First hyperfine structure resolved OH FIR spectrum of a star-forming region

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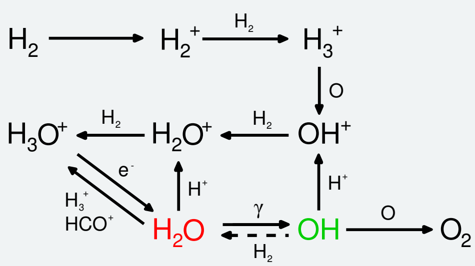
Motivation

- Water is one of the most abundant molecules in star-forming regions. We study related species to understand formation and destruction routes of H_2O.

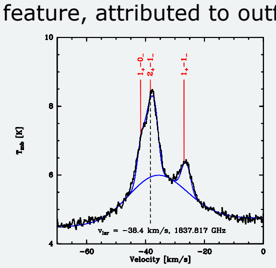
Fig. 1: Chemical reaction network of water



- OH is one of the molecules most closely linked to H_2O in the chemical network.
- OH is an important reactant in the oxygen chemistry and a major molecular coolant in star forming regions.
- OH far-IR lines are only observable from space.

Herschel/HIFI results

- We obtained the first velocity resolved hyperfine OH spectrum of the high-mass star-forming region W3 IRS 5 ($L \sim 10^5\ L_\odot$, d = 2 kpc) with HIFI.
- The line profile reveals a narrow component, attributed to envelope emission, on top of a broad feature, attributed to outflow emission.



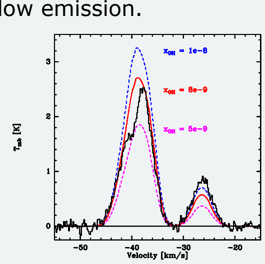


Fig. 2: Velocity resolved OH line triplet at 1837 GHz (163.1 µm) towards W3 IRS 5 observed with HIFI. The blue lines indicate the best fit slab model.
Fig. 3: Radiative transfer models of W3 IRS 5 with different OH abundances compared to the envelope component of the observed spectrum.

Derived OH/H_2O abundance ratios in W3 IRS 5:
- Envelope $\sim 10^{-3}$ ($T \geq 100$ K) consistent with prediction from high-temperature chemistry.
- Envelope ~1 ($T < 100$ K) consistent with laboratory results on photodesorption.
- Outflow ≥ 0.028 can be explained by fast J-type shock or slower UV irradiated C-type shock.

Herschel/PACS results

- Complementary observations with PACS in six low- and intermed.-mass sources in four OH transitions.

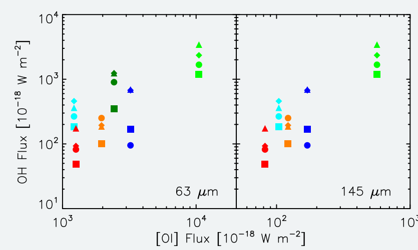


Fig. 4: OH vs. [OI] fluxes observed with PACS. Symbols indicate different OH transitions, colors different sources.

- Similar excitation of OH in sources with very different physical properties → emission might arise from gas at similar conditions, likely shocked gas.
- Correlation of OH and [OI] fluxes, indicative for a dissociative shock.
- Tentative correlation of the OH line luminosity with the bolometric luminosity, indicative for a correlation with outflow force.

Conclusions & Outlook

- The hyperfine resolved OH spectrum allows us to determine the OH/H_2O abundance ratios. The ratios are consistent with dense-cloud chemistry.
- OH emission observed with PACS agrees with shock interpretation. Additional PACS data obtained in the WISH key program will improve statistics.
- Herschel GT1 program to study OH excitation in detail for one source (observations completed).
- Herschel OT1 proposal to observe additional species (HCO^+, H_3O^+) in the H_2O network with HIFI.

References:
S. Bruderer et al., 2010, A&A 521, L44
M.R. Hogerheijde, F.F.S. van der Tak 2000, A&A 362, 697
S.F. Wampfler et al., 2011, accepted by A&A, arXiv:1105.5026
S.F. Wampfler et al., 2010, A&A 521, L36
van Dishoeck et al., 2011, PASP 123, 138

WISH

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