Observing water in proto-stellar outflows with Herschel: the case of L1448

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I. Introduction

H2O is one of the most abundant molecules in star-forming regions and a unique probe of the physical properties and the chemical processes in proto-stellar outflows. In the framework of the WISH (“Water In Star-forming regions with Herschel”) key program, we present Herschel observations of H2O towards the outflow driven by the L1448 low-mass proto-stellar system, located in the Perseus cloud (d=235 pc).

The instruments on board the Herschel Space Observatory, providing both high spatial and spectral resolution over a large wavelength range, are ideal to study the kinematics and the physical conditions of the warm shocked gas.

II. Observations: HIFI & PACS maps

The L1448 outflow has been mapped, with the HIFI and PACS instruments (Fig.1), in the ortho-H2O J=1-0 557 GHz and para-H2O J=2-1 1670 GHz lines respectively.

The outflow from the L1448-C source is well delineated by the H2O in the ortho-H2O 2-1 line (557 GHz), while the para-H2O 1-0 line (1670 GHz) is seen in absorption. The comparison between H2O and CO suggests that H2O is a unique probe of the gas component at intermediate velocities (10–40 km s⁻¹).

III. Observations: HIFI line survey

Several ortho- and para-H2O lines have been observed in R4 and B2 along L1448 (Fig.1) with HIFI. The aim was to study the H2O excitation conditions in the shocked gas, exploring excitation variations with velocity.

IV. Excitation Analysis

The excitation conditions of the gas in R4 and B2 along the L1448 outflow have been analyzed (Fig 3). The two velocity components in R4 ([R4-LV and R4-HV]) and B2 have been studied separately.

R4: in R4-LV the lines are reproduced (within the errors) only considering a very high-density (n(H2)=10⁶ cm⁻³) and extended gas with T=500–600 K (green); while they are not fitted by the lower density gas component (n(H2)=10⁴ cm⁻³) inferred from the SiO (Nisini et al. 2007) emission (blue).

The lower excitation of R4-HV in respect to R4-LV could be due to either a lower Td (~150 K) or a lower n(H2) (~10⁵ cm⁻³) (red).

B2: we derived velocity-averaged physical conditions that again point towards a warm (T=400–500 K) and dense (n(H2)=10⁷–10⁸ cm⁻³) gas.

V. Conclusions

Herschel observations of H2O emission towards the outflow driven by the L1448 low-mass proto-stellar system have been presented, as part of the WISH key program:

• H2O appears to be unique in tracing gas components at intermediate velocities (10–40 km s⁻¹).
• The two investigated positions (R4 and B2) show strong variations in the excitation conditions as a function of velocity.
• The observed emission is best represented by a very dense (n(H2)=10⁵–10⁶ cm⁻³) and warm (T=400–500 K) gas, having moderate H2O column densities: N(H2)=(10⁴–10⁵) cm⁻² in R4-LV and 10⁵–10⁶ cm⁻² in R4-HV and B2, corresponding to H2O/H2=(10⁻⁴–10⁻³) and H2O/H2=(10⁻⁴–10⁻³) in B2 and 2 (10⁻⁴–10⁻³) in R4 after comparison with the derived from Spitzer observations (Giannini et al. submitted). Similar results are found also in Vasta et al. paper on L1157 (n-96 session 2).
• These physical conditions are better reproduced by a J-type shock, where high-density compression factors are expected. Also, the relatively low observed column densities are consistent with models where H2O is dissociated.

References: