Probing Water Chemistry in Young Stellar Objects with Hydroxyl (OH) Observations

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I. Introduction

Water is one of the most abundant molecules in star-forming regions and a unique probe of the physical properties and the chemical processes in protostellar envelopes. The 'Water in Star-Forming Regions with Herschel (WISH)' key program aims at investigating the excitation as well as the formation and destruction routes of H_2O in protostars. The sample covers wide ranges of evolutionary stages, masses and luminosities.

The hydroxyl radical (OH) is linked to the chemical formation and destruction paths of H_2O through high-temperature chemistry (T ≥ 250) and photo-dissociation processes.

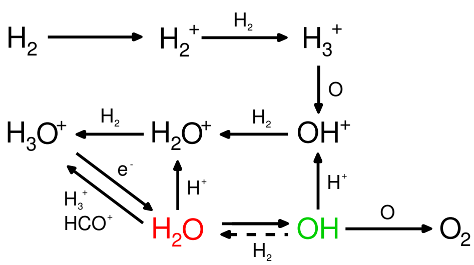

Fig. 1: Chemical reaction network of water and related species

Because of atmospheric absorption, OH far-infrared emission is only accessible from space. The instruments on the Herschel Space Observatory, providing both high sensitivity (PACS) and high spectral resolution (HIFI), are thus ideal for OH observations.

II. PACS results

OH was observed at 79, 84, 119 and 163 µm with PACS in six sources: HH 46, TMR 1, IRAS 15398-3359 (class I), NGC 1333 IRAS 2 (class 0), NGC 7129 FIRS 2 (intermediate-mass) and DK Cha (Herbig Ae). The relative strengths of the OH lines are similar for all these sources, which might indicate similar excitation conditions. There is a correlation of OH line luminosities with the bolometric luminosity of the sources. Furthermore, the OH fluxes seem to be correlated with the [OI] 63 and 145 µm fluxes also observed with PACS.

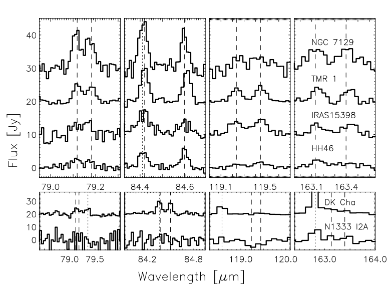

Fig. 2: PACS spectra of OH

These results are all consistent with an interpretation of the OH emission being produced in a (dissociative) shock.

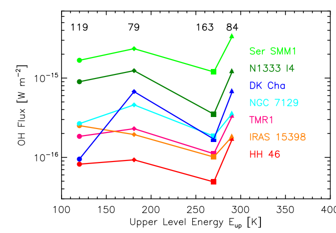

Fig. 3: Observed OH line fluxes plotted vs. upper level energy of the transition. ISO results from Ser SMM1 and NGC 1333 IRAS 4 are included for comparison.

III. HIFI results

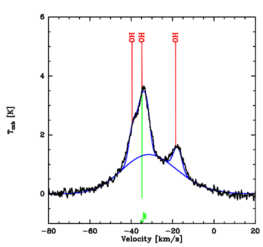

Fig. 4: Velocity resolved OH line triplet at 1837 GHz (163.1 µm) towards the high-mass star-forming region W3 IRS 5 observed with HIFI.
The blue lines show models calculated using the method of Bruderer et al. 2010. Narrow components from the envelope reside on top of a broad component attributed to outflow emission.

One of the OH doublets at 163 µm was observed with HIFI towards HH 46, NGC 1333 IRAS 2A, DK Cha and W3 IRS 5 to resolve the hyperfine structure. OH was clearly detected only from the high-mass protostar W3 IRS 5. Two physical components can be identified in the HIFI spectrum (Fig. 4): A narrow component (FWHM ≈ 4-5 km/s) for all three hyperfine transitions, and a broad underlying component (FWHM ≈ 30 km/s), which we attribute to outflow emission. The narrow component is in good agreement with results of spherically symmetric envelope models, calculated with RATRAN. The OH emission is modeled using the method of Bruderer et al. 2010, yielding an OH column density of 4.4e16 cm^{-2} for the envelope component and 6.5e13 cm^{-2} for the outflow component.

IV. Conclusions and Outlook

We present the first velocity resolved OH spectrum from HIFI towards a protostar. Two components can be identified, broad outflow emission and a narrow component from the envelope. The broad component is consistent with PACS results, where we attribute the OH emission to shocked gas.
More detailed modeling will allow to determine OH/H_2O abundance ratios.

References:

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