New Probes of Chemistry in the Inner Regions of Planet-Forming disks

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Abstract

The study of warm molecular gas in the inner regions (<10 AU) of circumstellar disks around stars is of importance to understand how planets are forming. Mid-infrared Spitzer spectra have detected H_2O, OH, HCN and C_2H_2 in these regions, but their low spectral resolution does not allow a quantitative analysis. In contrast, the VLT-CRIRES instrument with a resolving power of 10^5 provides fully resolved profiles. We present one of the first near-infrared (3-5 μm) searches for various molecules from these regions, including detections of HCN, H_2O, OH and tentatively C_2H_2 and upper limits of CH_4 and NH_3. We use both a slab model and a 2D ray-tracing code called RADLite (Pontoppidan et al. 2009) to model the lines from which the abundance structure of the different molecules can be determined. This information helps to constrain chemical models of disks which can tell what type of planets may form there.

Observations

Observations of two T Tauri stars, AS 205 and DR Tau, have been done using the high resolution spectrometer CRIRES at the VLT.

Even at this high resolution, the lines from molecules other than CO are extremely weak and need special observing and data reduction techniques to boost the S/N on the continuum.

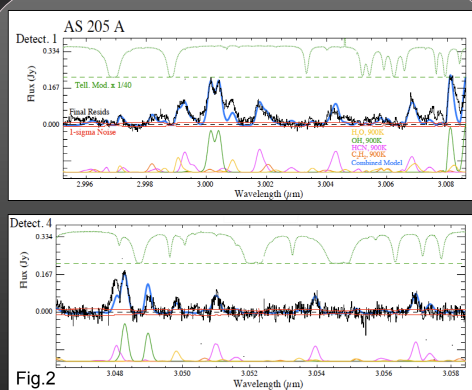

Fig.2

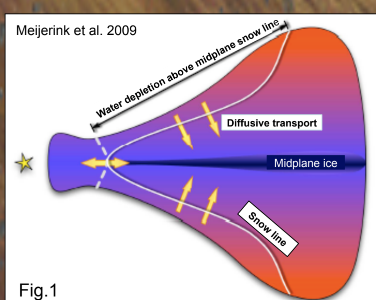

Fig.1

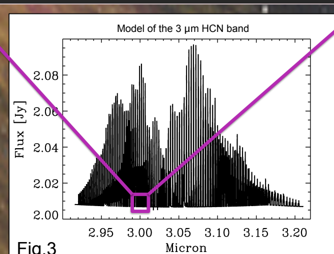

Fig.3

Disk model

RADLite is a two-dimensional ray tracing disk model coupled with the 2D radiative transfer code RADMC (Dullemond & Dominik 2004) that takes into account both radial and vertical temperature and density variations, the motion of the gas and the geometry of the disk. Four different models using AS 205 disk parameters are shown below, Fig. 5.

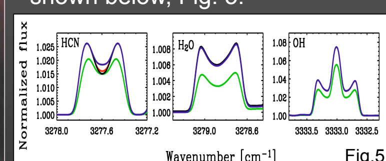

Fig.5

- Constant abundance
- Density dependent freeze out
- Vertical cold finger effect
- Lower gas/dust ratio (1280*)

The vertical cold finger effect introduces a diffusion of the gas to below the snowline where the gas is frozen out, see Fig. 1.

*A gas/dust ratio of 12800 is used in the other models

Results

A slab model is used (assuming Local Thermodynamic Equilibrium, LTE) to extract molecular abundance ratios using a constant abundance and temperature structure, see Fig. 2 and 4. A non-LTE model would probably give better estimates of the ratios (Meijerink et al. 2009).

AS 205: OH/H_2O = 0.3, HCN/H_2O = 0.1, H_2C_2/H_2O = 0.1
DR Tau: CH_4/OH < 0.1

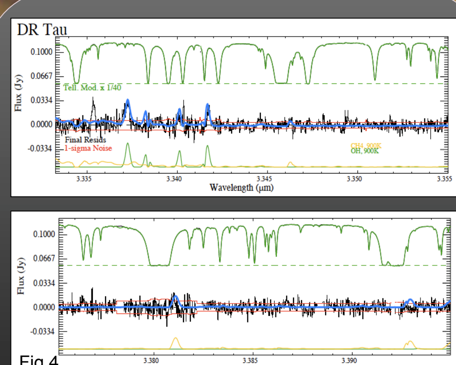

Fig.4

Conclusions

- HCN, H_2O and OH are clearly detected.
- Modeling using RADLite shows that:

1. H_2O, OH and HCN (3-5 μm) are not sensitive towards freeze out and the vertical cold finger effect since the main part of the emission comes from within the inner radius of the snow line (<1 AU).
2. A lower gas/dust ratio has some impact on the line intensities.

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