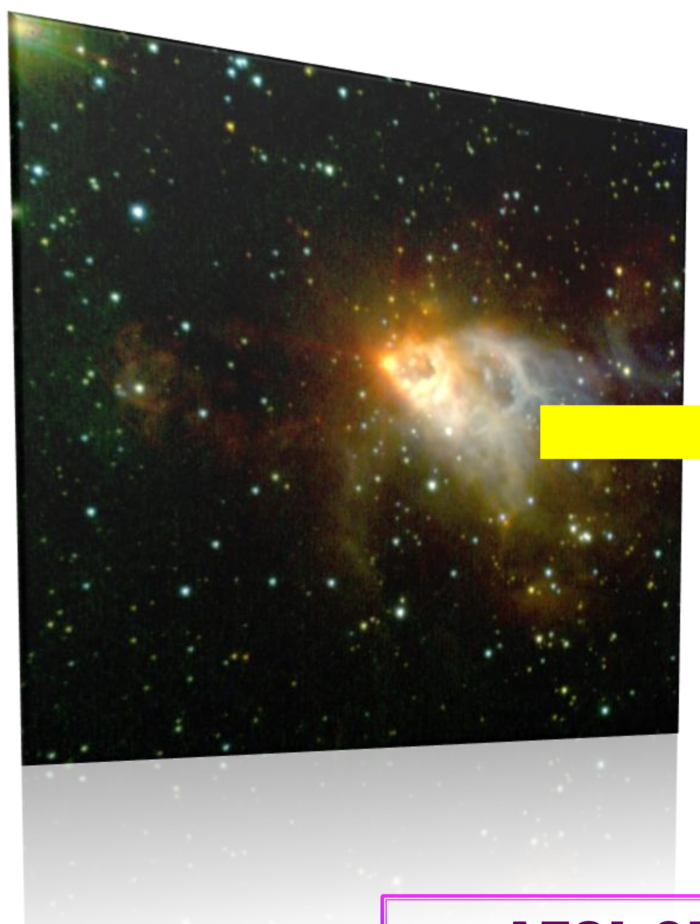
Water Observations with *Herschel* /HIFI toward AFGL 2591

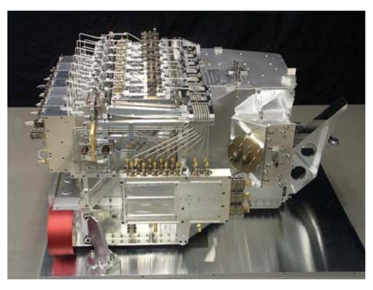
Yunhee Choi[1,2,★], Floris van der Tak[2,1], Ewine van Dishoeck[3,4], and the *Herschel*/WISH team

[1]Kapteyn Astrophysical Institute, Groningen, The Netherlands
[2]SRON Netherlands Institute for Space Research, Groningen , The Netherlands
[3]Leiden Observatory, Leiden , The Netherlands
[4] Max Planck Institut für Extraterrestrische Physik, Garching, Germany
★Contact : y.choi@astro.rug.nl

AIMS

We present *Herschel*/HIFI observations of water lines toward the high mass star-forming region AFGL 2591 as part of the guaranteed time key program Water In Star-forming regions with Herschel (WISH). We analyze these observations to obtain physical processes in this region and to identify links in the water abundance between the various evolutionary stages of high-mass star formation.





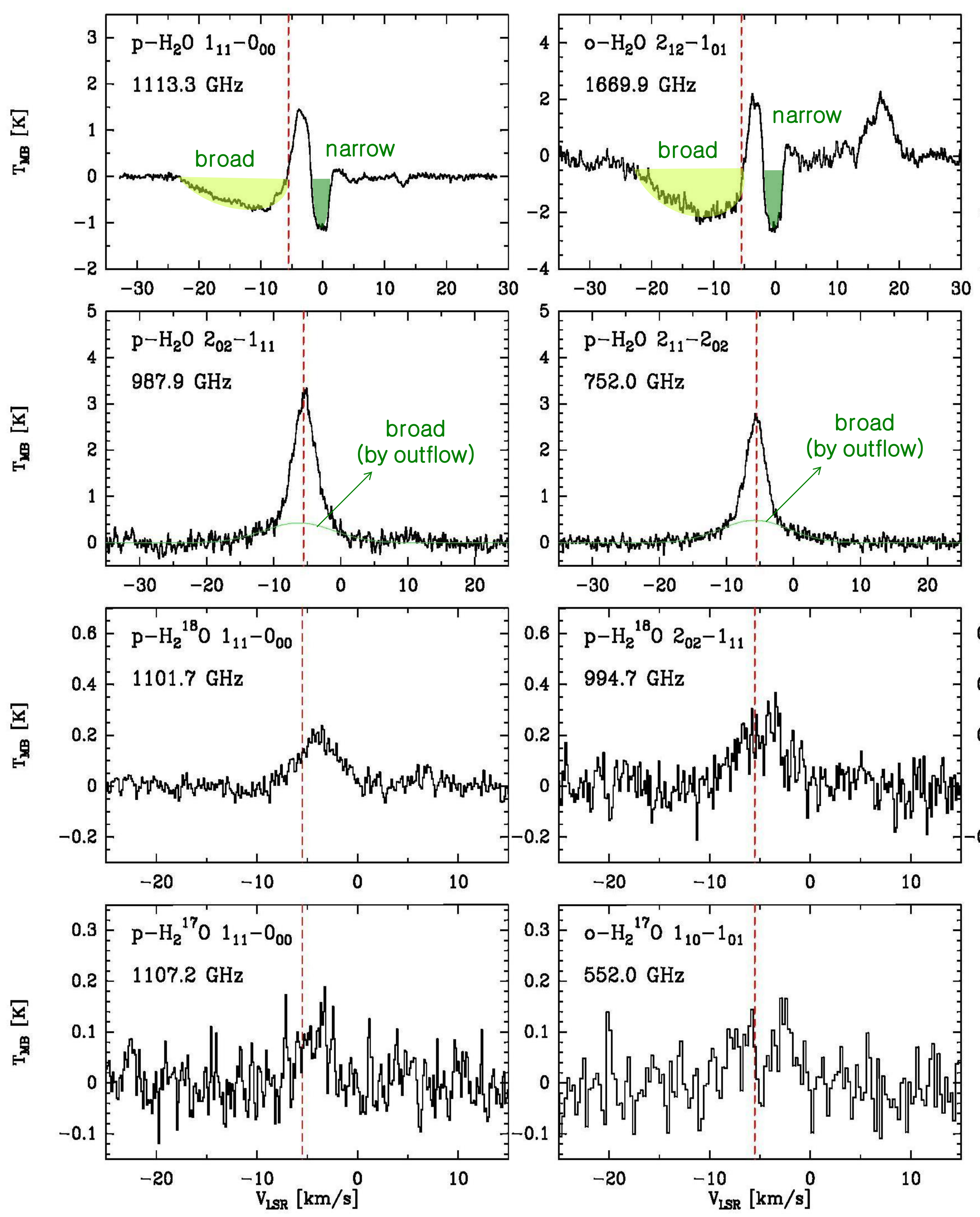
AFGL 2591

- High mass protostellar object with a bipolar outflow.
- Located in the Cygnus X region.
- Large amounts of gas and dust toward the source.
  → bright infrared emission.
- One of the rare cases of massive star formation in relative isolation.
- Menv = 40 $M_\odot$ / R = 30,000 AU / L = $2\times10^4 L_\odot$

(Image : AFGL 2591 in infrared light from the NIRI instrument mounted on the Gemini North in 2001)

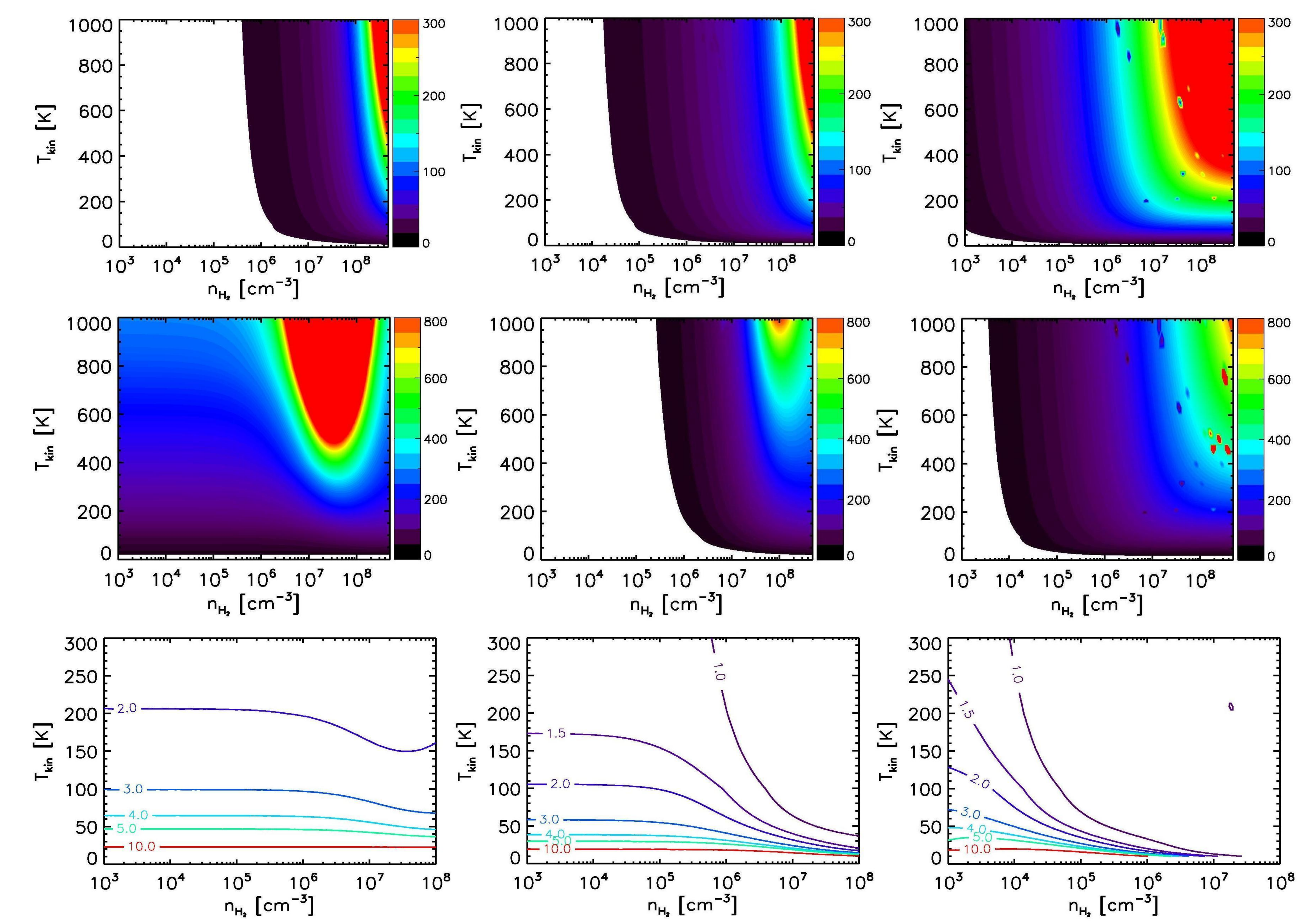
HERSCHEL / HIFI

- Herschel Space Observatory performs imaging photometry and spectroscopy in the far infrared and sub-mm regions.
- Heterodyne Instrument for the Far Infrared (HIFI) is one of the science instruments on Herschel.
  - Broad coverage 490-1250 GHz and 1410-1910 GHz
  - 7 bands utilizing low-noise dual-polarization receivers



Spectra of eleven water lines in the high-mass star-forming region AFGL 2591. Dashed lines drawn at V_{LSR} (-5.5 km s^{-1}).

Non-LTE CALCULATIONS



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*=10^{12} cm^{-2}, *left*) to optically thick emission (*N*=10^{16} cm^{-2}, *right*) as function of kinetic temperature and H_2 density calculated with RADEX (Non-LTE, large velocity-gradient code, van der Tak et al. 2007).

RESULTS & DISCUSSION

1. We detect eleven rotational transitions of H_2O, $H_2^{17}O$, and $H_2^{18}O$ toward the massive star-forming region AFGL 2591.
   - Absorption line : H_2O 1_{11}-0_{00} and H_2O 2_{12}-1_{01}
     (broad : by outflow / narrow : by foreground cloud)
   - Emission line : H_2O, $H_2^{17}O$, and $H_2^{18}O$
     (broad : by outflow / narrow : by envelope)
2. We derive the optical depth and column densities with absorption lines of H_2O 1_{11}-0_{00} and H_2O 2_{12}-1_{01}.

Molecule	Column Density [10^{13} cm $^{-2}$]	
	Broad (blue-shifted outflow)	Narrow (foreground cloud)
H_2O 1_{11}-0_{00}	3.0±0.5	2.1±1.8
H_2O 2_{12}-1_{01}	12.9±3.8	3.8±1.4

3. We construct rotational diagrams for emission lines in $H_2^{17}O$, $H_2^{18}O$, and H_2O (only broad component). We derive rotation temperatures and column densities.

	Trot [K]	*N* [10^{13} cm^{-2}]
$H_2^{17}O$ & $H_2^{18}O$	101±17	0.5±0.1
H_2O (broad component)	46±5	12.3±4.8

4. Considering the error and the blue-shifted outflow, the column density from broad absorption line in H_2O 1_{11}-0_{00} is similar to that from broad emission component in H_2O.
5. Non-LTE models indicate that a kinetic temperature of ~ 200 K, density of ~ 10^8 cm^{-3}, and column density of ~ 10^{14} cm^{-2} reproduce the observations.