# WATER EMISSION TOWARDS THE CHEMICAL RICH OUTFLOW L1157: THE WISH SPECTRAL LINE SURVEY


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## The chemical active outflow L1157

**At a distance of 250 pc, the L1157 bipolar outflow is :**

- The ideal laboratory to observe the effects of shocks on the gas chemistry as it is chemically rich. (Bachiller & Pérez Gutiérrez 1997, hereafter BP97, Bachiller et al. 2001).
- Driven by a low-luminosity (~ 4 L☉) Class 0 protostar and associated with several blue-shifted (B0, B1, B2) and red-shifted (R0, R, R2) bow shocks.

**The two lobes (Fig. 1) are seen in CO (Gueth et al. 1998), and in IR $H_2$ images (e.g. Neufeld et al. 1994, Nisini et al. 2010):**

- Both outflow lobes, from their kinematical ages, appear to have been created simultaneously and have a symmetrical clumpy structure.

**Recently L1157-B1 Herschel observations (Codella et al. 2010, Lefloch et al. 2010):**

- Confirm the rich chemistry associated with the B1 position.
- Show bright $H_2O$ emission.

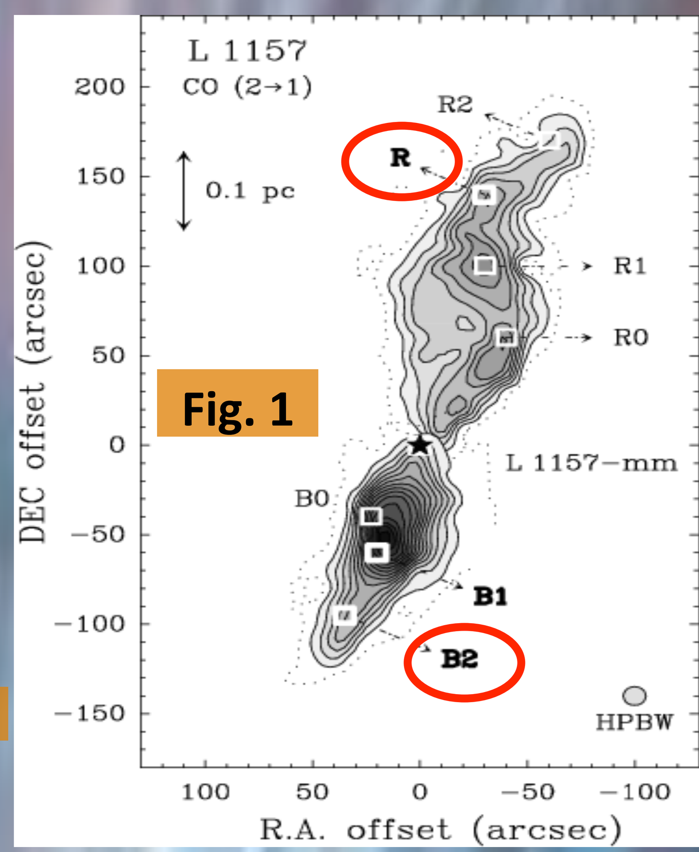


Fig. 1

Bachiller & Pérez Gutiérrez (2001)

**Our work:**

**We report the results of the Herschel-HIFI water line survey, from 500 to 1700 GHz, performed in two bow shock regions (B2 and R) towards L1157. Observations are obtained as part of the WISH key project.**

**The first aim is to use water lines analysis as a diagnostic of the physical conditions towards the blue (B2) and red-shifted (R) lobes to infer different excitation conditions.**

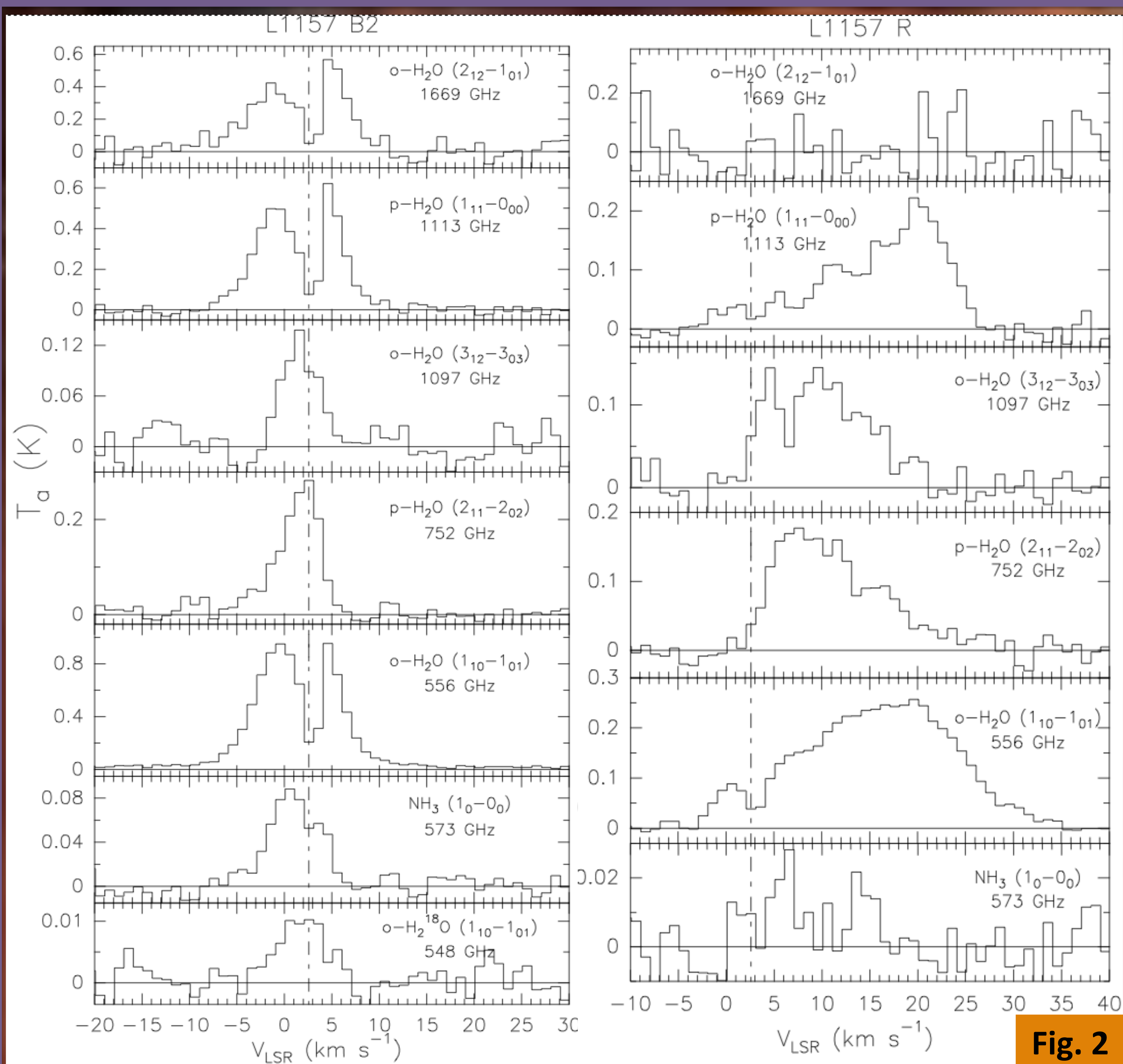


Fig. 2

## $H_2O$ in blue(B2) and red(R)-shifted lobes

**Observations :**

- 5 water emission lines with a wide range of excitation energies (27≤Eu≤215).
- o–$H_2$ $^{18}$O ($1_{10}$ −$1_{01}$ ) (observed only in B2) used to constrain the optical depth $\tau_{16}$ ~2 at the wings.

**The B2 and R spectra (Fig. 2) :**

- B2 spectra are associated with a narrower velocity range with respect to R spectra.
- B2 spectra show bright emission at systemic velocity while the bulk of the R emission is clearly red-shifted.
- Absorption dip in $H_2O$ lines with Eu≤80 K at the systemic velocity (B2).

**Clear dichotomy in R:**

- $H_2O$ transitions with Eu≤60 K peak at ~+20 km s$^{-1}$ .
- $H_2O$ transitions with Eu≥136 K peak at ~+10 km s$^{-1}$ .
- Surprisingly the high velocity emission is associated to the low excitation emission lines.

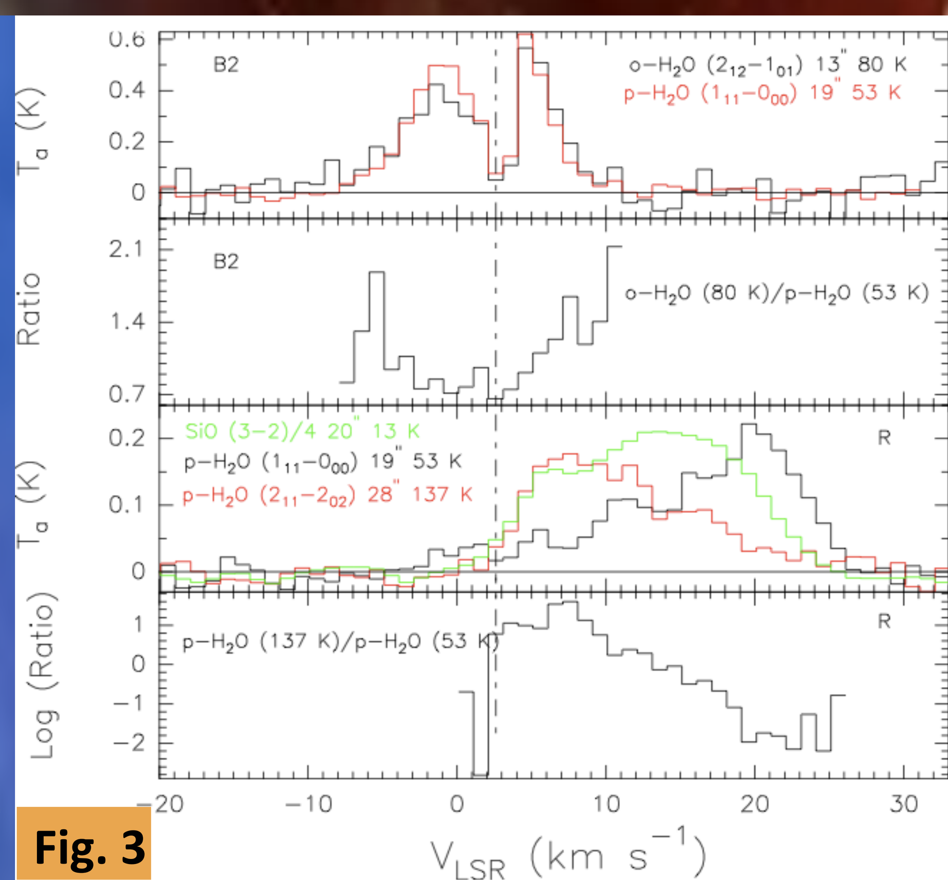


Fig. 3

**Fig. 3 Intensity ratios measured in B2 and R:**

- the o–$H_2O$ ($2_{12}$–$1_{01}$)/p–$H_2O$ ($1_{11}$–$0_{00}$) water ratio increases with velocity (B2)
- the p–$H_2O$ ($2_{11}$ –$2_{02}$)/p–$H_2O$ ($1_{11}$–$0_{00}$) water ratio decreases the velocity. This effect is due to the distinctive dichotomy that was observed. (R)
- SiO does not show the dichotomy and peaks where the $H_2O$ emission is fainter.

## Excitation Analysis: Results and Discussion

**To constrain the physical parameters ($T_{kin}$, $N_{H2O}$ and $n_{H2}$ ) of $H_2O$ emissions:**

- We ran the plane parallel RADEX non-LTE model (van der Tak et al. 2007) using orto/para=3 ratio, 50<$T_{kin}$<1000 K, 5*10$^{12}$ <$N_{H2O}$<5*10$^{17}$ cm$^{-2}$, 10$^4$ <$n_{H2}$<10$^8$ cm$^{-3}$.
- To correct for the unknown emitting size regions we assume three different sizes 3'', 15'' and 30''.

**Non-LTE RADEX model predictions against integrated flux $H_2O$ ratios. Each coloured curve corresponds to the labeled $N_{H2O}$ (see insert at the top- left corner). $H_2$ density increases from right to left as the values labeled. Triangles with error bars indicate the size of the emitting region (30'', 15'', 3'' ) The green triangle represents the $n_{H2}$ =5*10$^5$ cm$^{-3}$ of SiO, in the case of B2 and $n_{H2}$=10$^6$ cm$^{-3}$ , in the case of R, fitted by Nisini et al. (2007).**

**Fig 4 L1157 B2**

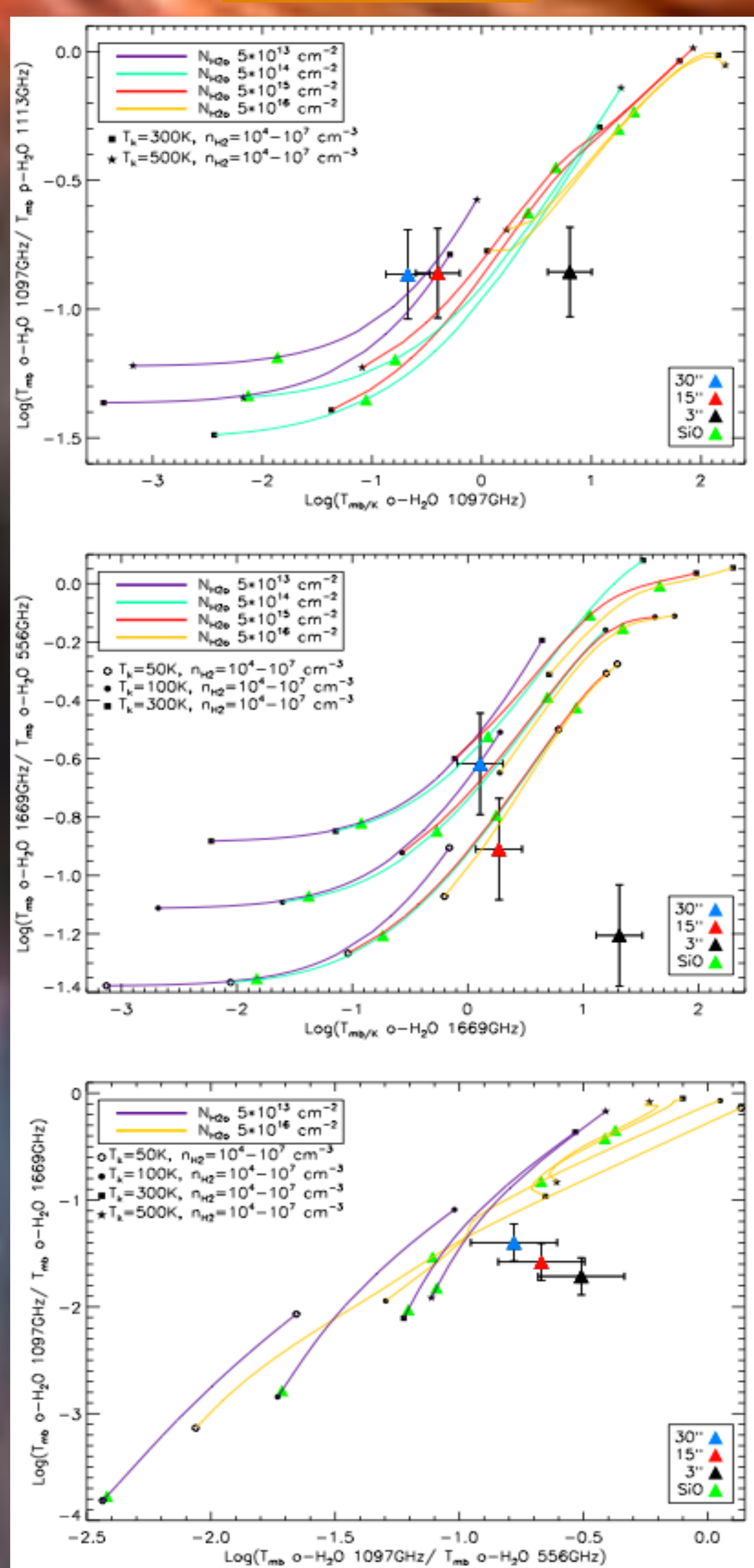


**Fig. 5 L1157 R**

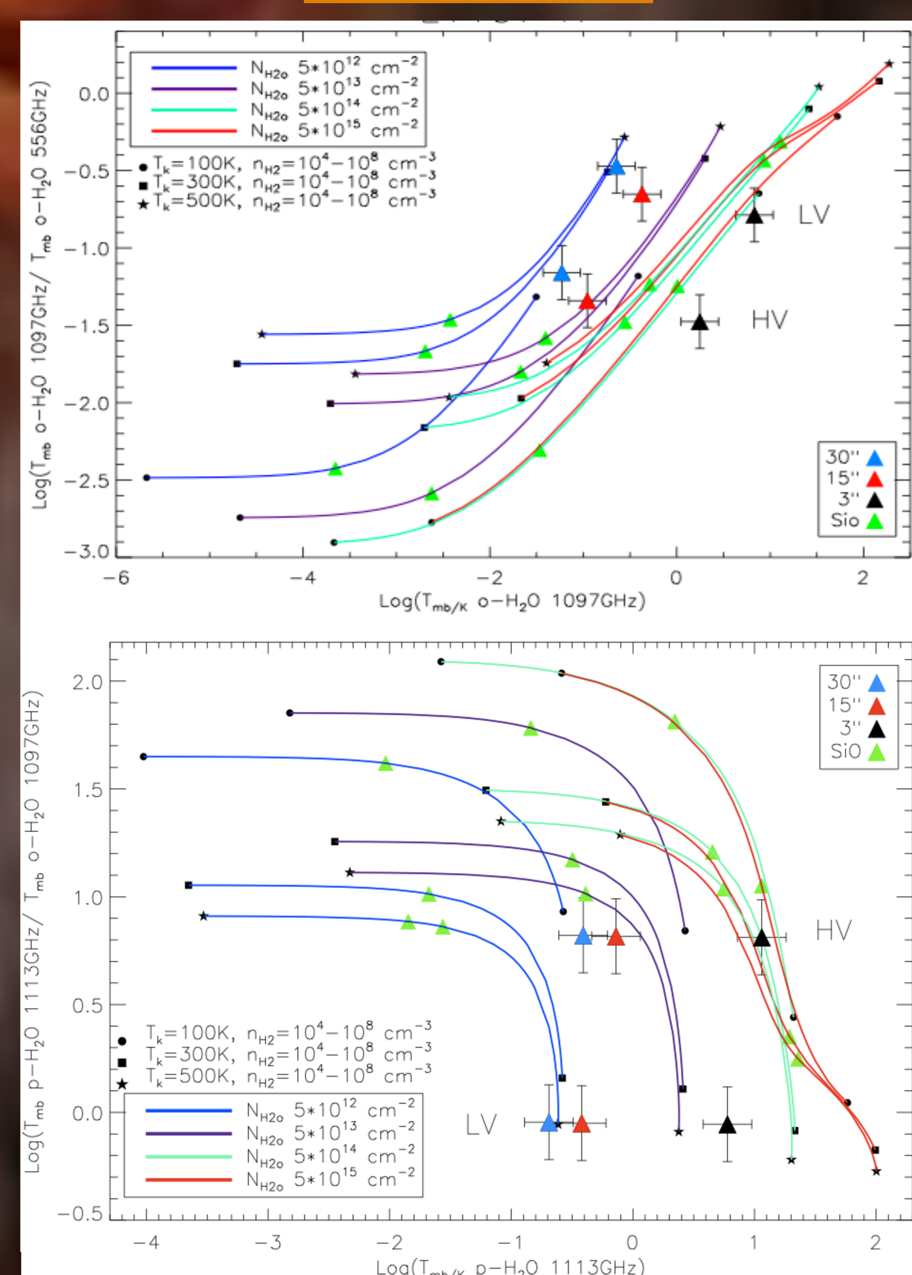


**Fig 4 L1157 B2:**

- size closer to >15'' in agreement with the L1157 $H_2O$ PACS map by Nisini et al. (2010 ) (bottom panel, Fig 4).

**Observed $H_2O$ ratio well constrained for:**

- low values of column density $N_{H2O}$ ≤5*10$^{13}$ cm$^{-2}$ (top panel)
- density range of 10$^5$ ≤$n_{H2}$ ≤10$^7$ cm$^{-3}$ is inferred from all panels.
- Temperature value of $T_{kin}$ ≥300 K.

**Fig 5 L1157 R:**

**Two different components are modelled (hereafter called LV, at ~+10 km s$^{-1}$, and HV, at ~+20 km s$^{-1}$ ).**

- LV associated with higher excitation conditions with respect to the HV.
- A compact region is not excluded as in the case of B2.
- HV water ratio traces the gas with $T_{kin}$ ≥100 K and $n_{H2}$~10$^6$ cm$^{-3}$ , $N_{H2O}$ ~5*10$^{13}$ cm$^{-2}$ as well as $n_{H2}$~10$^8$ cm$^{-3}$ , $N_{H2O}$ ~5*10$^{12}$ cm$^{-2}$.
- LV water ratio traces a very dense gas with $n_{H2}$~10$^8$ cm$^{-3}$, temperature $T_{kin}$≥300 K and column density 5*10$^{12}$≤$N_{H2O}$ ≤5*10$^{13}$ cm$^{-2}$.

**Similar warm and high density conditions for the LV are found also on the L1448 outflow (See Santangelo et al. poster 77 session I IAU)**

## Conclusions

**$H_2O$ WISH spectral survey in the 500–1700 GHz band in L1157 B2 and R:**

- For the first time a surprising dichotomy at different excitations, in R, where two emission peaks (LV and HV) can be distinguished. The LV component is associated with higher excitation. The low column density (5*10$^{12}$≤$N_{H2O}$ ≤5*10$^{13}$ cm$^{-2}$) and the high $n_{H2}$~10$^8$ cm$^{-3}$ are more consistent with J-shocks where high compression factors and low water abundances are expected.
- For the HV (R) we estimated the $H_2O$ abundance of ~10$^{-6}$ using the N($H_2$) estimated by Nisini et al. (2007).
- We estimate, from the absorption dip in B2, an opacity of the absorbing layer ~1 when neglecting the $H_2O$ emission due to the foreground gas.
- The comparison between the SiO(3-2) emission profile (green profile in Fig 3) and the $H_2O$ profiles suggests that these molecules are tracing different gas portions and they are associated with different excitation mechanisms. Note that the density inferred by $H_2O$ in LV (10$^8$ cm$^{-3}$ ) is definitely larger than what derived with SiO (green triangles in Fig.5)


**References:**

Bachiller et al. 2001 A&A 372 899 – Bachiller R. & Peréz Gutièrrez M. 1997, ApJ 487, L93 (BP97) - Gueth et al. 1996 A&A 307 891- Codella et al. 2009 A&A 507 L25 - Codella C. et al. 2010, A&A 518, L112 - Nisini et al. 2007 A&A 462 163 - Nisini et al. 2010, A&A, 518, L12 - Gueth F. et al. 1998, A&A 333, 287 - Lefloch B. et al. 2010, A&A 518, L113 - Neufeld D.A. & Green S. 1994, ApJ 432, 158 - van der Tak F. F. S. et al.2007, A&A, 468, 627