# Water in massive star-forming regions: HIFI observations of W3 IRS5

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## Introduction

Understanding how the accretion of matter overcomes radiative pressure in massive protostars is a major astrophysical problem that can be addressed by studying the water molecule. In the cool regions of molecular clouds (T < 100 K), water is present as ice in the mantles of dust grains. However, in the immediate surroundings of high-mass protostars, the dust is heated to temperatures well above 100 K, evaporating the ices and increasing the gaseous water abundance by several orders of magnitude, making water one of the most abundant molecules. Due to the abundance jump, water makes it possible to specifically study the inner regions from which the massive protostar accretes.

## The Source

We report water observations of the region W3 IRS5, which is a bright infra-red source located in the active star-forming region W3 in the Perseus arm at a distance of 2.0 kpc. Its high FIR luminosity (1 - 2x10$^5$ L$_\odot$) and the detection of radio emission indicates that W3 IRS5 hosts high-mass stars in an early stage of evolution (Fig. 1).

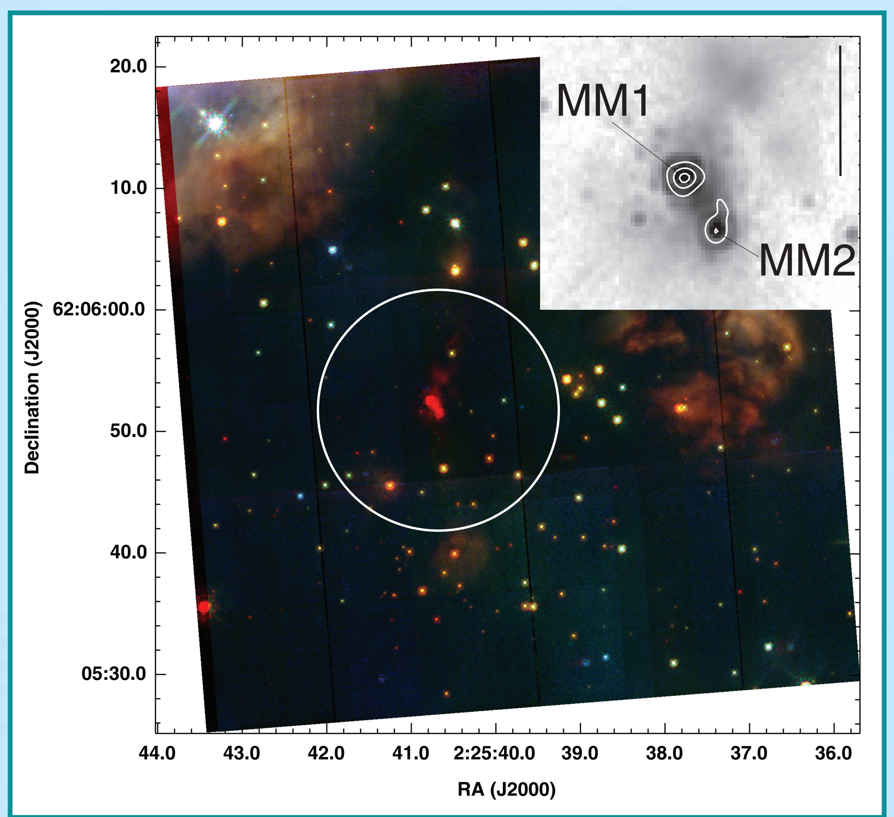


Figure 1: NICMOS color-composite image of W3 IRS5 and its surroundings from Megeath et al. (2005). The white circle represents the HIFI beam size at 1100 GHz (20''). The gray-scale inset is a close-up of the central area at 2.2 microns with white contours corresponding to 30, 60 and 90% of the peak flux at 1.4 mm (Rodon, 2008). There are 2 sources, MM1 and MM2 that dominate the millimetric emission inside the HIFI beam. The black bar (top right of inset) represents a distance of 5.000 AU (2.5'').

## Observations

We observed 11 water lines with the Heterodyne Instrument for the Far-Infrared (HIFI), mounted on the Herschel Space Telescope. We covered a frequency range from 552 to 1670 GHz. The observations are part of the Guaranteed-Time Key Program Water In Star-forming regions with Herschel (WISH; van Dishoeck et al. 2010). Data were taken simultaneously in H and V polarizations using both the Wide-Band Spectrometer (WBS) with 1.1 MHz resolution and the High-Resolution Spectrometer (HRS) with 480 kHz resolution (resolutions of 0.30 and 0.13 km/s, respectively, for the 1100 GHz lines). Data were calibrated using the Herschel Interactive Processing Environment (HIPE). Further analysis was done with CLASS.

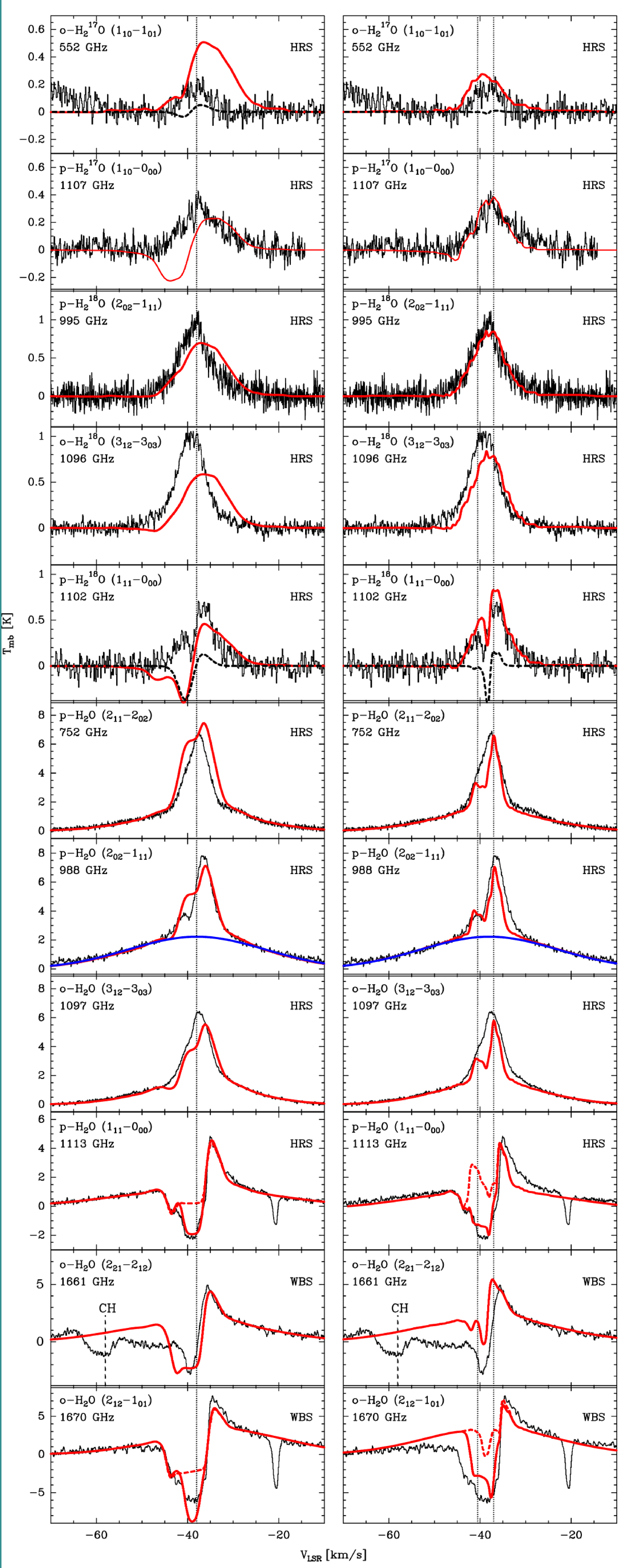

Figure 2: HIFI spectra of water lines observed in W3 IRS5. The single protostellar envelope model fits are shown as red lines over the spectra on the left side. The two-protostellar envelopes model is shown as red lines over the spectra on the right side. The dashed red line over the 1113 and 1670 GHz spectra show the corresponding model without the cold molecular cloud. The dashed black line over the 552 and 1102 GHz spectra shows the model without the abundance jump. Vertical dotted lines indicate the $V_{LSR}$ at -38 km/s for the single protostellar envelope model and -37 and -40.5 km/s for the two protostellar envelopes model. Vertical dashed lines in the 1661 GHz spectra show the position of the CH line. As an example, the outflow component for the 988 GHz line is shown in blue.

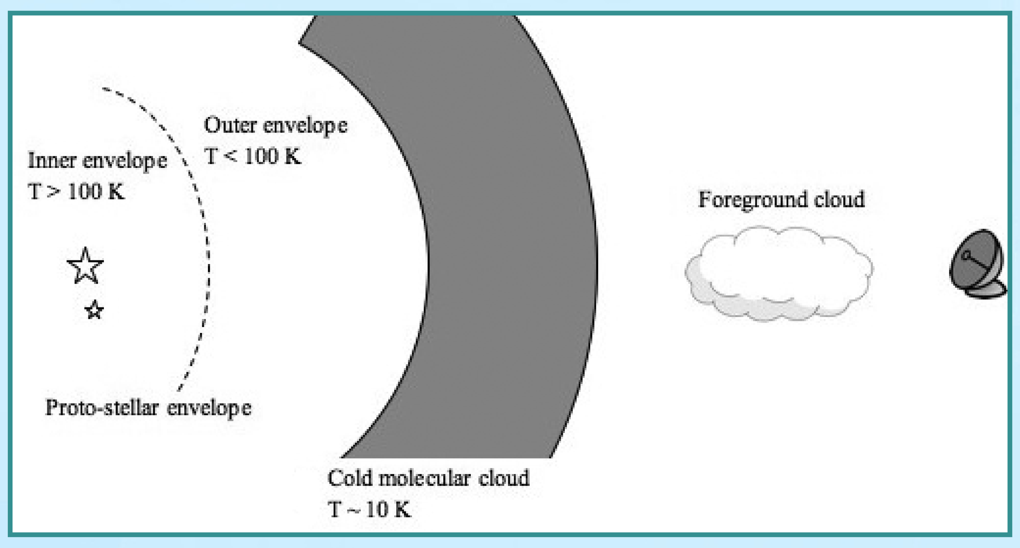


Figure 3: Schematic representation. The protostellar envelope (inner + outer envelope) is embedded in a cold molecular cloud.

## Modeling

We used the Monte Carlo code MC3D (Wolf, 2003) and the radiative transfer program RATRAN (Hogerheijde & van der Tak, 2000) to model the water emission in W3 IRS5 in 1 dimension. Our models have three components: an outflow, one (or two) protostellar envelopes, and a cold cloud. Three parameters are used to fit the line profiles in the envelope model: water abundance, turbulent velocity, and expansion velocity (see Table 1).

**Table 1.** Parameters of single and two protostellar envelope (PE) models.

| Parameter | Single PE | PE 1 | PE 2 |
|---|---|---|---|
| Outer radius (AU) | 12000 | 12000 | 12000 |
| Luminosity ($L_\odot$) | $10^5$ | $5 \times 10^4$ | $5 \times 10^4$ |
| Mass ($M_\odot$) | 250 | 125 | 125 |
| $X_{H_2O}$ | $2 \times 10^{-8}$ | $1.8 \times 10^{-8}$ | $8 \times 10^{-10}$ |
| Post-jump $X_{H_2O}$ | $1 \times 10^{-4}$ | $1 \times 10^{-4}$ | $1 \times 10^{-4}$ |
| $V_{tur}$ (km s$^{-1}$) | 2.0 | 0.4 | 0.5 |
| $V_{exp}$ (km s$^{-1}$) | 2.0 | 1.1 | 1.2 |
| $V_{LSR}$ (km s$^{-1}$) | –38 | –37.0 | –40.5 |

## Results

- We detect strong water emission and absorption.
- A strong outflow component is detected in the water lines.
- Water emission shows absorption from cool molecular gas hosting the protostellar envelope. Blueshifted absorption suggests an expansion of the outer envelope, and no infall signature is detected.
- Radiative transfer models indicate water abundances ranging from $10^{-8}$ to $10^{-10}$ in the outer envelope.
- Based on our model, a jump in water abundance in the inner envelope is needed to reproduce the $H_2{}^{17}O$ and $H_2{}^{18}O$ lines.
- The optically thin line profiles are better fit using a model with two protostellar envelopes, in agreement with previous interferometric continuum observations of W3 IRS5.

**References**

Hogerheijde, M. & van der Tak, F., 2000, A&A, 362, 697

Megeath, T., Wilson, T. & Corbin, M., 2005, ApJ, 622, 141

Rodon, J., Beuther, H., Megeath, T. & van der Tak, F., 2008, A&A, 490, 213

Wolf, S., 2003, ApJ, 582, 859

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