WATER EMISSION FROM THE CHEMICAL RICH OUTFLOW L1157

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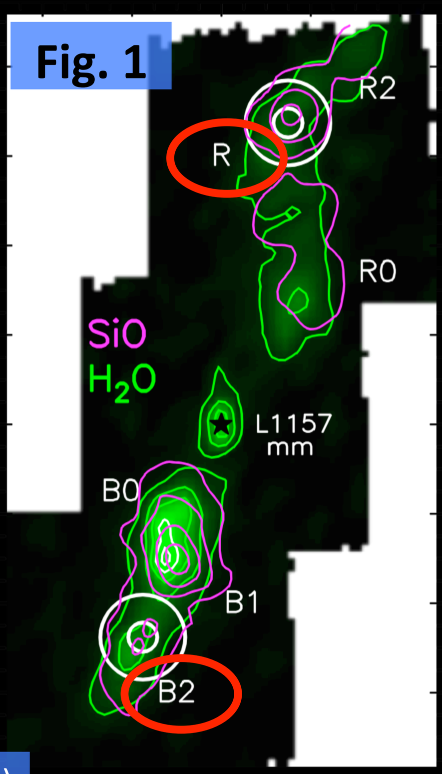
Our work:
We report the results of the Herschel-HIFI water line survey, from 500 to 1700 GHz, performed in two bow shock regions (B2 and R) towards L1157.
Observations are obtained as part of the WISH key project.
The first aim is to use water lines analysis as a diagnostic of the physical conditions towards the blue (B2) and red-shifted (R) lobes to infer different excitation conditions.

Fig. 1



Nisini et al. (2010)

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.

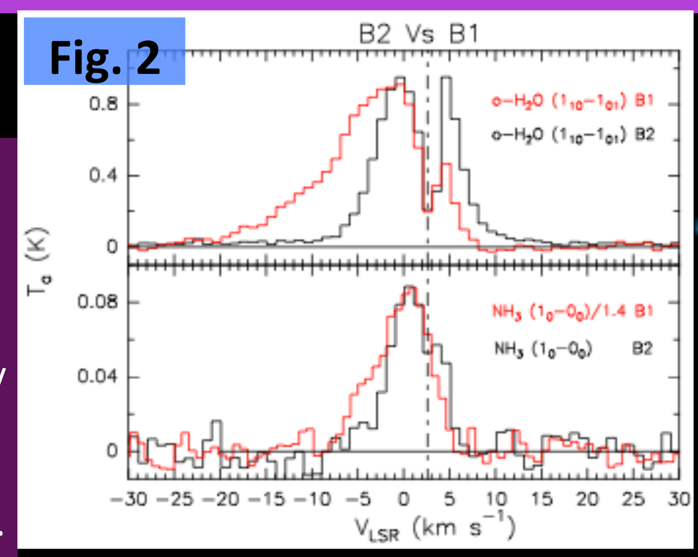
The two lobes (Fig. 1) are seen in SiO (Bachiller et al. 2001), CO (Gueth et al. 1998), and in IR H_2 images (e.g. Neufeld et al. 1994, Nisini et al. 2010):

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

Recently L1157-B1 CHESS-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. 2



B1 versus B2: (Fig. 2)

- The 557 GHz profile observed at B2 is associated with a much narrower wing than that observed in B1, This could be an indication of lower shock velocities at B2.
- B2 has a broader red wing than B1, supporting the idea that the profiles are strongly affected by geometrical effect

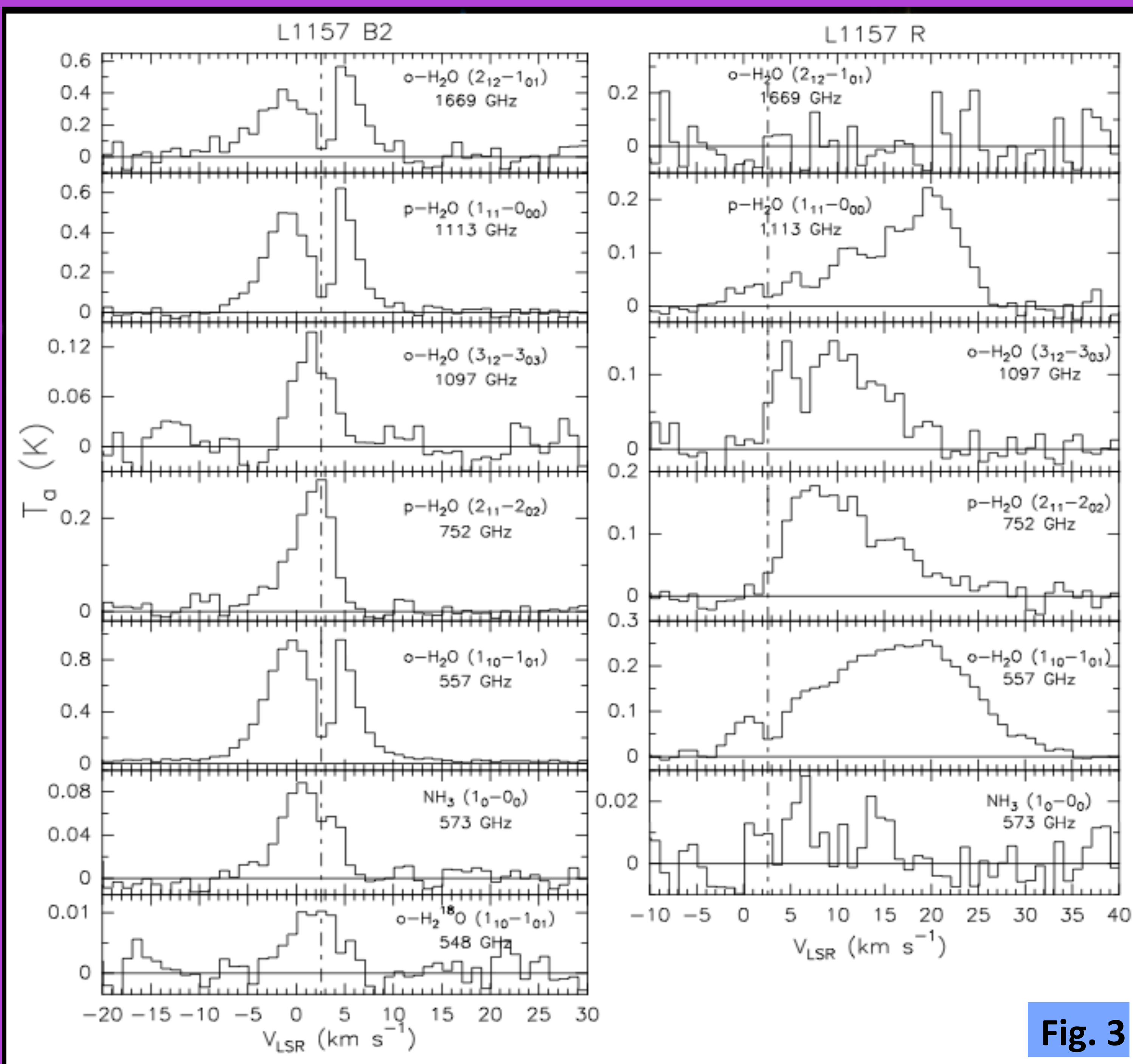


Fig. 3

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

Observations :

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

The B2 and R spectra (Fig. 3):

- 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.

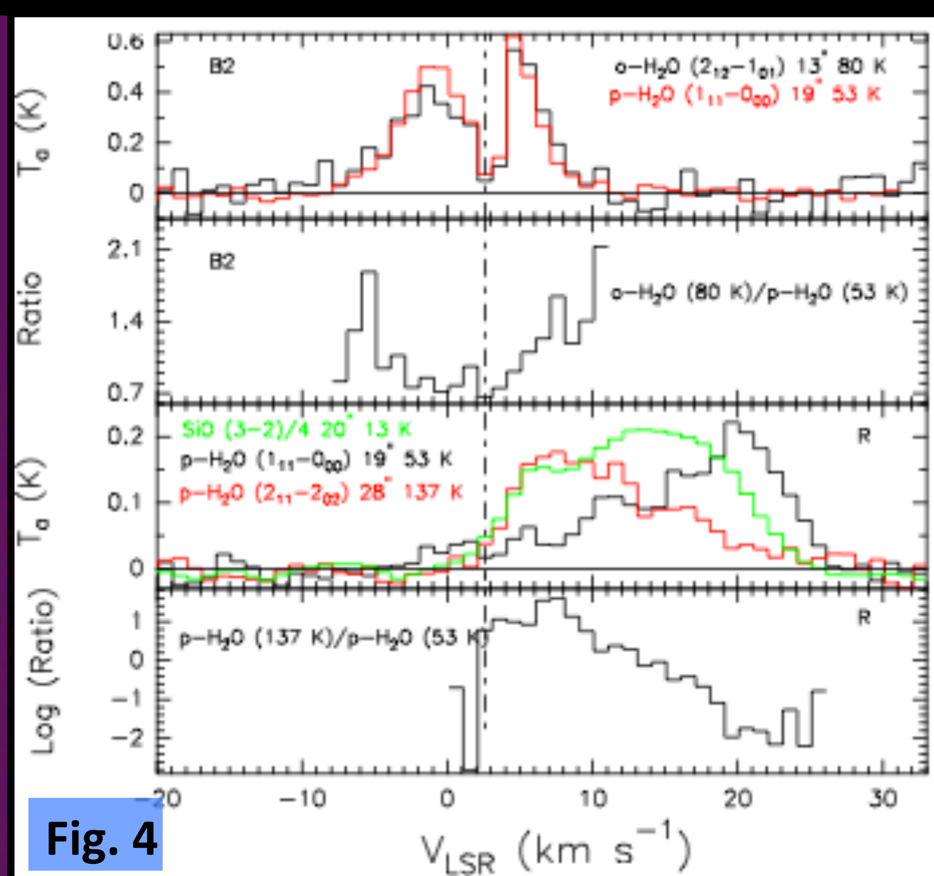


Fig. 4

Fig. 4 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 (green line) 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, coll rates Faure, A. 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 left to right as the values labeled. Triangles with error bars indicate the size of the emitting region (30'', 15'', 3'')

Fig 5 L1157 B2:

- size closer to >15'' in agreement with the L1157 H_2O PACS map by Nisini et al. (2010) (bottom panel, Fig 5).

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 6 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}.

Fig. 5 L1157 B2

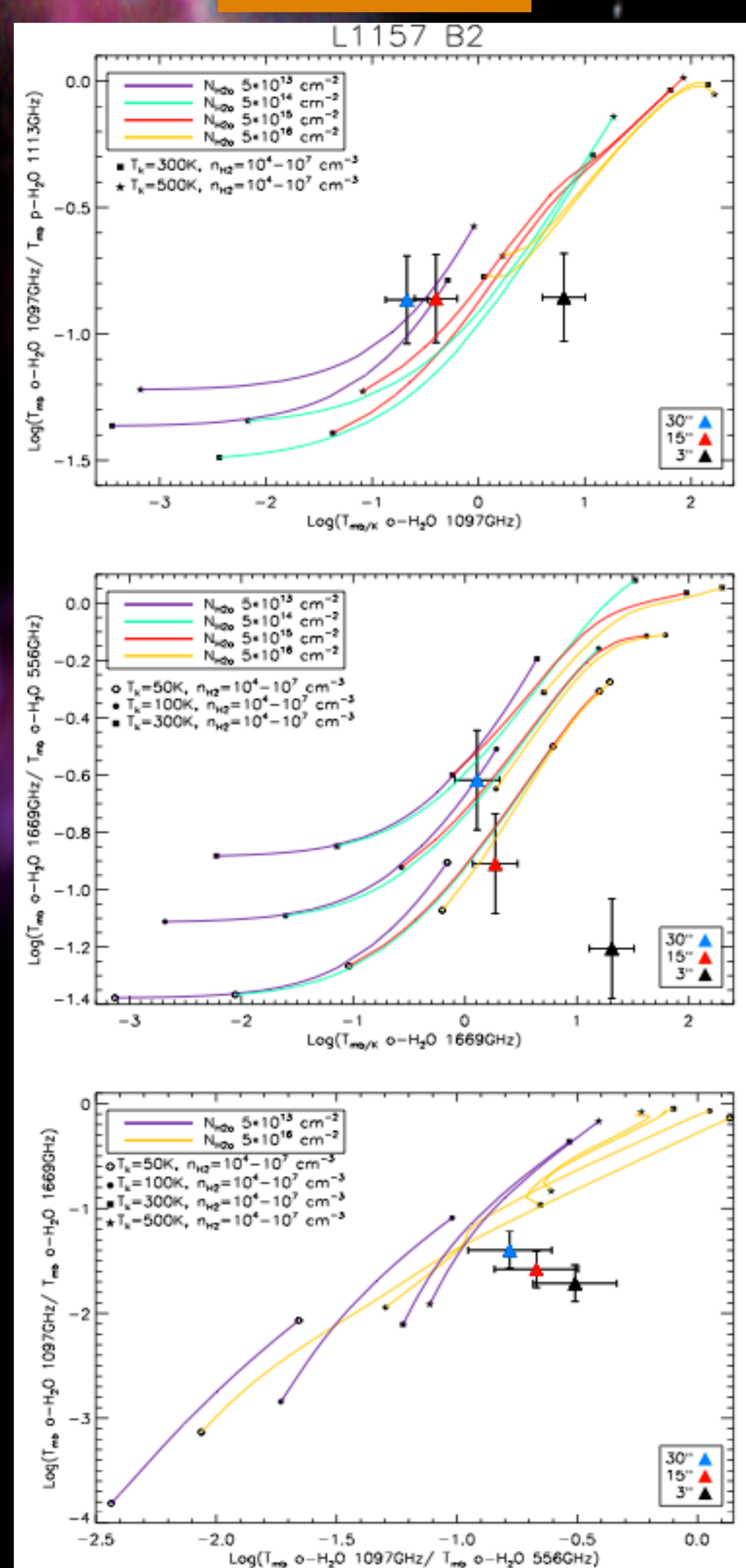
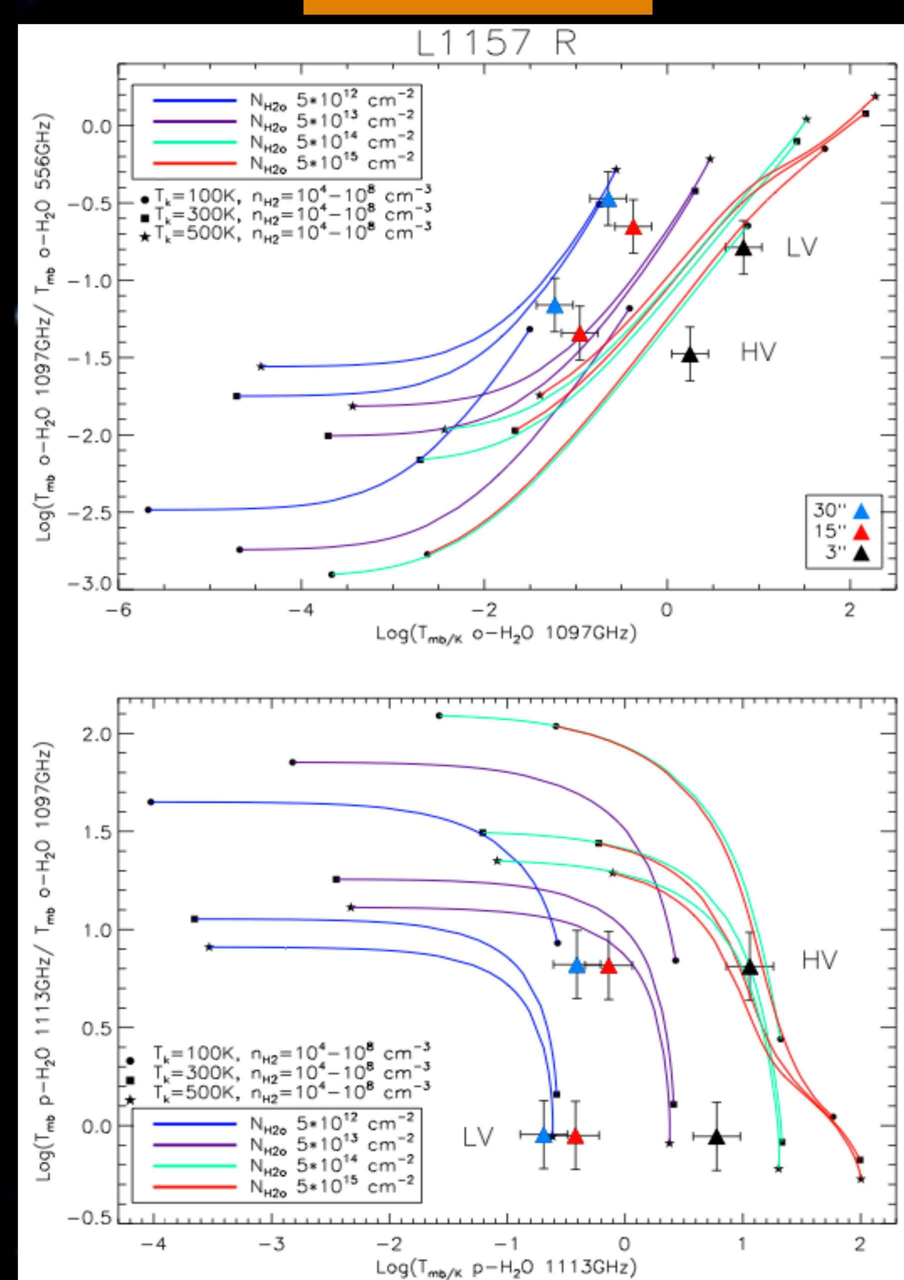


Fig. 6 L1157 R



Similar warm and high density conditions for the LV are found also on the L1448 outflow (See Santangelo et al. 2012)

Conclusions

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

- The comparison between H_2O and SiO profiles, and their physical characteristics casts serious doubt on the assumption that emission from these species has a similar physical origin.
- We have derived H_2O abundances of R ~10^{-6} –10^{-7} and for B2 ~10^{-6}. This result is consistent with the water abundance found at B1 at low velocities. On the other hand, the X(H_2O) measured at the highest velocities in B1 is two orders of magnitude greater than in B2 (~10^{-4}). These differences could provide evidence for an older shock in B2 compared to that in B1.
- The emerging scenario highlights the importance of J- shocks, which are expected to be associated with a thin layer and very densely compressed material in these environments. The results found in R are comparable with those obtained by Santangelo et al. (2012) in the L1448 outflow. These low water abundances could support the possibility of having a J-shock instead of a C-shock.
- Interestingly, the highest excitation conditions are observed at low velocities. However, if we were to assume that high excitation is tracing portions of gas near the shock, we could assume that we have observed a very collimated region located along the plane of the sky., where the fast collimated gas should be re- projected and thus have lower radial velocities. Also, a less excited region could be more extended with a wider velocity range due to the geometry.

References:
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