Water in High-mass Protostars with Herschel/HIFI :
Using H_2O line profiles to probe physical conditions

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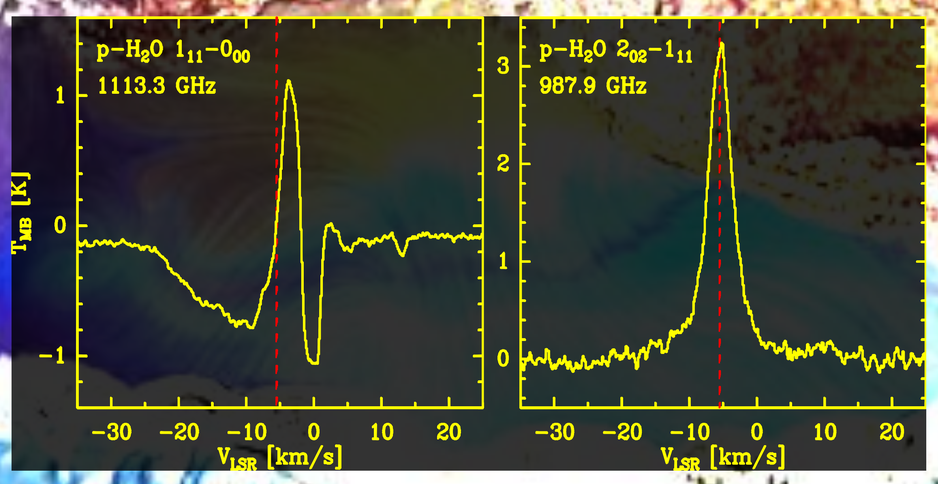
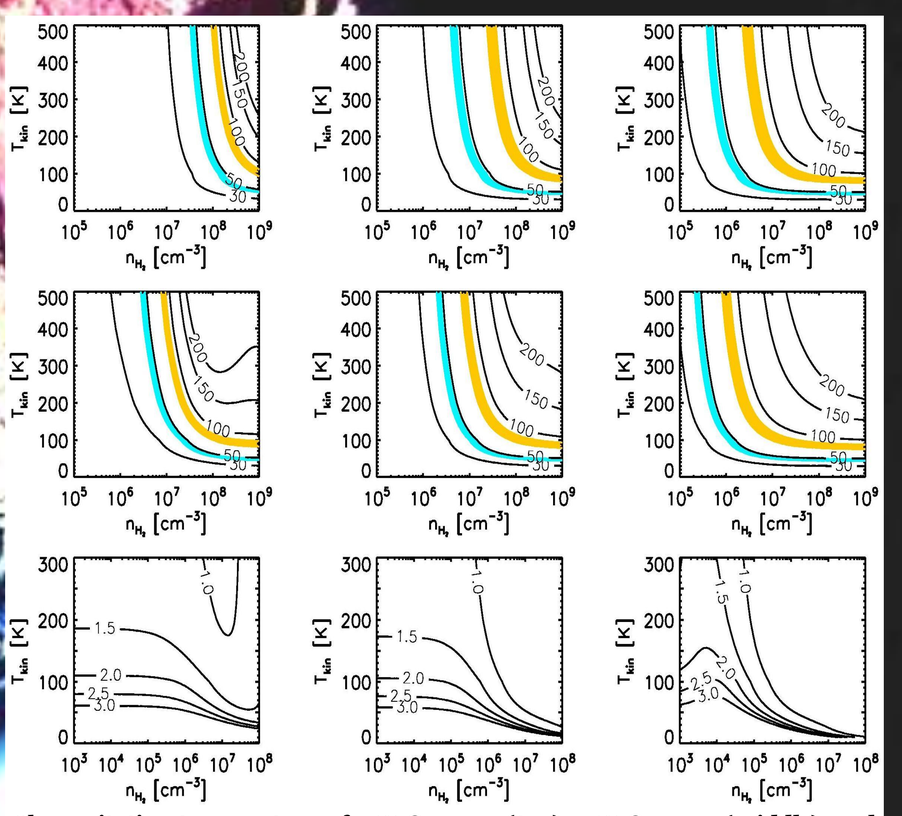
ABSTRACT

Massive stars play a major role in the interstellar energy budget and the shaping of the galactic environment. However, the formation of high-mass stars is not well understood for several reasons: they are rare, they have a short evolution time scale, they are born deeply embedded, and they are far from us. The water molecule is thought to be a sensitive tracer of physical conditions and dynamics in star-forming regions because of its large abundance variations between hot and cold regions. Therefore, measurement of the water abundance is a step towards understanding the star formation process. We present *Herschel*/HIFI observations of water lines toward the high-mass protostellar objects to learn about physical processes in these regions and to identify links in the water abundance between the various evolutionary stages of high-mass star formation. This work is part of the guaranteed time key program Water In Star-forming regions with Herschel (WISH).

AFGL2591
d = 3.3 kpc
L_{bol} = 5.8x10⁴ $L_\odot$

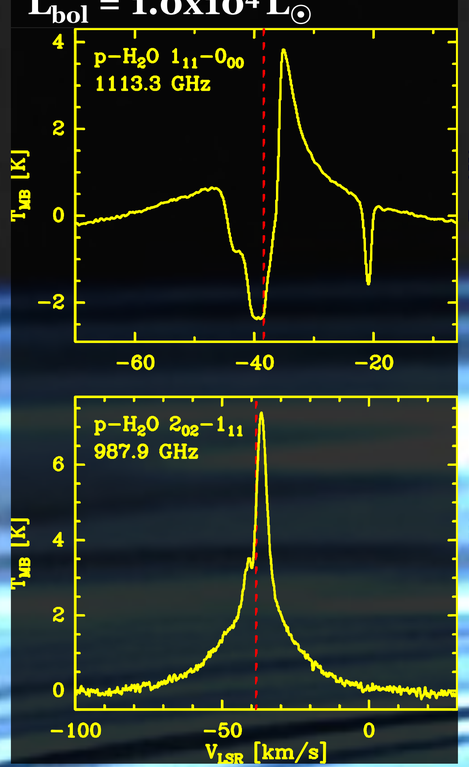
J, H, and K bands color-composite image obtained from Gemini NIRI



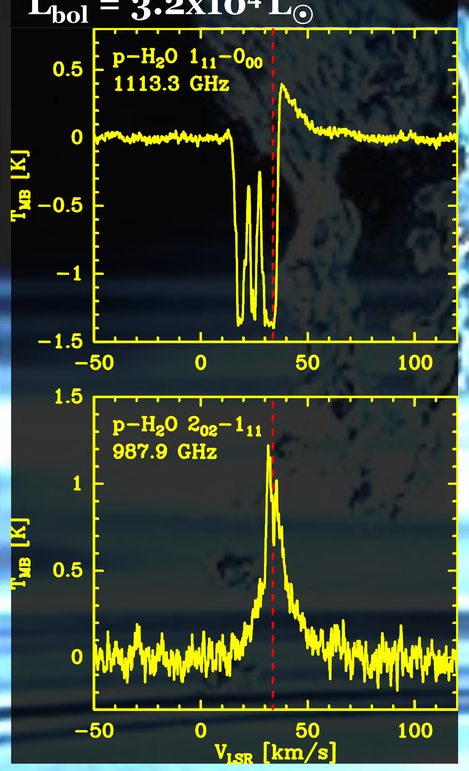


The excitation temperature of p-H_2O 1_{11}-0_{00} (*top*), p-H_2O 2_{02}-1_{11} (*middle*), and the p-H_2O 1_{11}-0_{00}/p-H_2O 2_{02}-1_{11} line ratio (*bottom*) from optically thin emission (N=10¹⁴ cm⁻², *left*) to optically thick emission (N=10¹⁶ cm⁻², *right*) as function of kinetic temperature and H2 density calculated with RADEX (Non-LTE, large velocity gradient code). The yellow and blue areas indicate the observed values of T_{rot} from envelope and outflow, respectively.

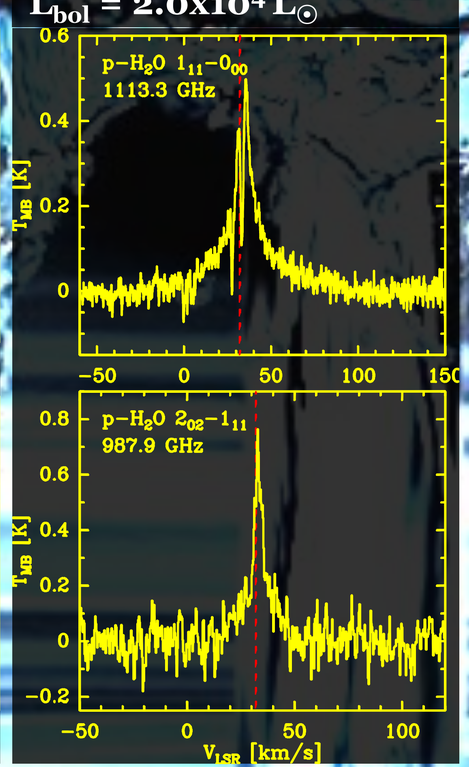
W33A
d = 4.0 kpc
L_{bol} = 1.0x10⁴ $L_\odot$



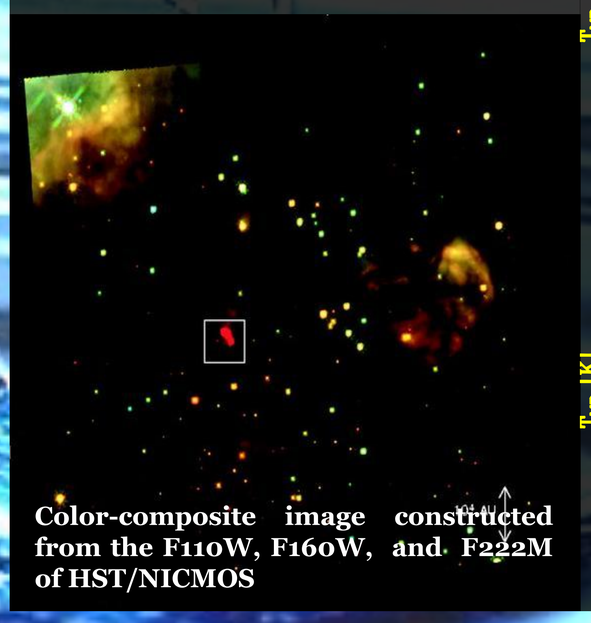
IRAS18089-1732
d = 3.6 kpc
L_{bol} = 3.2x10⁴ $L_\odot$



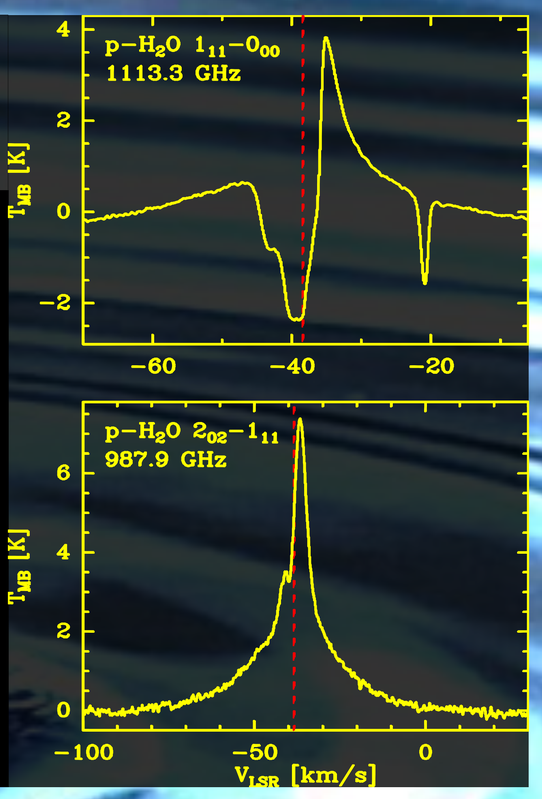
IRAS18151-1208
d = 2.9 kpc
L_{bol} = 2.0x10⁴ $L_\odot$



W3 IRS5
d = 2.2 kpc
L_{bol} = 1.7x10⁵ $L_\odot$



Color-composite image constructed from the F110W, F160W, and F222M of HST/NICMOS



RESULTS & CONCLUSIONS

- **Water detection in 5 high-mass protostars**
  - **11 water lines in W3 IRS5 and AFGL2591**
  - **8 water lines in IRAS18089-1732**
  - **7 water lines in W33A**
  - **5 water lines in IRAS18151-1208**
- **p-H_2O 1_{11}-0_{00} (1113.3 GHz) line**
  - **emission line only in IRAS18151-1208**
  - **mix of emission and absorption lines in other 4 sources**
- **p-H_2O 2_{02}-1_{11} (987.9 GHz) emission lines with 2 components in 5 sources**
  - **broad component by outflow**
  - **narrow component by envelope**
- **No detection of $H_2{}^{17}O$ and $H_2{}^{18}O$ lines in IRAS18151-1208**
  - **due to optical depth effect**
- **No detection of o-H_2O 3_{12}-3_{03} (1097.4 GHz) line in W33A**
  - **not high temperature region to excite this line**
- **Non-LTE models of AFGL 2591 indicate that**
  - **a gas density of > 10⁸ cm⁻³ , a kinetic temperature of > 150 K for envelope**
  - **a gas density of > 10⁷ cm⁻³, a kinetic temperature of > 60 K for outflow**

FUTURE WORK

- **Calculate column densities and water abundances**
- **Compare o/p ratio and D/H ratio**
- **Full radiative transfer analysis (RATRAN)**
- **Analyze the HIFI map data**

REFERENCES

- **Chavarría et al. 2010, A&A, 521, L37**
- **Megeath et al. 2005, ApJ, 622, L141**
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- **van der Tak et al. 2007, A&A, 468, 627**
- **van Dishoeck et al. 2011, PASP, 123, 138**