The CHESS survey of the L1157-B1 shock

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on behalf of the CHESS outflow team

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- The L1157 chemically rich outflow
- CHESS Observations
- Molecular content in L1157-B1
- Shock structure and comparison with models
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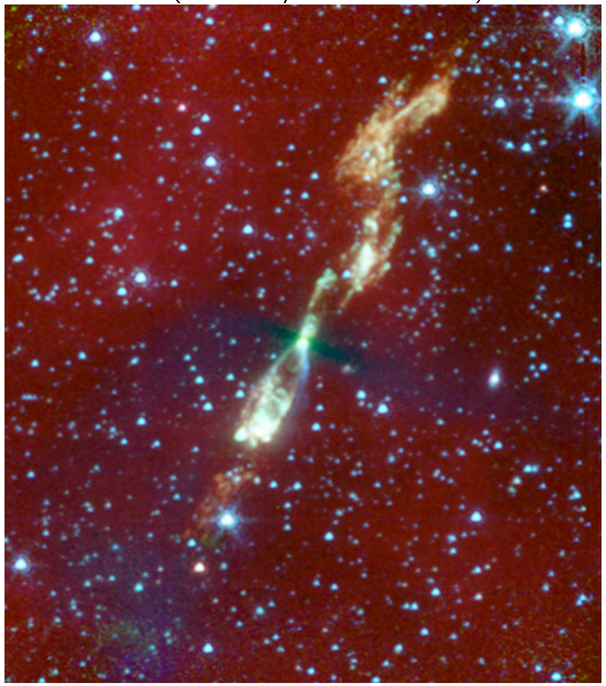
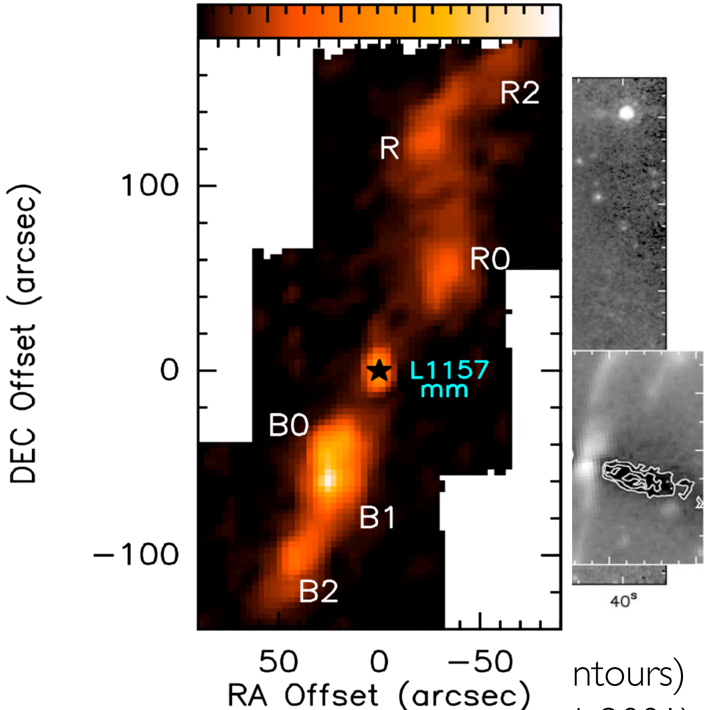
The L1157 chemically rich outflow

Spitzer composite image -3.5/4.5/8 μr
(Looney et al. 2007)





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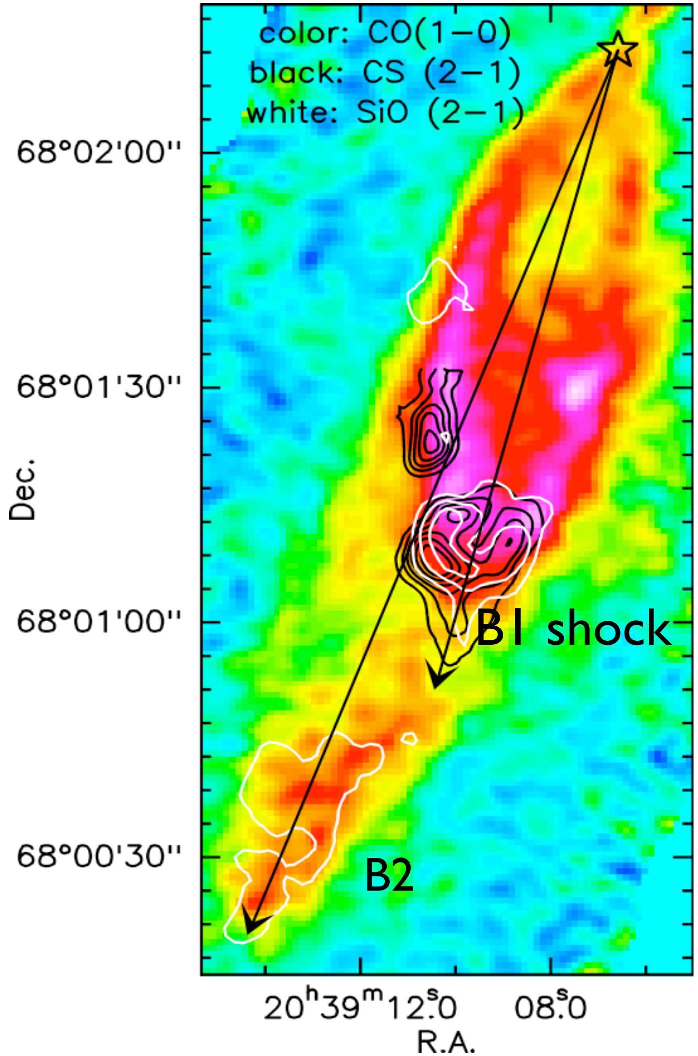
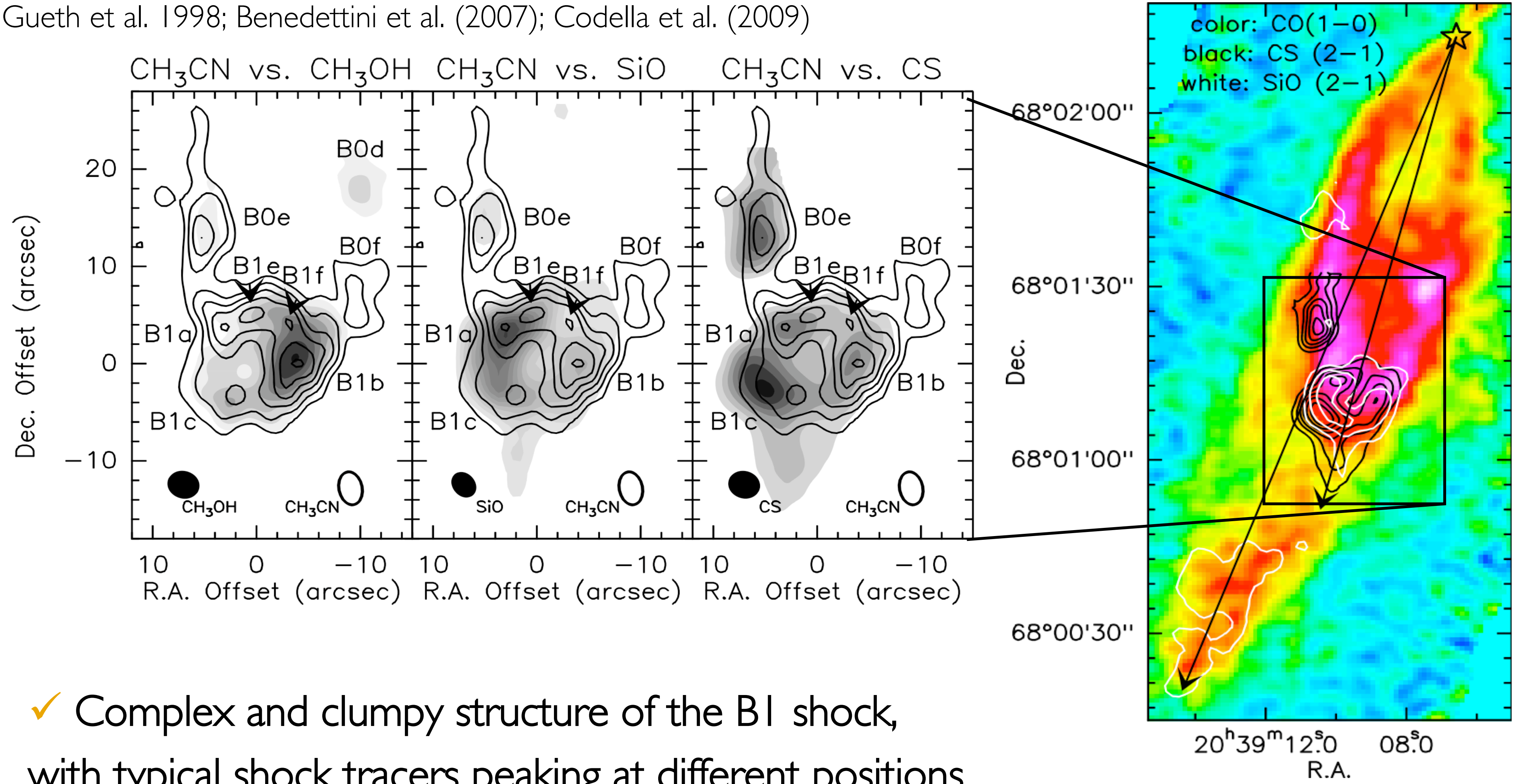
Herschel-PACS H_2O image @179 μm
(Nisini et al. 2010)



- ✓ Distance of 250 pc; powered by a Class 0 source
- ✓ Most chemically rich outflow know so far: SiO, SO, NH_3, CH_3OH, C_2H_5OH, H_2O, and many other molecules!
- ✓ Precessing molecular outflow associated with several bow shocks seen in CO (Gueth et al. 1996) and H_2 (Neufeld et al. 2009; Nisini et al. 2010): **B1 is the brightest shocked region**

Gueth et al. 1998; Benedettini et al. (2007); Codella et al. (2009)



✓ Complex and clumpy structure of the B1 shock, with typical shock tracers peaking at different positions

L1157-B1 is an excellent laboratory to investigate the effects and the structure of shocks on the gas chemistry

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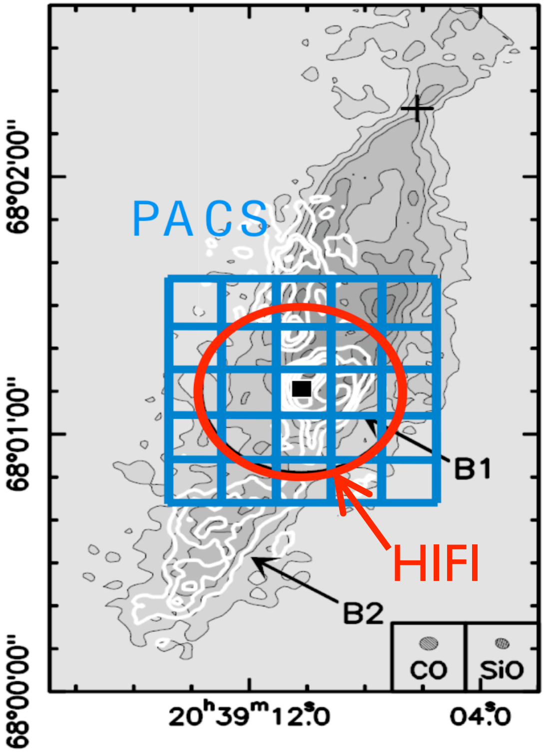
Herschel



Band	Freq. (GHz)	Lines of interest
1a	488-555	CI, HDO
1b	555-636	CO(5-4), o-H_2O 1_{10}-1_{01}
2a	680-700	CO(6-5)
2b	734-754	H_2S, p-H_2O 2_{11}-2_{02}
4a	984-1004	p-H_2O 2_{02}-1_{11}
4b	1094-1114	o-H_2O 3_{12}-3_{03}
5a	1110-1170 1150-1179	CO(10-9), o-H_2O 3_{21}-3_{12}
6b	1600-1670	CO(14-13), o-H_2O 3_{12}-1_{01}

- Pointed observations: CO, H_2O, CI, CII, NH, NH_2, HF, HCl, CH^+
- PACS: full spectrum 55-95.2 μm and 101.2-210 μm. Stared mode: 5x5 spaxels of 9.4" (FOV of 47"x47")
- SPIRE: full spectrum 190-672 μm
- IRAM 30m survey

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Molecular content in L1157-B1

Species	Lines	HIFI	SPIRE	PACS	E_{up} (K)
CO	18	9	9	10	83 - 1397
^{13}CO, $C^{18}O$	5,1	5,1	-	-	79 - 291
H_2O (o/p)	14	8 (5,3)	2 (p)	6	26 - 323
OH	6	-	-	6	120 - 291
OI	2	-	-	2	228 - 253
CI	2	2	2	-	24 - 63
HCO^+	2	2	-	-	90 - 120
H_2CO (o/p)	12	12	-	-	
CH_3OH	63	63	-	-	
HCN	2	2	-	-	89 - 119
NH_3 (o)	1	1	-	-	28
H_2S (o/p)	3	3	-	-	48 - 86
CS	3	3	-	-	129 - 183
SiO	*1*	*1*	-	-	*163*
NO	*1*	*1*	-	-	
HCl	[illegible]	1	-	-	30
All (3 σ)	134	113	13	24	

✓ 17 molecular species detected with HIFI

✓ 3 new species in outflows: NO, HCl (Codella et al. 2012)

see poster by Codella et al.

and N_2H^+

✓ Species searched for but not detected with HIFI: CH^+, HF, NH, NH_2, HDO, C^+

Ongoing projects:

- N-bearing species (HIFI and IRAM) ⟶ see poster by Vasta et al.

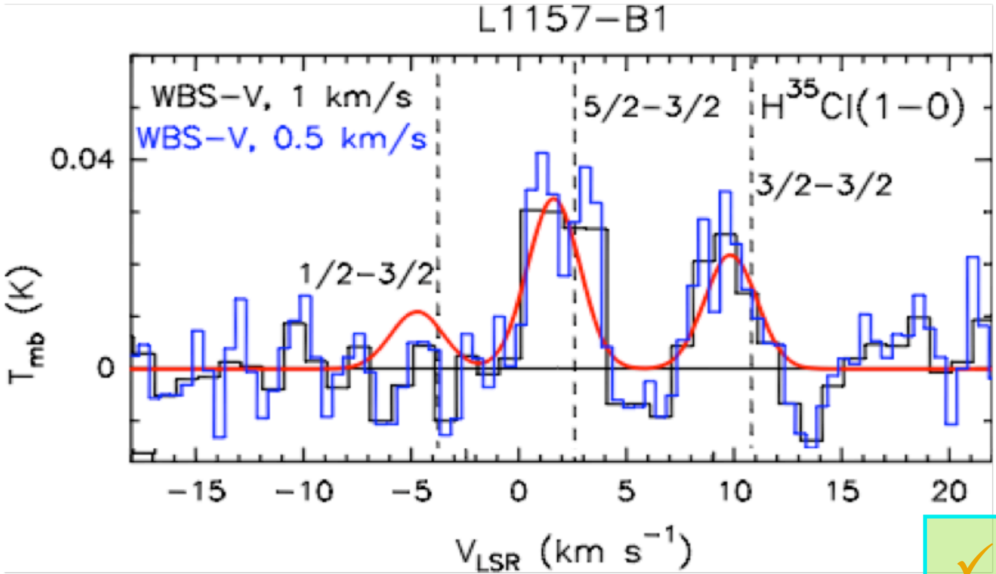
from simple (PN, NS, CN) to very complex molecules (CH_2CHCN…).

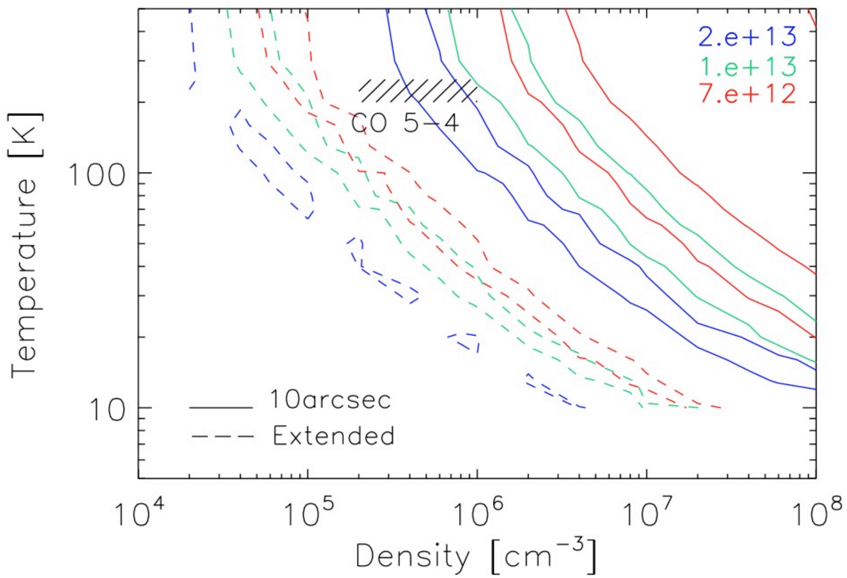
N_2H^+ detected for the first time in outflows

- H_2O emission (HIFI and PACS) ⟶ see poster by Busquet et al.

HCl (1-0) @625.9 GHz towards L1157-B1

Codella, Ceccarelli, Bottinelli et al. (2012)





See poster by Codella et al.

- HCl emission does not come from the cloud component
- HCl comes from compressed ($> 10^5$ cm^{-3}) gas

✓ X(HCl) around 10^{-9}: similar to that observed in protostars
✓ BUT grain erosion in the shock has returned up to 10% of Si to the gas phase
✓ chlorine is depleted into a more refractory phase than silicon?
✓ HCl in not the main reservoir of chlorine?

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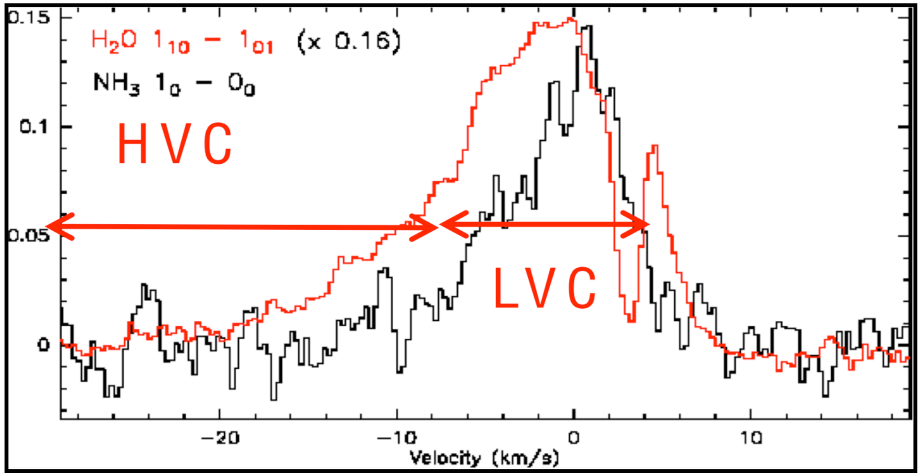
Different velocity regimes

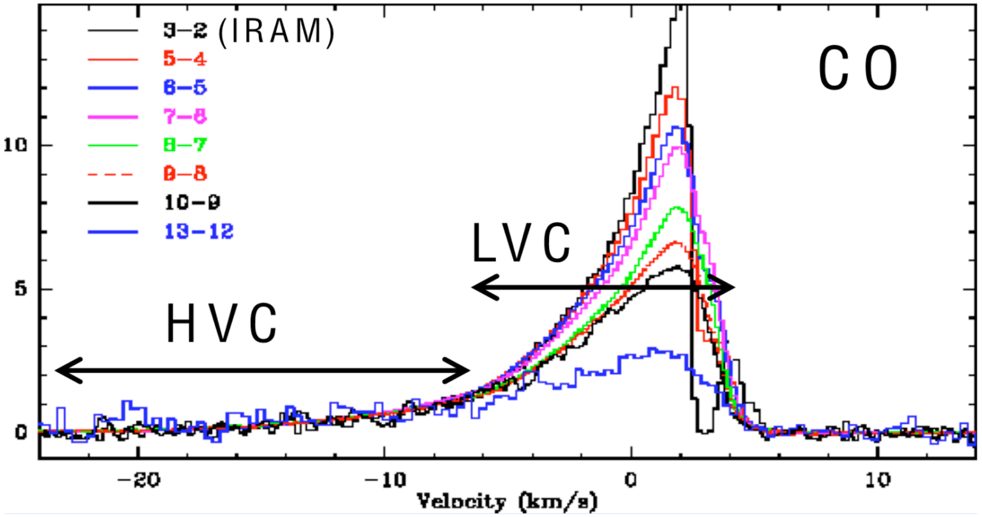
(Codella, Lefloch, Ceccarelli et al. 2010; Lefloch, Cabrit, Codella et al. 2010)



Different excitation regimes

(Lefloch et al. 2010, Lefloch et al. in prep)

see poster by Lefloch et al.

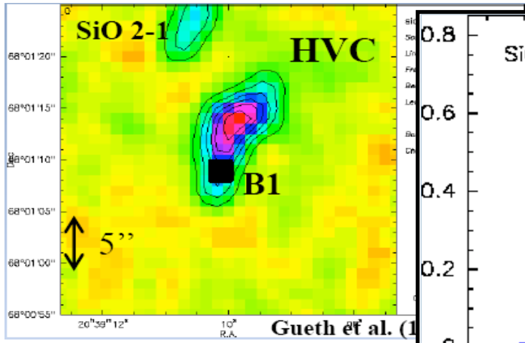


Lefloch et al. (2010) derived the physical condition from low-J_{up} CO lines:

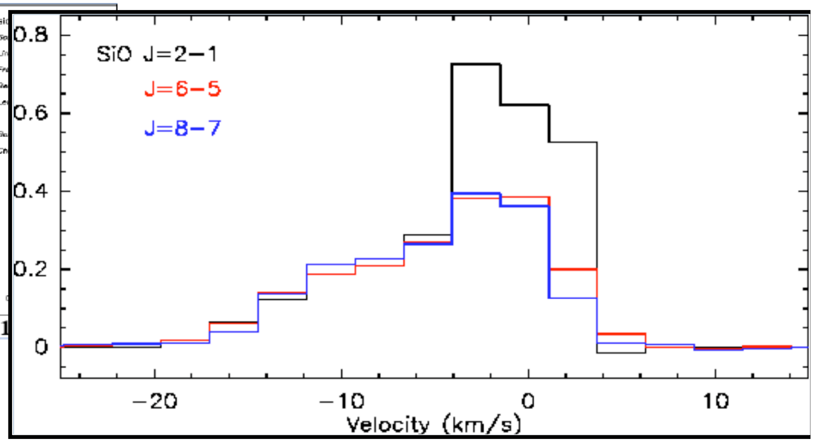
- Low-velocity component (LVC): -7< v < 4 km/s, molecular rich and relatively cold (T~100 K) and high density gas
- High-velocity component (HVC): -30< v <-7 km/s, molecular poor and associated with hot gas (T>400 K) at moderate densities

The high-velocity gas

Excellent match in the HV regime for high-J_{up} CO and SiO

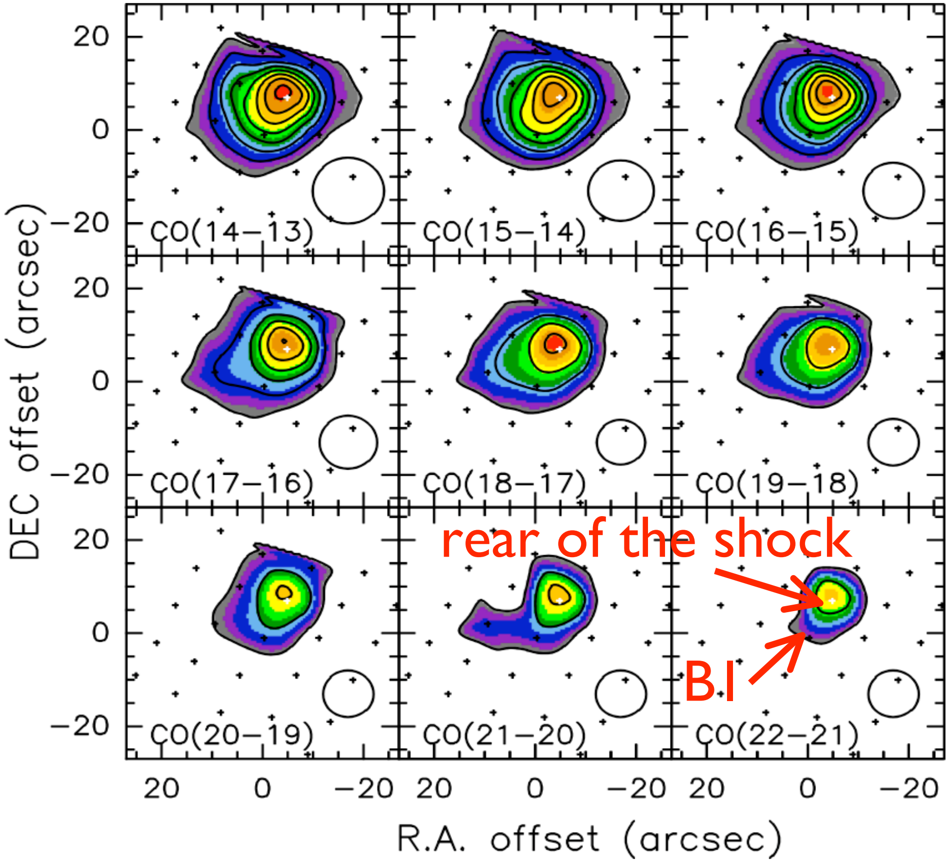


SiO HVC: size ~7''



PACS CO maps

(Benedettini, Busquet, Lefloch et al. 2012)



- PACS CO lines associated with HVC
- B1 position: PACS and HIFI data to constrain temperature and density using LVG model

$T = 200 - 600$ K

$n(H_2) > 10^5$ cm^{-3}

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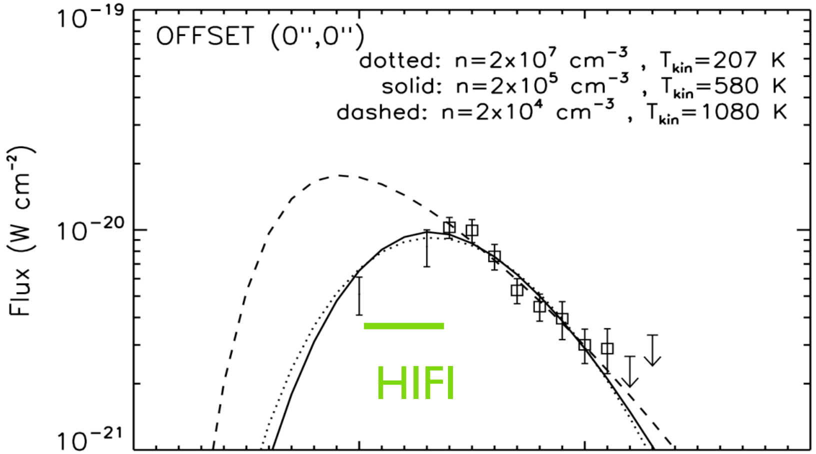
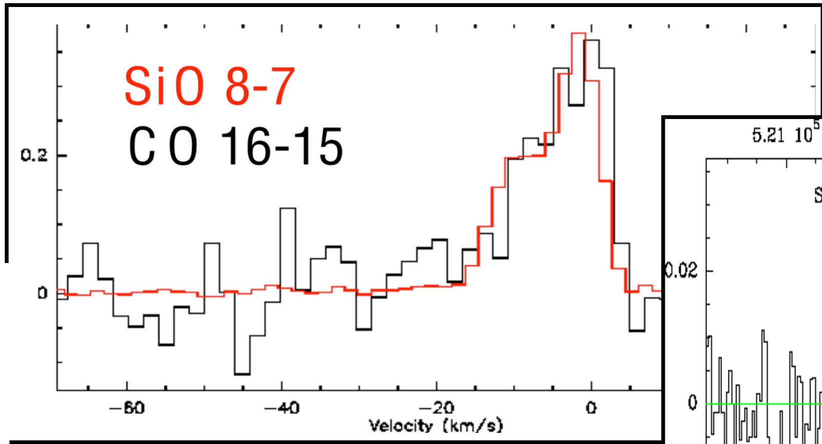
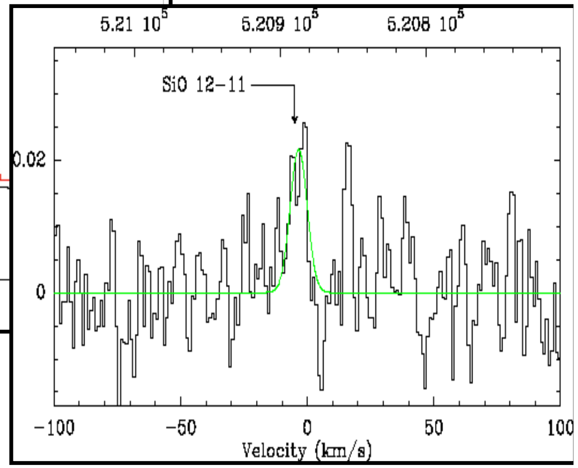
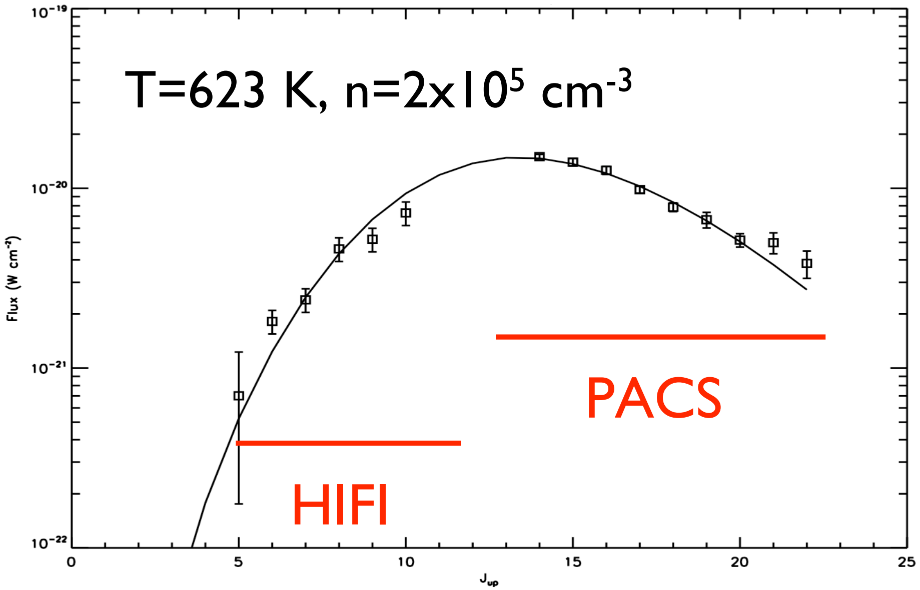
Excellent match in the HV regime for high-J_{up} CO and SiO









- PACS CO lines associated with HVC
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T= 200 - 600 K

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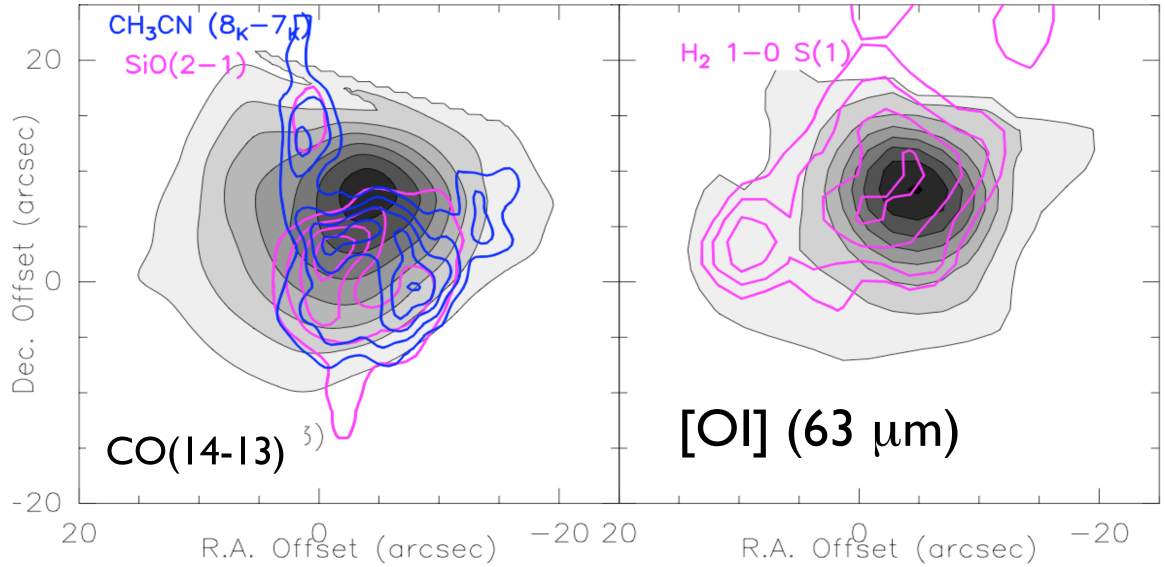
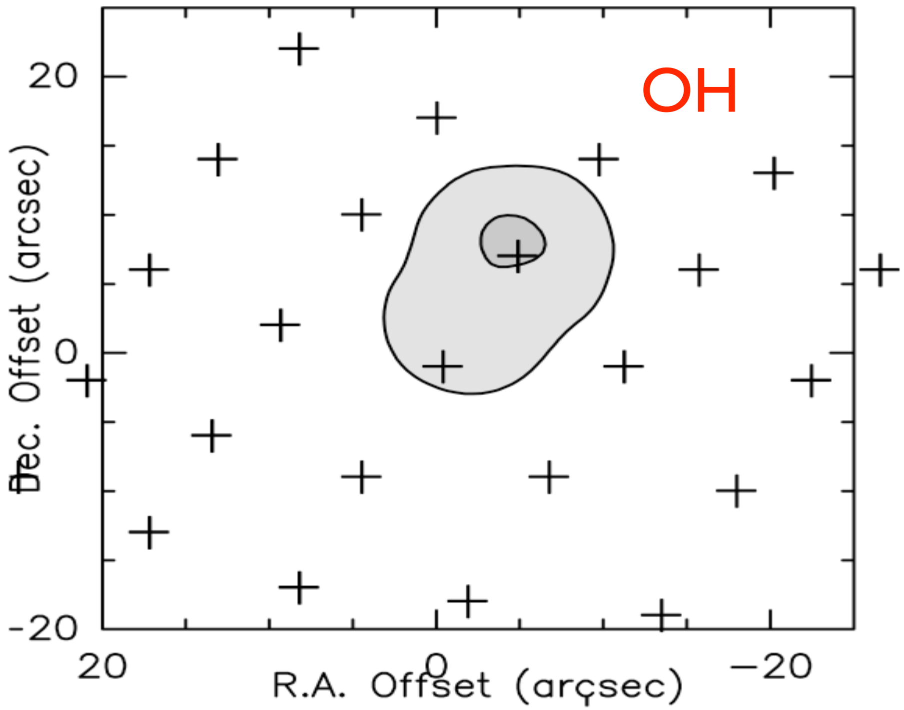
Shock structure and comparison with models

- OH and [OI] peak at the same position of CO, at the rear of the bow shock
- They also correlate with [FeII] (Neufeld et al. 2009)
- Tracers of postshock gas trace the extended bow shock



Benedettini et al. (2012); SiO: Gueth et al. (1998); CH_3CN: Codella et al. (2009): H_2: Caratti o Garatti et al. (2006)



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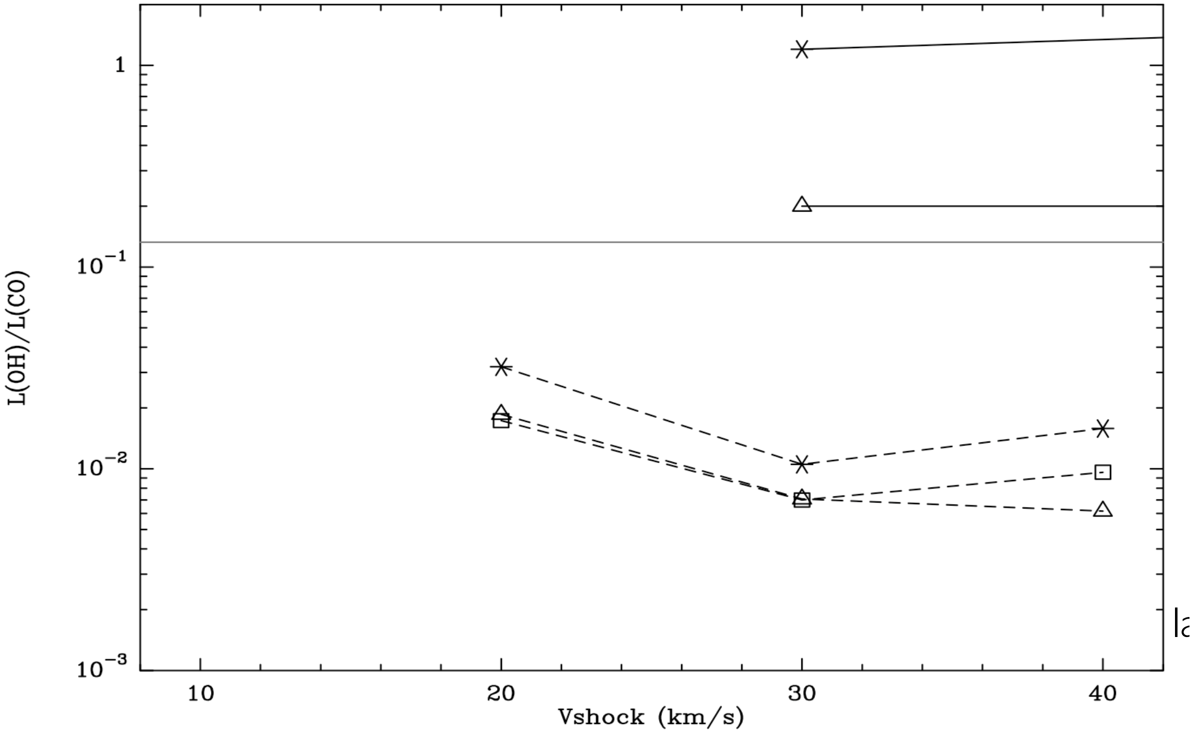
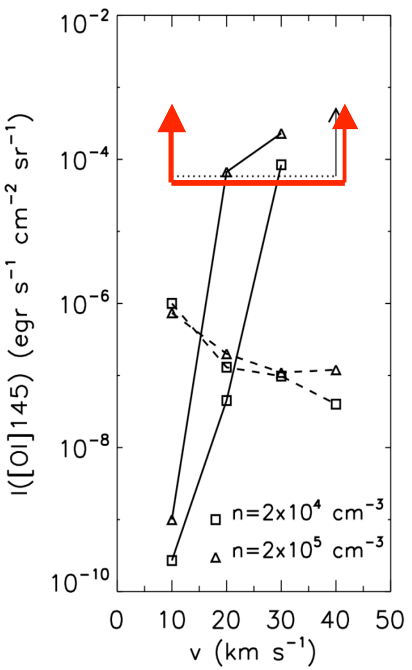
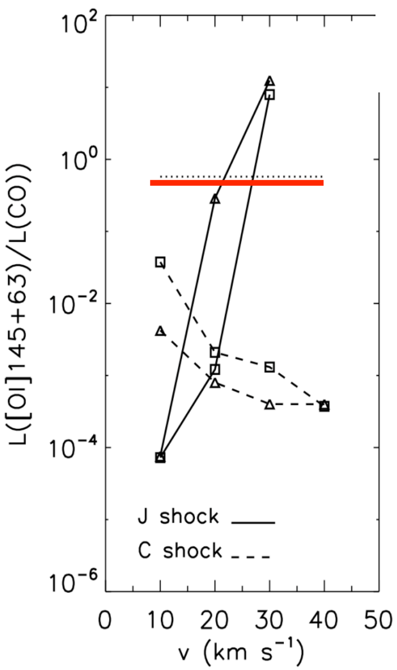


Shock models

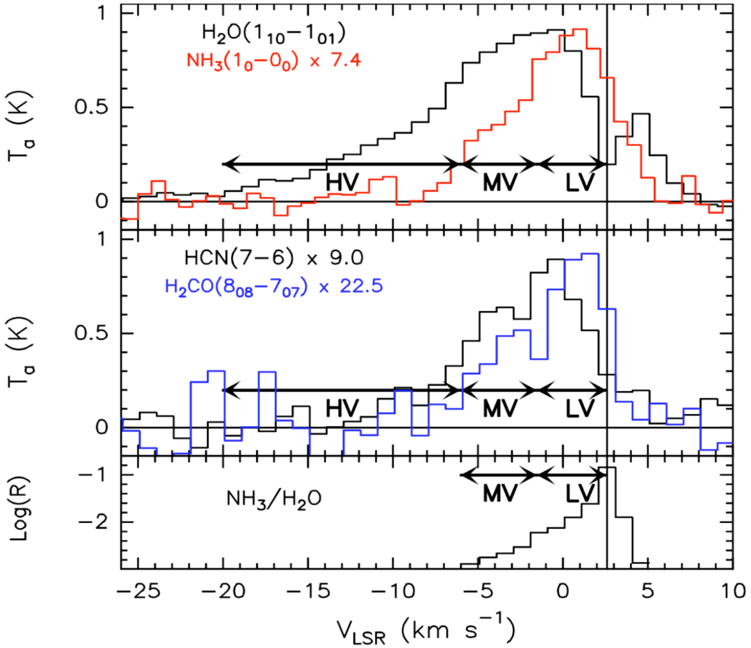
(Flower & Pineau des Forêts 2010, Neufeld & Hollenbach 1994)





[OI] brightness, total CO, OH and [OI] luminosity are consistent with dissociative J-type shock models

The low-velocity gas



- NH_3, H_2CO, and CH_3OH emit at low outflow velocities; H_2O is bright at high velocities (Lefloch et al. 2010, Codella et al. 2010)

Modelling of NH_3 and H_2O profiles (Viti et al. 2011) at B1 position:

UCL_CHEM (Viti et al. 2004) + parametric shock model (Jimenez-Serra et al. 2008)

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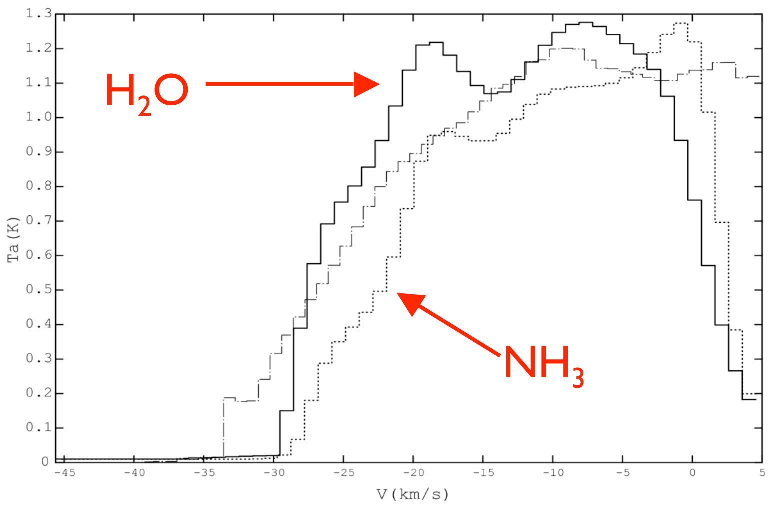
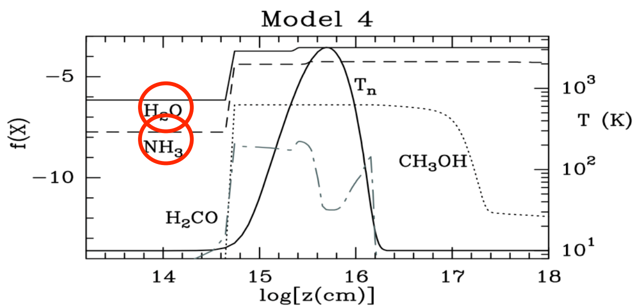


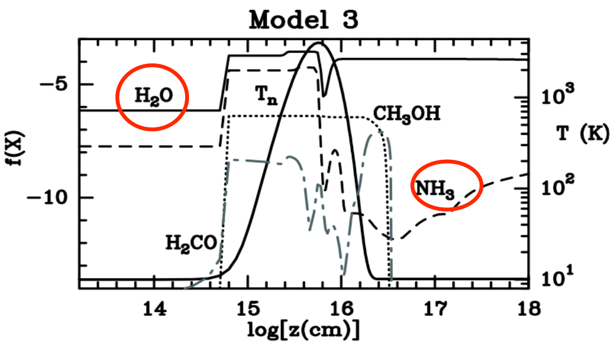
- NH$_3$, H$_2$CO, and CH$_3$OH emit at low outflow velocities; H$_2$O is bright at high velocities (Lefloch et al. 2010, Codella et al. 2010)

➢ **Modelling of NH$_3$ and H$_2$O profiles (Viti et al. 2011) at B1 position:**

UCL_CHEM (Viti et al. 2004) + parametric shock model (Jimenez-Serra et al. 2008)

Differences are purely chemical: NH$_3$ is destroyed at very high T while destruction of H$_2$O has very high barrier. Explained by C-type shock

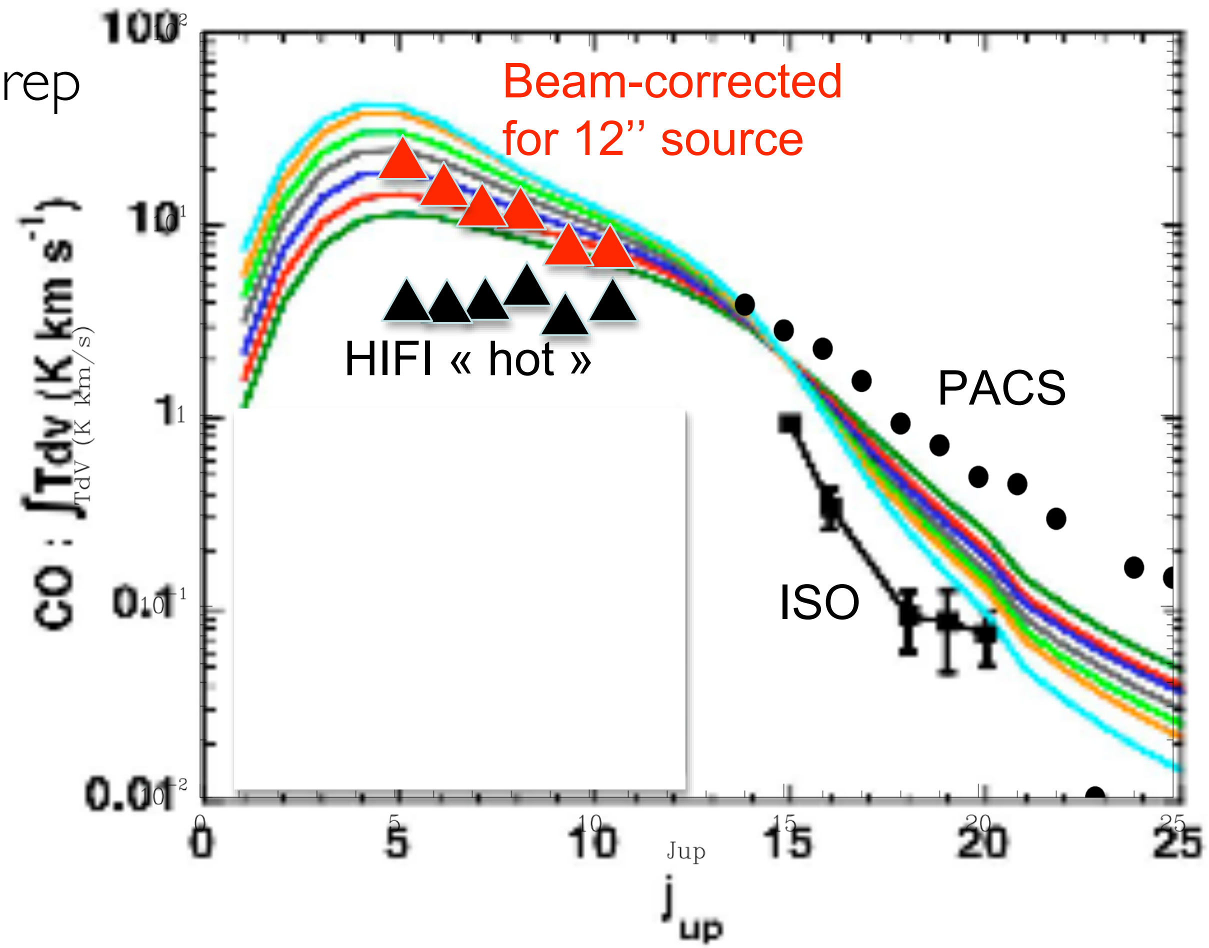




v_{shock}~40 km/s, n_H~10^5 cm^{-3}, T_{max}~4000 K

Comparison with C+J shock model that fits H_2 and SiO in L1157-B1 (Gusdorf et al. 08b)

Cabrit et al. in prep



Shock parameters: n_H = 10^4 cm^{-3}, Vs = 20 km/s, age ~1000 yrs, b = 0.45-2.0

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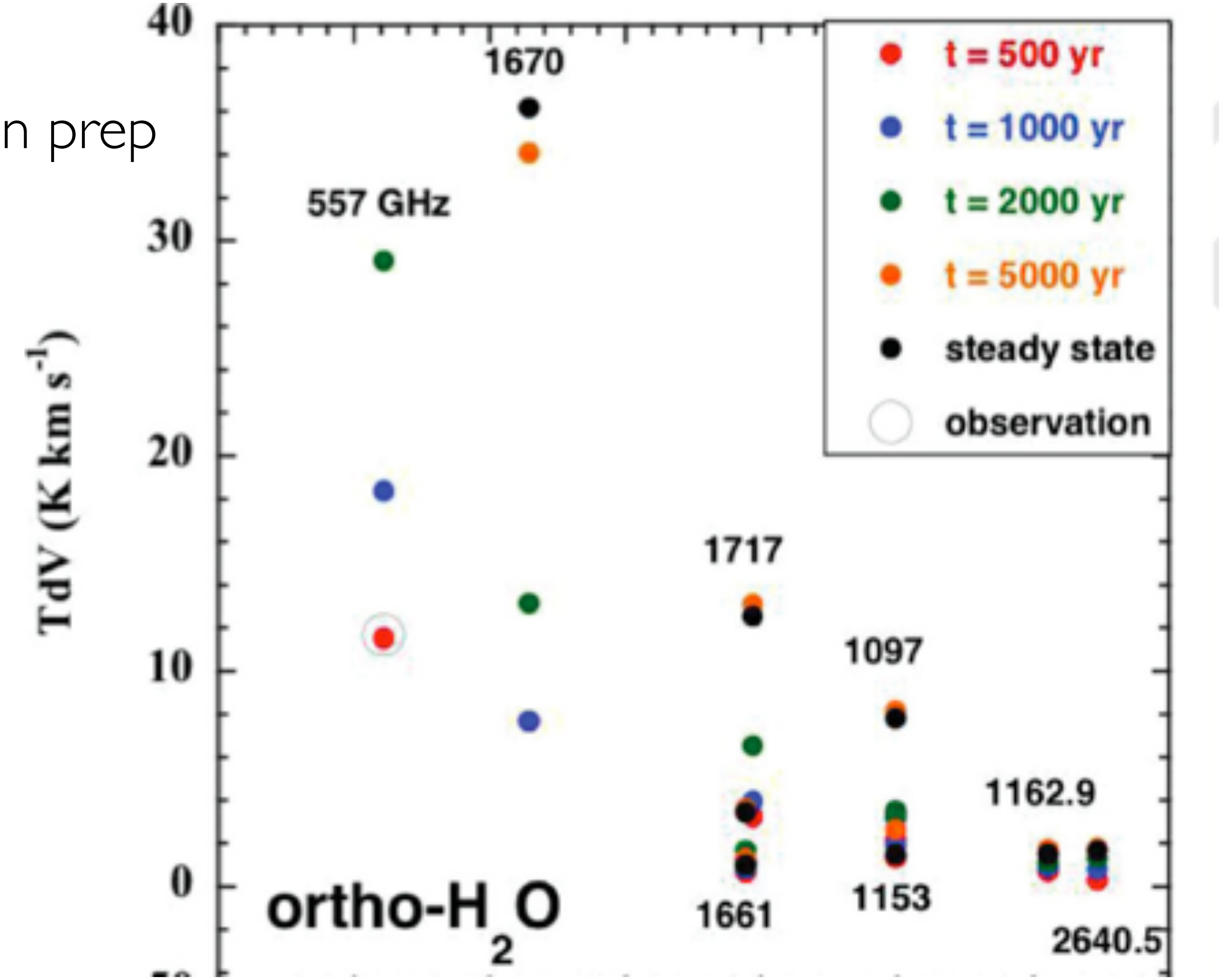

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✓ We obtained a complete chemical census of a shocked material in L1157-B1

✓ A comprehensive picture of outflow shock region L1157-B1 is emerging, showing a chemical and physical differentiation

✓ Two CO gas components are detected:

Hot component at T~600 K, $n(H_2)$~10^5 cm^{-3}

Warm component at T~130 K, $n(H_2)$~$2x10^5$ cm^{-3}

✓ Comparison with shock models suggests that the hot component, at the rear of the bow shock, arises from a dissociative J-type shock

✓ At the B1 position, NH_3 and H_2O line profiles agree with a C-type shock scenario

THANKS!