THE L1157-B1 ASTROCHEMICAL LABORATORY: TESTING THE ORIGIN OF DCN

GEMMA BUSQUET

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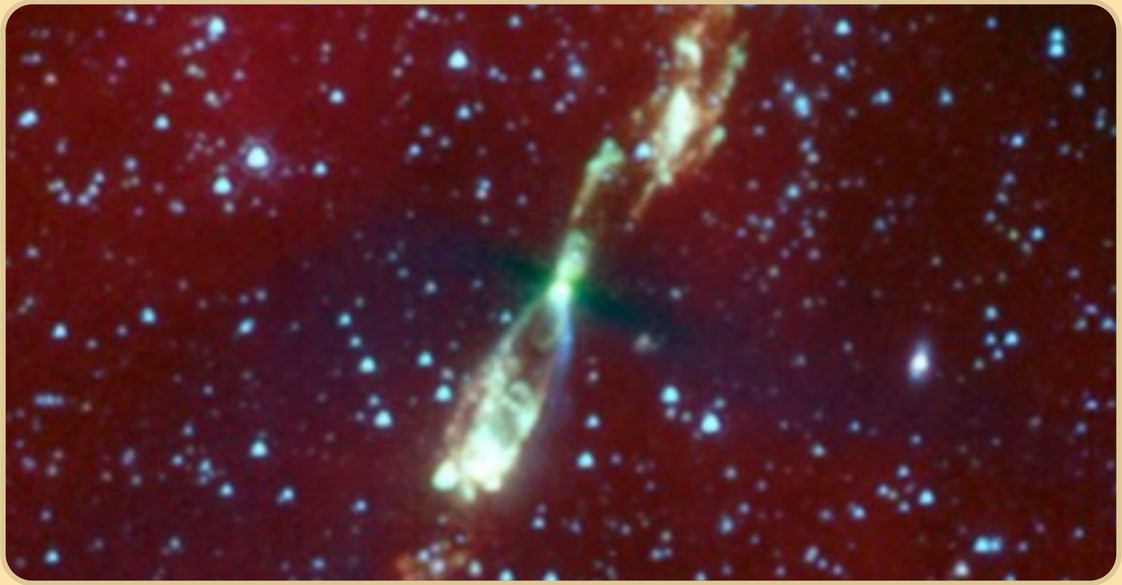
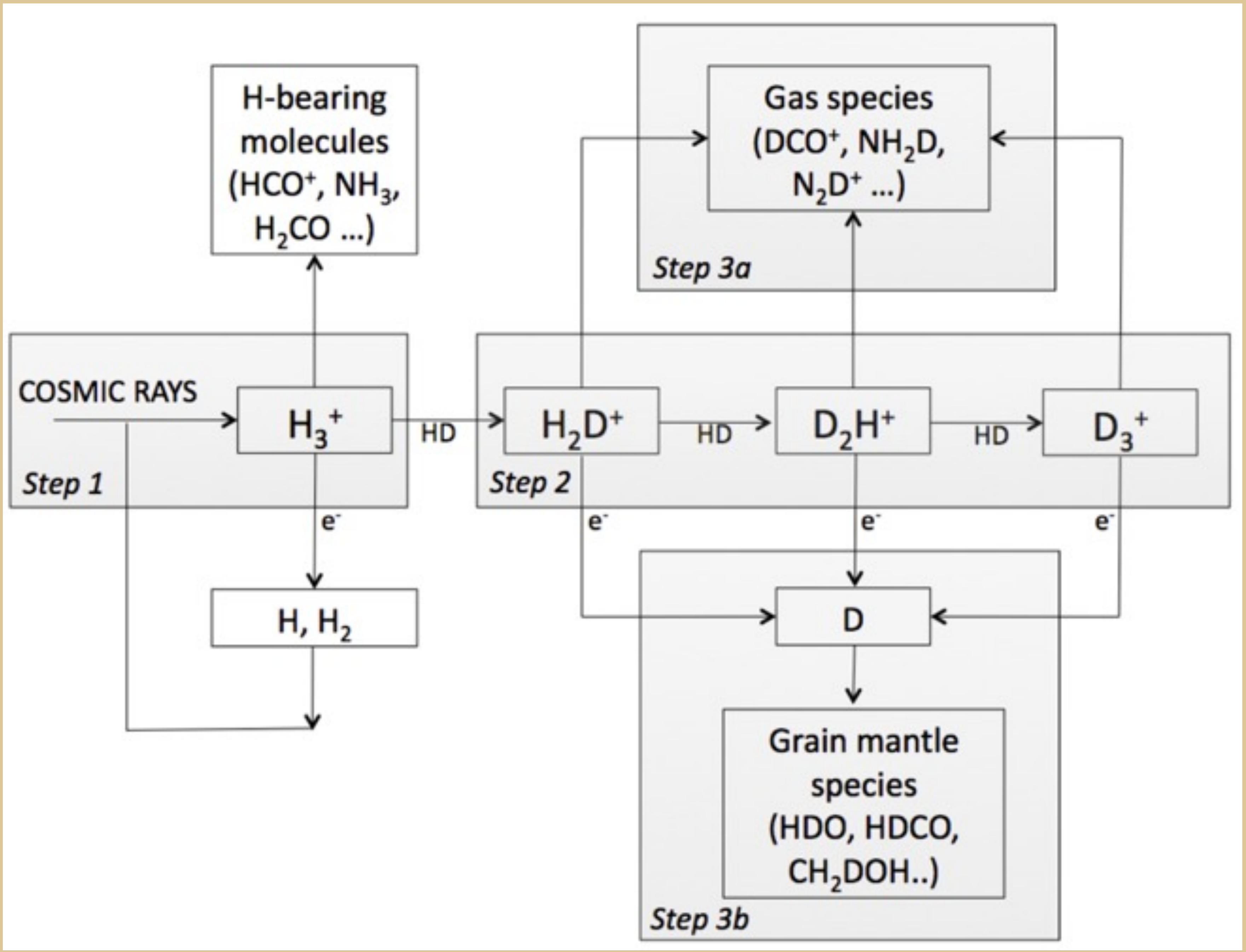


Francesco Fontani, Serena Viti, Claudio Codella,
Bertrand Lefloch, Milena Benedettini, Cecilia Ceccarelli

DEUTERIUM ENRICHMENT

- In cold molecular gas (T~10 K)



1. Formation of H_3^+
2. Formation of H_2D^+ (D_2H^+, and D_3^+)

$$H_3^+ + HD \longrightarrow H_2D^+ + H_2 + 232\ K$$

3. Formation of other D-bearing molecules:
   - In the gas-phase
   - In the grain mantles

from PPVI: Ceccarelli et al. (2014)

DEUTERIUM ENRICHMENT

- In warm /hot environments (such as in **SHOCKS)**

$H_3^+ + HD \longrightarrow H_2D^+ + H_2 + 232\ K$

$CH_3^+ + HD \longrightarrow CH_2D^+ + H_2 + 370\ K$

$C_2H_2^+ + HD \longrightarrow C_2HD^+ + H_2 + 550\ K$

Gas-phase deuteration (T~30-50 K)

- Evaporation of ices surrounding grains: remnants of the cold prestellar phase
- Sputtering

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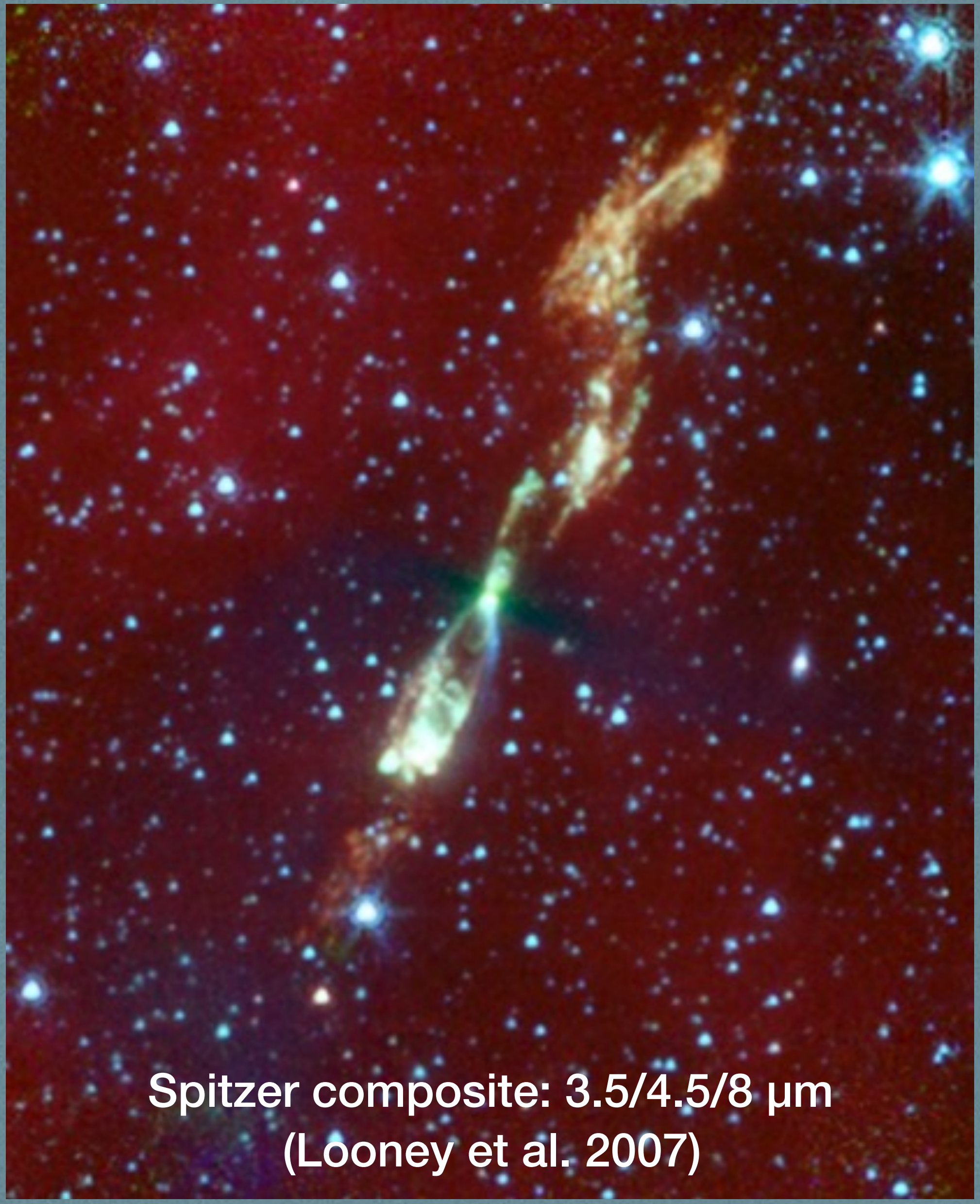

- distance of 250 pc; powered by a Class 0 protostar
- Most chemically rich outflow known so far: SiO, CO, SO, CH_3OH, H_2O, C_2H_5OH and many other molecules!
- Precessing molecular jet, detected recently toward the protostar (Podio et al. 2016), associated with several bow shocks seen in CO (Gueth et al. 1996) and H_2 (Neufeld et al. 2009)

B1 is the brightest shocked region

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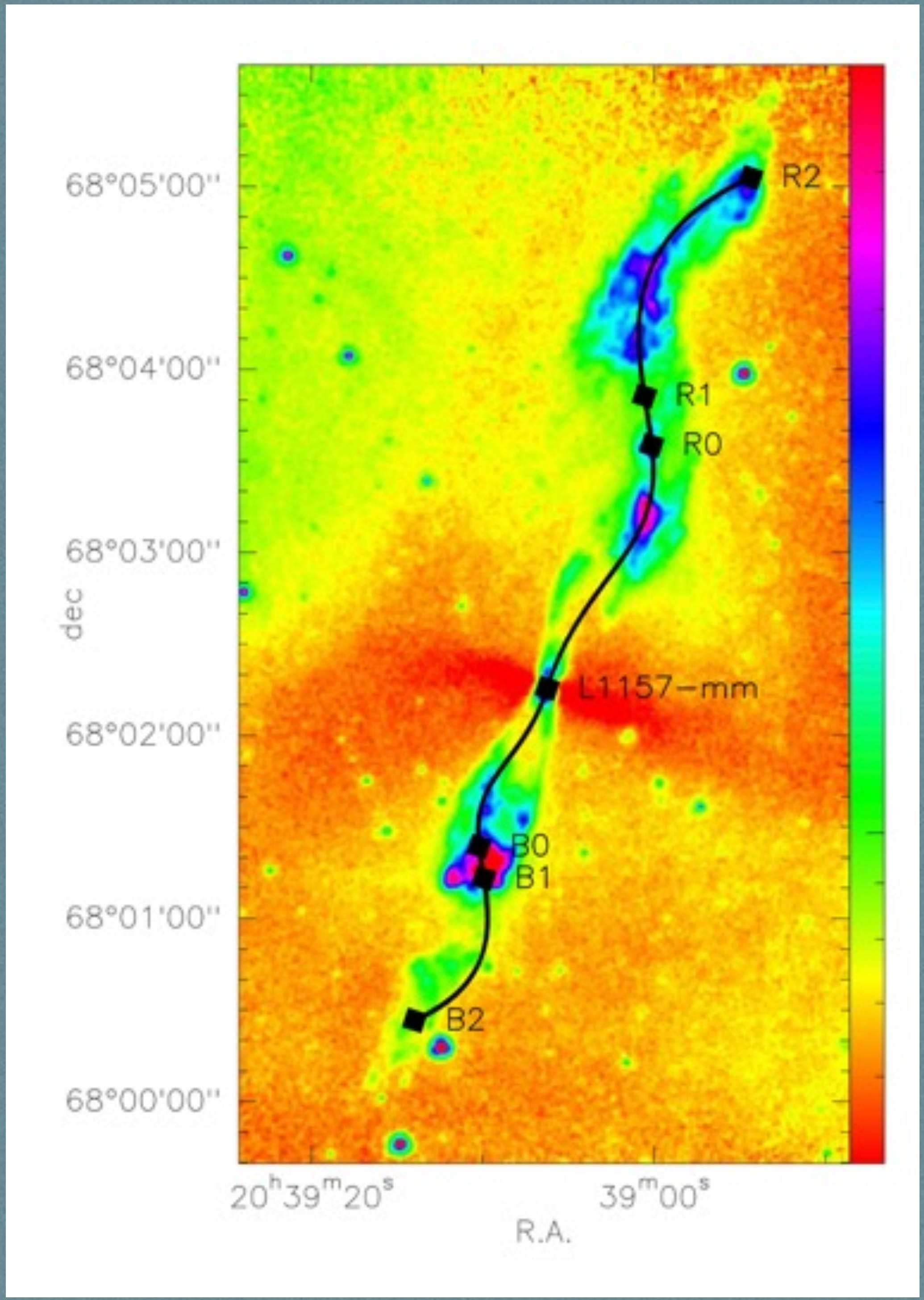

Image from Podio et al. (2016): Spitzer 8 μm (Looney et al. 2007, Takami et al. 2011)

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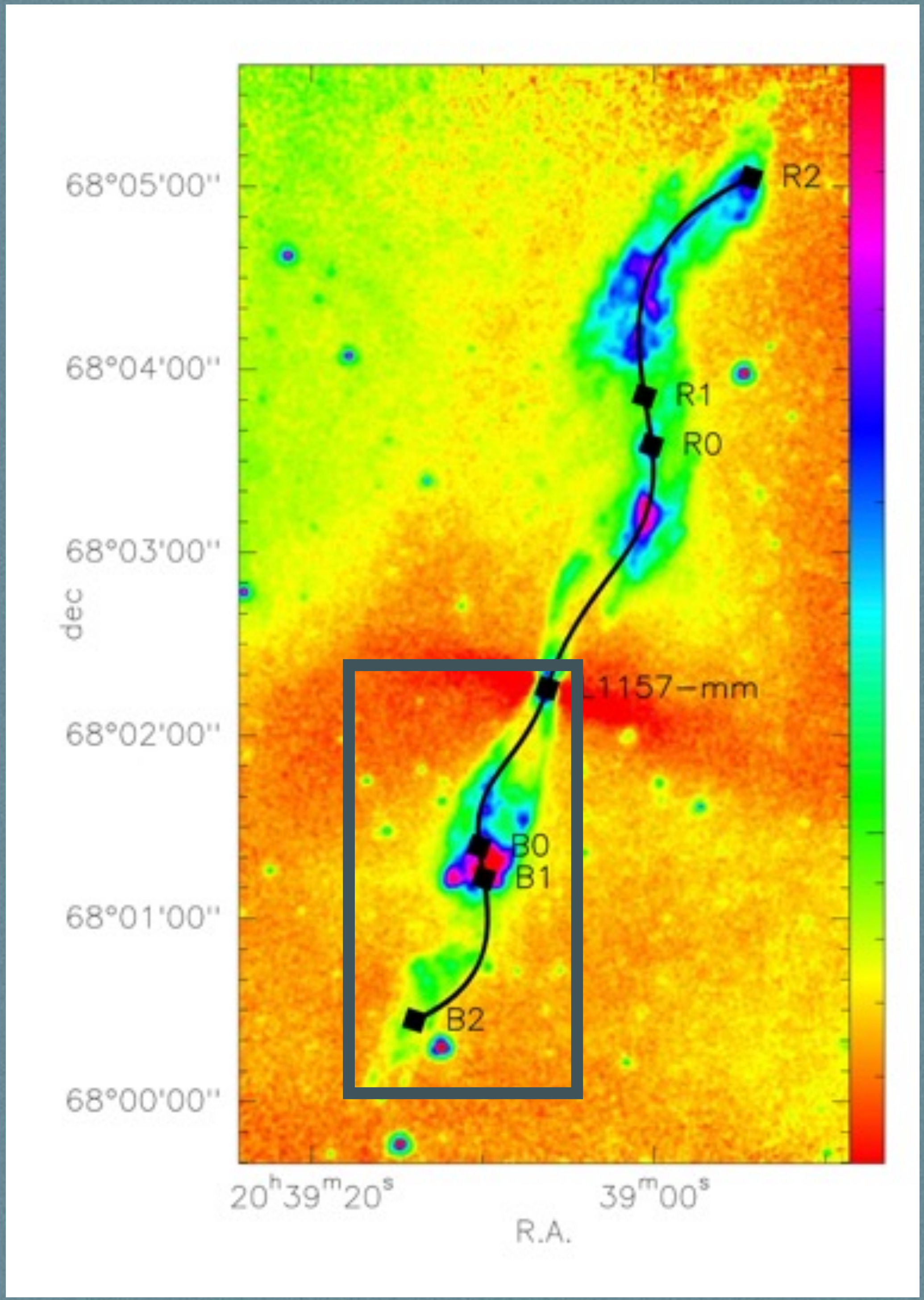

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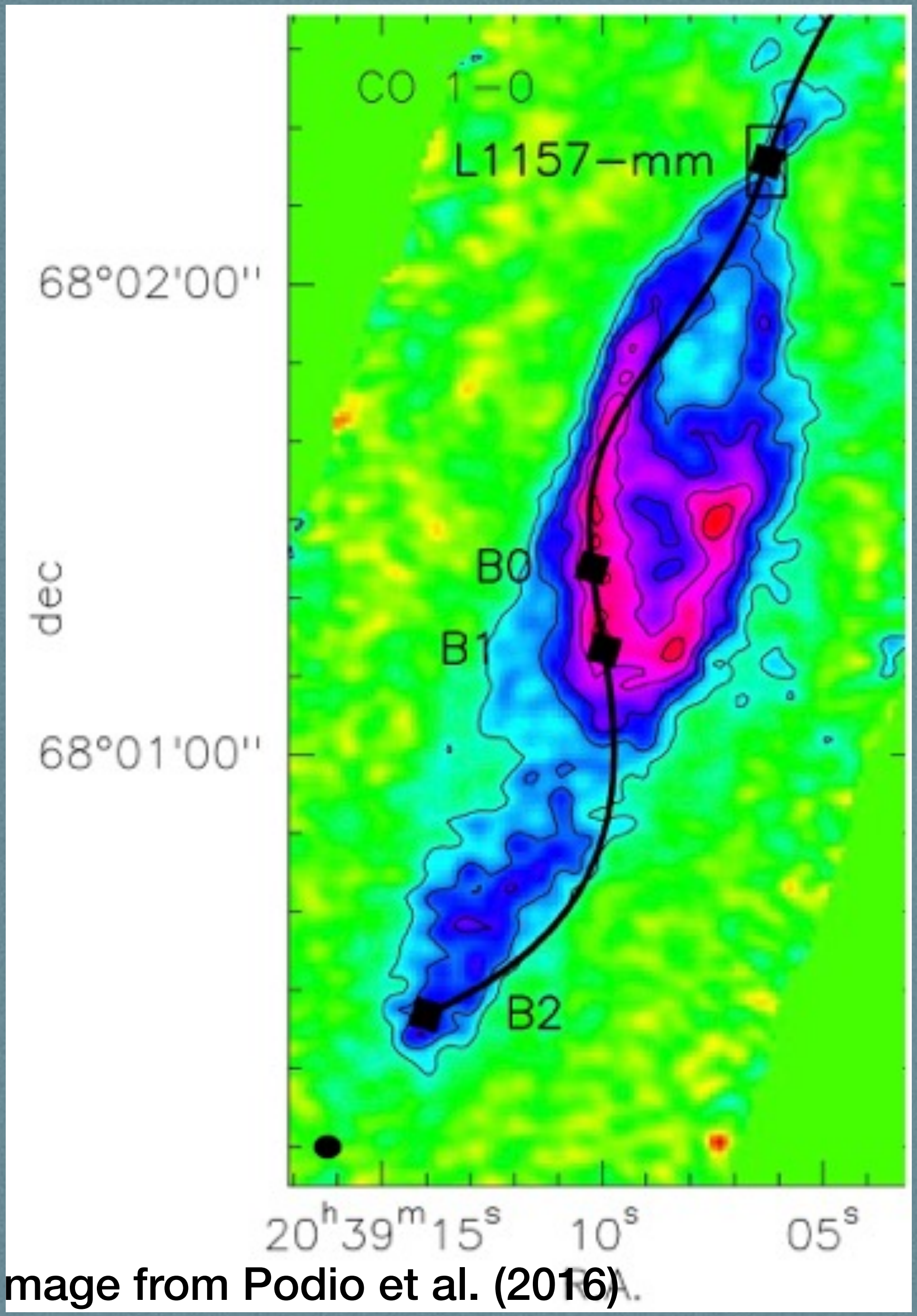

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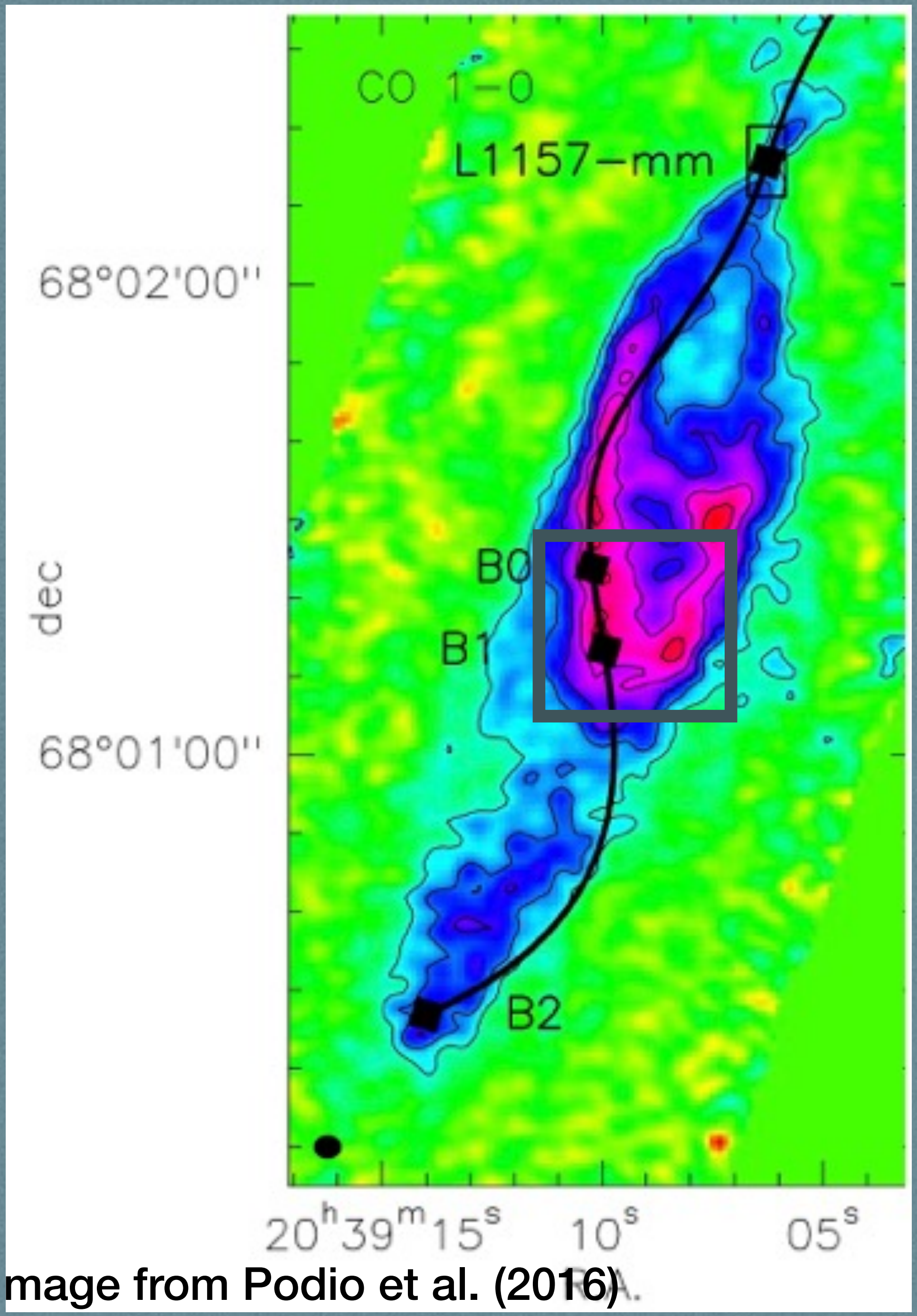

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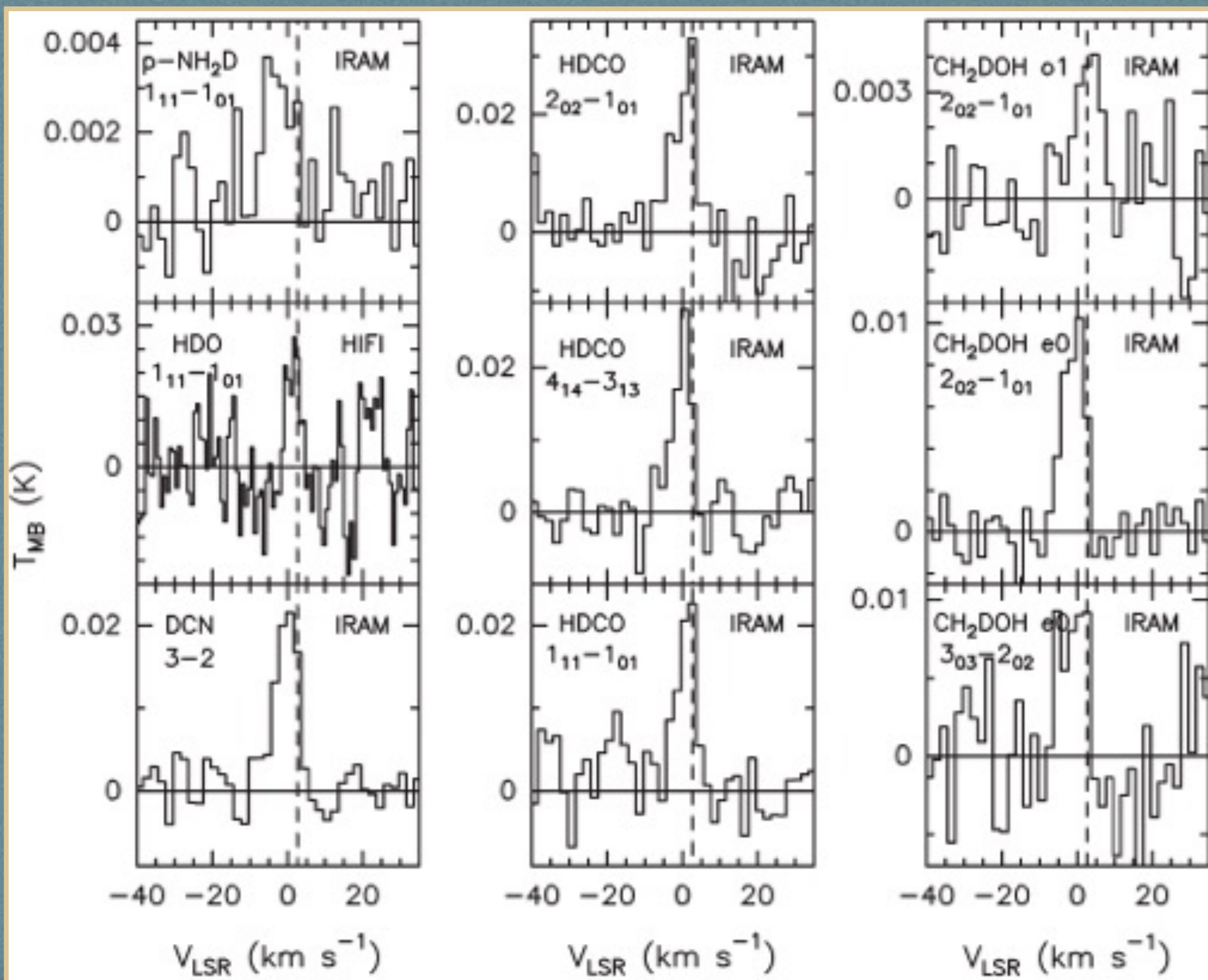
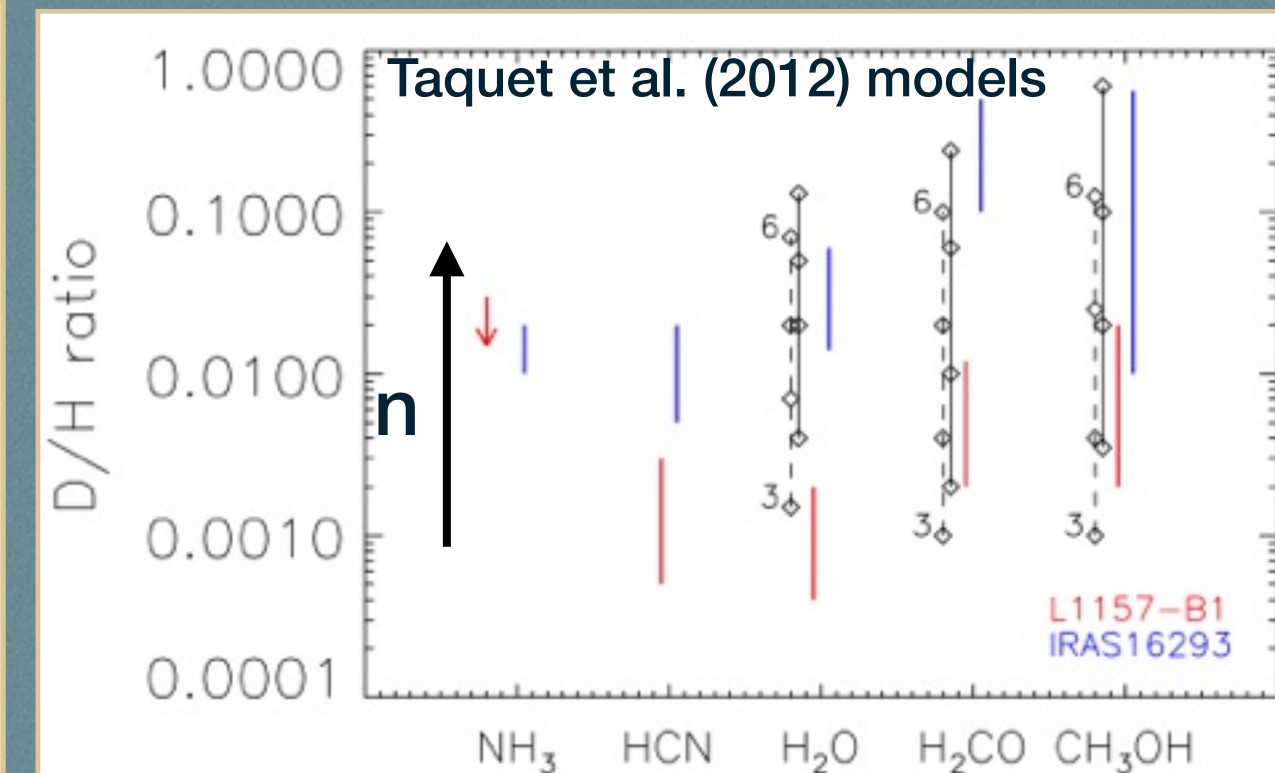
DEUTERIUM FRACTIONATION IN L1157-B1

Deuterated molecules observed with IRAM 30m and Herschel (Codella et al. 2012)





- HDO, HDCO, and CH_2DOH provide us with a fossil record of the conditions at the time when ices were formed
- The shock released in the gas phase part of the grain mantles ices

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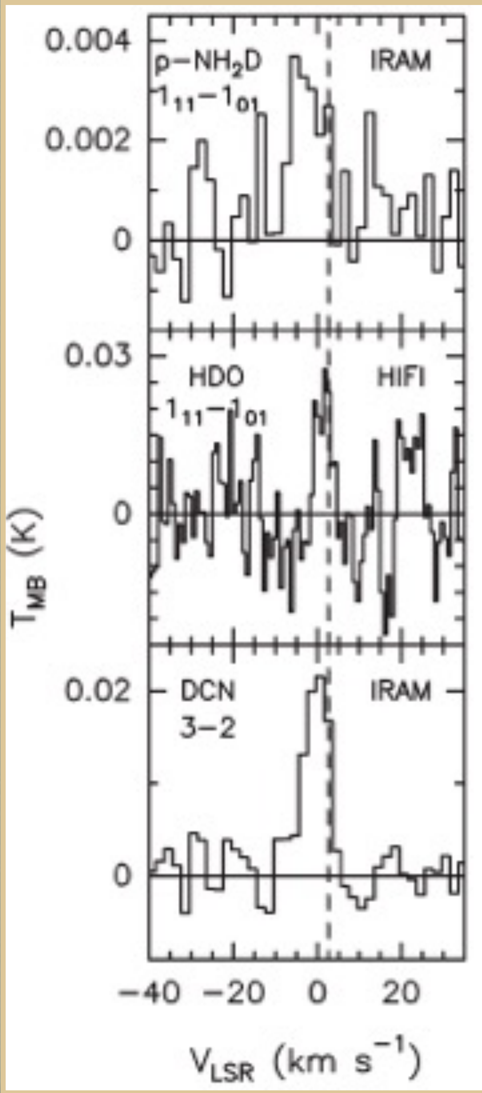

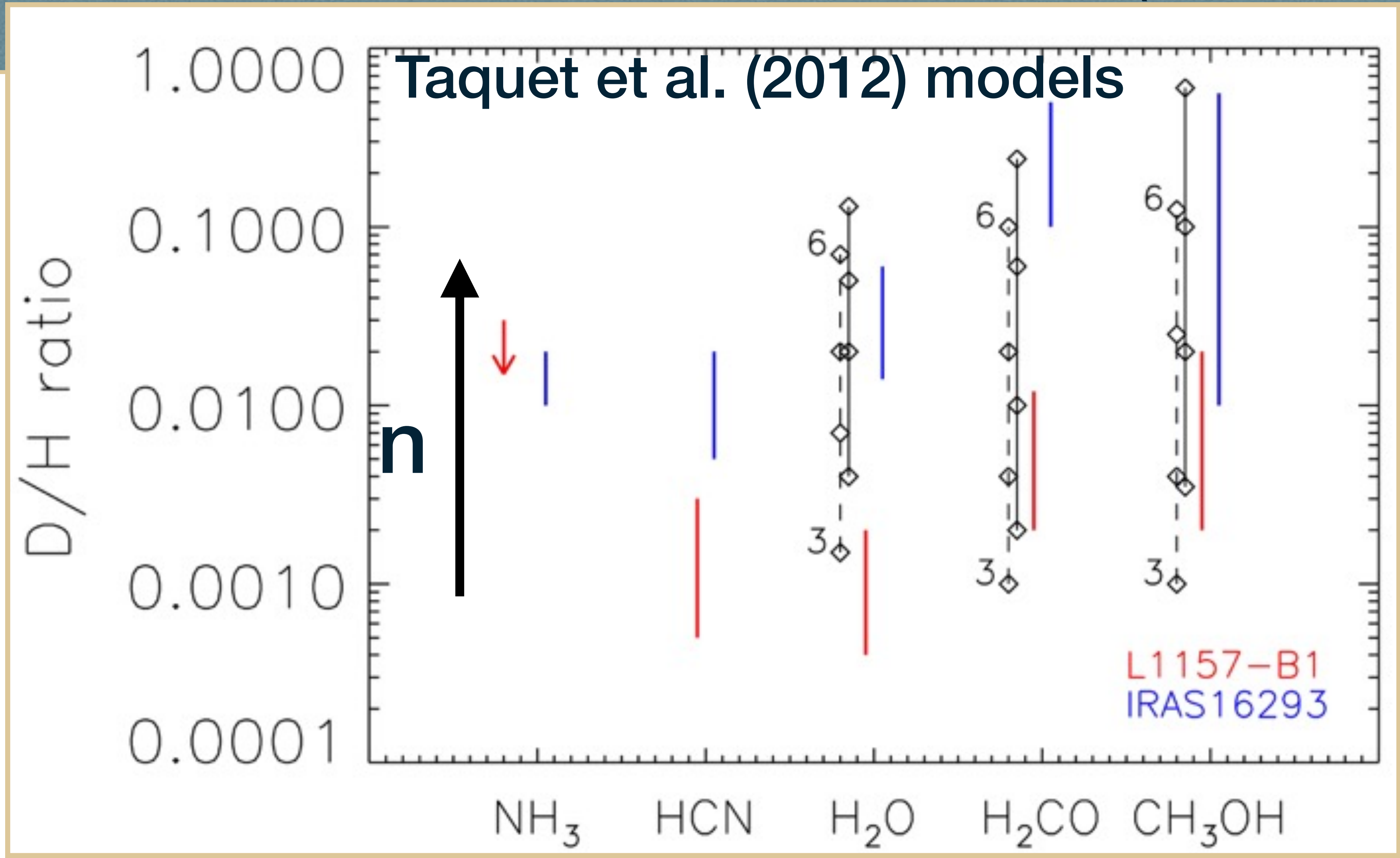

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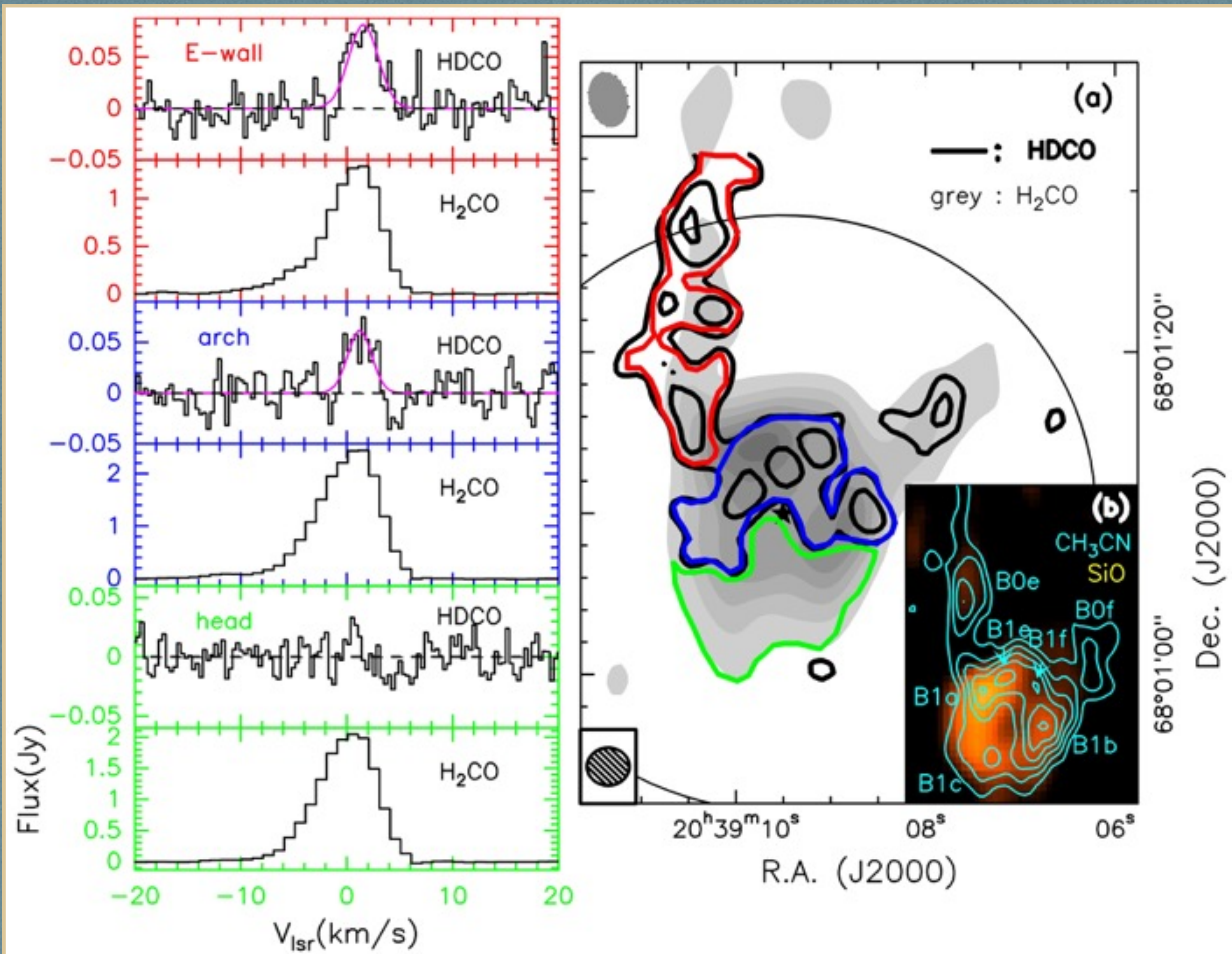
HDCO and CH_2DOH maps from NOEMA (Fontani et al. 2014)

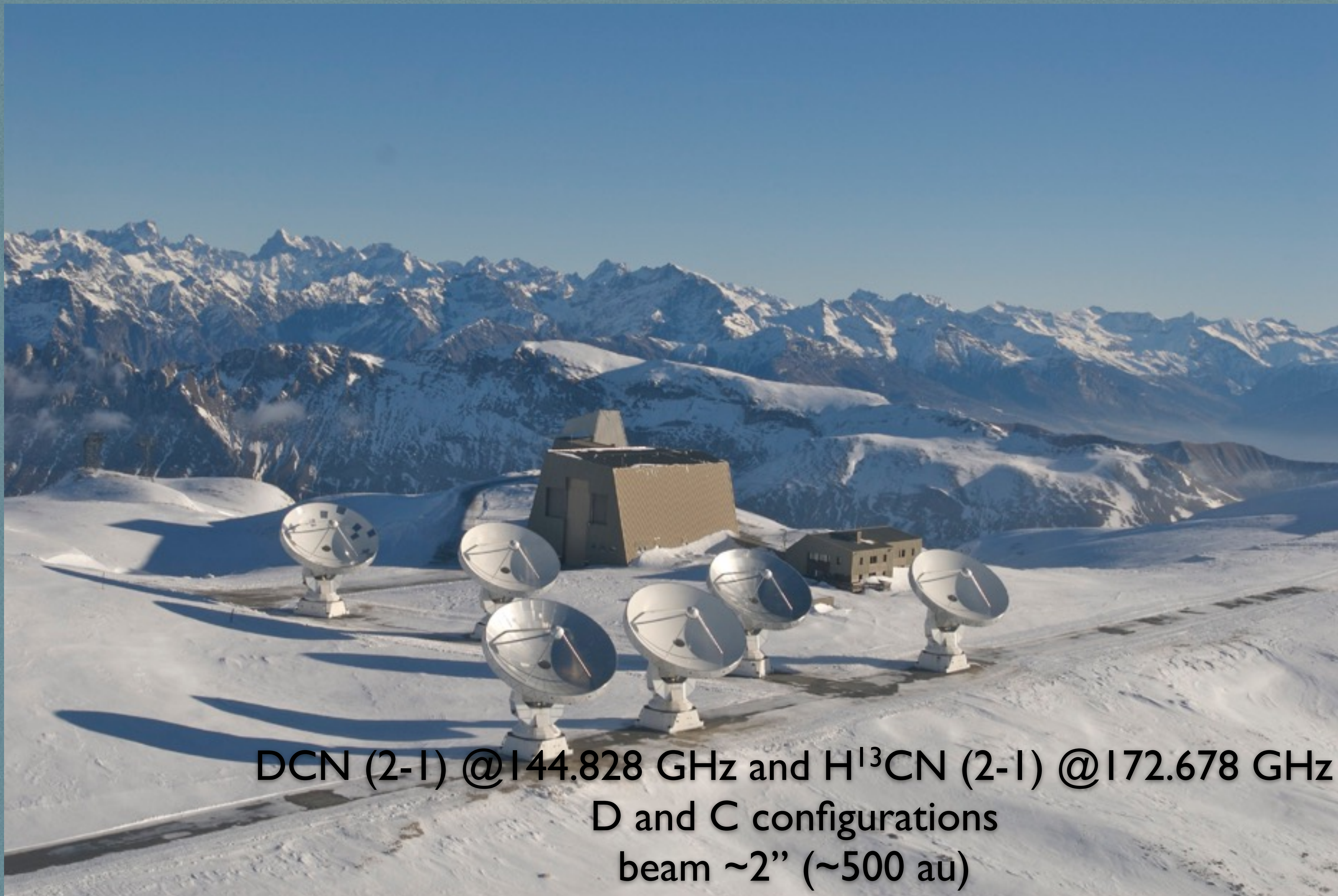


HDCO: region of the interface between the fast jet and the slower ambient material

$D_{frac}(H_2CO)$:
~0.1 E-Wall
~0.04 Arch
< 0.02 Head

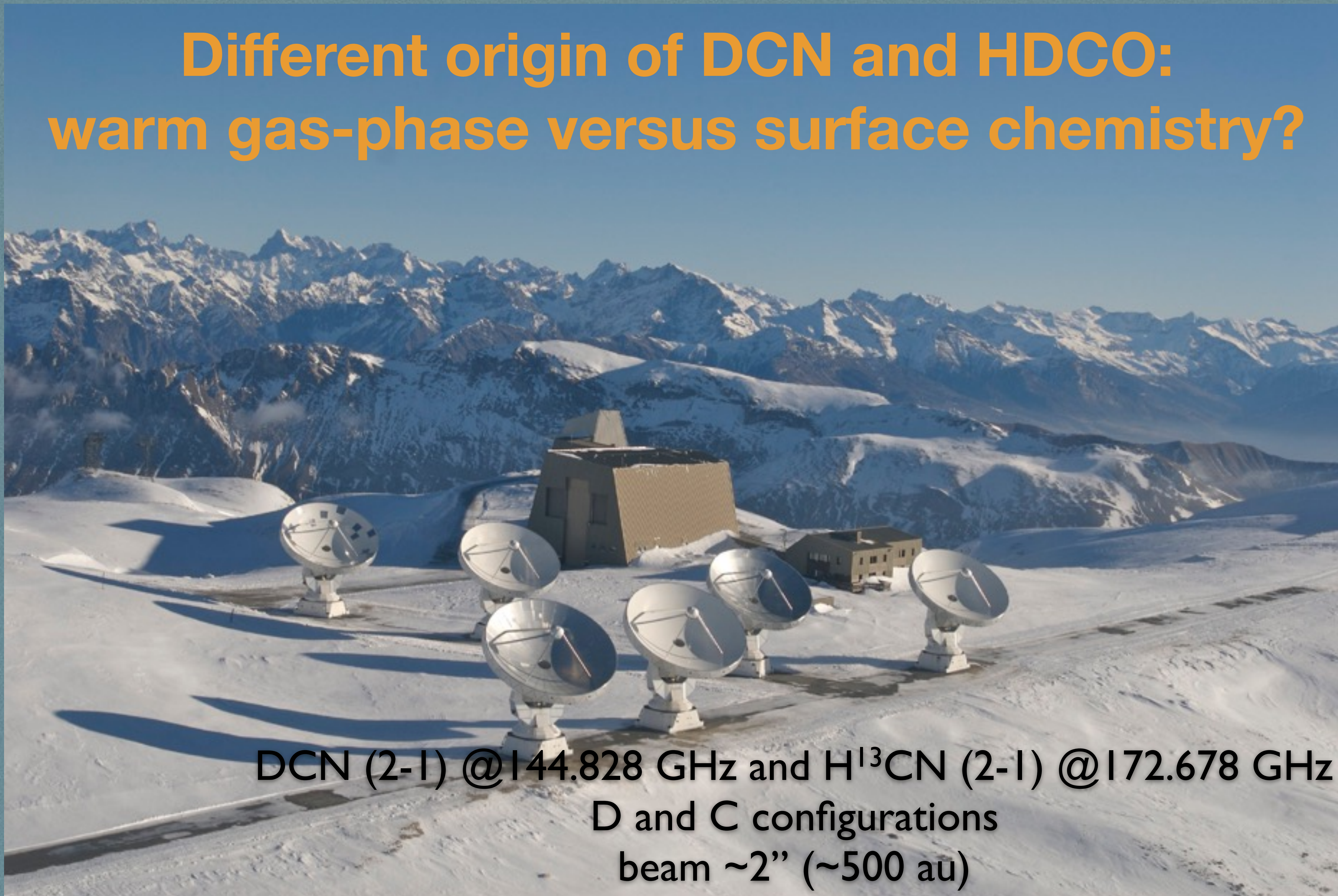
First clear evidence of a deuterated molecule as a shock tracer
Obtain $D_{frac}(H_2CO)$ on dust grain mantles

NOEMA OBSERVATIONS



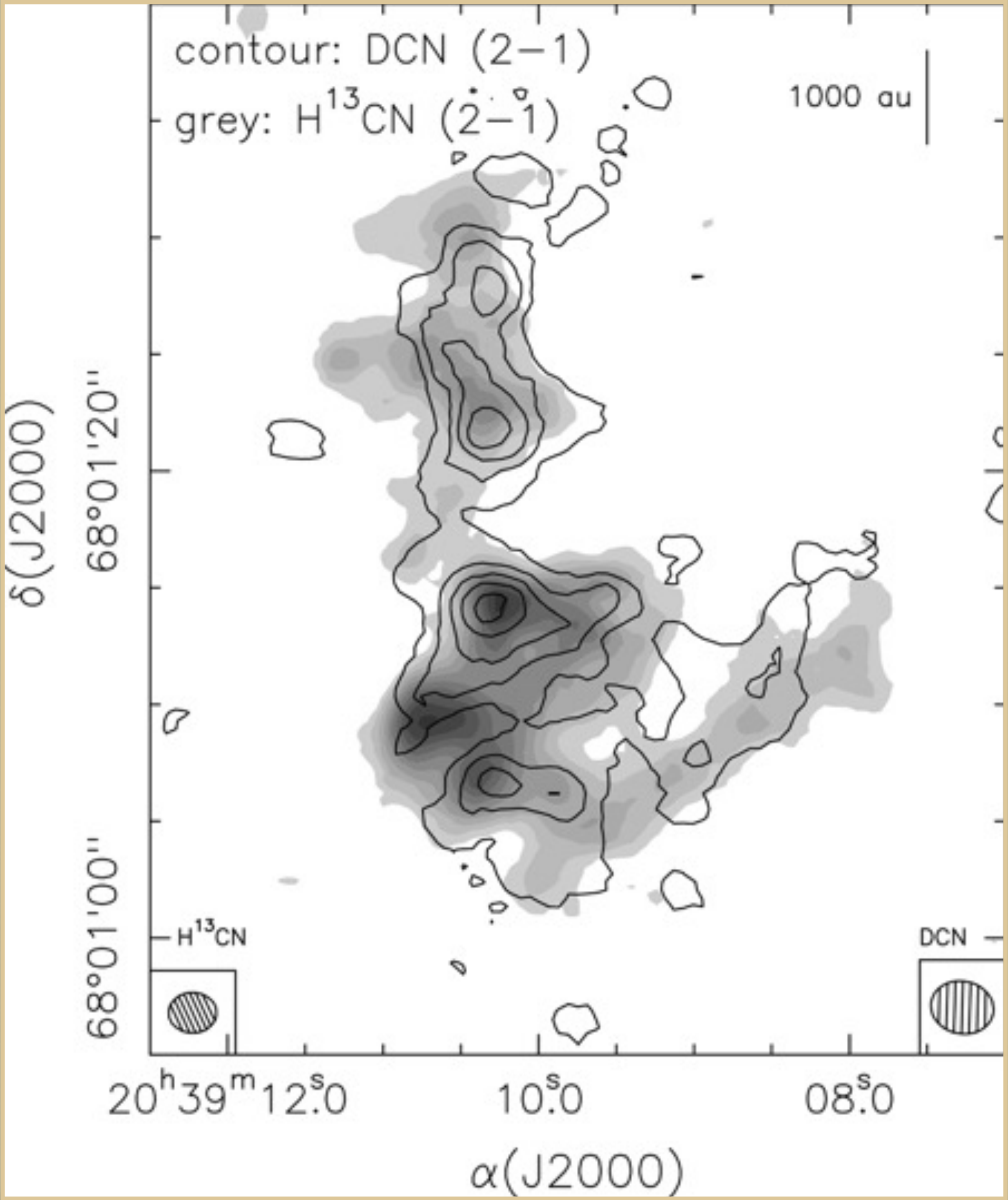
NOEMA OBSERVATIONS

Different origin of DCN and HDCO: warm gas-phase versus surface chemistry?



DCN (2-1) @144.828 GHz and $H^{13}CN$ (2-1) @172.678 GHz
D and C configurations
beam ~2” (~500 au)

DCN AND HCN: MORPHOLOGY



B1a: peak of the SiO where the precessing jet impacts

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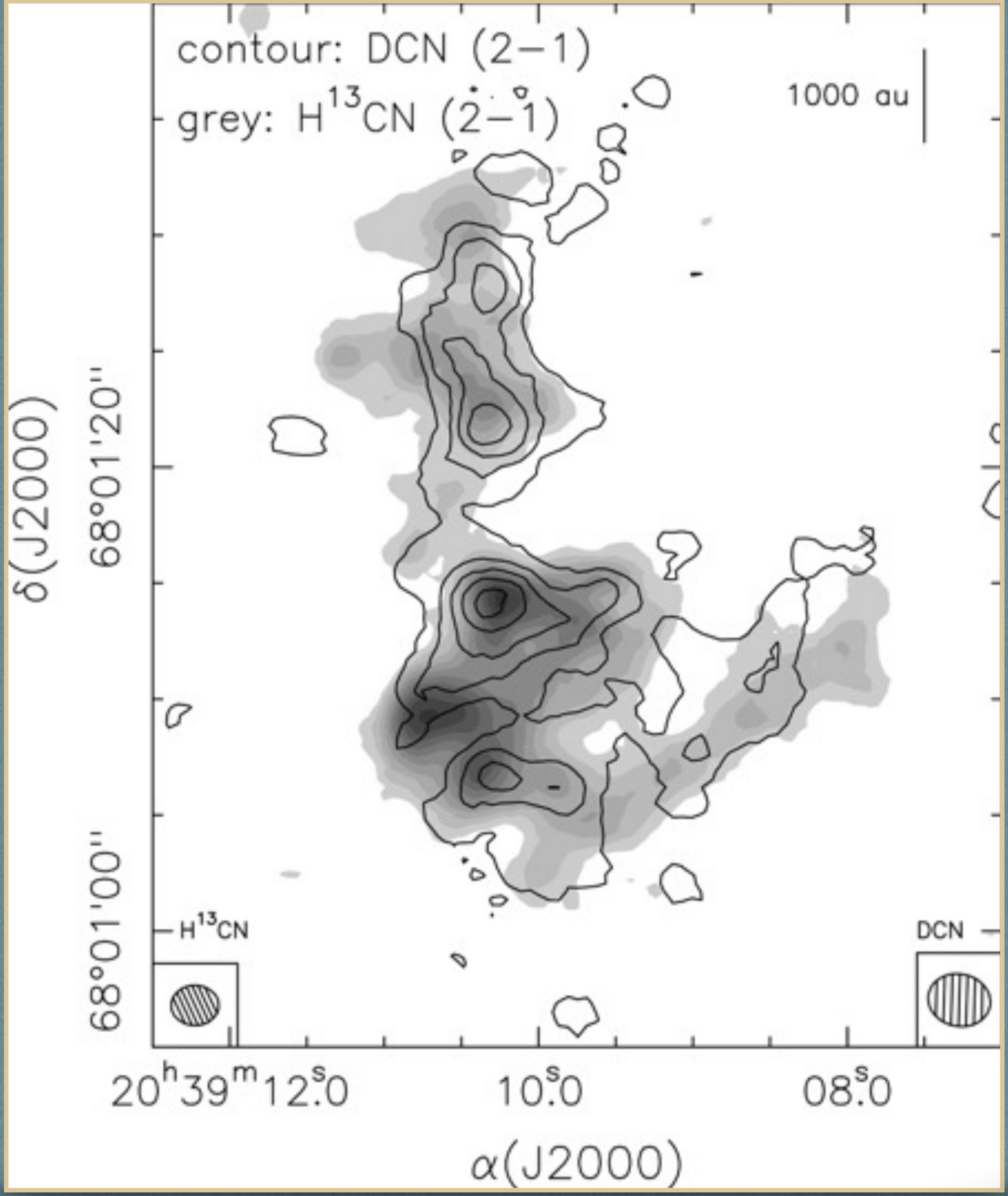

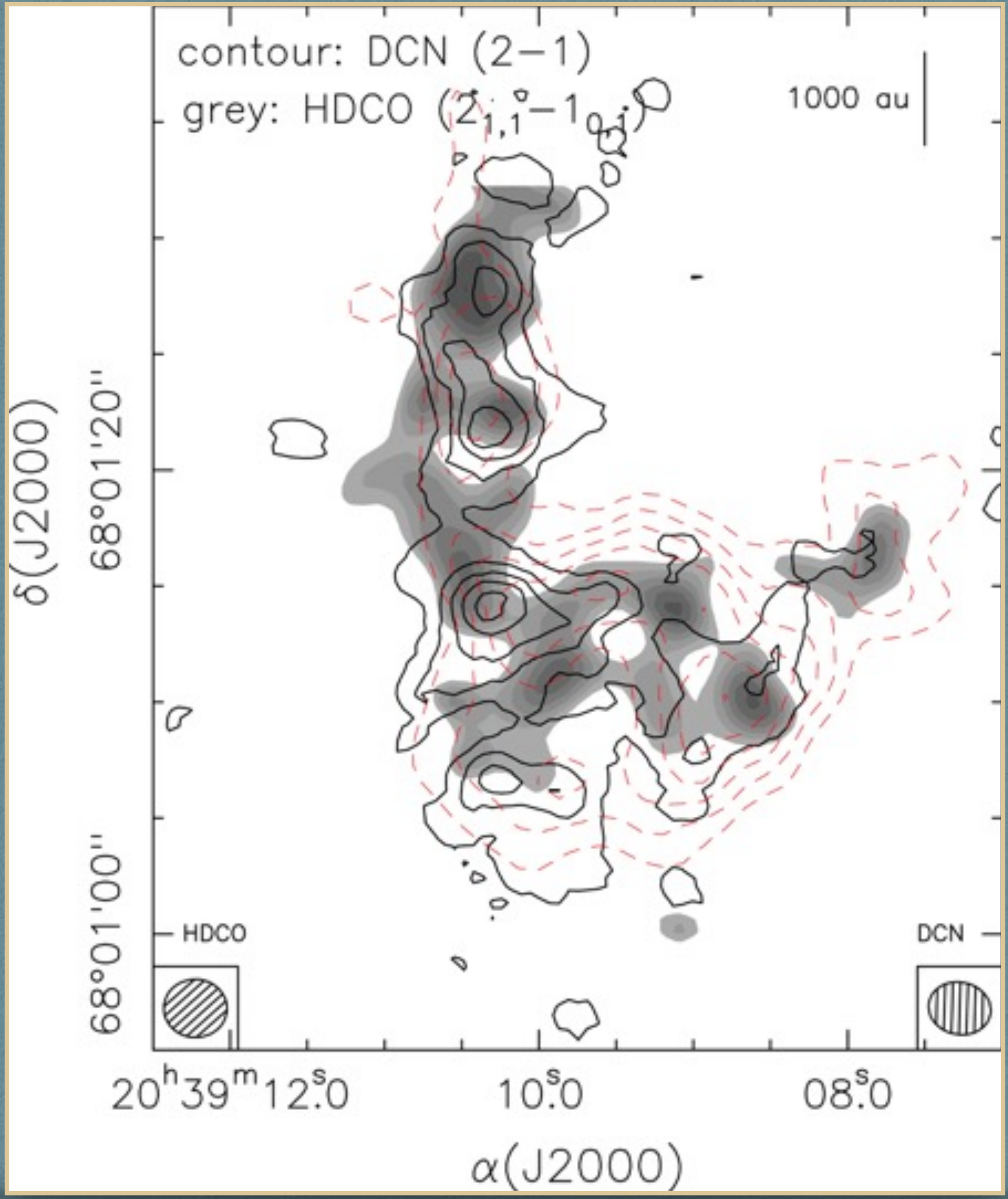

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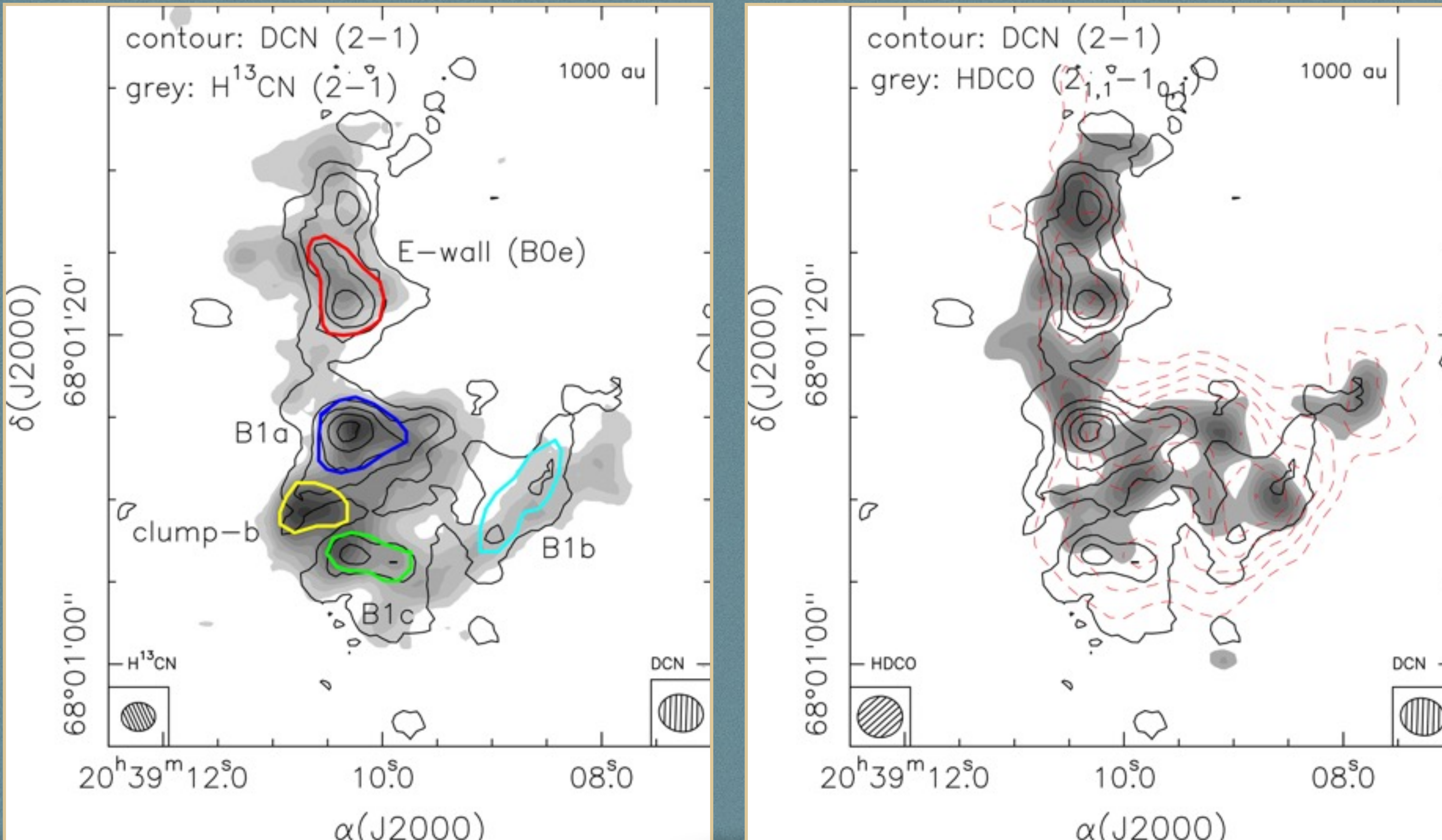

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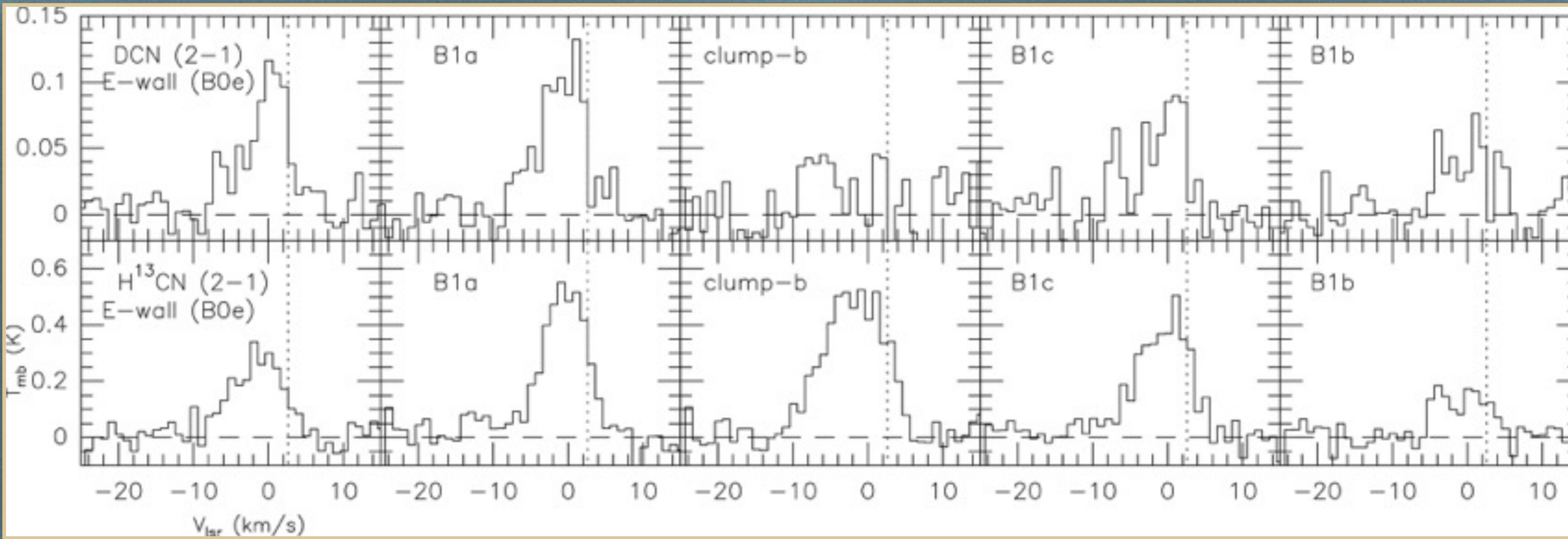
DEUTERATED FRACTION: DCN/HCN



T_{ex}= 10-70 K	E-wall (B0e)	B1a	clump-b	B1c (head)	B1b
$D_{frac} \times 10^{-3}$	4-5	3	<0.8	2-3	5-6

D_{frac}(HCN) < D_{frac}(H_2CO) & D_{frac}(CH_3OH)
D_{frac}(HCN) in L1157-B1 < D_{frac}(HCN) L1157-mm

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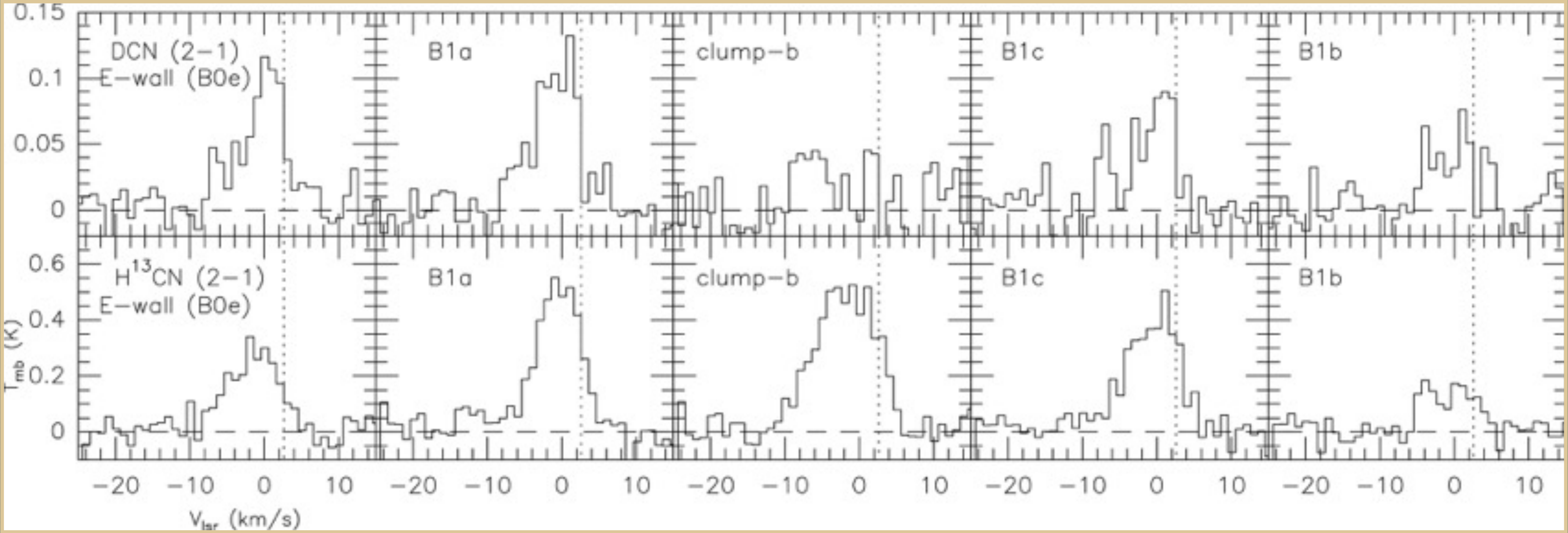

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D_{frac}(HCN) < D_{frac}(H_2CO) & D_{frac}(CH_3OH)
D_{frac}(HCN) in L1157-B1 < D_{frac}(HCN) L1157-mm

Contrary to HDCO, there is **no segregation in D_{frac}(HCN)**
Dominant mechanism for deuteration in the head of the bow-shock:
gas-phase chemistry

CHEMICAL MODEL

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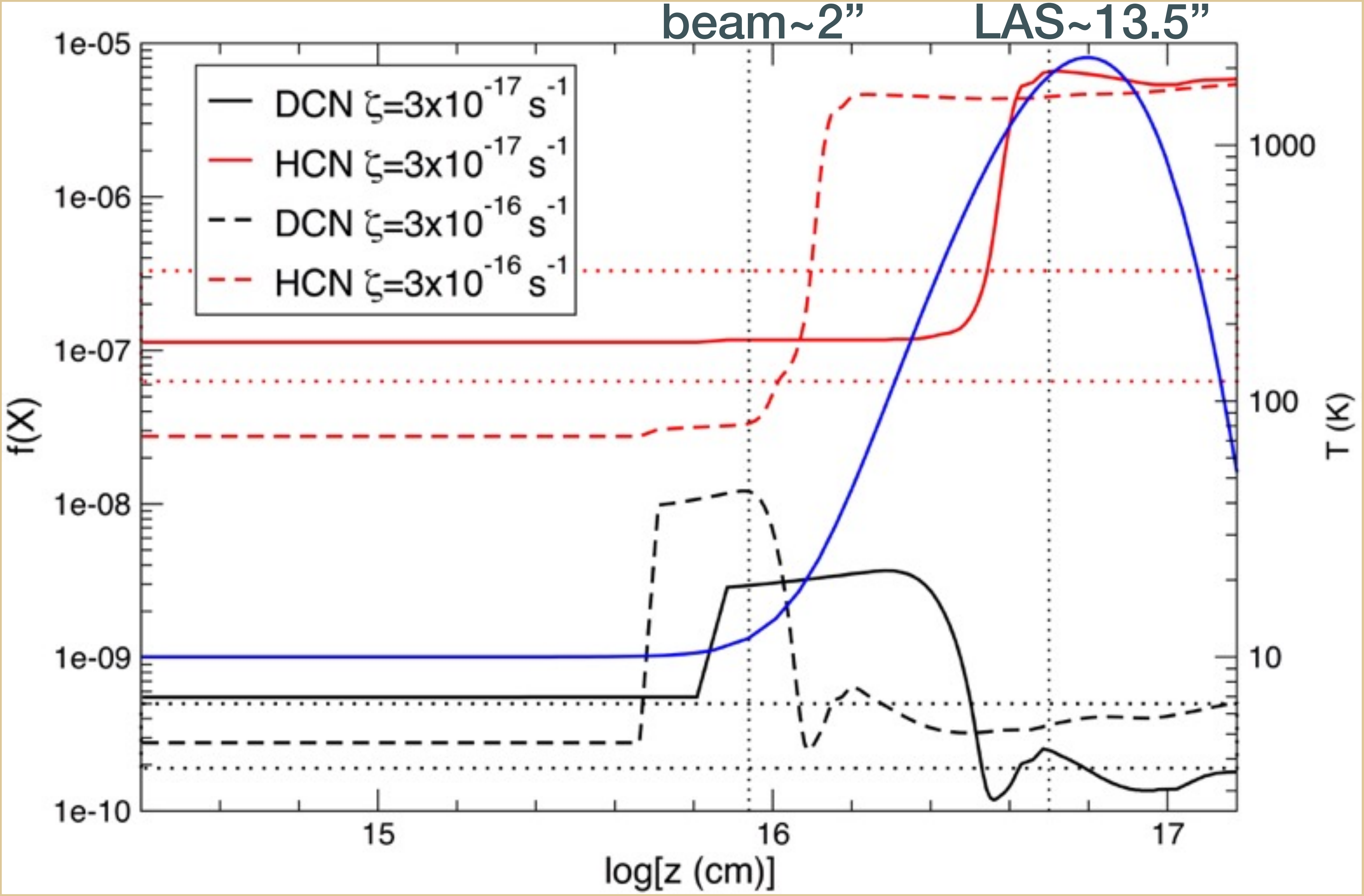
- Shock model of Viti et al. (2011): time dependent gas-grain chemical model **UCL_CHEM** (Viti et al. 2004) + **parametric shock model** (Jimenez-Serra et al. 2008)
- Initial solar abundances for all species; metals and sulfur depleted factor of 100
- **ζ=3x10^{-17} s^{-1} and 3x10^{-16} s^{-1}** (as found in Podio et al. 2014)
- pre-shock density **n(H_2)=10^3, 10^4, and 10^5 cm^{-3}**
- Shock velocity **v_s= 40 km/s** (30 km/s for 10^3 cm^{-3} case)
- **Thermal desorption and sputtering of icy mantles**
- Non-deuterated chemical network: UMIST 12
- Deuterated network: Esplugues et al. (2013)
- Triple-D species non included; only some double-D species

CHEMICAL MODEL: ABUNDANCES

$n(H_2)=10^4$ cm^{-3}, $v_s=40$ km/s



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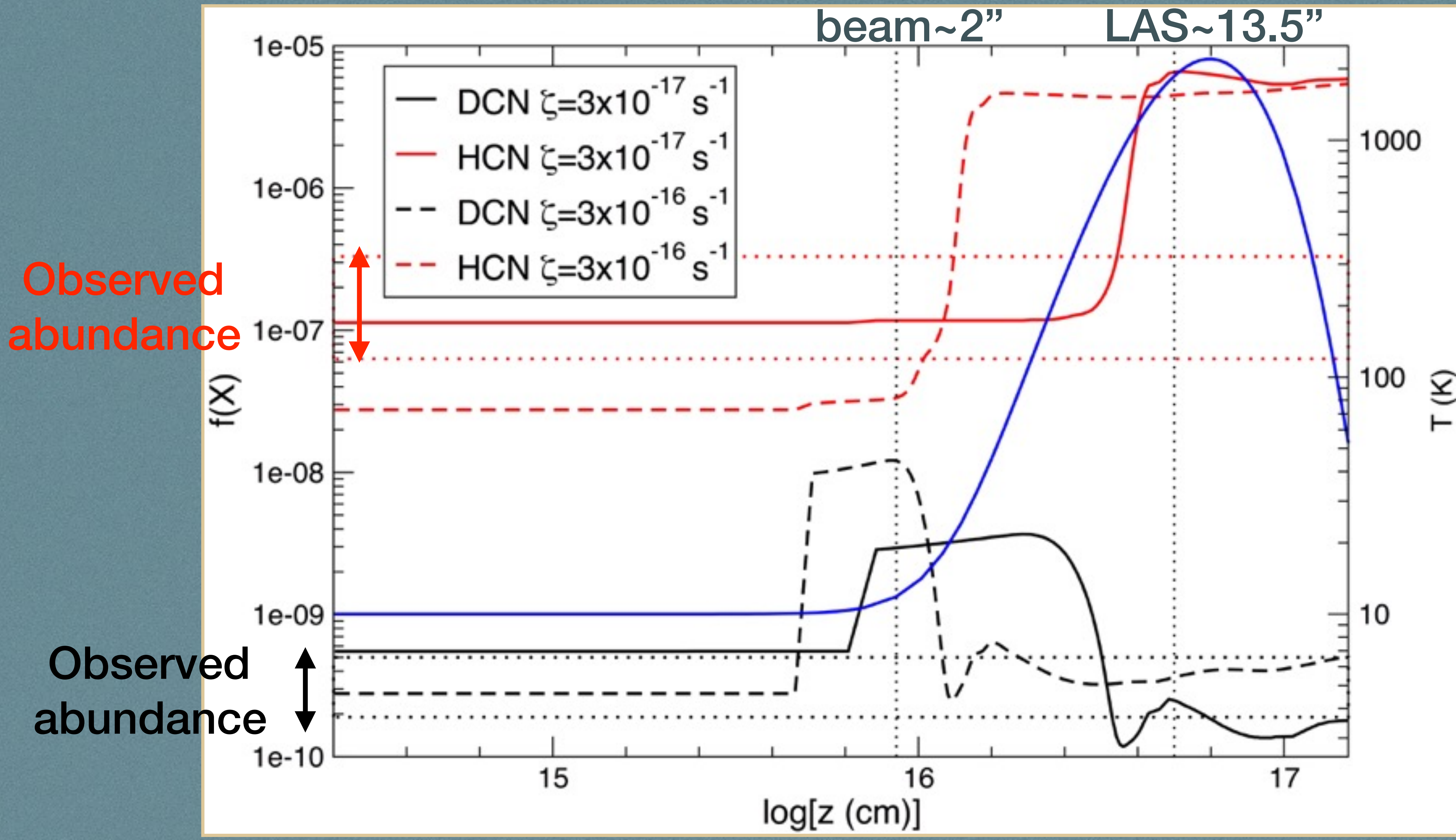

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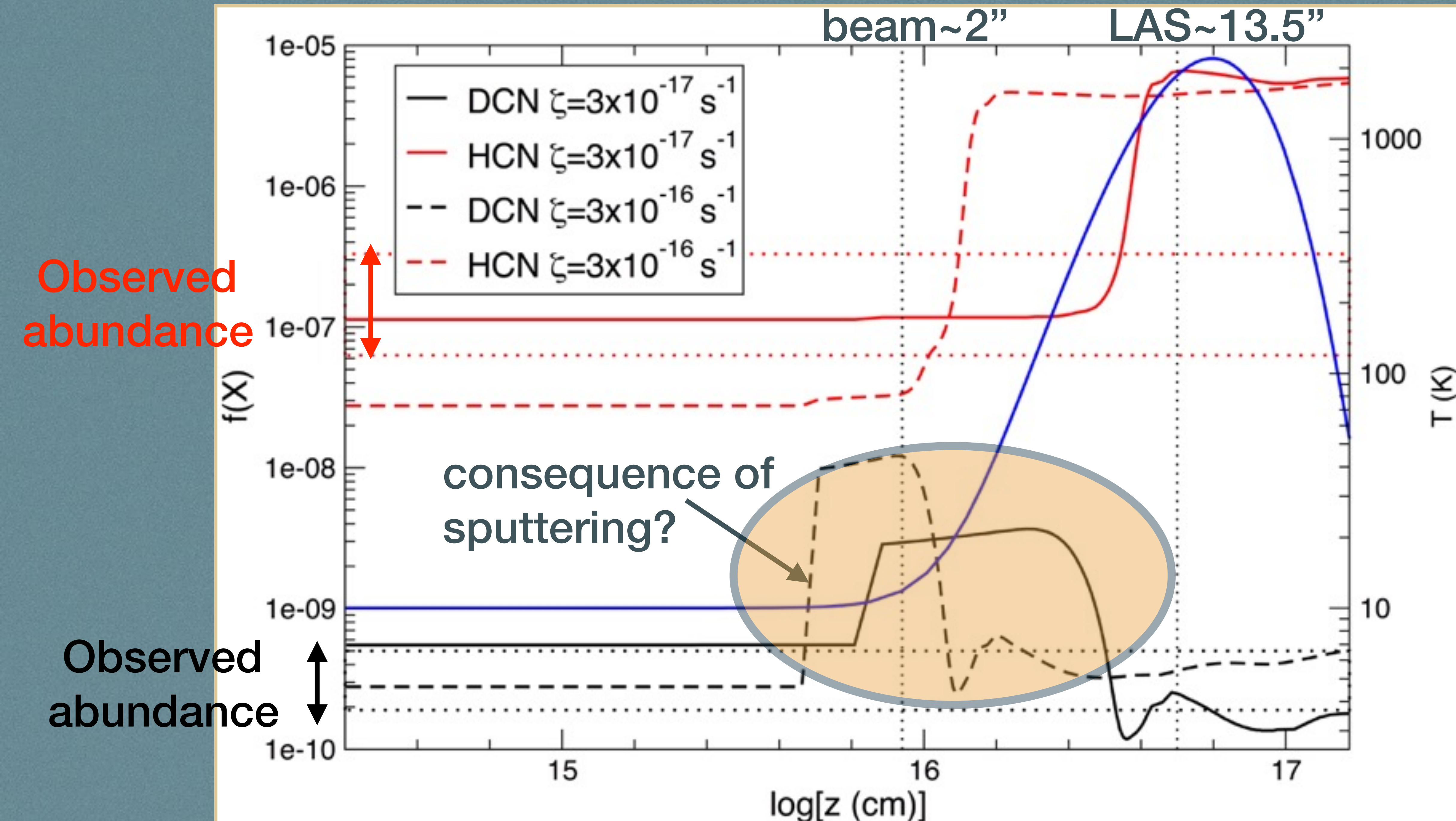

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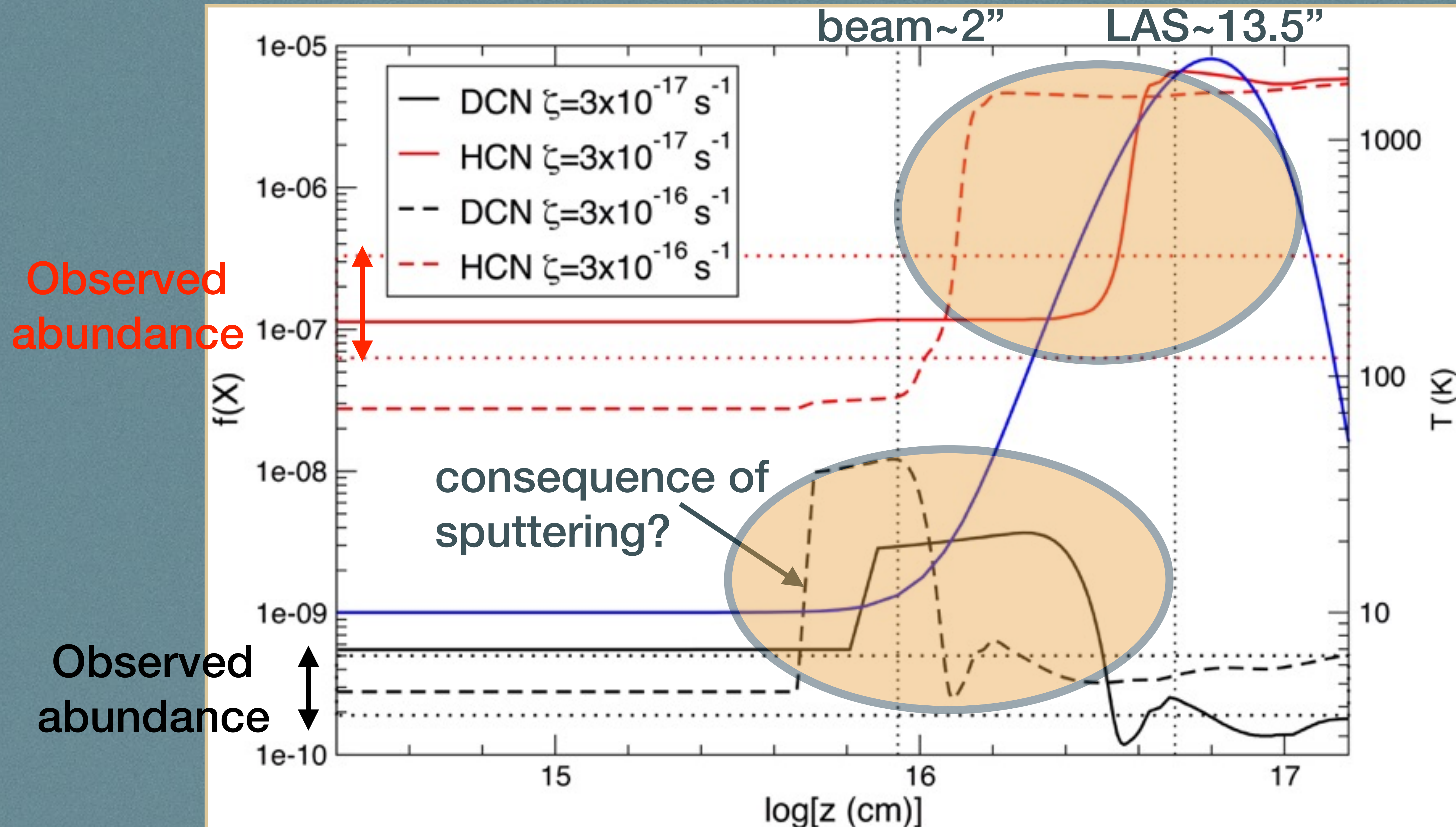

CHEMICAL MODEL: D_{FRAC}(HCN)

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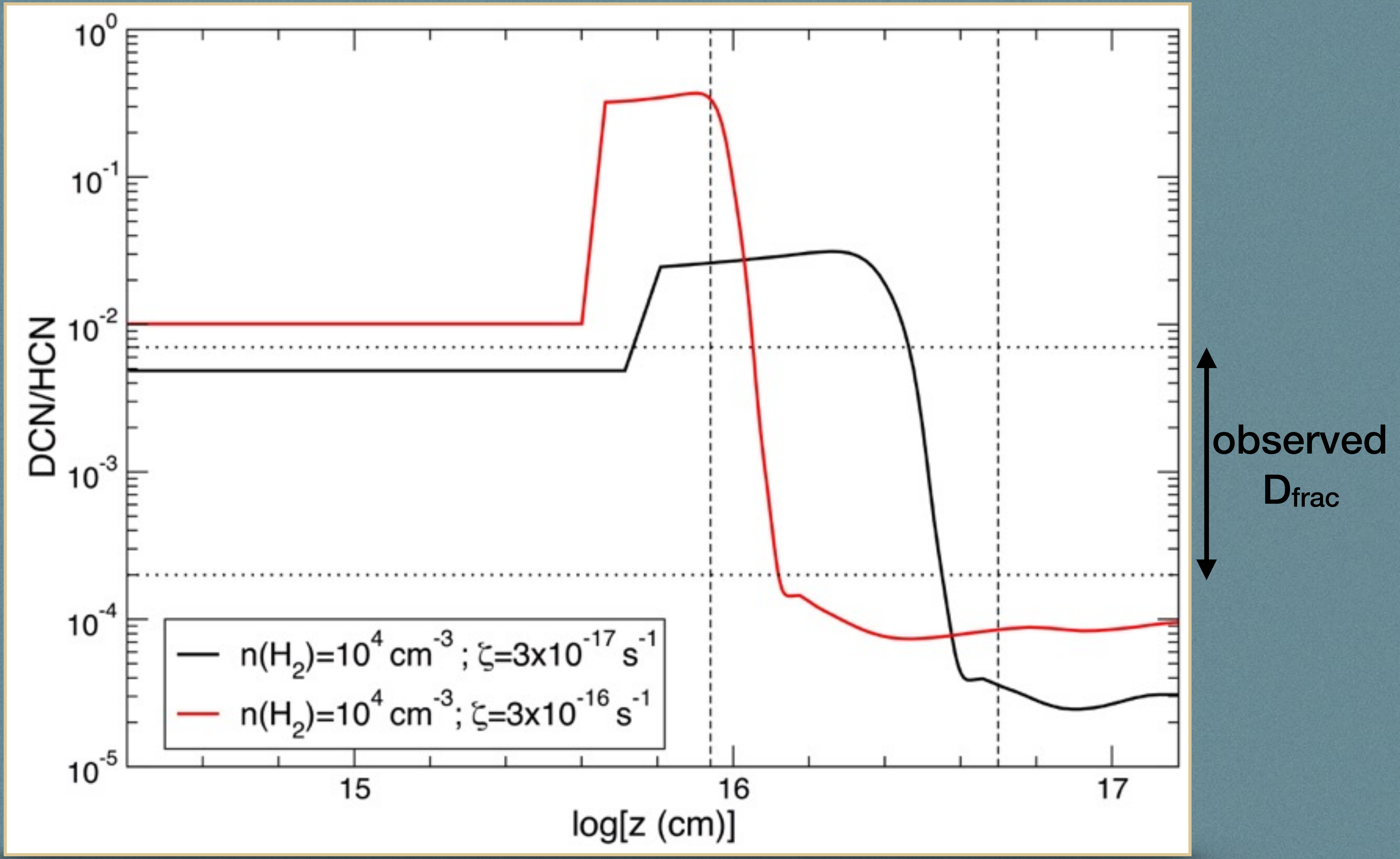
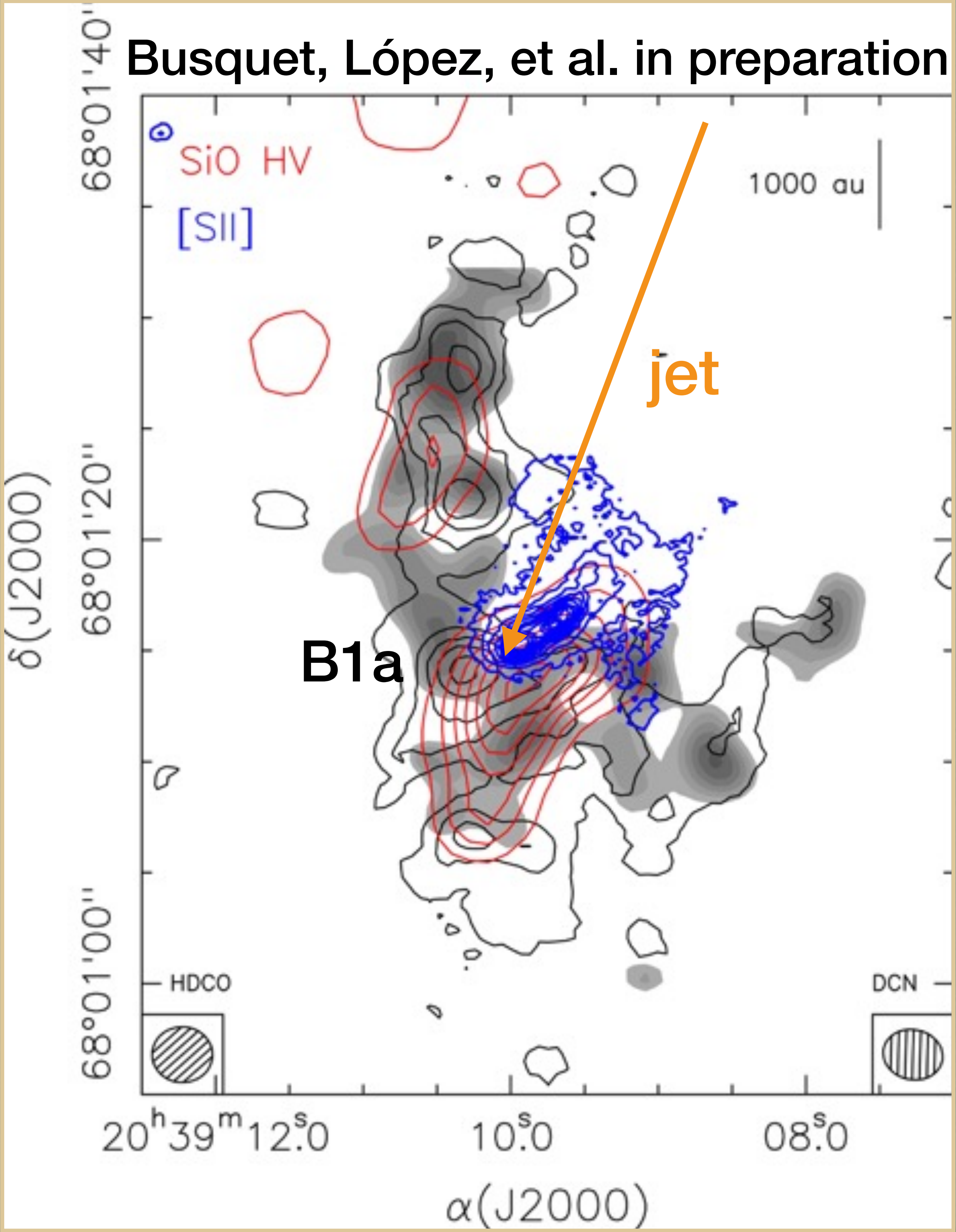


THE JET IMPACT REGION

- [SII] optical image seems to trace the inner parts of the cavity walls
- [SII] points toward the SiO (2-1) high-velocity peak and the bright DCN clump



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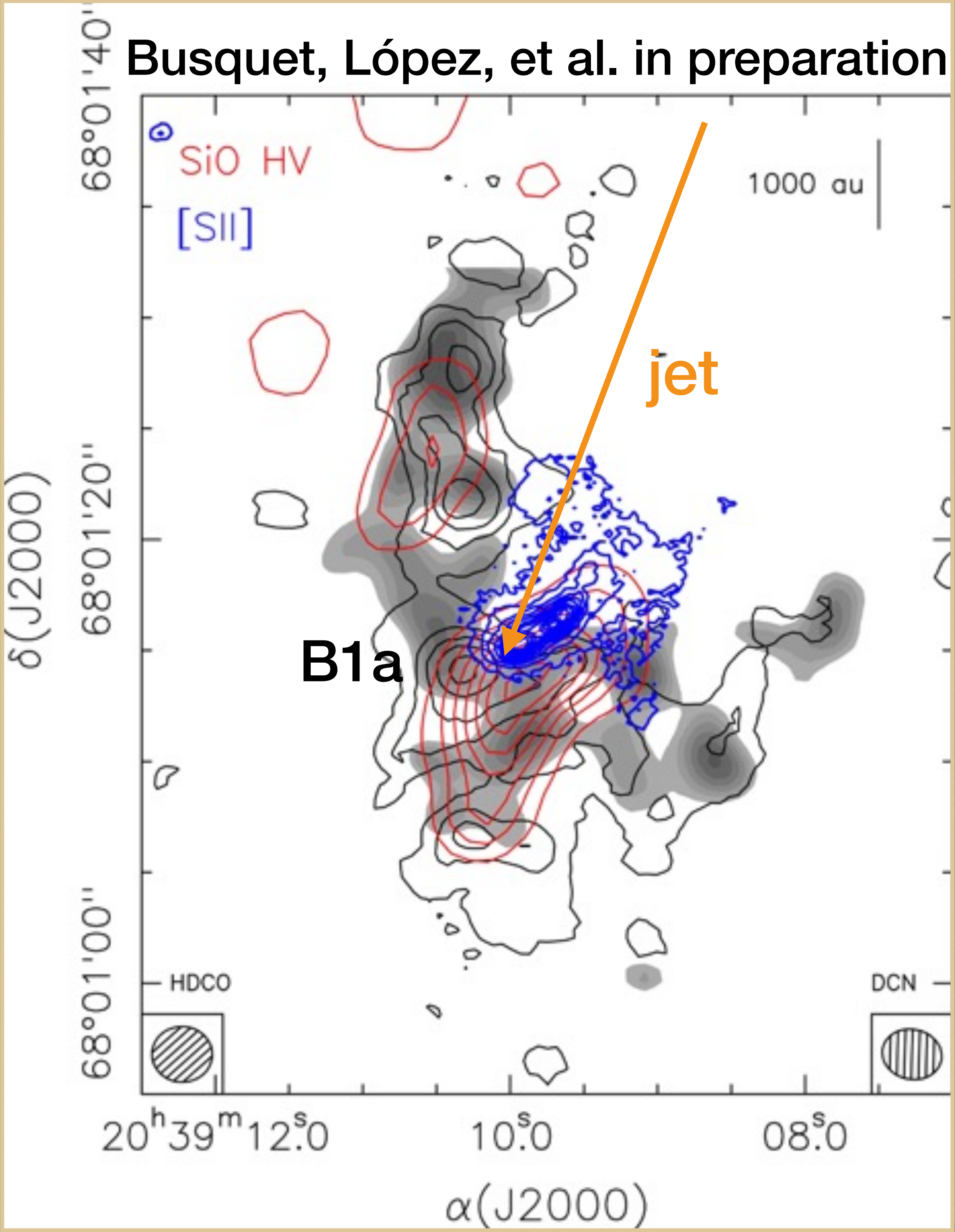
DCN formation:

- Warm gas-phase chemistry at the head of the bow-shock

and widespread in all the emitting region

- Sputtering at the interface between the fast jet and the ambient medium?

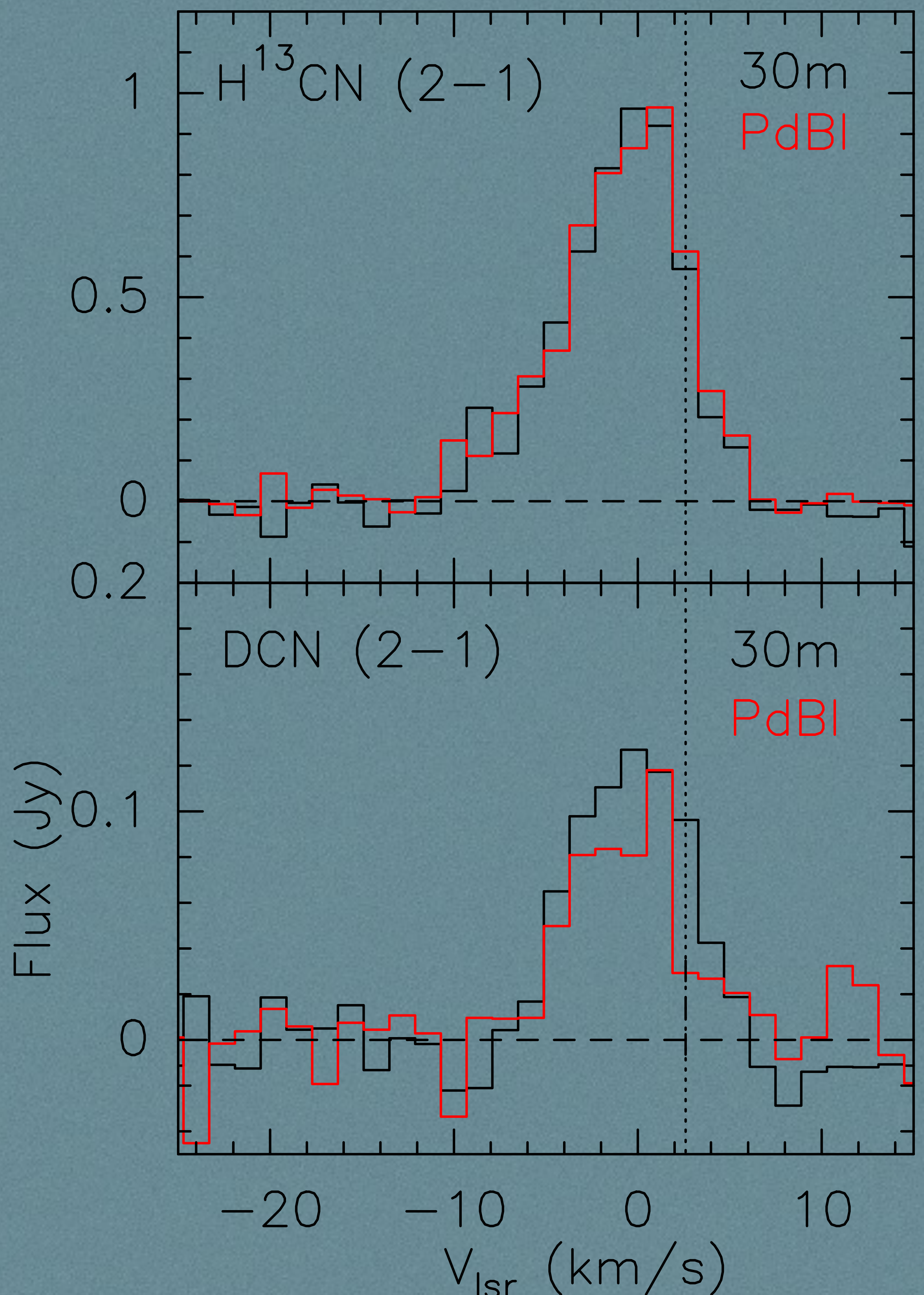


SUMMARY AND CONCLUSIONS

- In L1157-B1: D_{frac}(HCN)~$3x10^{-3}$ << D_{frac}(H_2CO) and D_{frac}(CH_3OH)
- HDCO and CH_2DOH found at the interface between the shock and the ambient medium: evaporation/erosion of grains mantles is maximum
- DCN is more widespread, not limited to the impact region and detected in the head of bow-shock: warm gas-phase chemistry
- UCL_CHEM + parametric C-type shock model: increase in X(DCN) and X(HCN) due to the passage of the shock
- Several mechanism at work: Sputtering of DCN from grain mantles + warm gas-phase chemistry

THANK YOU!

NOEMA VERSUS IRAM 30M: MISSING FLUX?



- NOEMA spectra extracted within a region corresponding to the mean of the single dish:

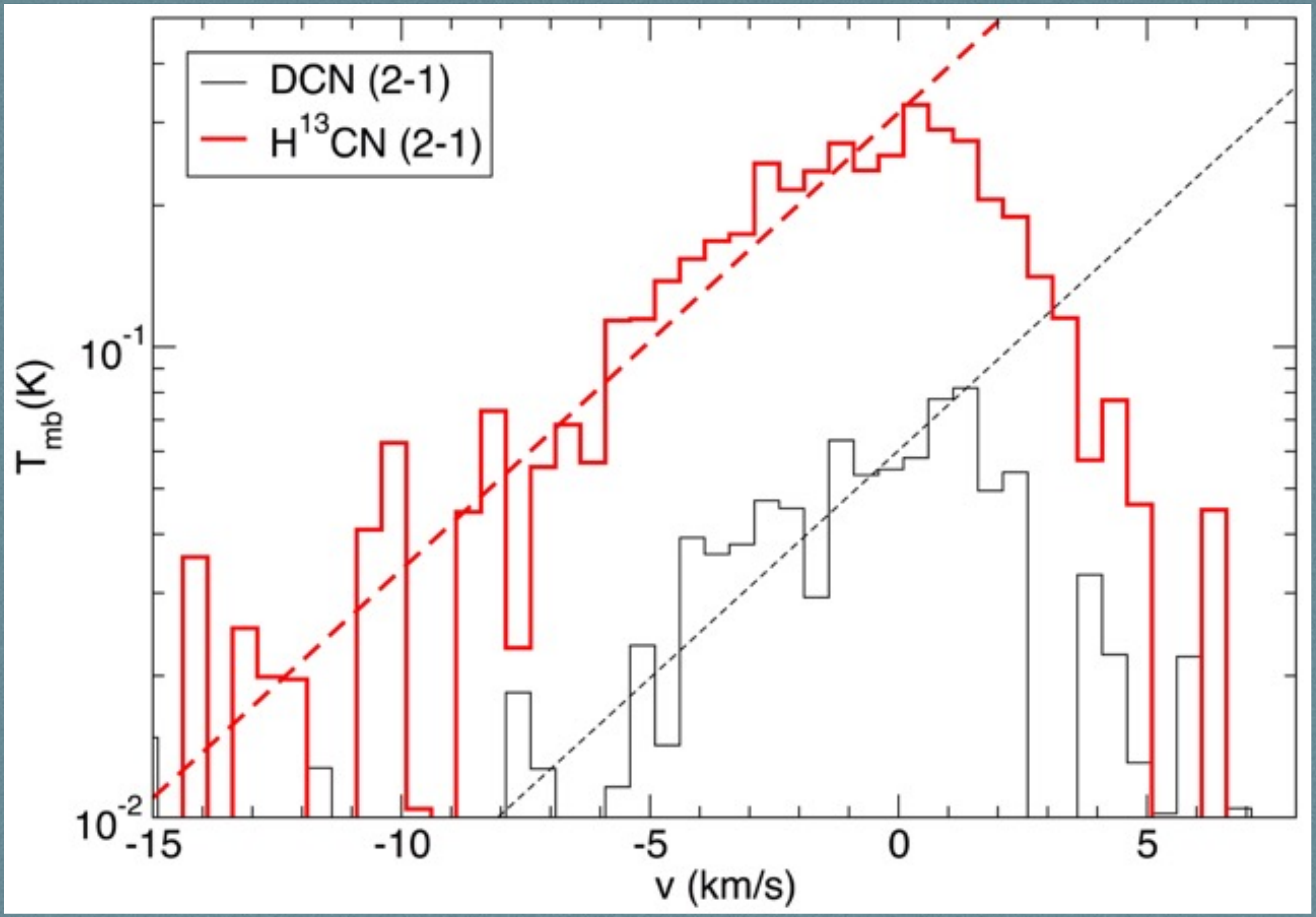
17.4” for DCN

14.6” for $H^{13}CN$

- 85% of the flux is recovered in DCN(2-1)
- Almost the total flux in $H^{13}CN$(2-1)

NOEMA VERSUS IRAM 30M: MISSING FLUX?

Multiple excitation components coexisting in the B1 shock: $I(v) \sim \exp(-|v/v_0|)$



- jet impact shock region associated with a partly dissociative J-type shock (g1)
- cavity walls of B1 (g2)
- cavity walls from the earlier ejection episode (g3)

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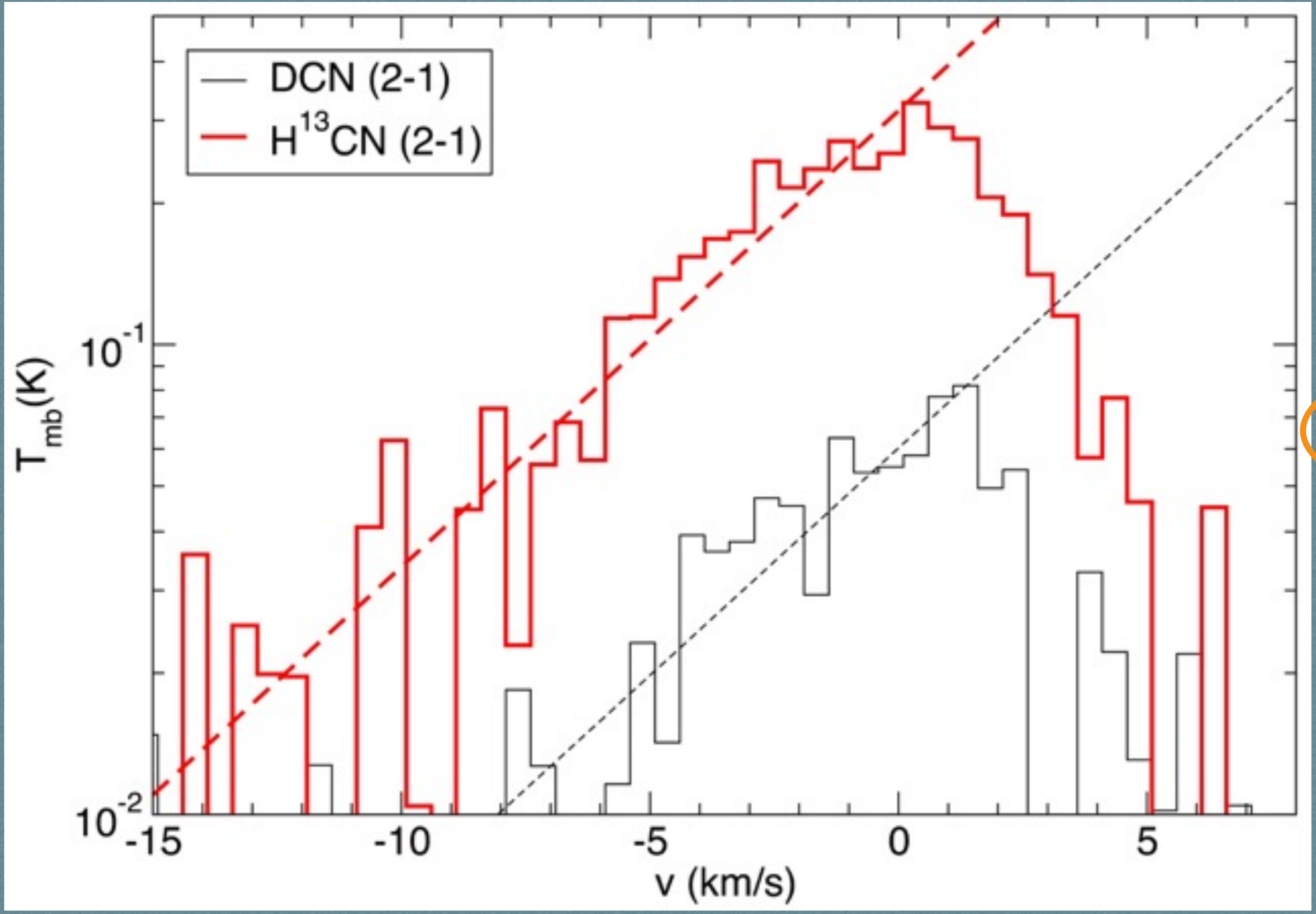

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