

Warm deuteration of HCN in Orion

Nuria Marcelino (NRAO)

B. Tercero (CSIC-INTA)

J. Cernicharo (CSIC-INTA)

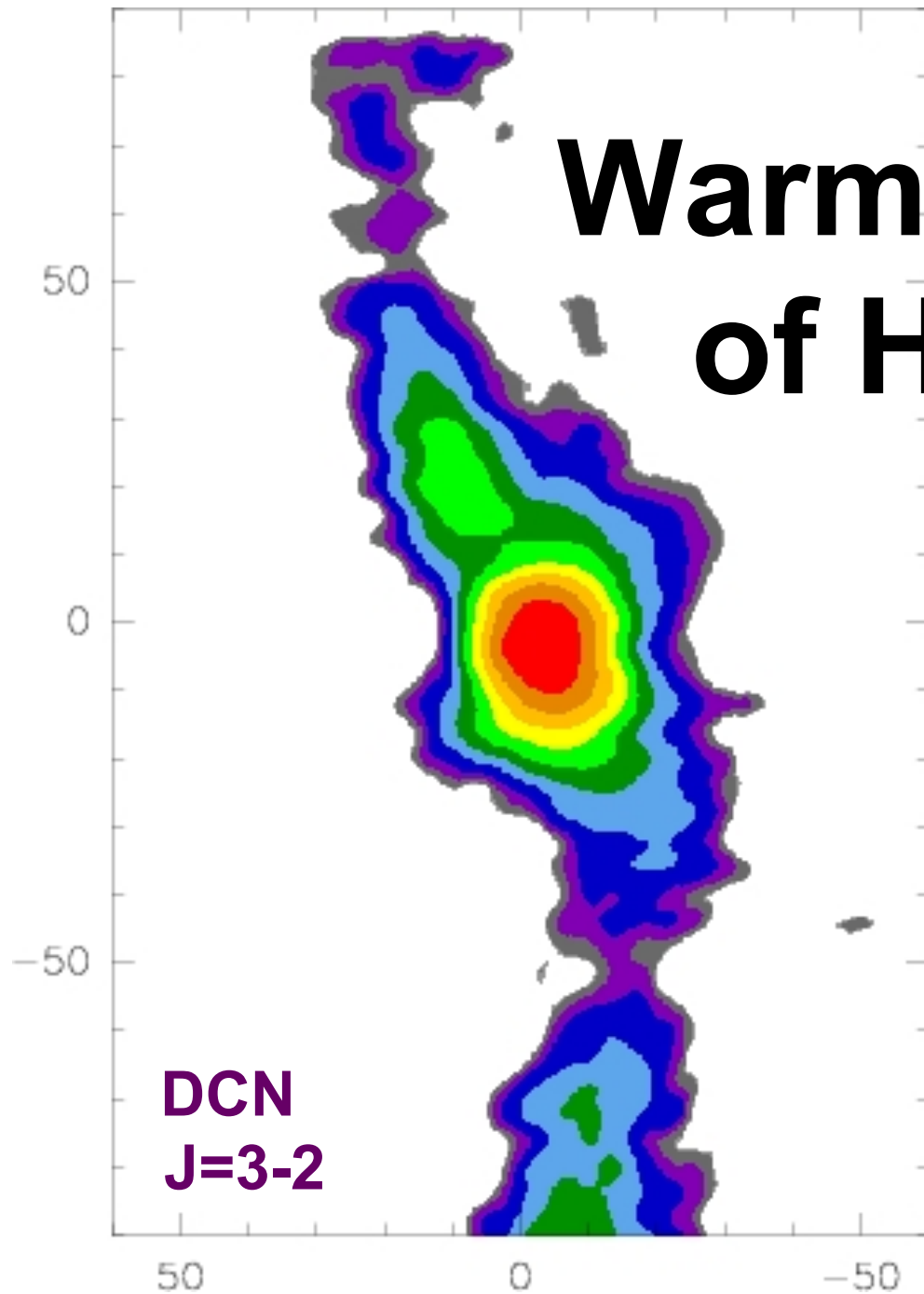
E. Roueff (Obs. Paris)

A. Palau (CSIC-IEEC)

J.R. Goicoechea (CSIC-INTA)

E. Bergin (Univ. Michigan)

and the HEXOS team



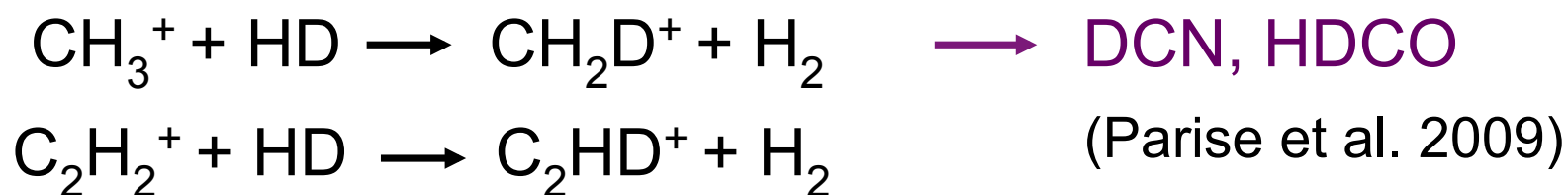
Deuteration in Molecular Clouds

- ✓ Dark clouds: gas phase at $T \sim 10$ K, depletion (CO):



- ✓ Hot cores/corinos: grain mantle desorption, i.e. remnant of the earlier cold phase and fractionation on grain surfaces (e.g. CH_3OH)

- ✓ Gas-phase deuteration at $T \sim 30$ -80 K (e.g. Orion Bar):



Deuterated molecules in Orion

- ✓ HDO, CH₃OD & CH₂DOH ~ 10⁻² – 10⁻¹
(Bergin et al.2010; Mauersberger et al.1988; Jacq et al.1993)
- ✓ NH₂D, D₂CO ~ 0.003 (Walmsley et al.1987; Turner 1990)
→ grain mantle evaporation
- ✓ DCN: ~ 10⁻³ in the HC, 0.01-0.06 in the ridge
(Schilke et al. 1992)
0.005 in the HC, 0.02 in the ER and CR
(Mangum et al. 1991)
→ gas-phase vs. grain desorption

Observations: 30m + HIFI

- ✓ 30m line surveys: IRc2 & 2x2' maps

Freqs : 80-280 GHz (IRc2), 200-250 GHz (2D survey)

spec.res. : ~1 MHz (3–1 km/s), 2 MHz (~2.6 km/s)

HPBW = 29''-9''

- ✓ HIFI: Orion KL line survey (HEXOS)

Freqs : 480-1240 GHz (bands 1–5, except 5b)

spec.res. : 0.5 MHz (0.3–0.1 km/s)

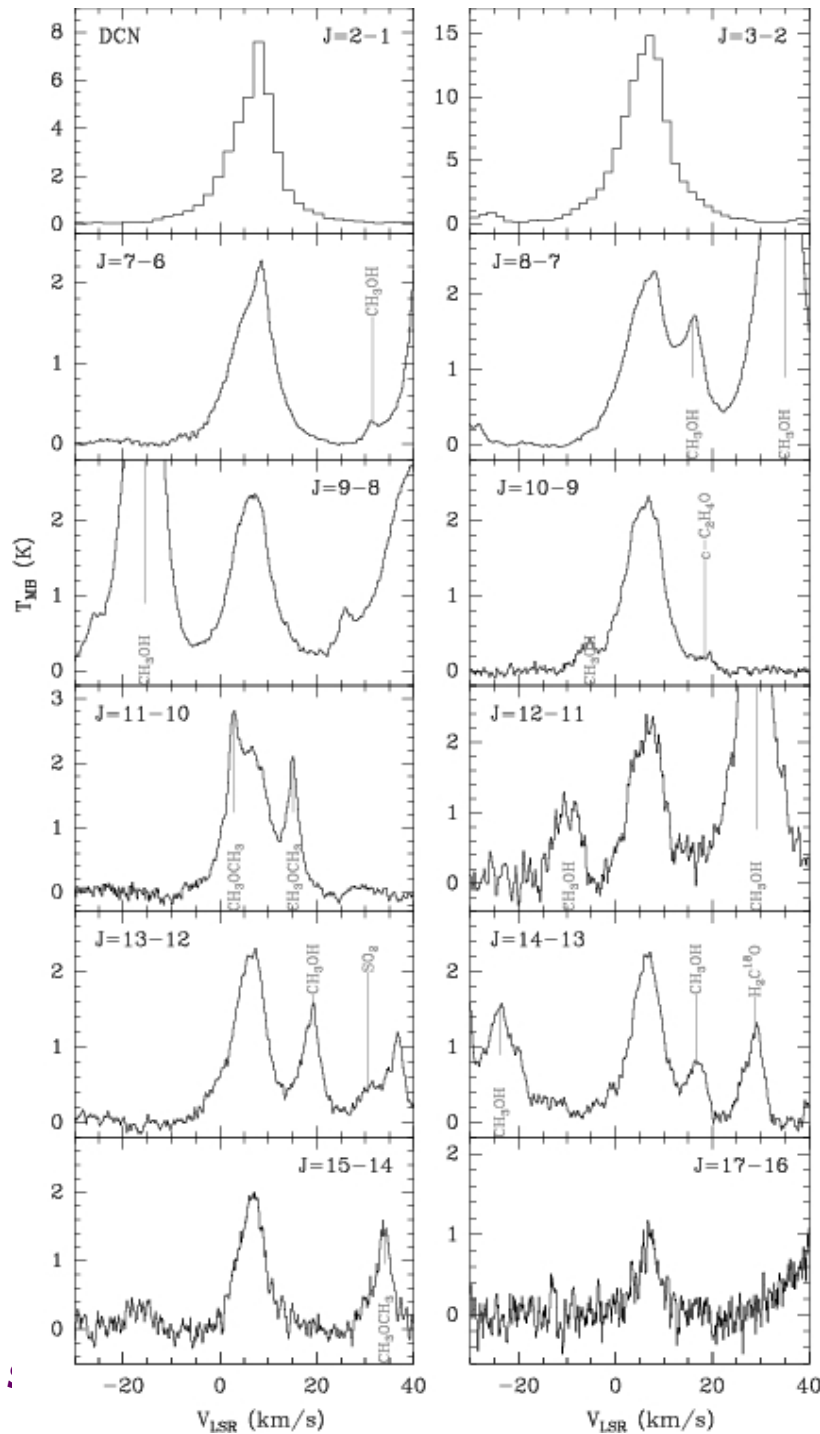
HPBW = 45''-18''

Results

✓ DCN : 12 transitions

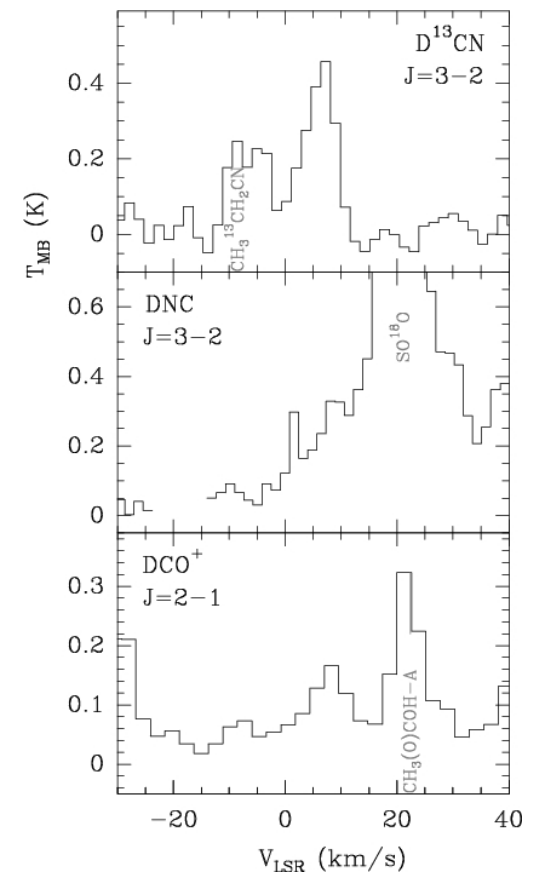
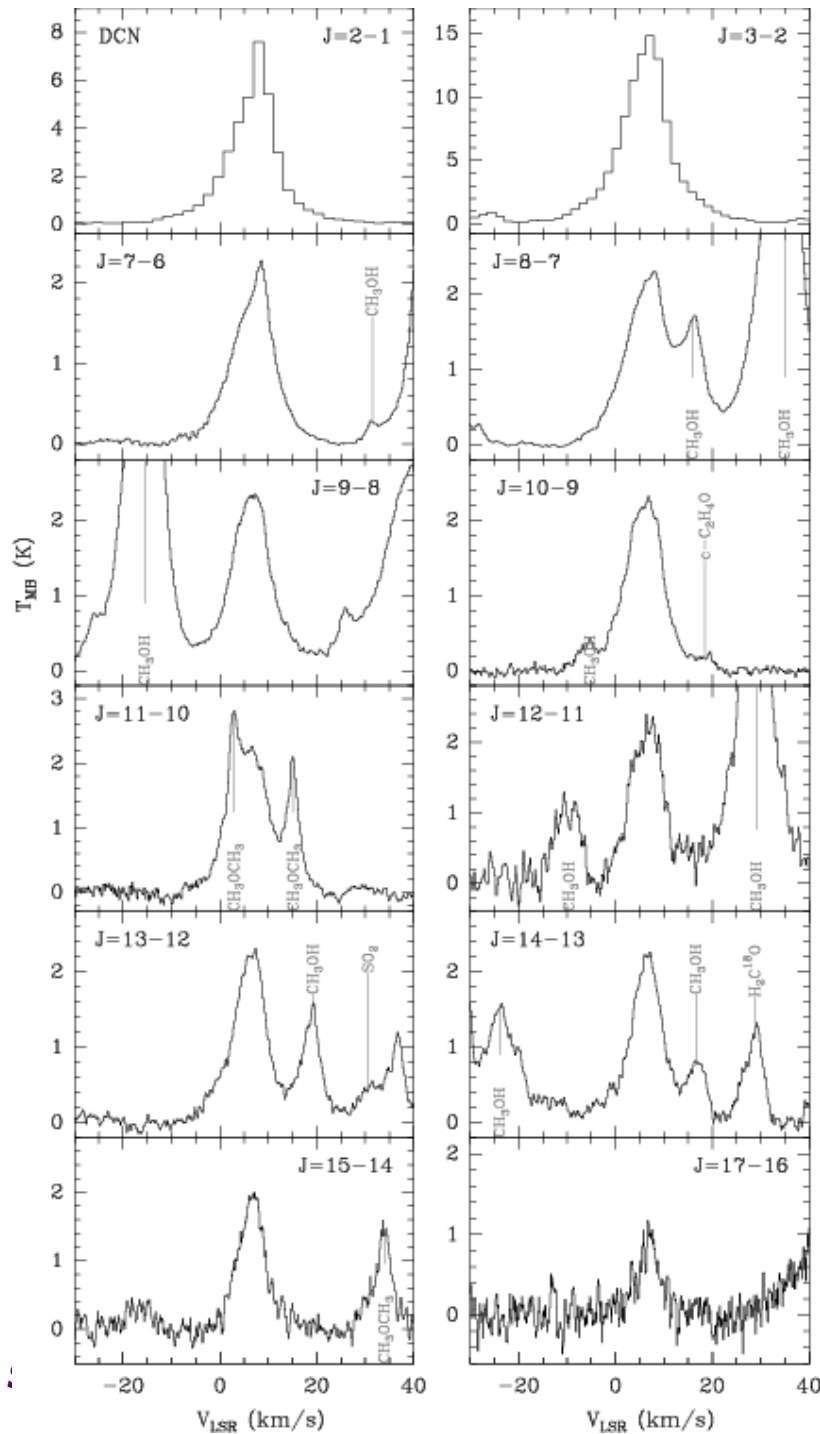
$E_{\text{up}} = 10\text{-}21$ K (30m)

$E_{\text{up}} = 97\text{-}532$ K (HIFI)



Results

- ✓ DNC and DCO⁺ only one transition
- ✓ D¹³CN



LVG model

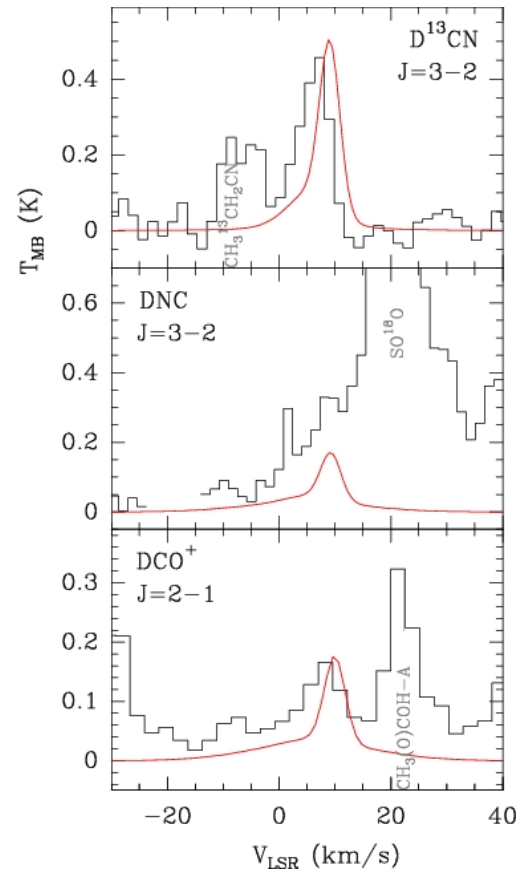
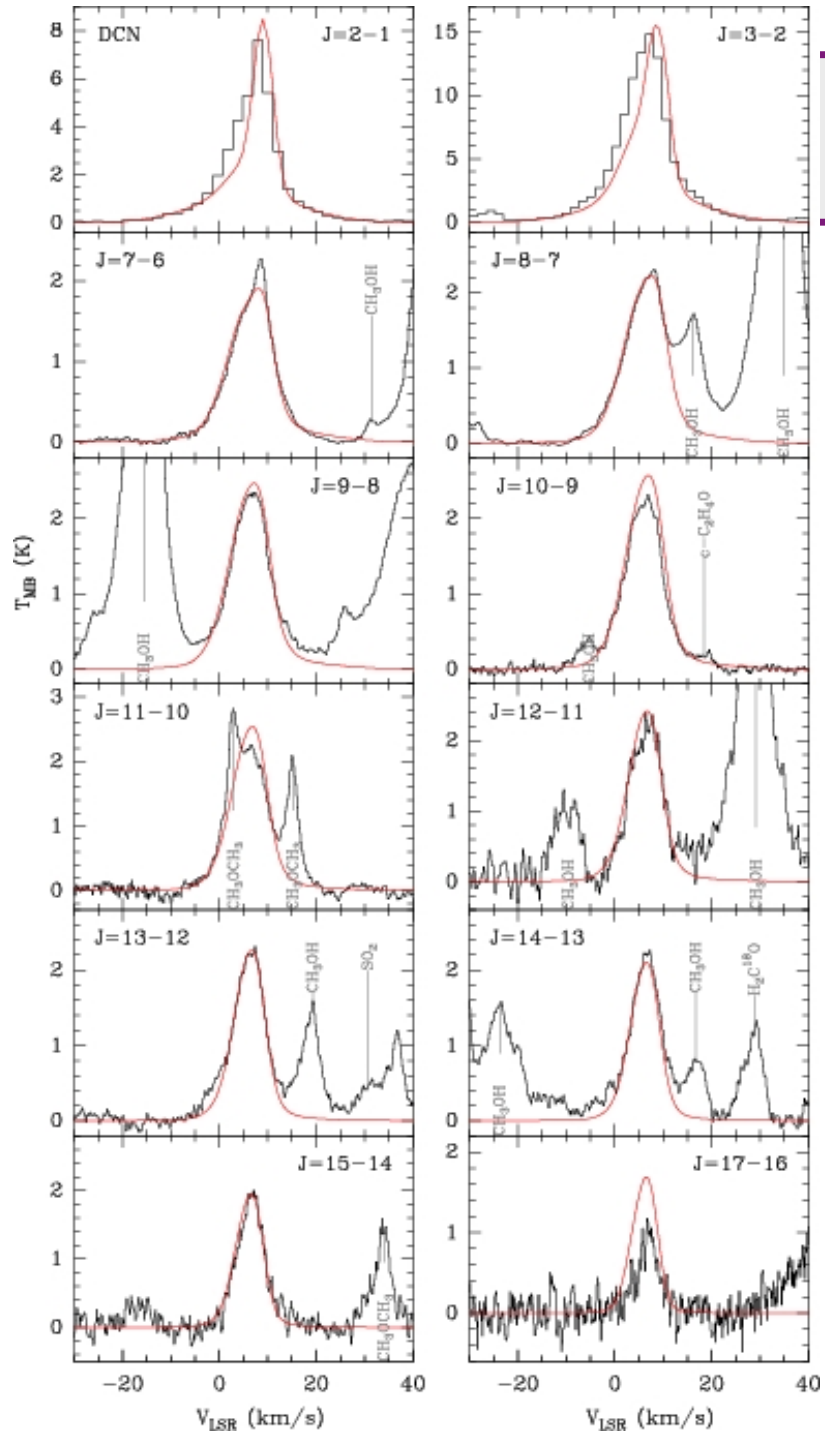
Parameter	Extended Ridge (ER)	Compact Ridge (CR)	Plateau (P)	Hot Core (HC)
Source diameter (")	120	15	30	10
Offset (from IRc2) (")	0	7	0	2
$n(\text{H}_2)$ (cm^{-3})	1.0×10^5	1.0×10^6	1.0×10^6	5.0×10^7
T_k (K)	60	110	125	225
Δv_{FWHM} (km s^{-1})	4	4	25	10
v_{LSR} (km s^{-1})	9	7.5	6	5.5

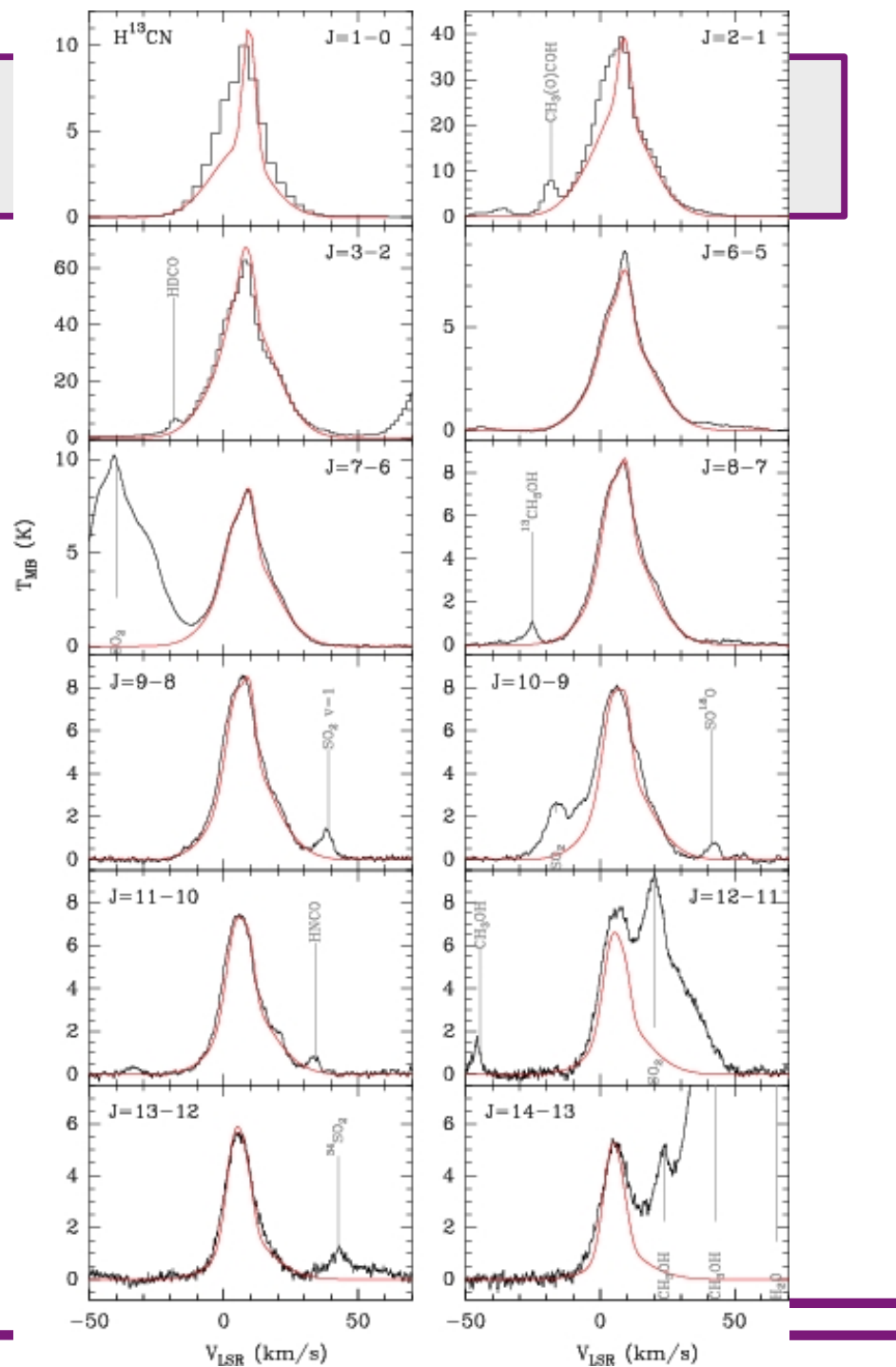
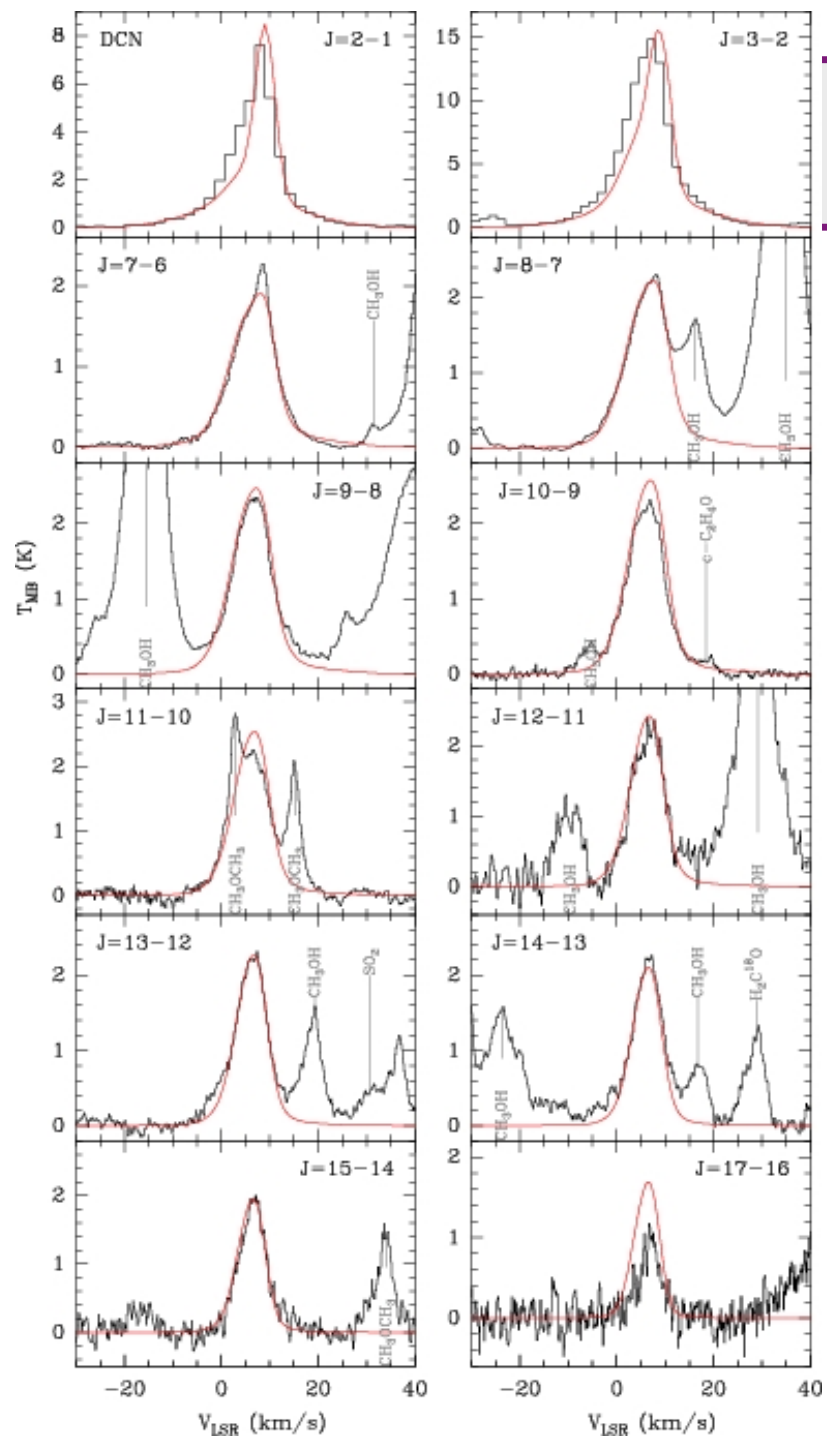
Tercero et al. (2010)

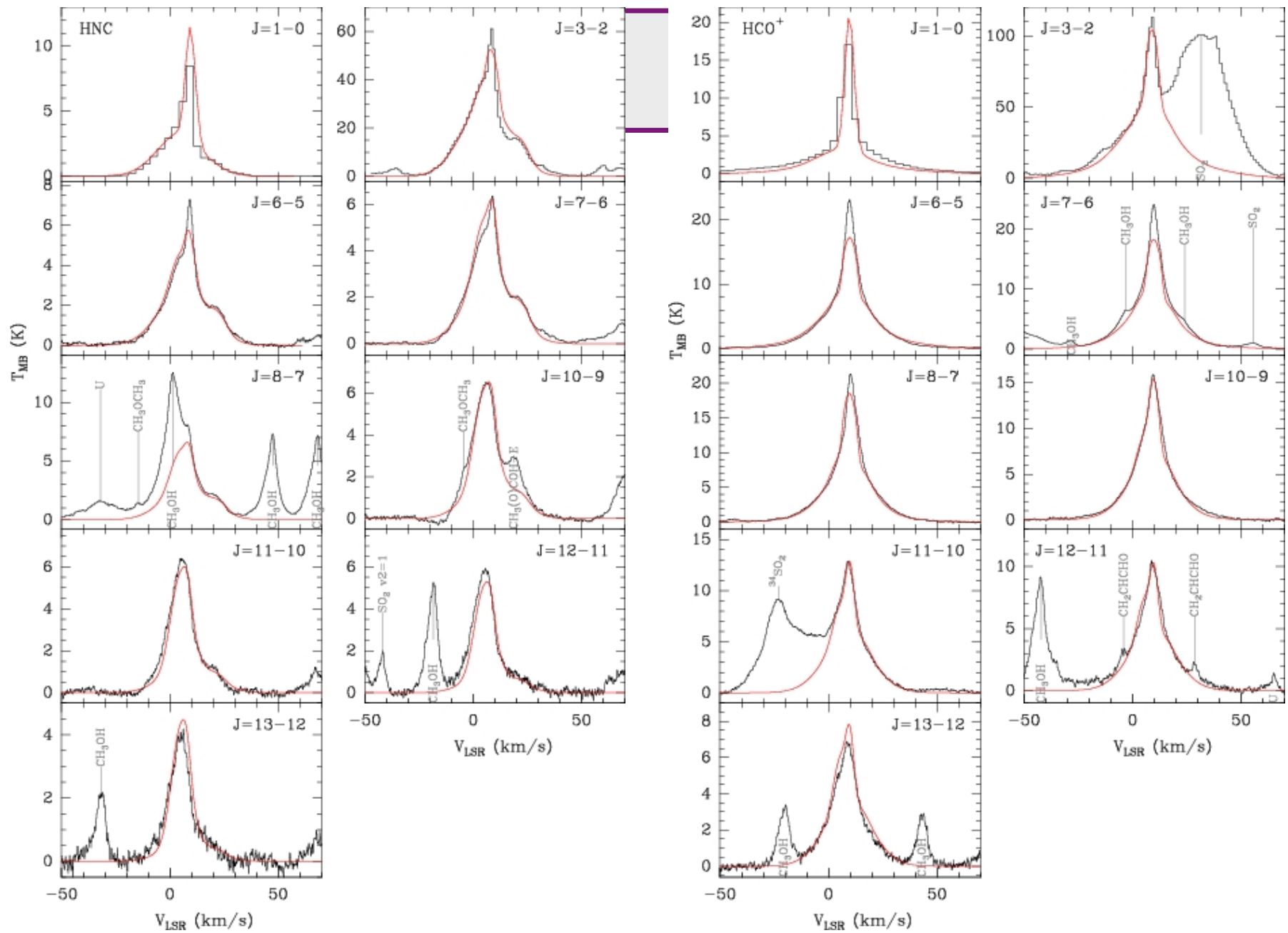
LVG model

Component	Source diameter ($''$)	Offset ($''$)	$n(\text{H}_2)$ (cm^{-3})	T_k (K)	Δv (km s^{-1})	v_{LSR} (km s^{-1})
Extended Ridge (ER)	120	0	$1 \cdot 10^5$	60	4	10
Compact Ridge (CR1)	15	7/3	$1 \cdot 10^6$	110	4	9/10
Dense Compact Ridge (CR2)	10	7/3	$5 \cdot 10^7$	150	4	9/10
Dense & Hot CR (CR3)	5	7/3	$1 \cdot 10^8$	300	4	7.5
Cold Plateau (P1)	30	0	$1 \cdot 10^6$	80	25	4
Plateau (P2)	20	0	$5 \cdot 10^6$	125	25	5–10
Dense Plateau (P3)	10	0	$5 \cdot 10^7$	150	25	9
High Velocity Plateau (HVP)	30	0	$1 \cdot 10^6$	125	55	10
Outer Hot Core (HC1)	10	2/3	$1.5 \cdot 10^7$	180	10–15	5.5
Hot Core (HC2)	7	2/3	$5 \cdot 10^7$	250	7–10	5–5.5
Dense & Hot HC (HC3)	5	2/3	$1 \cdot 10^8$	300	5–7	4.5–5
15.5 km s^{-1} Component (15.5C1)	10	5/2	$5 \cdot 10^6$	200	9–15	15.5
Dense 15.5 km s^{-1} C. (15.5C2)	7	5/2	$1.5 \cdot 10^7$	220	9–15	15.5
23 km s^{-1} Component (23C)	10	0	$1 \cdot 10^7$	220	8	23

LVG model



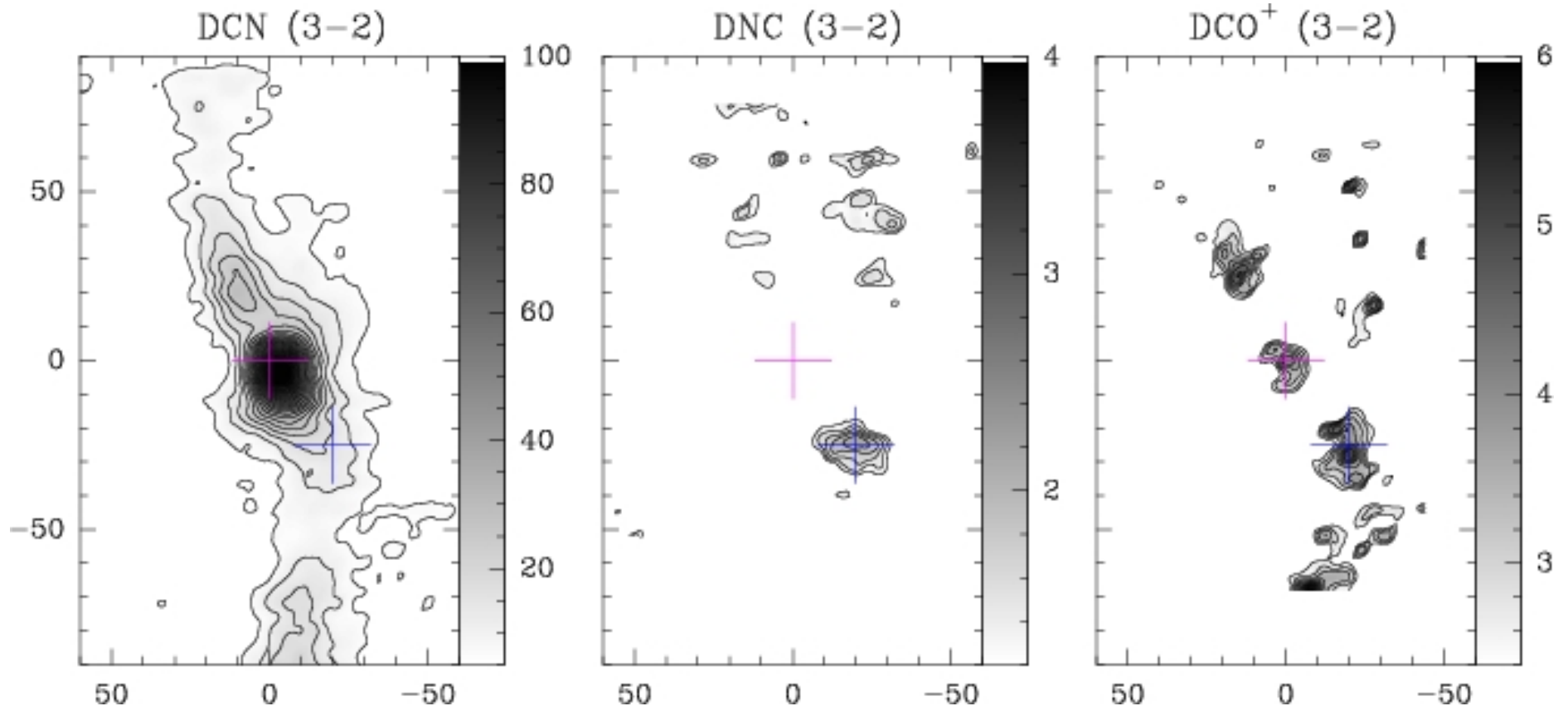




LVG model

	DCN/HCN 10^{-3}	DNC/HNC 10^{-3}	DCO ⁺ /HCO ⁺ 10^{-3}
ER	4.00	16.7	4.38
CR1	7.43	2.67	0.14
CR2	6.25	2.50	1.25
CR3	55.0	3.33	10.0
P1	1.60	2.00	3.33
P2	1.33	1.00	8.33
P3	0.57	0.22	0.20
HC1	17.6	15.0	10.0
HC2	5.33	0.20	1.25
HC3	4.67	1.25	10.0
Total	4.62	1.73	1.54

2D Line Survey



Summary

- ✓ 12 transitions from DCN, but only one from DNC and DCO⁺
- ✓ A three layer stratification model for CR, P and HC, has been used to simulate the source and obtain column densities. Only possible thanks to high excitation HIFI transitions !
- ✓ DCN/HCN~0.005, highest at the CR3 component.
DNC/HNC~DCO⁺/HCO⁺~0.0016 (upper limit)
- ✓ DCN (3-2) emission is extended in the molecular ridge, peaks at CR, Ori-S and ER. DNC and DCO⁺ peak at (-20'',-25''), and show narrower lines → different deuteration processes ?
H-species maps coming soon...
- ✓ ALMA will provide wide frequency range together with high spatial resolution to identify the main deuteration source