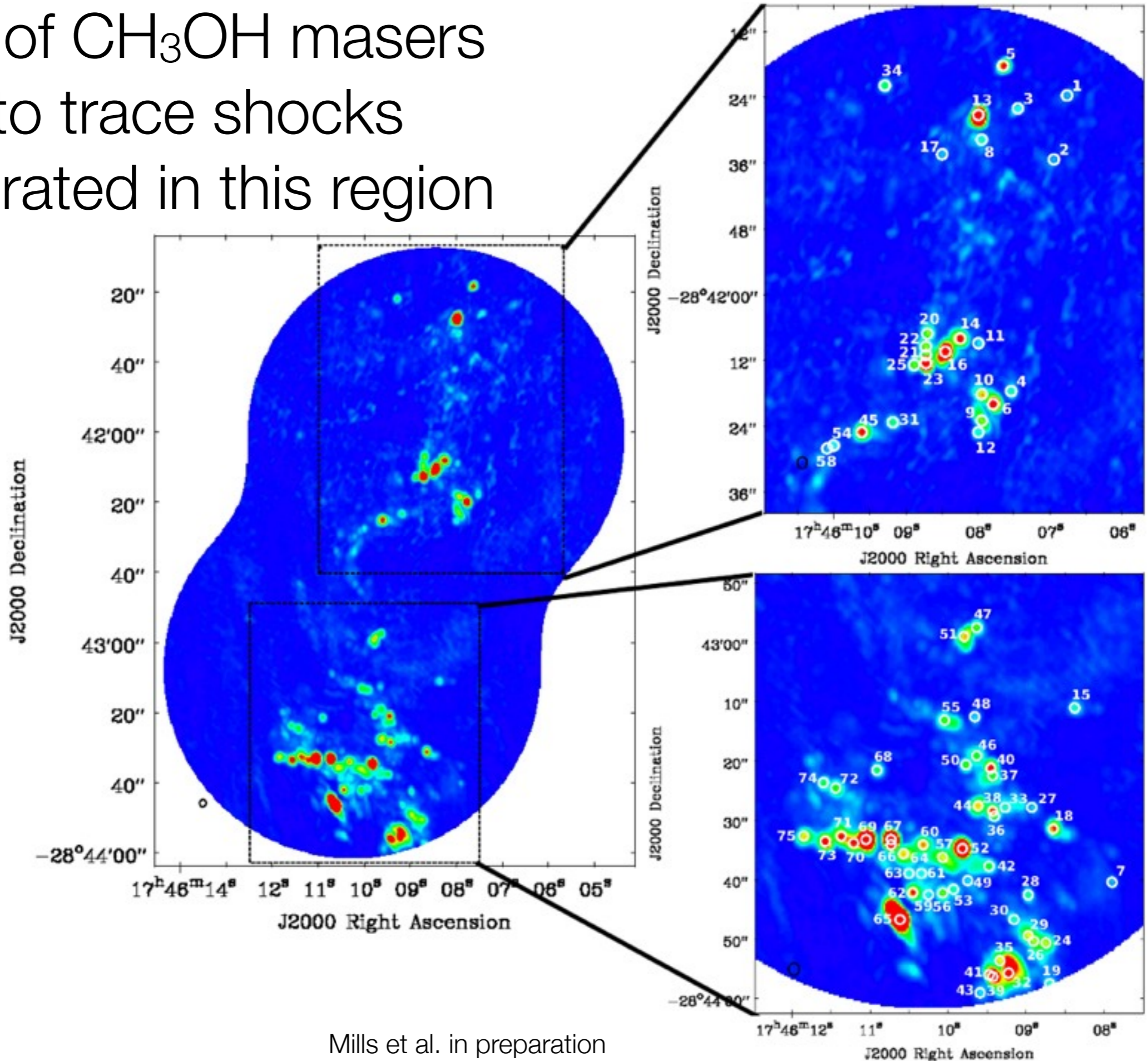




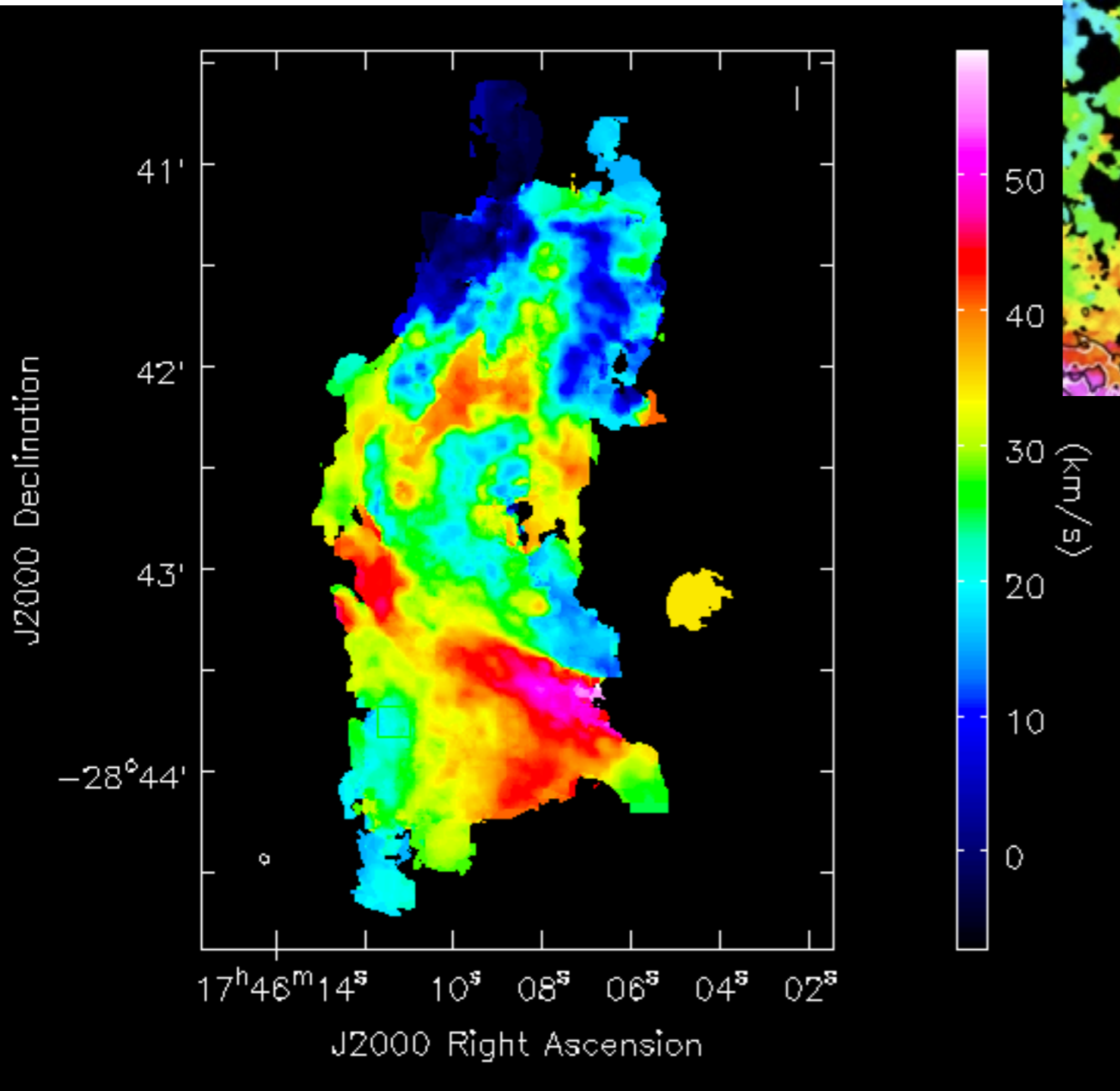
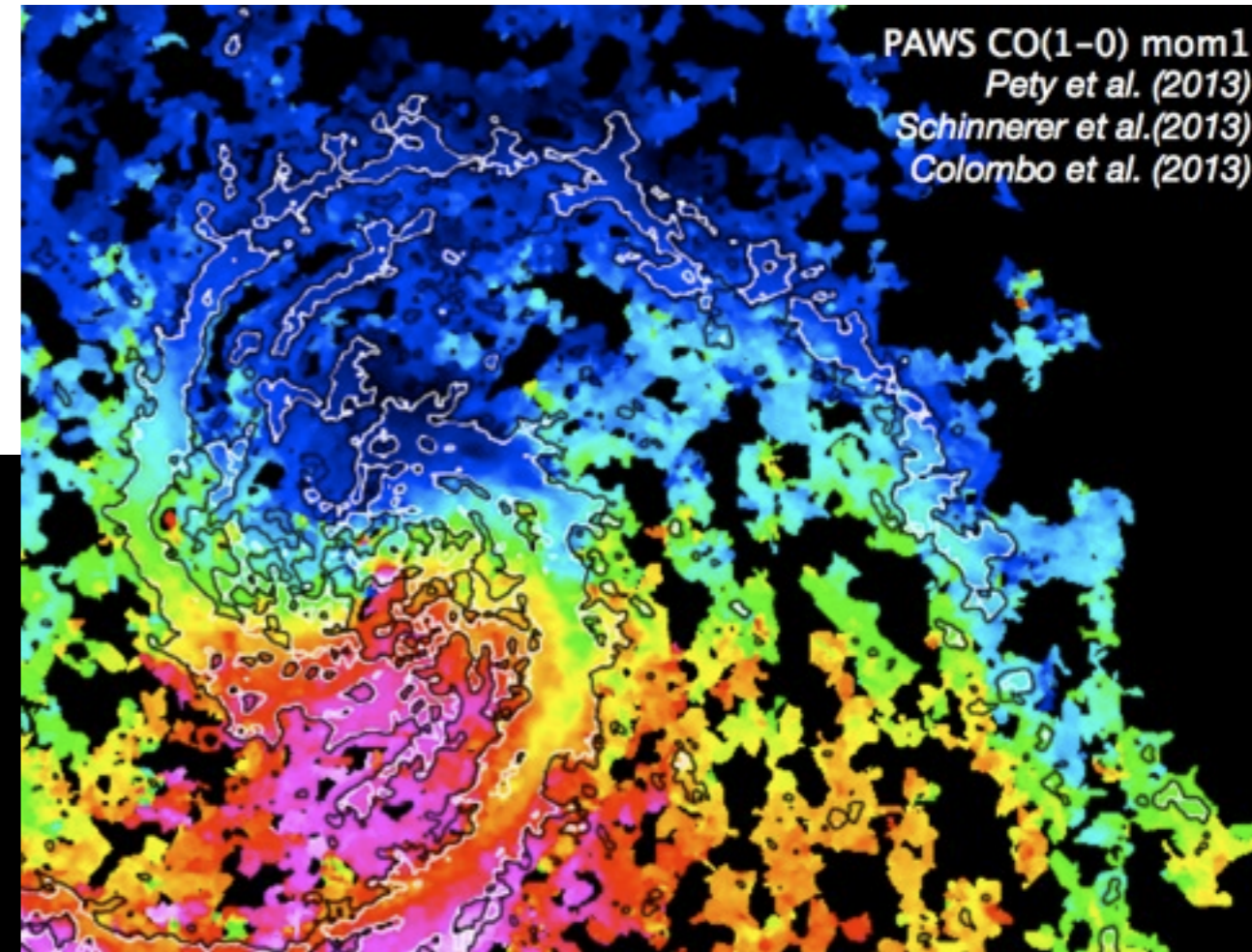
Position-velocity diagrams show converging features



Dozens of CH<sub>3</sub>OH masers appear to trace shocks concentrated in this region



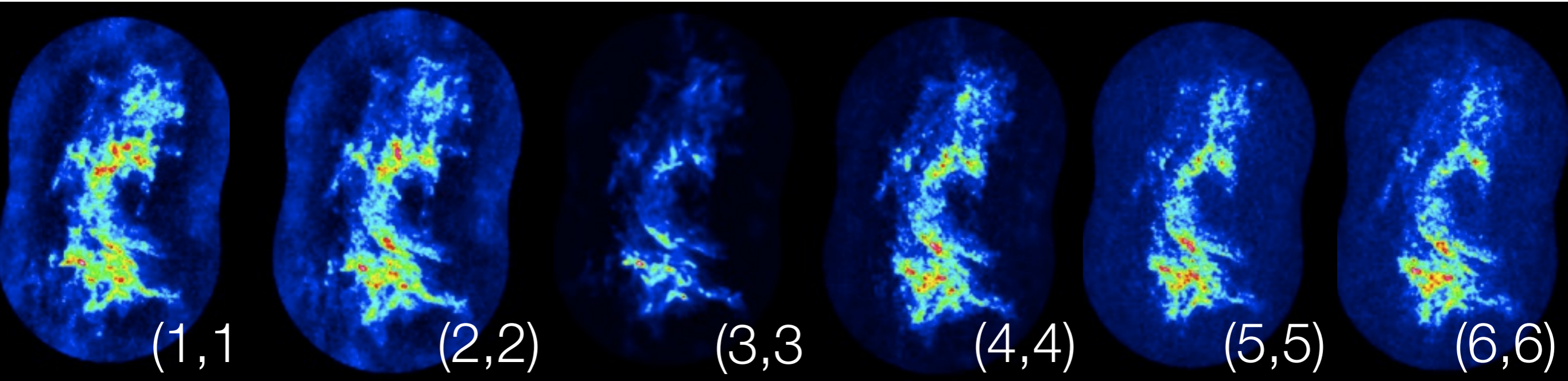
But why are stars not forming?



Does large velocity gradient and streaming contribute?

# How Hot?

# Ammonia in the Brick:



Mills et al. in preparation

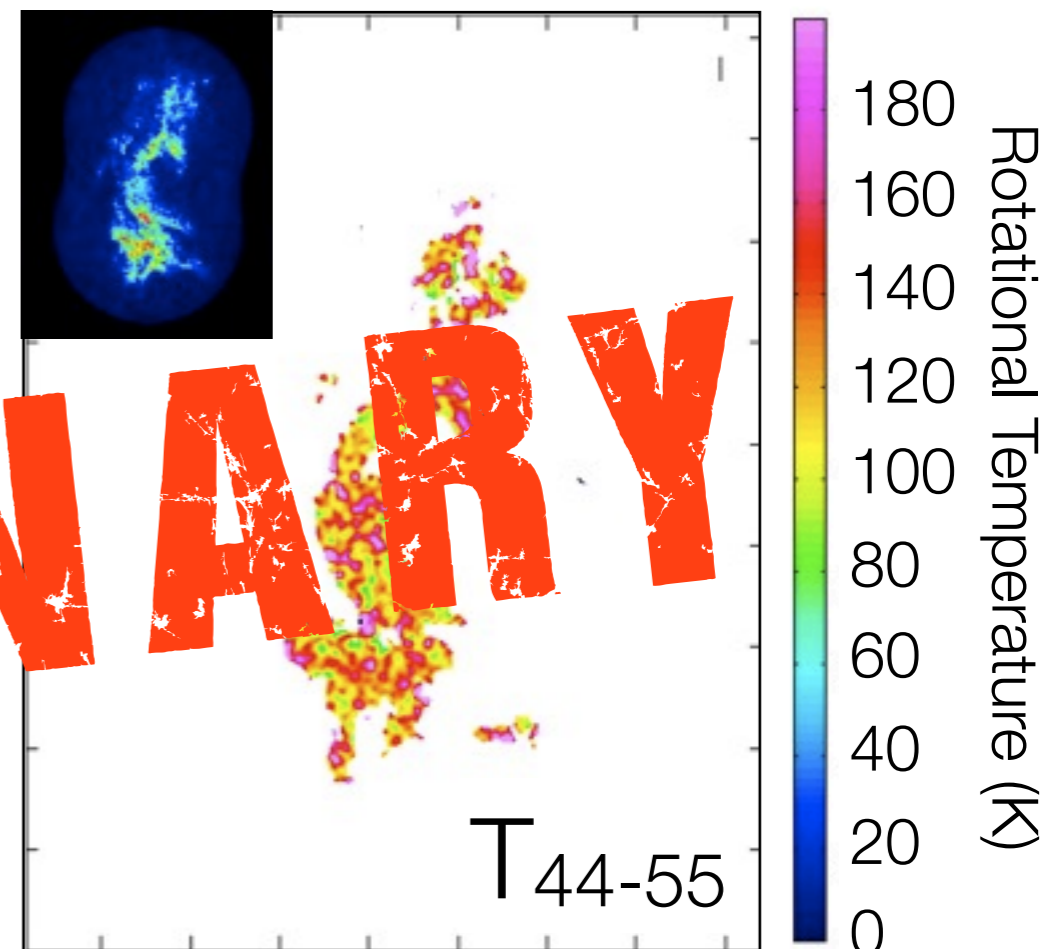
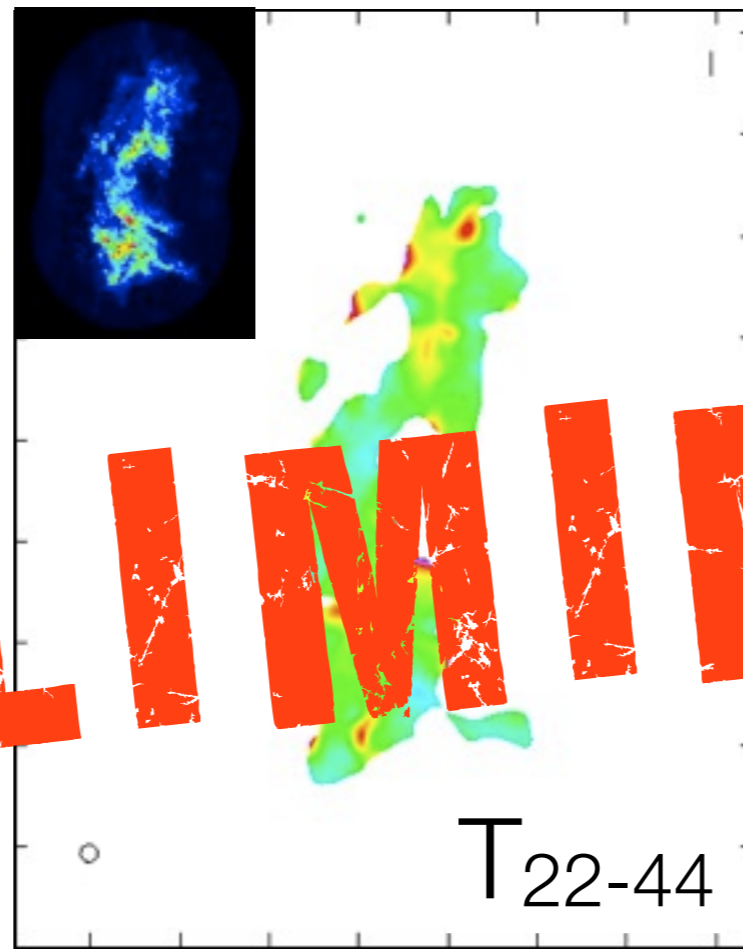
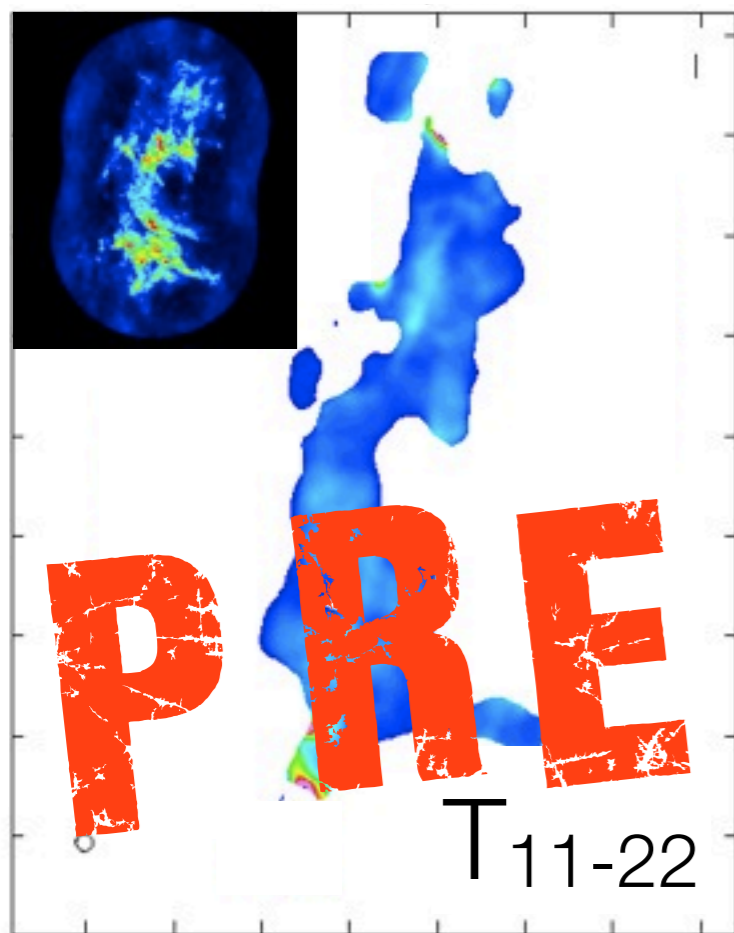
Also have (7,7) and (9,9) -- latter has excitation energy of 840 K!

Similar gas structure seen in all ammonia lines, with a wide range of apparently coexisting temperatures:

$T_{\text{KIN}} \sim 25\text{-}50 \text{ K}$

$T_{\text{KIN}} \sim 100 \text{ K}$

$T_{\text{KIN}} \sim 200 \text{ K}$

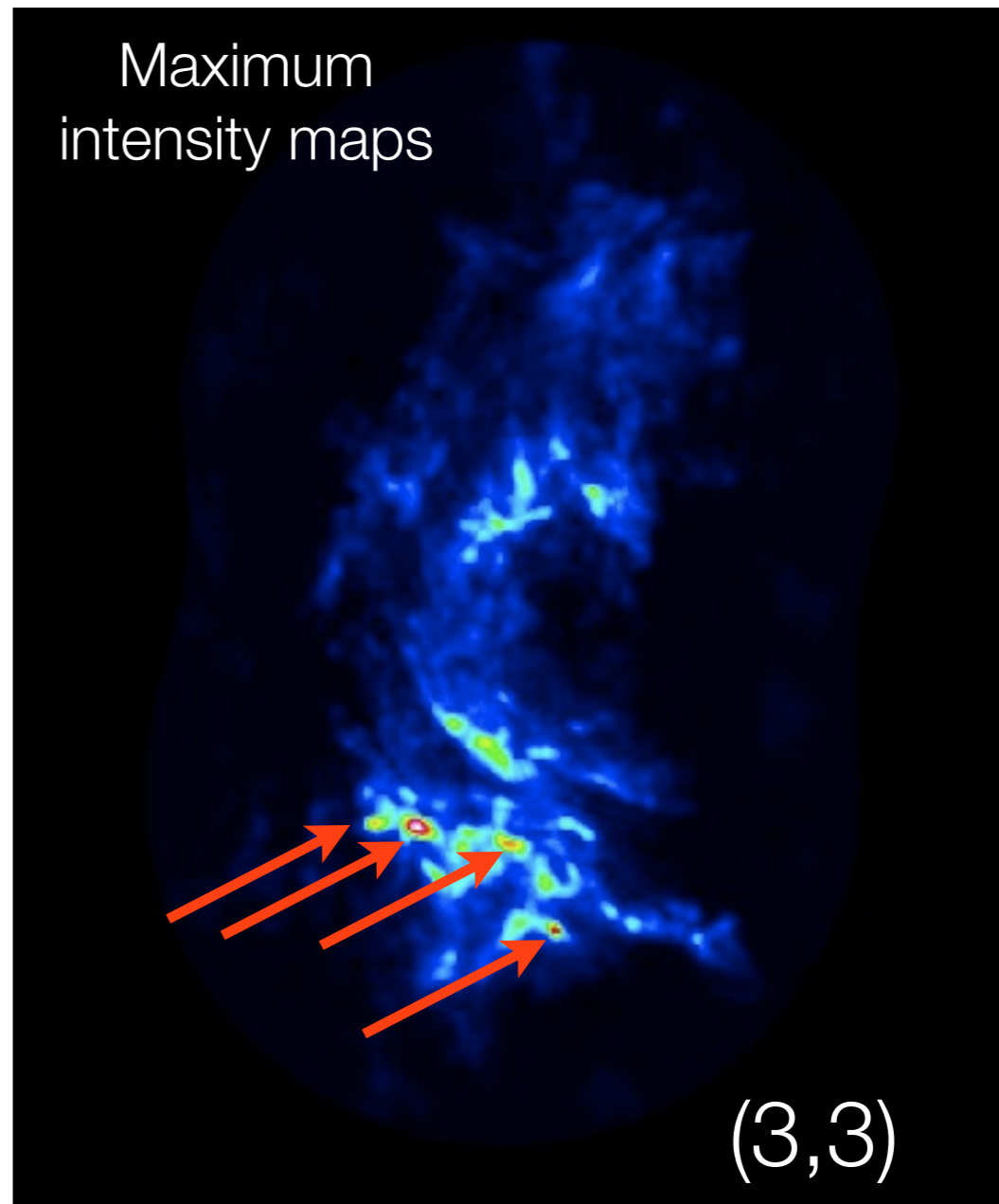
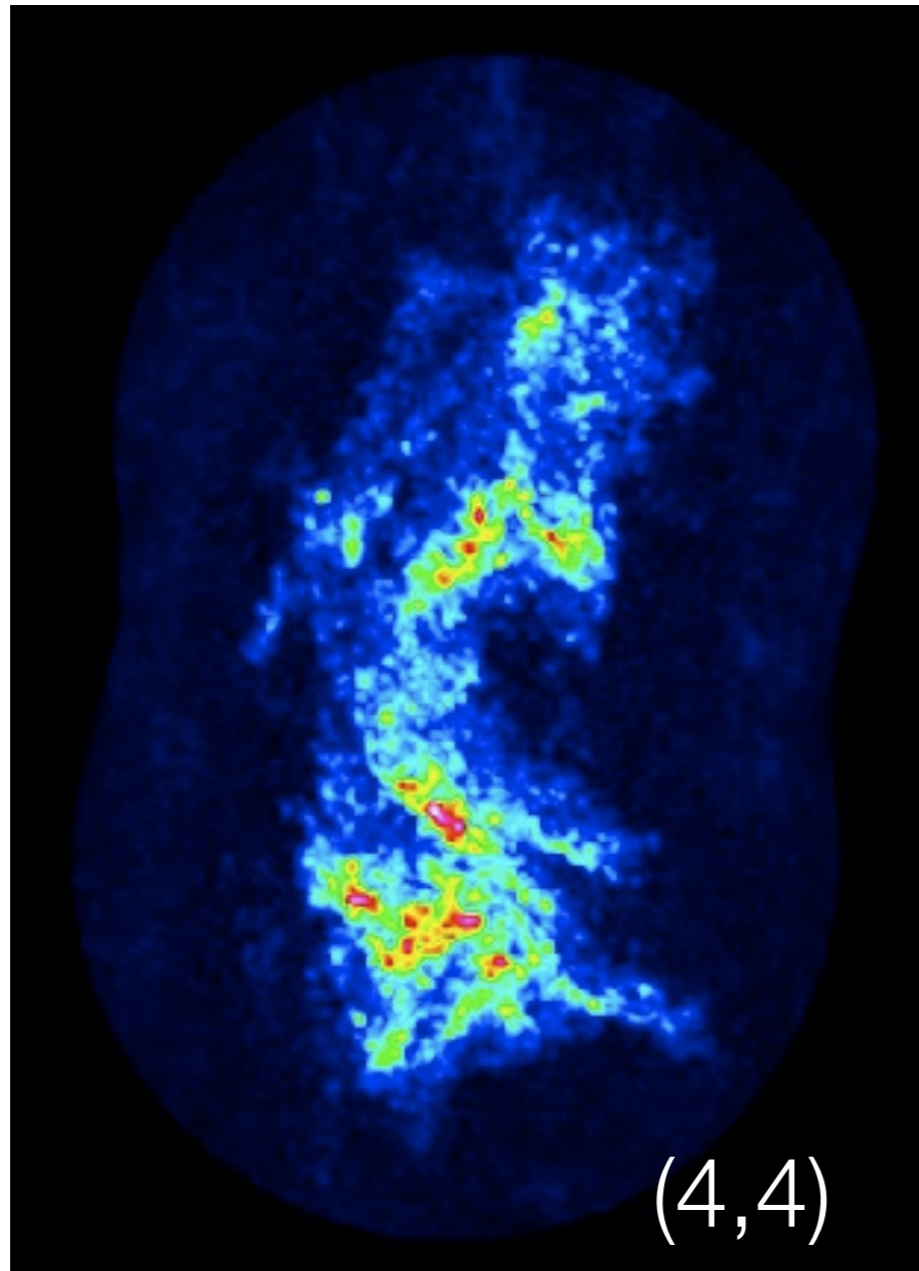


**PRELIMINARY**

(not yet corrected for optically-thick lines)

# How Dense?

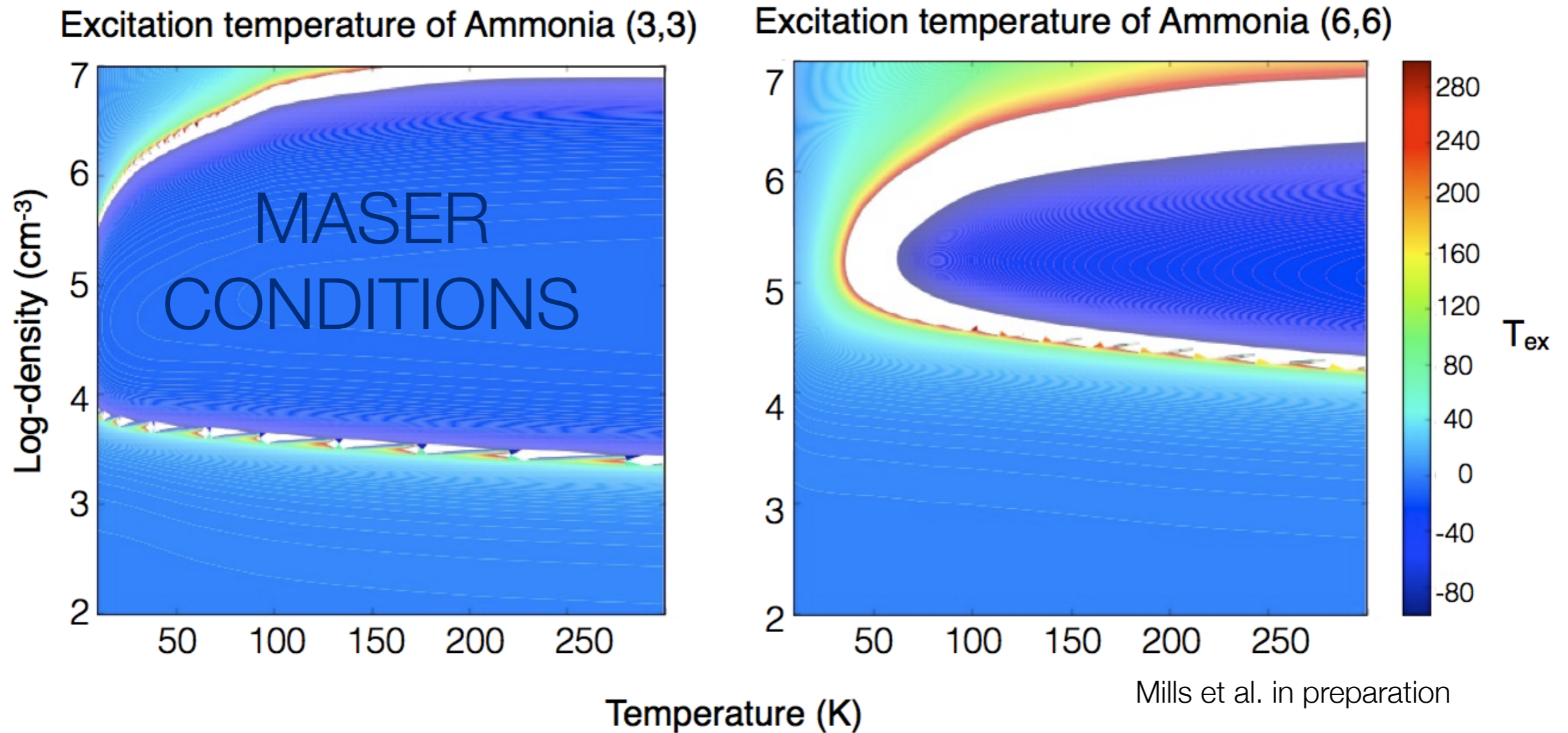
One of these lines is not like the other...



Mills et al. in preparation

(3,3) line appears to be masing in several locations.

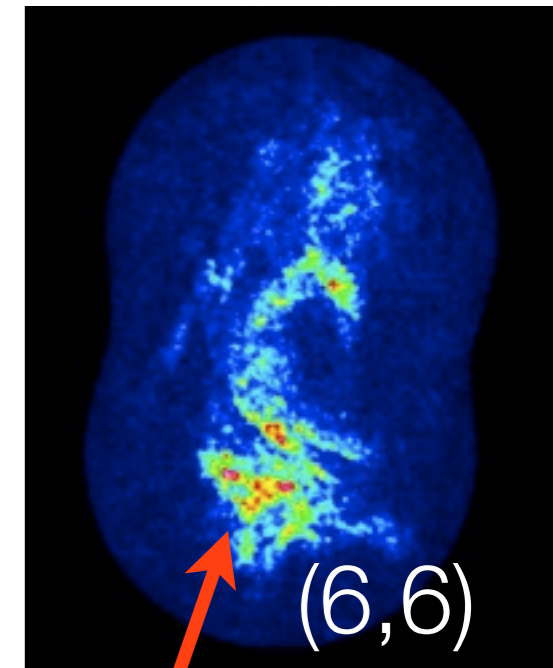
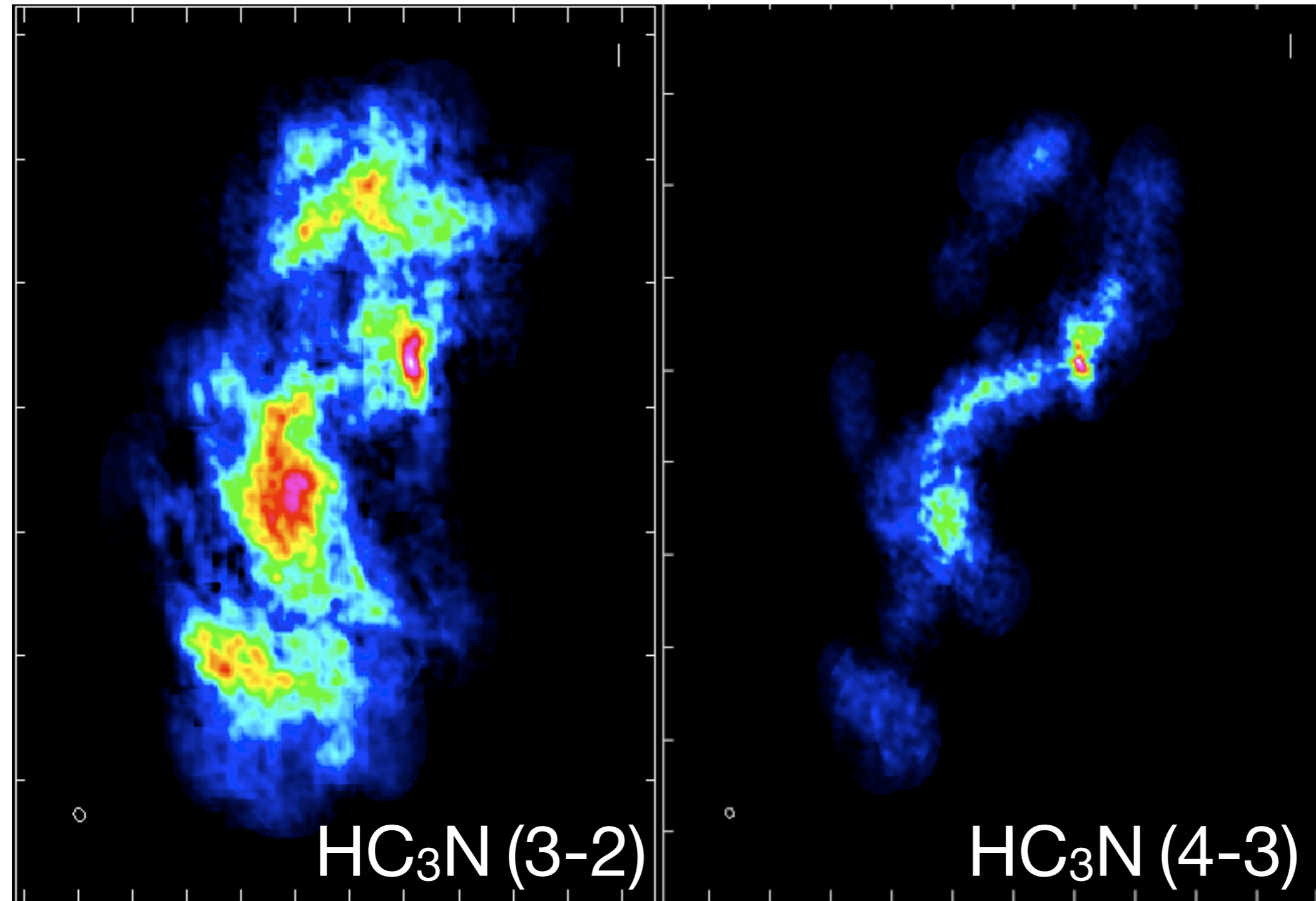
# (3,3) masering can constrain cloud densities



But is ammonia tracing the densest cloud gas?

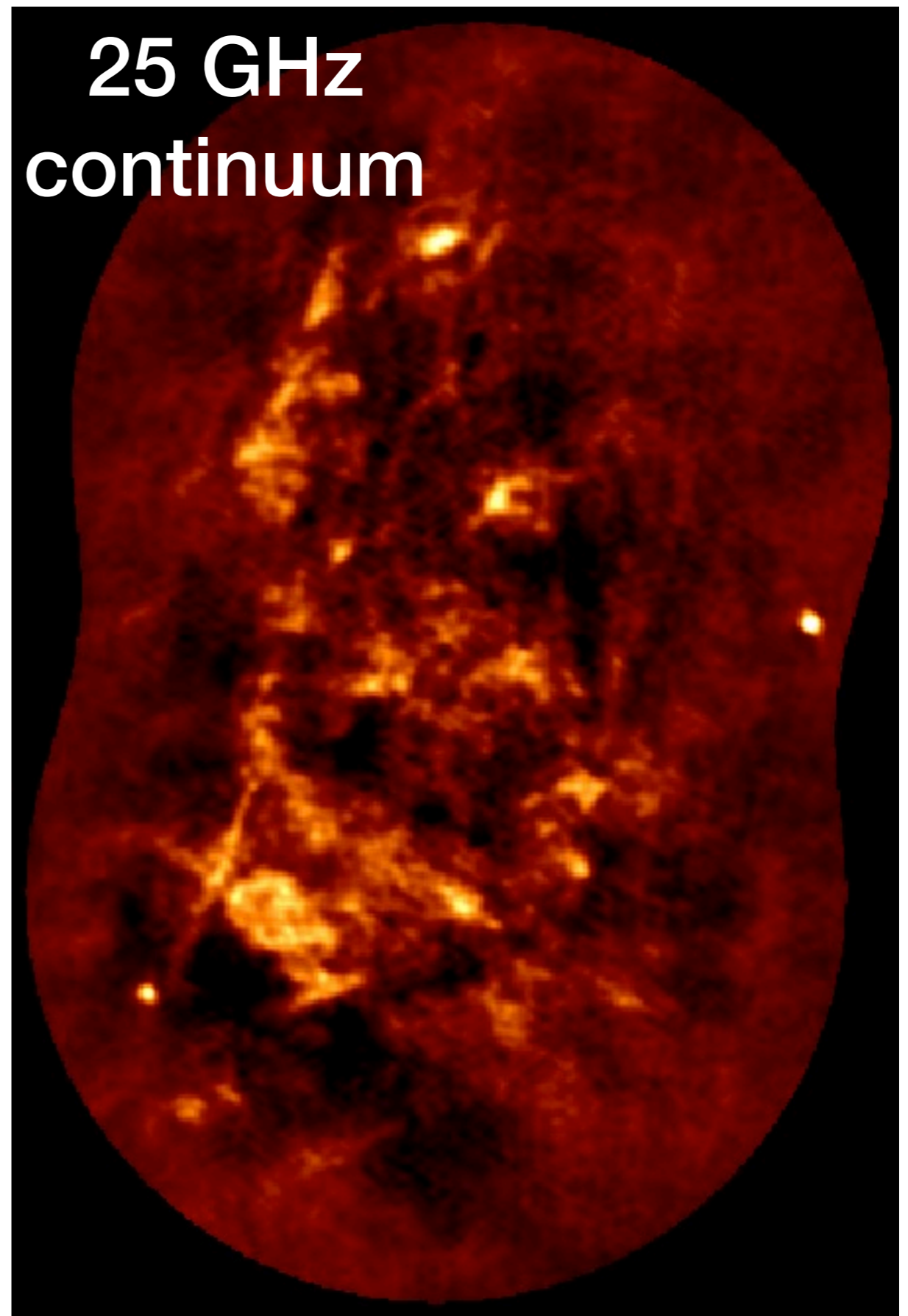


Dense gas tracer  $\text{HC}_3\text{N}$  is strongest toward the center of M0.25+0.01

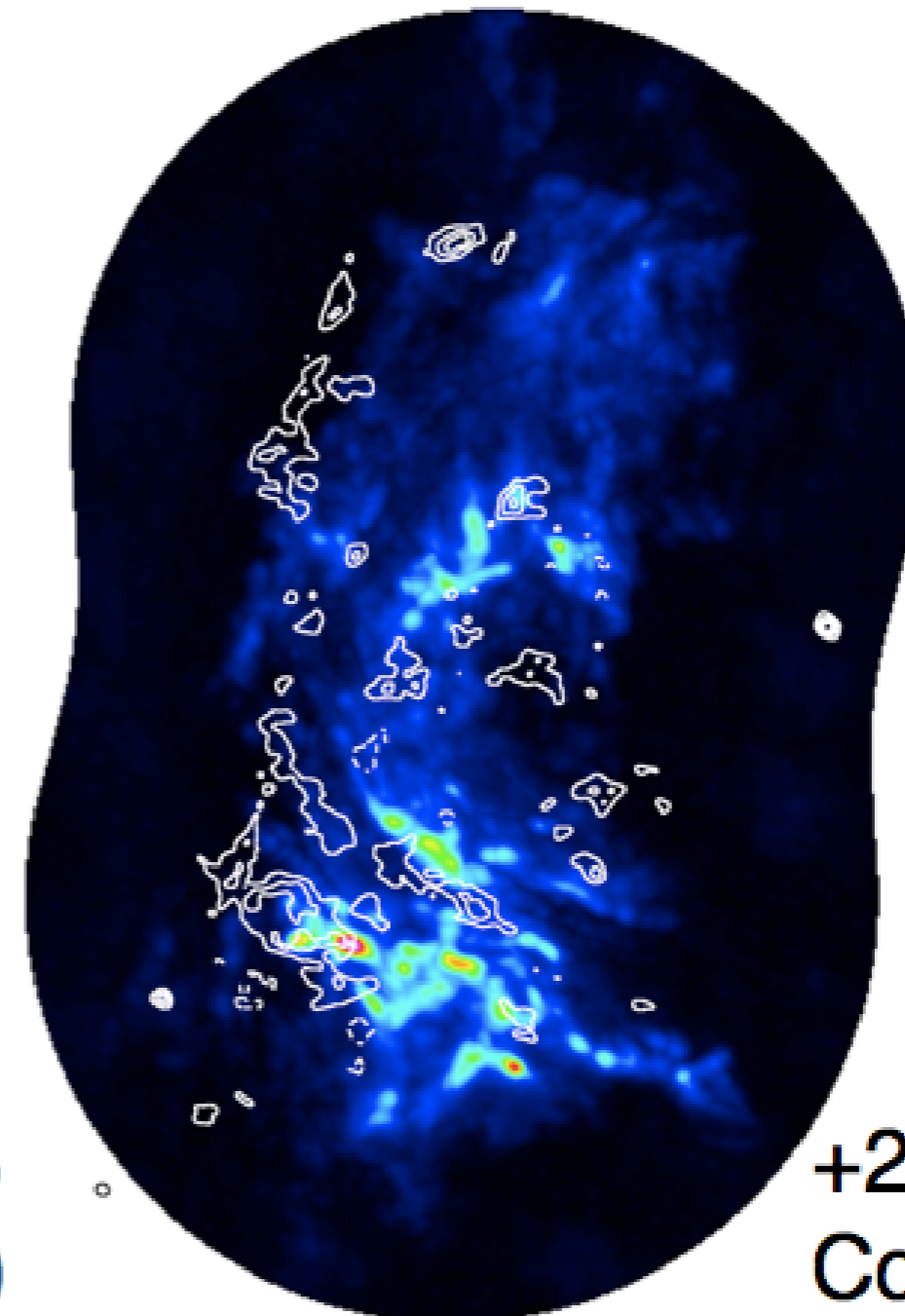
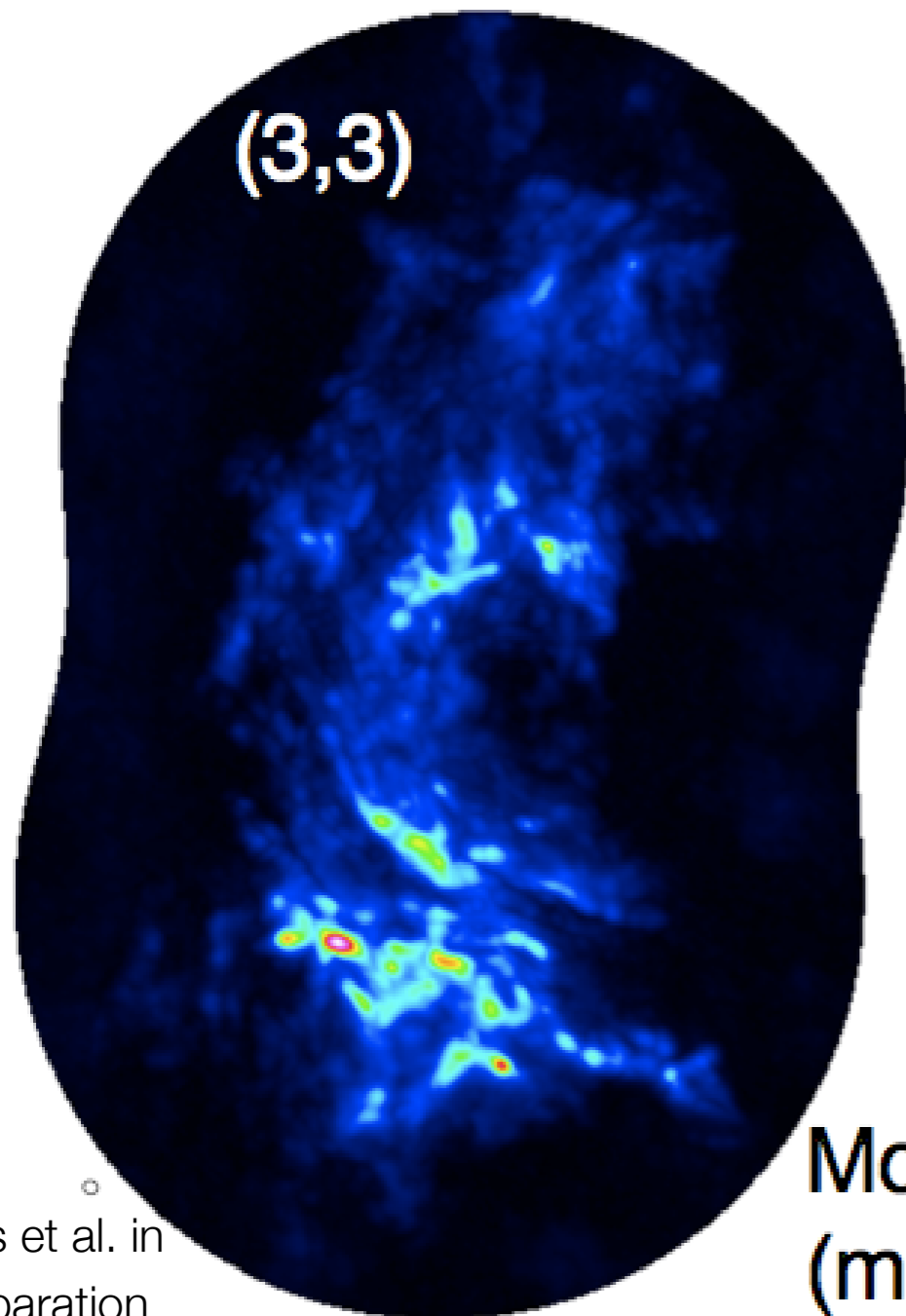


$\text{NH}_3$  peaks  
in the south

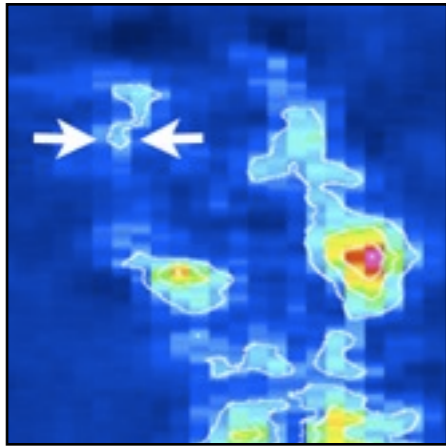
What is the  
cloud  
environment?



Majority of emission appears to be consistent with external ionization

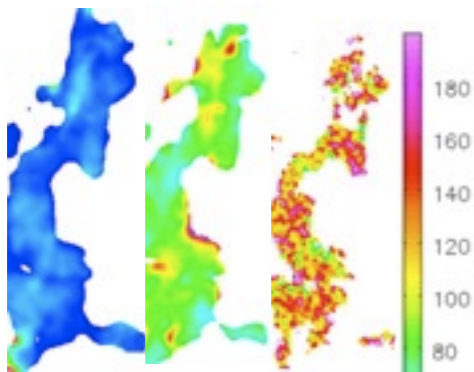


Mills et al. in  
preparation

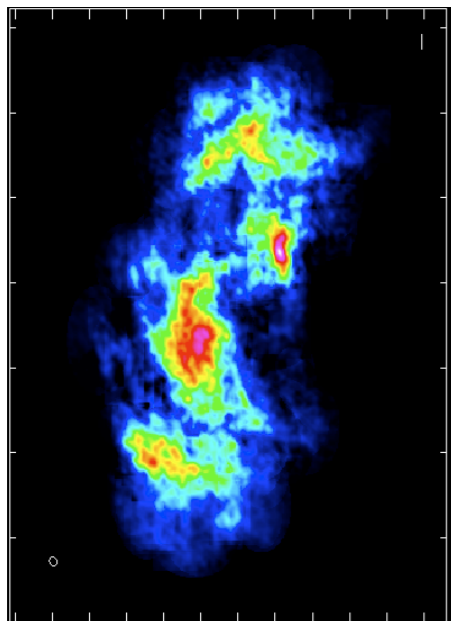


**Less Turbulent:** clump linewidths are just 3-7 km/s

Cloud collision traced by masers?



**Both hot and cold:** uniformly includes components from 25 to >200 K



**Truly Dense:** Ammonia (3,3) masers indicate gas densities between  $10^4$  -  $10^6$   $\text{cm}^{-3}$ , and it is not clear ammonia traces the densest gas