Fragmentation in (Pre)cluster Forming Regions

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Questions:

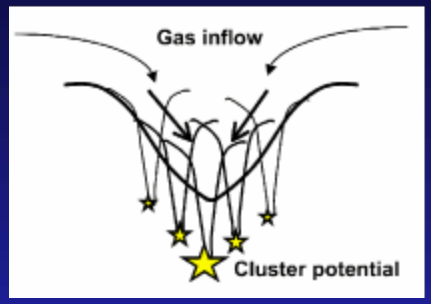
- What is the physical and chemical state in (pre) massive star/cluster forming clouds?
- What drives the structure formation: Thermal fragmentation or other processes?

What drives the initial structure in cluster formation?

Competitive Accretion

$$M_J = \left(\frac{\pi C_s^2}{G}\right)^{3/2} \rho_o^{-1/2} \Rightarrow 0.4 Msun$$

Bonnell et al. 2001, 2004



$M_{core} \neq M_*$

Monolithic Collapse (Tan & McKee 2004)

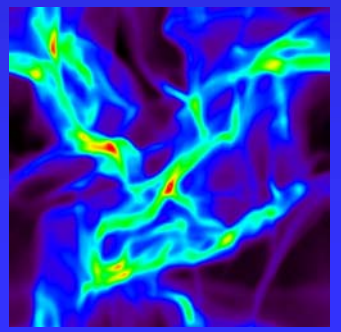
Stellar heating increase M_J

Krumholz et al. 2007, 08

$M_{core} \sim M_*$

Turbulent Fragmentation

Padoan et al. 2004

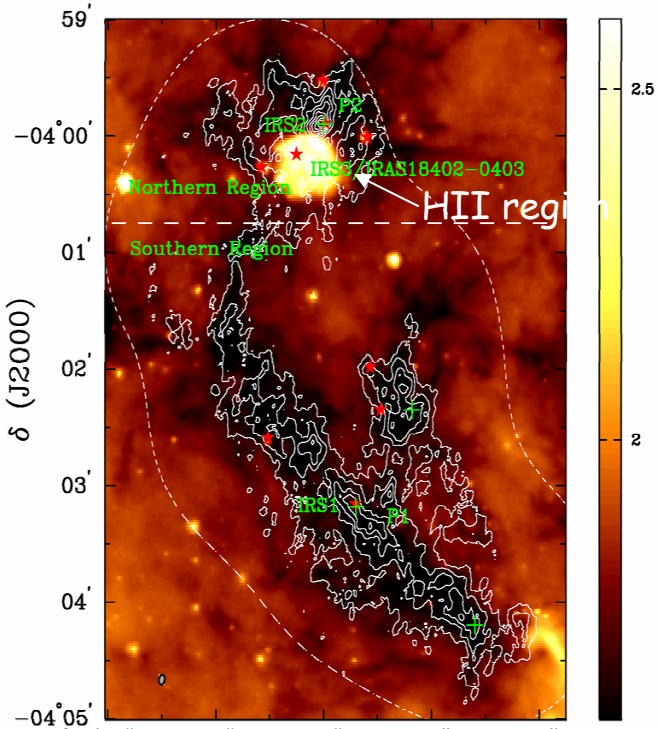


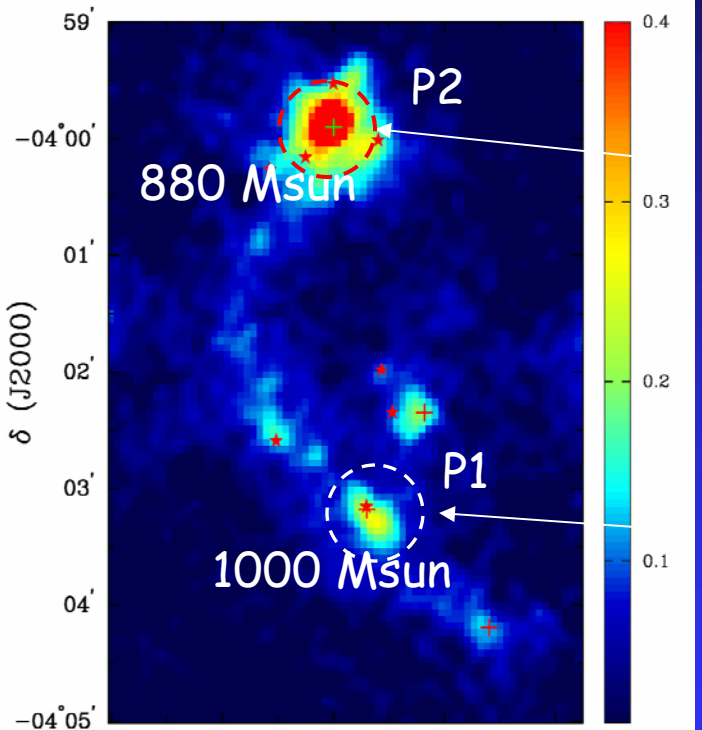
Initial conditions: IRDC G28.34

VLA NH_3 (Contours)
Spitzer 8um(color)

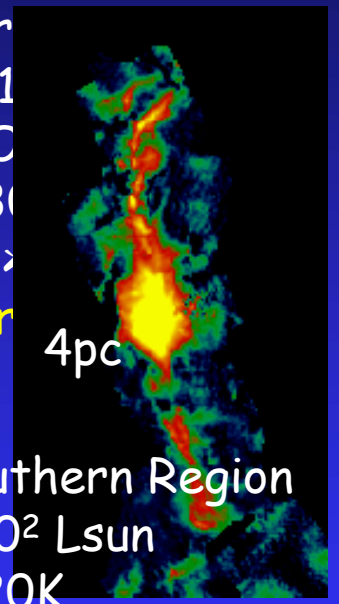
P1 will evolve into P2

1.2mm continuum





OMC

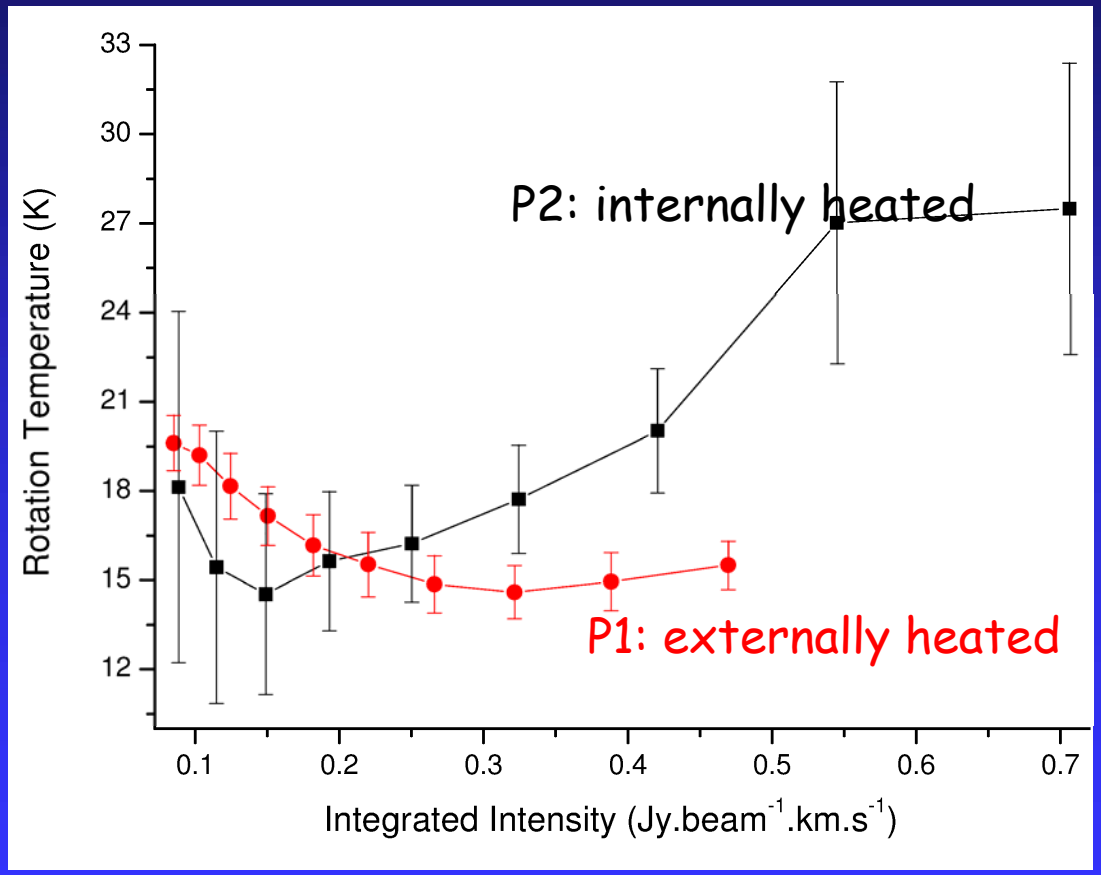


Nor
L~ 1
H_2C
T>3
Δv >
Mor

Southern Region
$L<10^2$ Lsun
T<20K
Δv < 2 km/s
Younger region

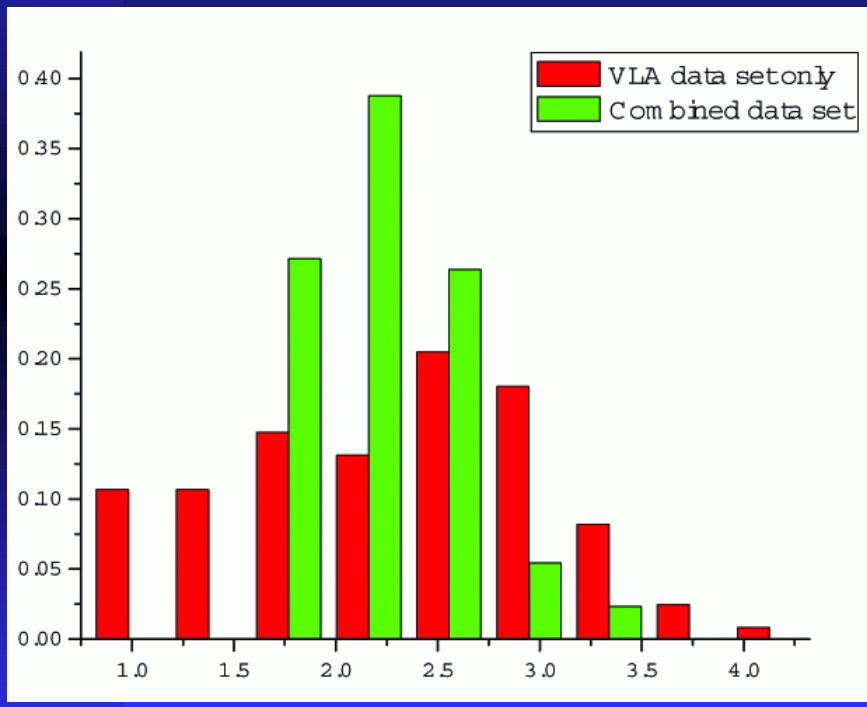
Wang, Zhang, Pillai, Wyrowski, Wu 2008
Wang, Zhang, Rathborne, Jackson, Wu 2006

T vs. NH_3 flux density

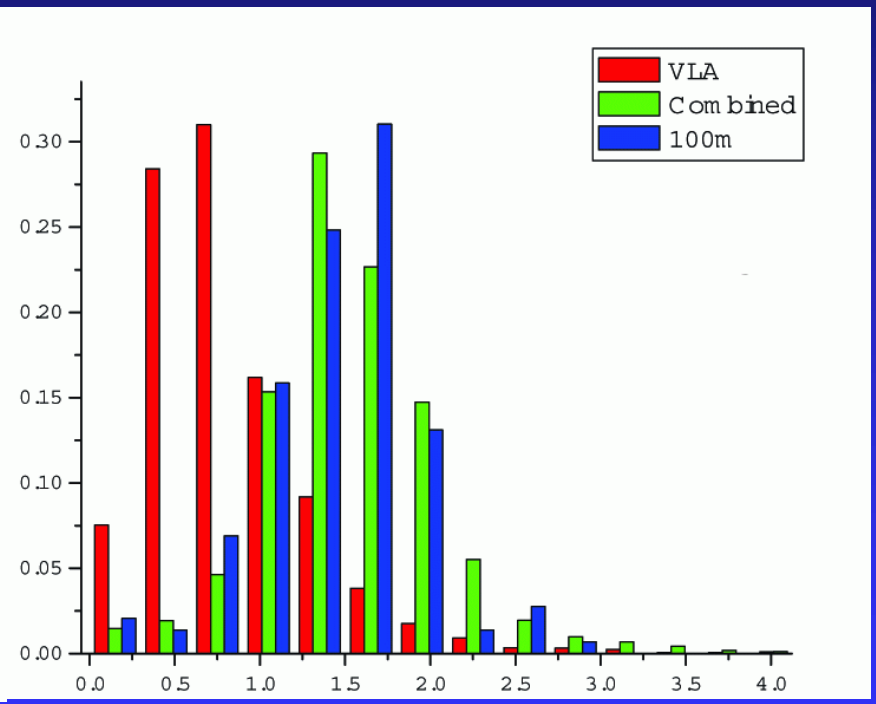


NH_3 Line width Distribution in G28

Northern active region



Southern quiescent region

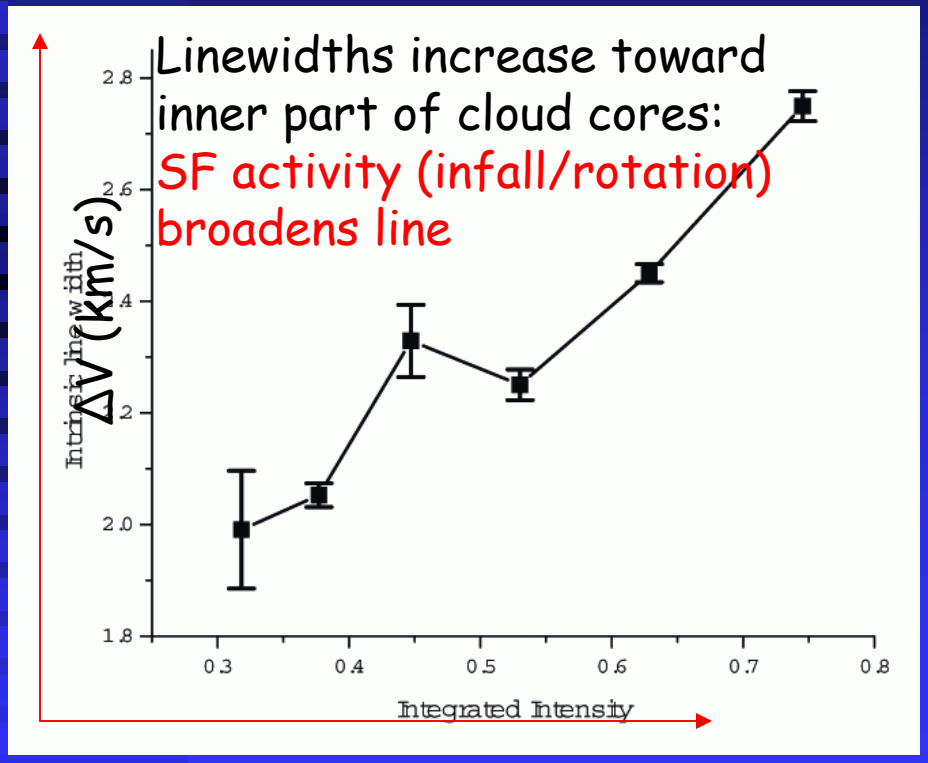


Fraction

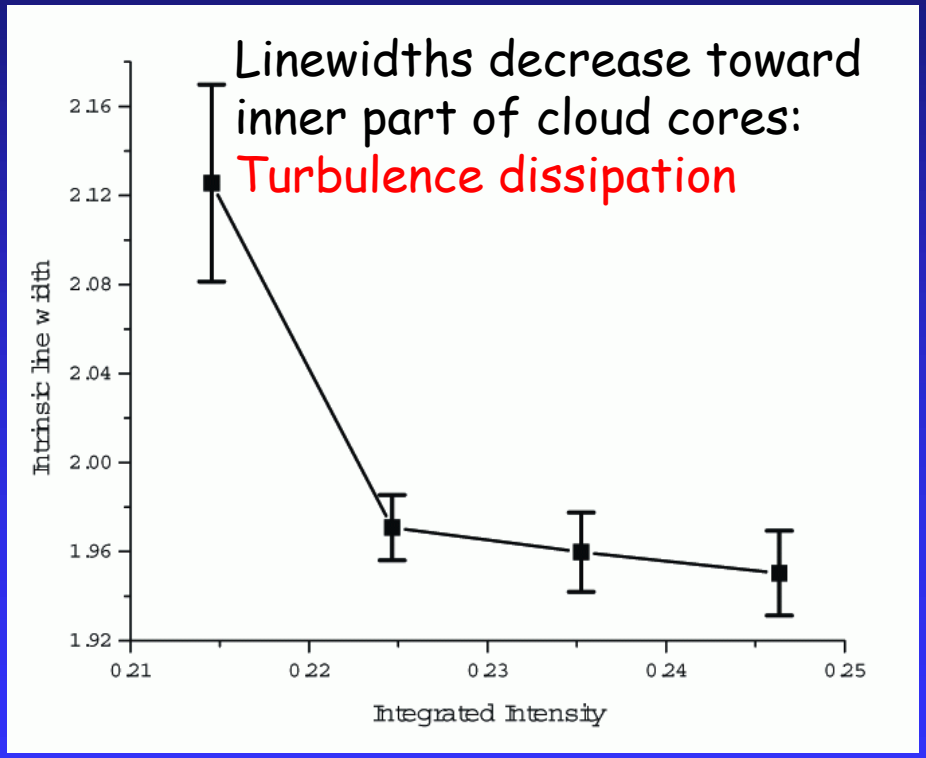
ΔV (km/s)

Line width vs NH_3 flux density in G28

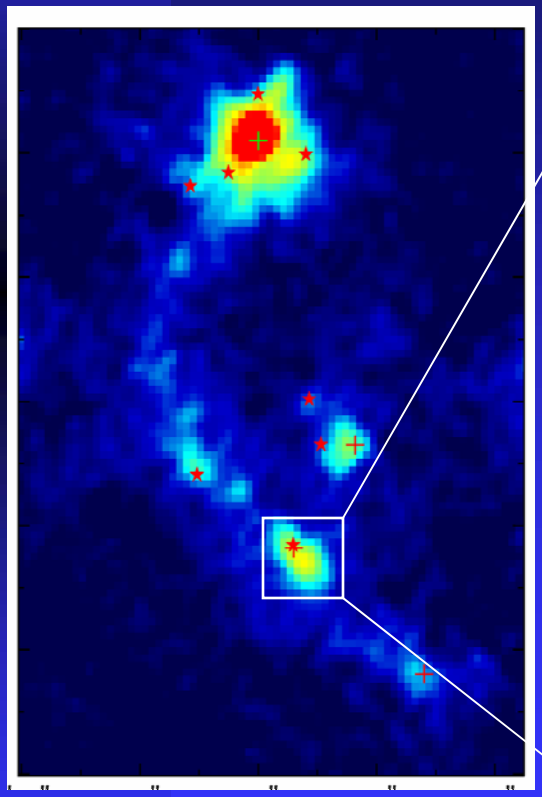
Northern active region P2



Southern quiescent region P1



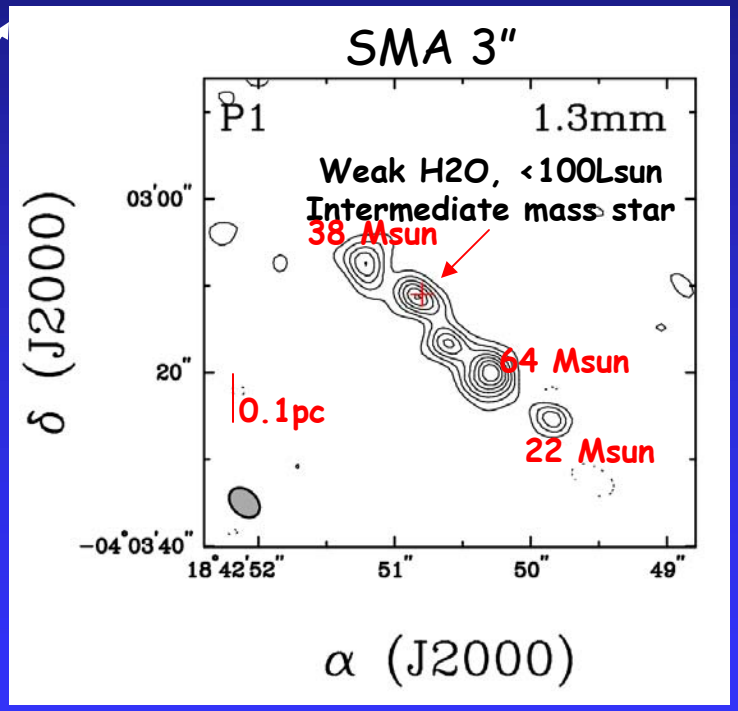
Fragmentation in P1



$n(H_2)=3\times10^5$ cm^{-3}, T=13K
M_J = 0.8 Msun
L_J = 0.1 pc

➔

For Spatially resolved Cores (res < L_J)
M_{core}/M_J ~ 10 - 10^2



V=1.7 km/s
M_{Vir} ~ 50 Msun

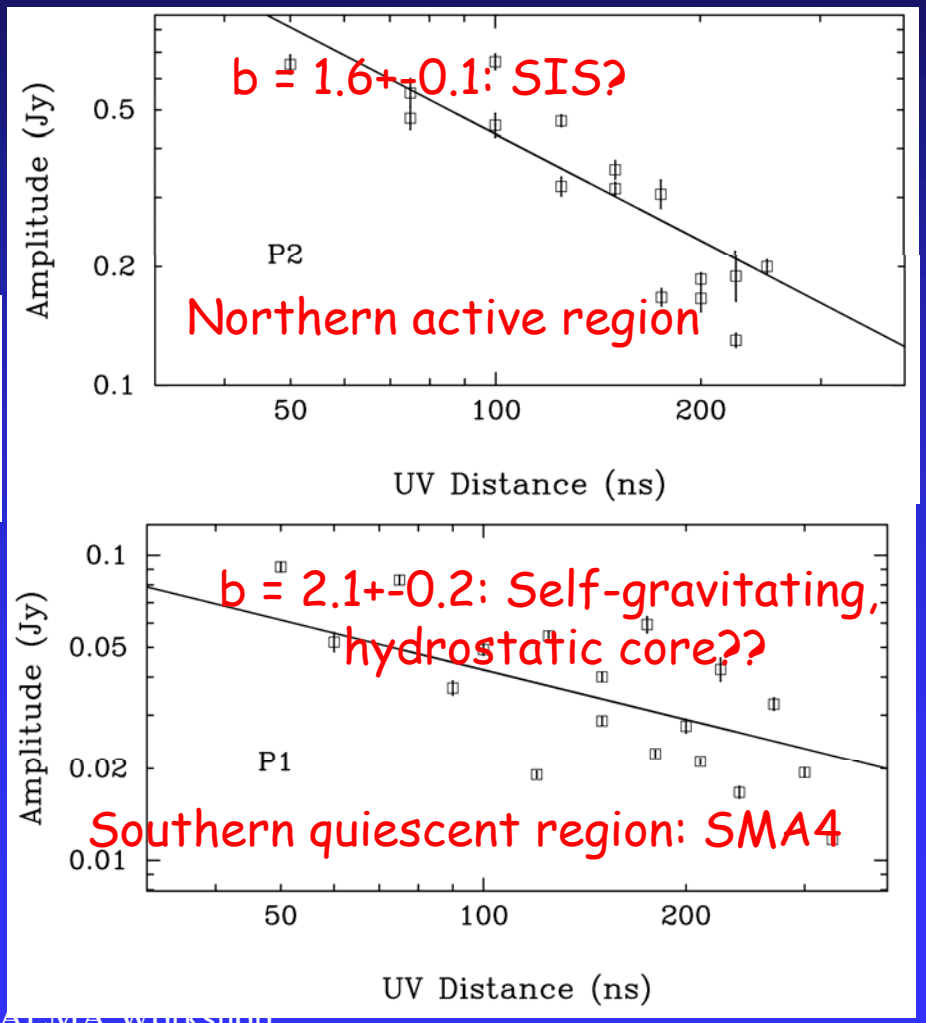
Turbulence/B field
Stop fragmentation?

Zhang, Wang, Pillai, Rathborne 2008

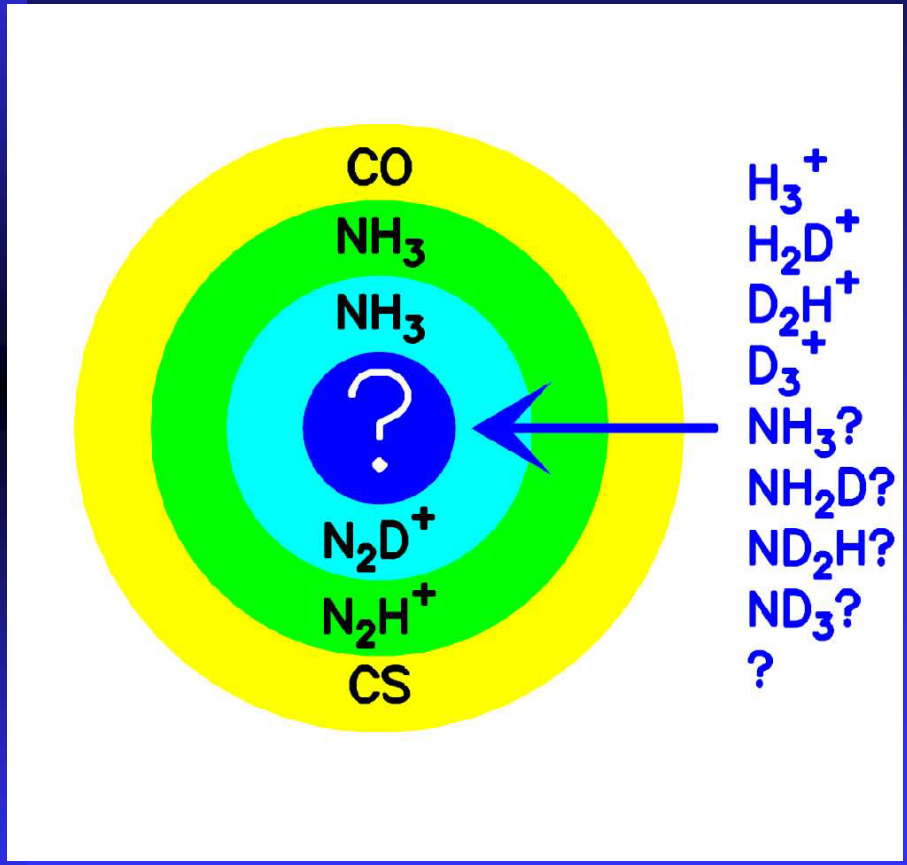
Density Structures

$$T \propto r^{-a}, \rho \propto r^{-b} \Rightarrow F \propto r^{-(a+b-1)}$$

$$F(r) \Leftrightarrow f(U,V) \propto S^{a+b-3}$$



Depletion/Deuteration



At Low T < 20K

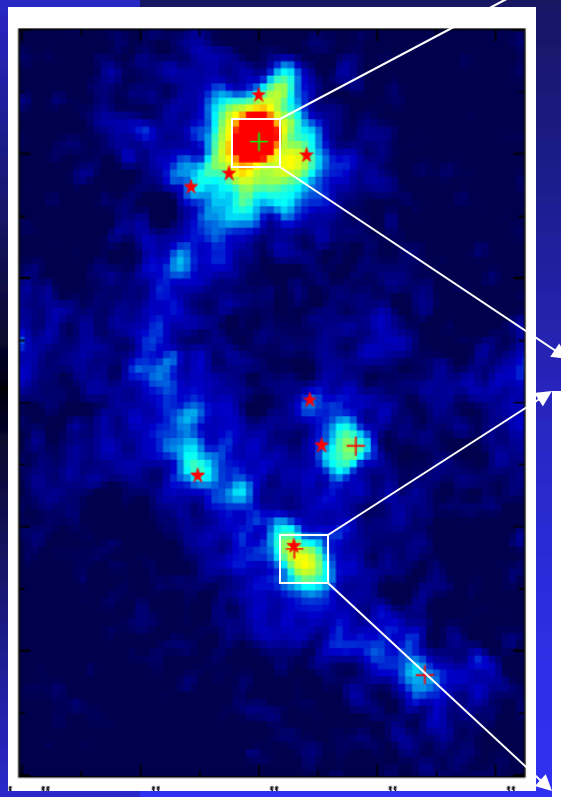
$$H_3^+ + HD \leftrightarrow H_2D^+ + H_2 + \Delta E$$

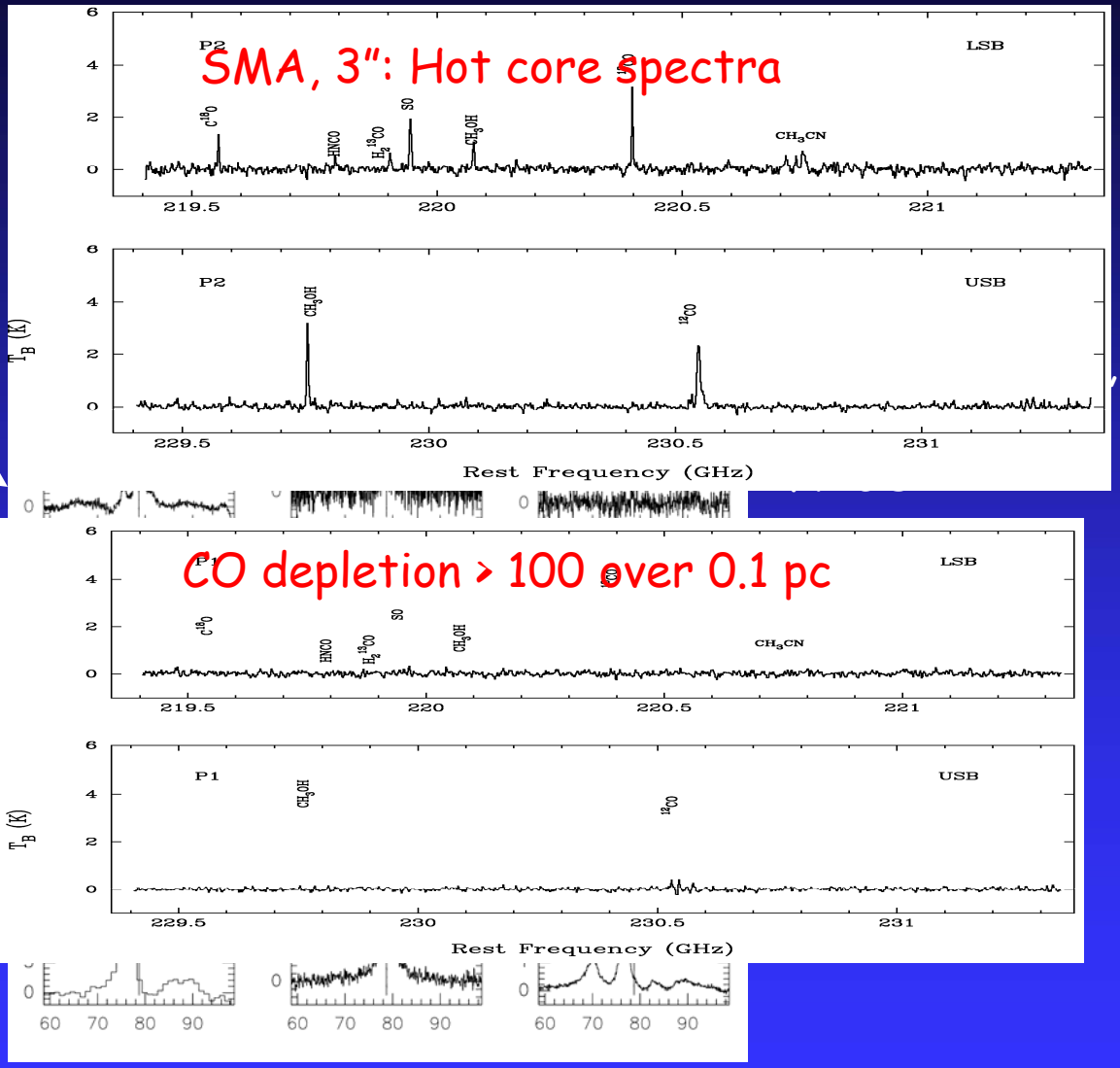
Secondary Deuteration

$$NH_3 + H_2D^+ \rightarrow \ldots \rightarrow NH_2D + H$$

G28.34+0.06: Depletion

1.2 mm Continuum

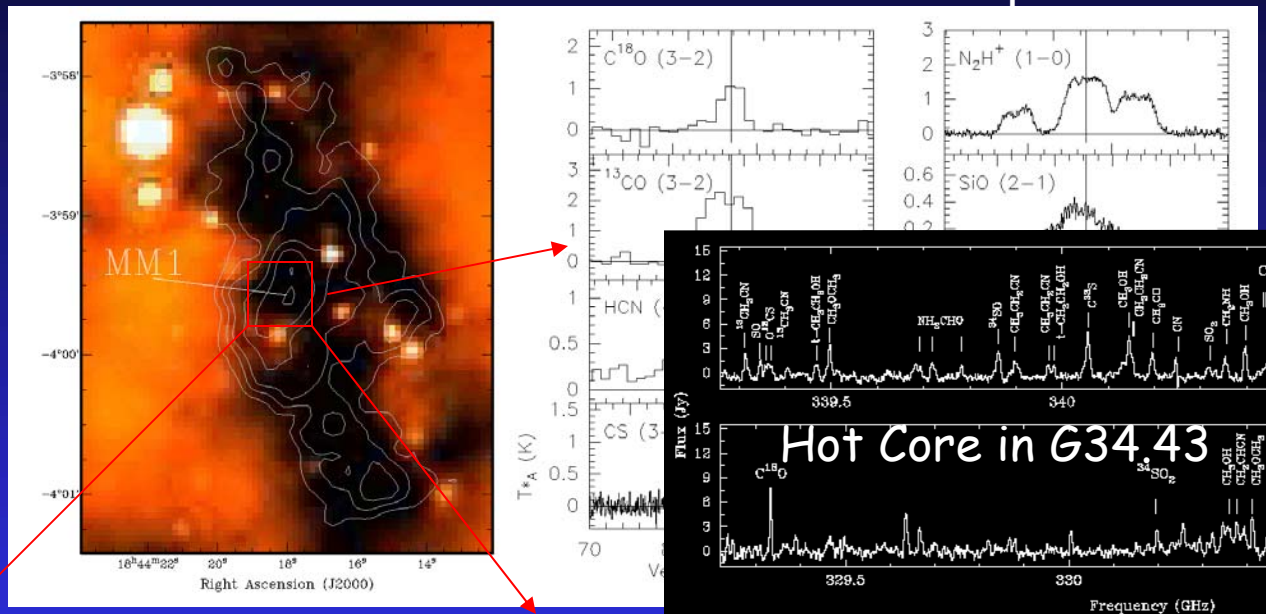




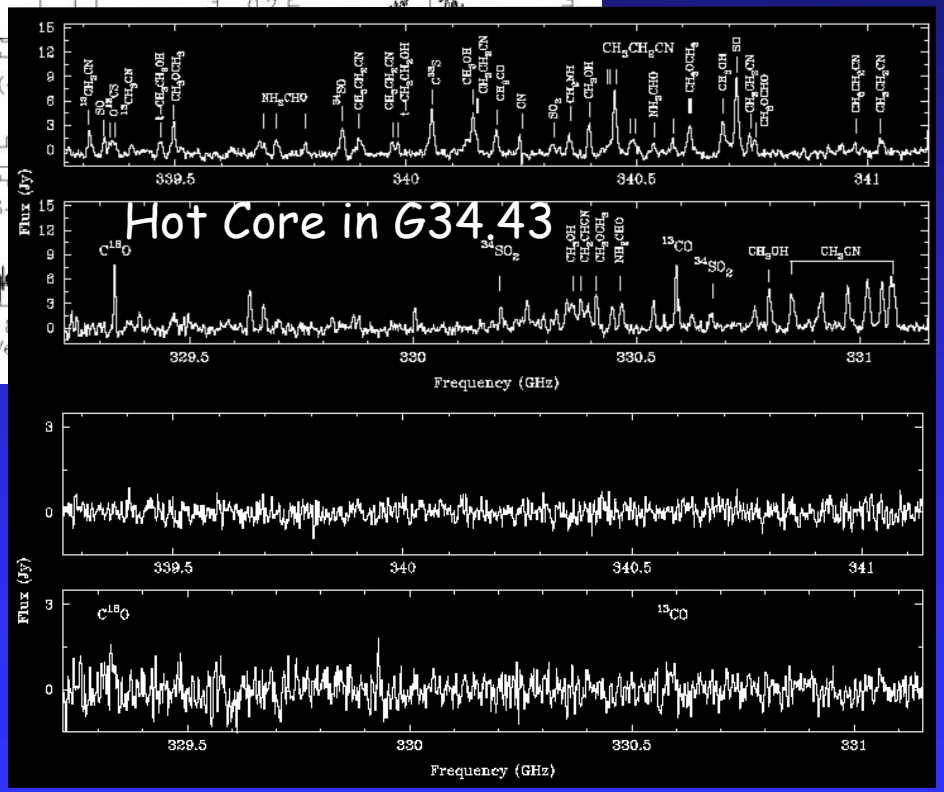
Zhang et al. 2008

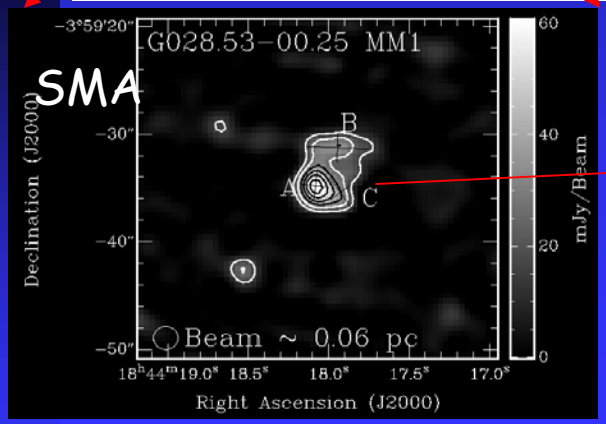
IRDC G28.53: Depletion

IRAM 30m Spectra



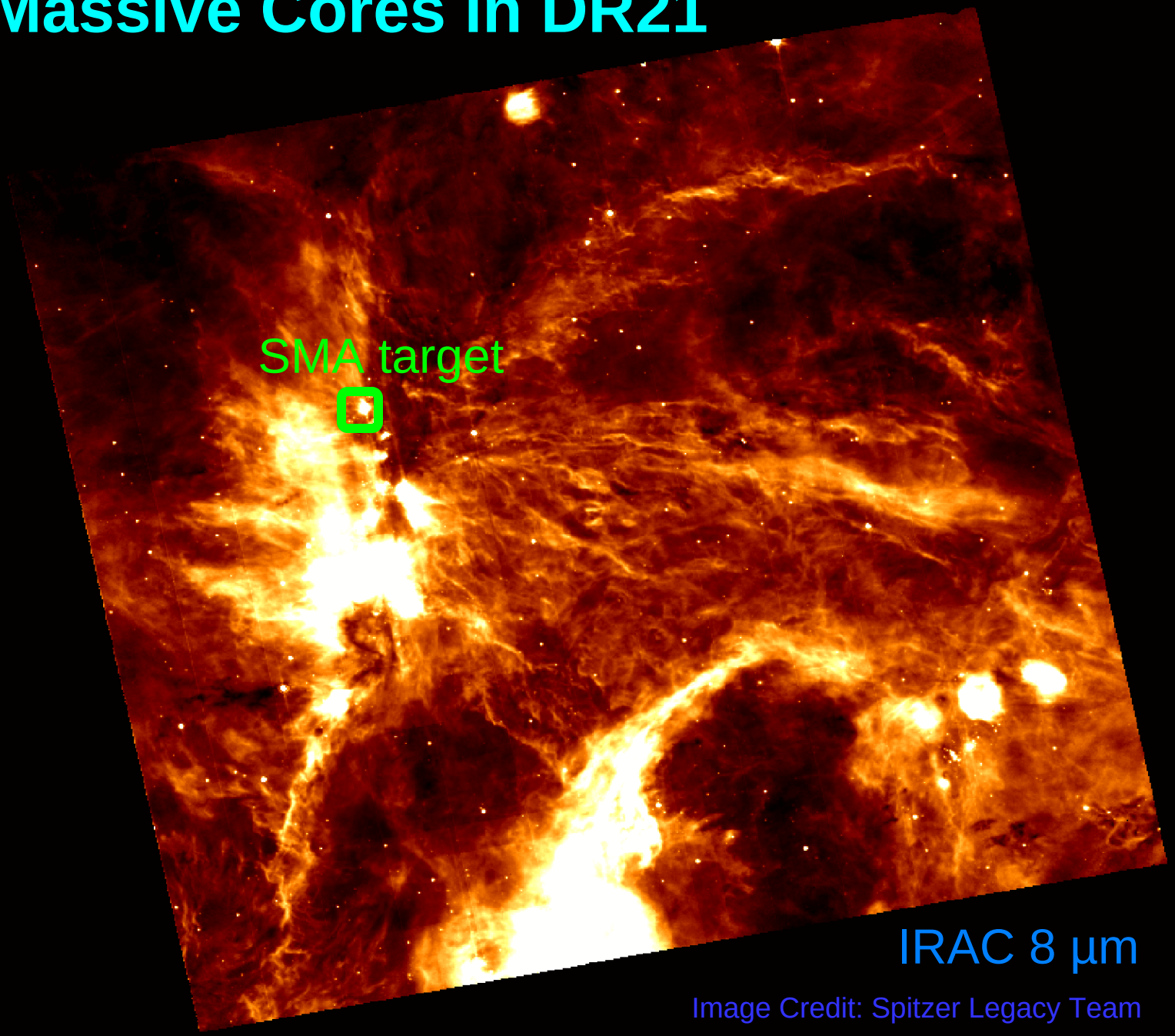
< 700 Lsun
1200 Msun





Rathborne, Jackson, Zhang, Simon 2008

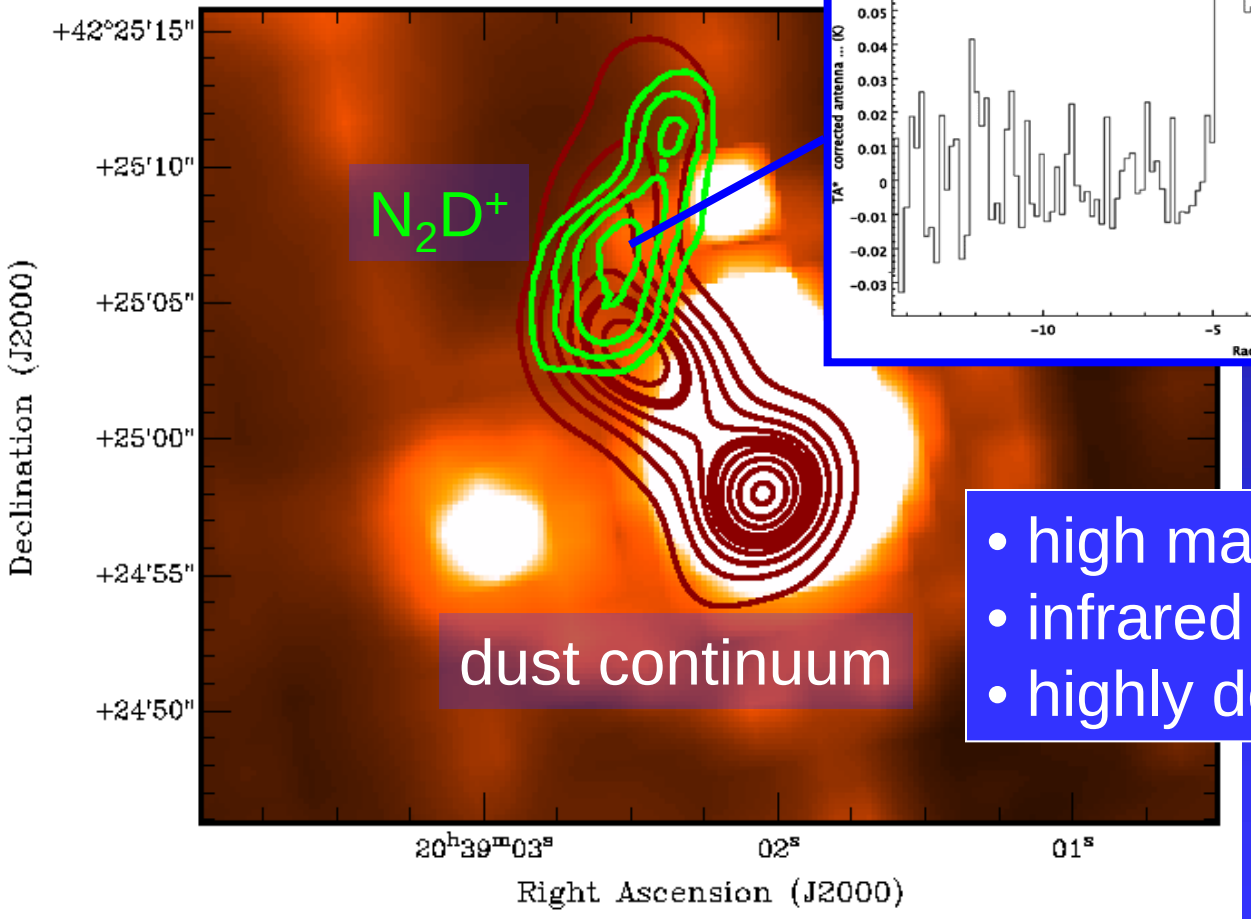
Massive Cores in DR21

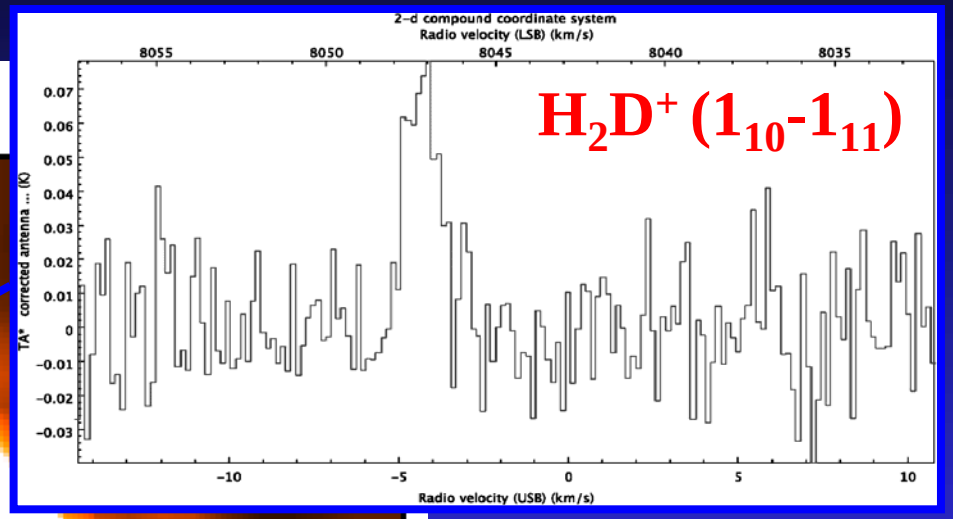


First Detection of H_2D^+

in a massive pre-stellar core

SMA Maps





- high mass (20 Msun)
- infrared quiet
- highly deuterated (>20%)

Pillai et al. (in prep.)

Summary

- Evidence for turbulence dissipation: Linewidths decrease toward the center of the quiescent cores toward G28-P1;
- Structures revealed at resolutions < the Jeans length, but with fragments' mass >> thermal Jeans mass → turbulent/magnetic support (?)
- Heavy depletion/Deuteration at the early stage

How Can ALMA Help?

- High sensitivity/High resolution imaging in both spectral line (N2H+, N2D+, and dust continuum): Best frequency band balancing mass sensitivity and weather is probably 345 GHz band: 1hr on source (2.3mm PWV) leads to 1-sigma of 0.015 Msun for sources at a distance of 4kpc! → Large surveys of IRDCs

- Dust polarization/Zeeman effect in molecular lines → B field

Related Posters

Hatchell: P14; Liu: P29; Pillai: P35; Reid: P37;
Plume: P36; Swift: P46