Modelling the infall of low-mass protostellar envelopes in Herschel water observations

J.C. Mottram[1], E.F. van Dishoeck[1,2], L.E. Kristensen[1] and the WISH Team

1: Leiden Observatory, Leiden University, P.O. Box 9513, 2300 RA, Leiden, Netherlands - email: mottram@strw.leidenuniv.nl

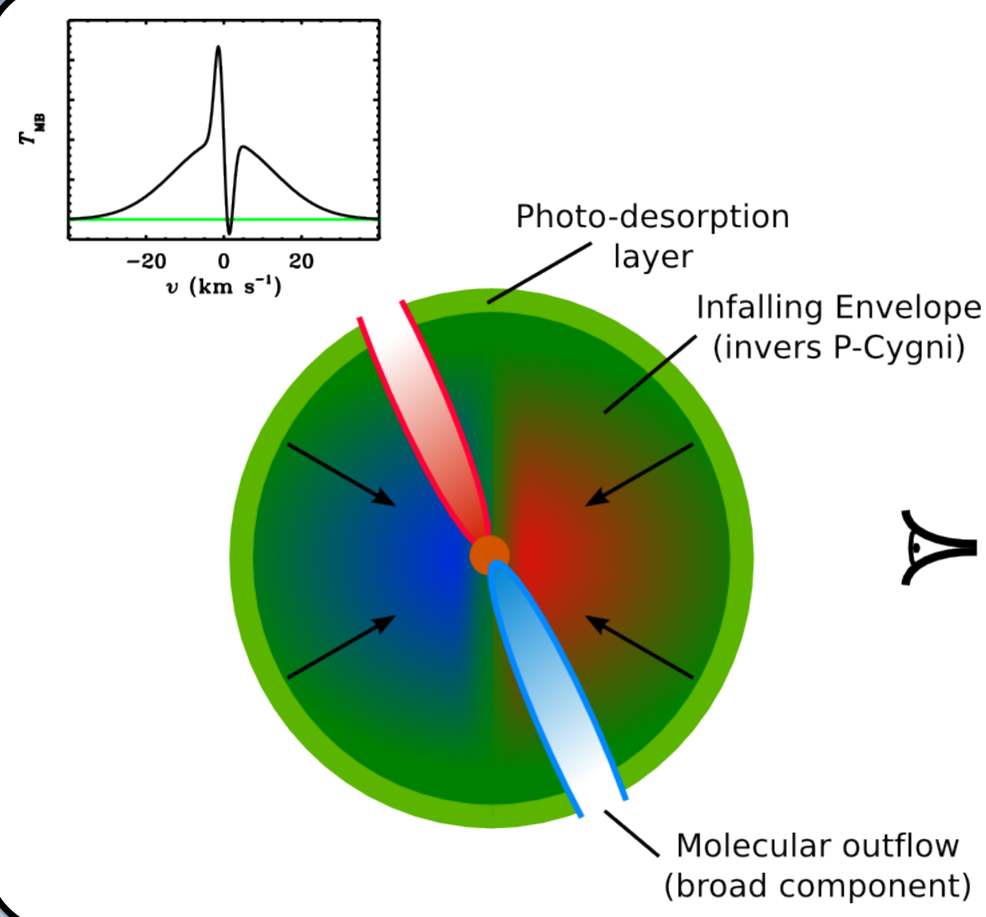
2: Max Planck Institut fűr Extraterrestrische Physik, Giessenbachstrasse 1, 85748 Garching, Germany

Context

Water is an extremely sensitive probe of the physics and kinematics of the dense parts of protostellar envelopes. Data from the ``Water in Star-forming regions with Herschel" (WISH, [1]) Key Programme have revealed that inverse P-Cygni (IPC) profiles are much more common in H_2O spectra than other previously studied chemical species.

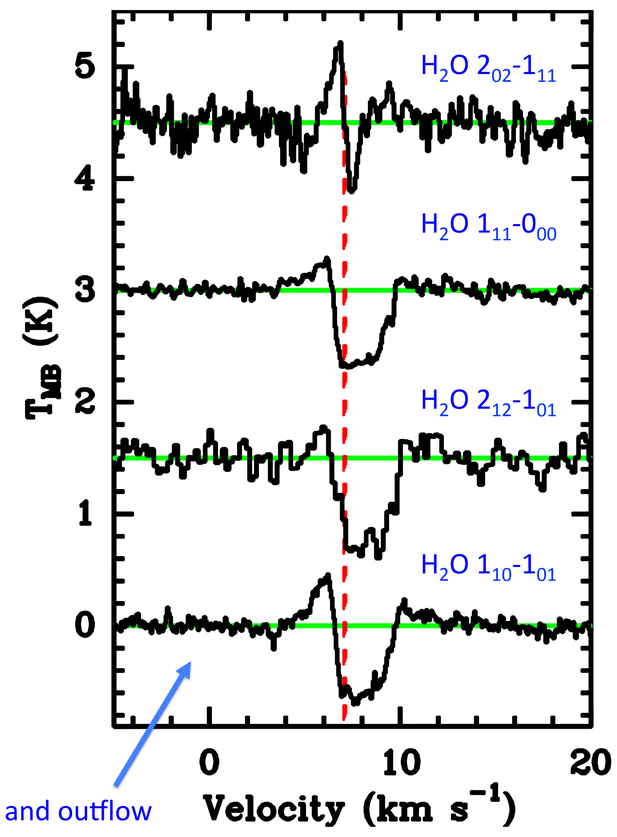
Summary

- A photo-desorption layer is required to reproduce the saturated absorption in the IPC profiles toward NGC1333-IRAS4A.
- The best-fit RATRAN 1-D model gives X_{env}= 1x10^{-9}, X_{pdl}= 1x10^{-7} and v_{in}= 1.6 kms^{-1} at 1000AU.
- This translates to a mass infall rate of 5x10^{-4} $M_\odot$yr^{-1} which compares well to [2,4] and is ~100 times the mass outflow rate measured in CO (J=3-2) by [5].



NGC1333-IRAS4A

- Class 0 protostar
- L_{bol}=9.1$L_\odot$, d=235pc, M_{env}=5.2$M_\odot$ [2]
- ICP observed in H_2O, H_2CO & N_2H^+ by [4], and other species [5,6]
- Outflow [5]:
  - R ≈10^{4}AU per lobe
  - Mass outflow rate ≈4x10^{-6} $M_\odot$yr^{-1}



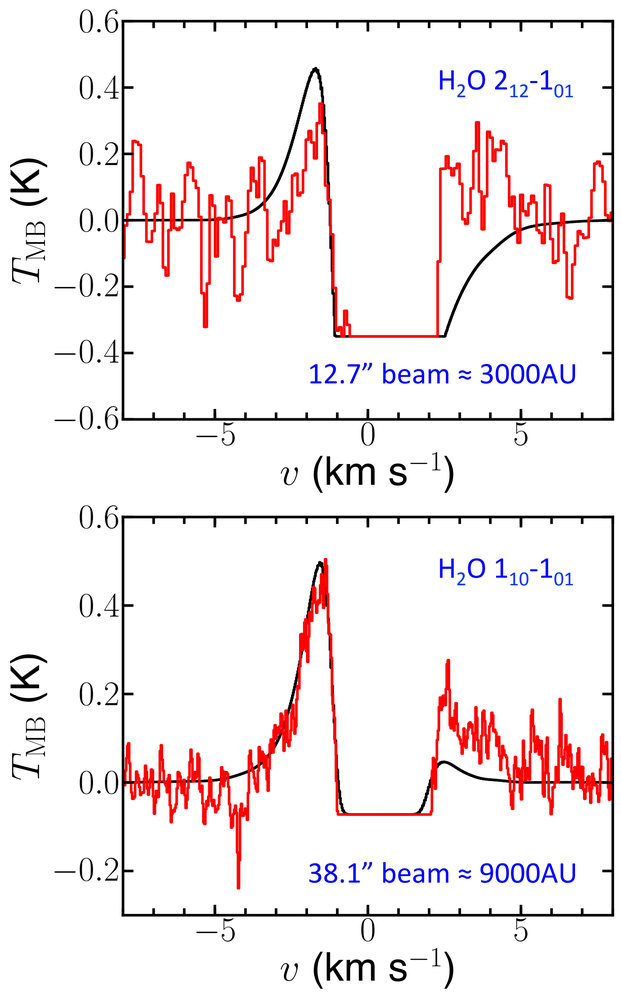
Results

Best fit for free parameters:

- v_0 = 9 kms^{-1} at r_0=33.5 AU
- X_{env}=1x10^{-9}
- X_{pdl}=1x10^{-7}

Next steps:

- Refine grid
- Run for para-H_2O, CO, HCO^+ and other relevant species
- Perform similar fitting for the 6 other WISH sources which show IPC profiles [2].



RATRAN Modelling

We use RATRAN to model HIFI ortho-H_2O 1$_{10}$-1$_{01}$ and 2$_{12}$-1$_{01}$ in NGC1333-IRAS4A.

Model Ingredients:

- n,T from DUSTY [2]
- $v_{infall} = v_0(r/r_0)^{-0.5}$
- v_{turb} = 0.8 km s^{-1}

Photo-desorption layer (PDL):

- PDL required to reproduce absorption as found by [3] for IRAS16293-2422.
- Assume n=10^4 cm^{-3}, A_V = 4

Free parameters:

- constant water abundance (X_{env})
- v_0
- water abundance in the PDL (X_{pdl}).

References

[1] van Dishoeck et al., 2011, PASP, 123, 138 [2] Kristensen et al., 2012, A&A, in press [3] Coutens et al., 2012, A&A, in press
[4] Di Francesdco et al., 2001, ApJ, 562, 770 [5] Yıldız et al., 2012, A&A, in press [6] Jorgensen et al., 2007, ApJ, 659, 479