Water in massive star forming regions

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As part of the program Water In Star forming regions with Herschel (WISH, [1]), we present HERSCHEL/HIFI results on water molecule observations *(Table 1)* towards 4 massive star forming regions: IRAS05358+3543, IRAS16272-4837, DR21-OH and W43-MM1.

What is the water abundance profile in the envelopes?

What does water tell us about the physical structure and dynamics?

Simple 1D radiative transfer codes Mctherm [2,3,4] and Ratran [5] were used to obtain the source profile (T and density) and model water lines respectively for all the sources. The input parameters for Mctherm are the source distance, size and luminosity. The density profile is determined by the code and close to -1.5. We vary the mass of the source in order to fit the spectral energy distribution (SED). We used the dust properties given by Ossenkopf & Henning (1994). The resulting SED and source profile are shown in *Fig. 1*.

The code Ratran uses the source profile from Mctherm to determine the water line emission for a given abundance, turbulence velocity and expansion/infall velocity. The model water lines are shown in *Fig. 2* and the parameters used for the best fit for all lines are listed in *Table 2*.

Up to three velocity components are detected and centered close to the source velocity: broad with FWHM between 20–30 km/s, medium with FWHM between 10–15 km/s and narrow with FWHM between 5–10 km/s. The broad component can be attributed to outflow powered emission.

Derived water abundances in the inner envelope are between 10e-6 and 10e-4. For the outer envelope are between 5e-9 and 4e-8.

Turbulence velocities between 2 and 3 km/s are used to fit the water lines.

Preliminary results indicate that DR21 (OH) is better fitted with infall in the water lines and expansion in the rare isotopologues lines.

W43-MM1 exhibits infall of 2.9 km/s leading to an accretion rate between 2.7x10^{-3} and 6.7x10^{-2} $M_\odot$/yr.

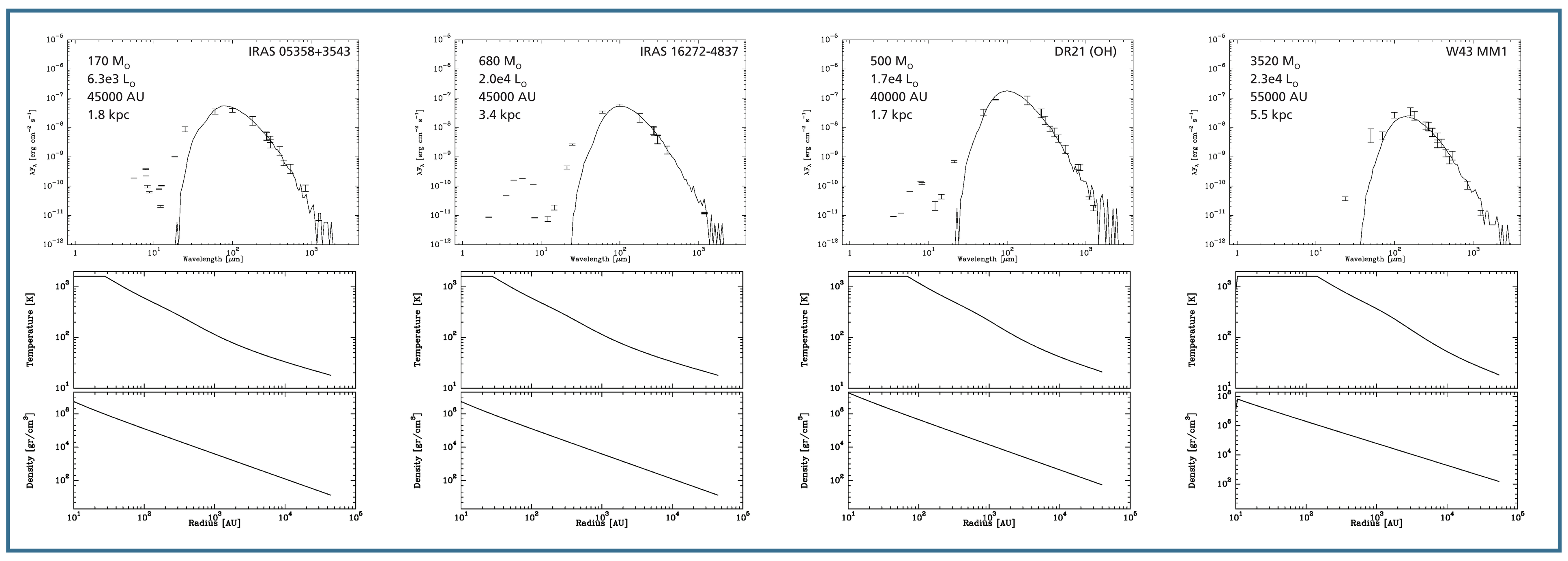


Fig. 1: SED, temperature and density profile for the observed sources. In the SED, the continuous line represents the used model. Points were taken from literature and from HERSCHEL data.

Table 1. Herschel/HIFI observed line transitions. Beam and η_{mb} are from [7]. The rms is the noise at the given spectral resolution. The forward efficiency is 0.96. The energy of the upper level, E_u, is the same for $H_2{}^{17}O$ and $H_2{}^{18}O$.

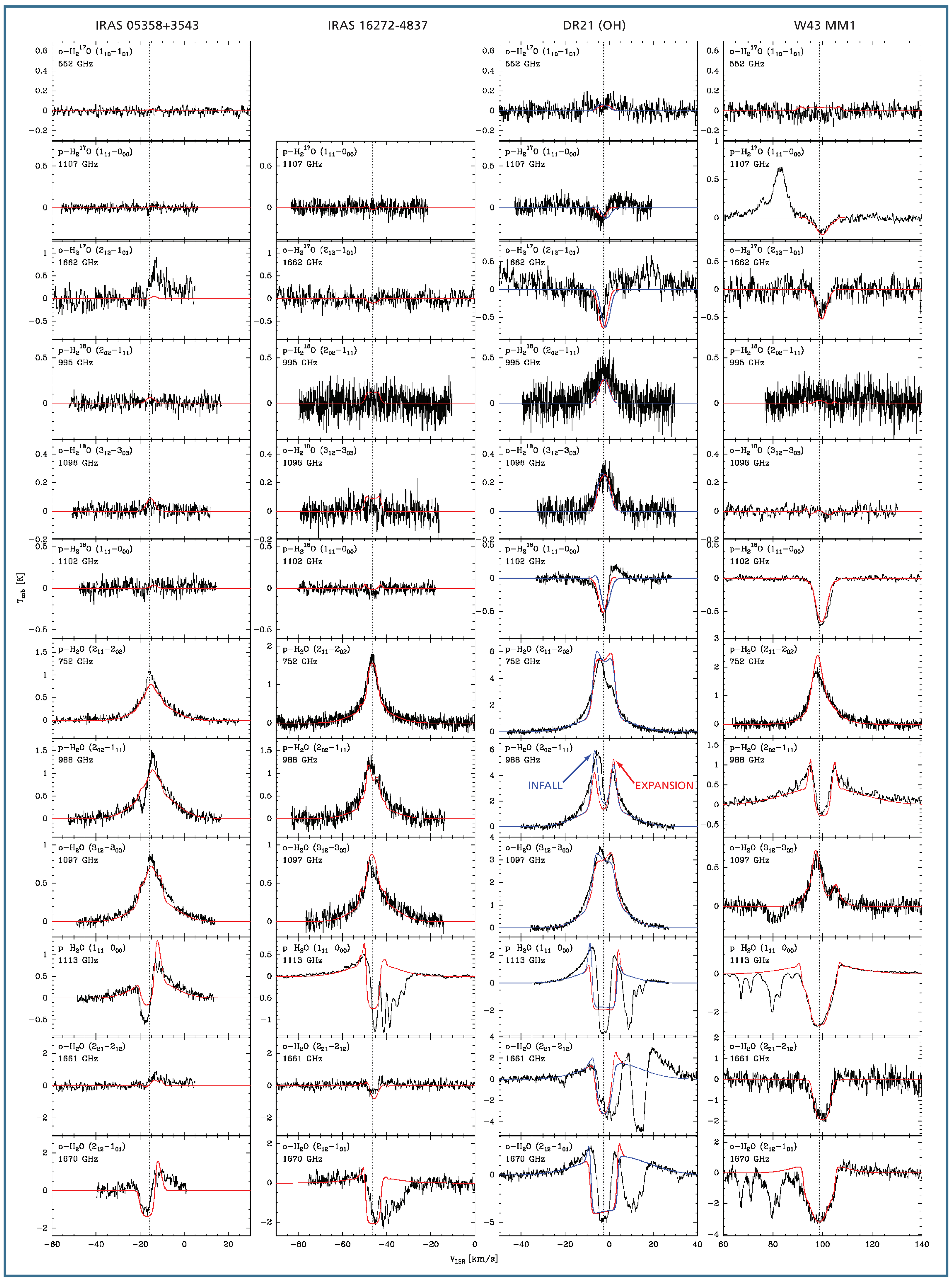
Water species	Frequency (GHz)	Wavelength (μm)	E_u (K)	Beam (″)	η_{mb}	T_{sys} (K)	$\delta\nu$ (kHz)	t_{int} (s)	rms (mK)
o-$H_2^{17}O$ 1_{10}-1_{01}	552.0209	543.1	61.0	38.0	0.754	71	0.24	158	46
p-$H_2^{18}O$ 2_{02}-1_{11}	994.6751	301.4	100.6	21.3	0.741	288	0.12	502	107
o-$H_2^{18}O$ 3_{12}-3_{03}	1095.6274	273.8	248.7	19.2	0.737	379	0.24	1723	54
p-$H_2^{18}O$ 1_{11}-0_{00}	1101.6982	272.1	52.9	19.2	0.736	3566	0.5	3566	17
p-$H_2^{17}O$ 1_{11}-0_{00}	1107.1669	272.1	52.9	19.1	0.737	379	0.24	1723	29
o-$H_2^{17}O$ 2_{12}-1_{01}	1662.4644	180.3	113.6	12.8	0.708	1407	0.5	1212	249
p-H_2O 2_{11}-2_{02}	752.0332	398.6	136.9	28.2	0.749	88	0.12	262	88
p-H_2O 2_{02}-1_{11}	987.9268	303.5	100.8	21.3	0.741	340	0.5	418	67
o-H_2O 3_{12}-3_{03}	1097.3651	273.2	249.4	19.2	0.737	379	0.24	1723	54
p-H_2O 1_{11}-0_{00}	1113.3430	269.0	53.4	19.0	0.736	393	0.5	3566	17
o-H_2O 2_{21}-2_{12}	1661.0076	180.5	194.1	12.8	0.708	1407	0.5	1212	225
o-H_2O 2_{12}-1_{01}	1669.9048	179.5	114.4	12.7	0.708	1407	0.5	1212	249

Table 2. Physical quantities used in the RATRAN models shown in Fig. 2.

Parameter	IRAS 05358	IRAS 16272	DR21 (OH)	W43-MM1$^{(a)}$
X_{H_2O}	4.0×10^{-9}	5.2×10^{-9}	4.0×10^{-8}	8.0 (±0.3) ×10^{-8}
Post-jump X_{H_2O}	1.0×10^{-6}	1.0×10^{-5}	1.0×10^{-6}	1.4 (±0.3) ×10^{-4}
V_{tur} (km s^{-1})	2.2	2.0	2.8	2.1-3.5
$V_{exp/inf}$ (km s^{-1})	1.5	−0.2	−0.2, 0.3$^{(b)}$	(-0.4)-(-2.9)
V_{LSR} (km s^{-1})	−15.6	−46.4	−2.5	99.8

(a) From [6].
(b) The blue model in Fig. 2 corresponds to -0.2 km/s, the red model to 0.3 km/s

Fig. 2: Water spectra for the studied sources. The red and blue lines correspond to the fitted models (see model parameters in Table 2). The rare isotopologue lines in DR21-OH seem to be better fitted by an expanding inner envelope and an infalling outer envelope. The model for W43-MM1 is taken from [6].



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