Searching for cool water in protoplanetary disks

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Abstract

We report upper limits on the H_2O 1_{10}-1_{01} and 1_{11}-0_{00} lines toward six gas-rich protoplanetary disks obtained with Herschel/HIFI in the framework of the WISH key program.

These upper limits tentatively rule out various models predicting water vapor abundances of $\leq 10^{-10}$ in the disks. Instead, we tentatively place an upper limit of X on the *disk-averaged* water vapor abundance in these disks.

Context and aims

Inside protoplanetary disks, we expect water to be present as ice frozen out on dust grains, and as vapor where the temperature is high enough to sublimate the ices or where the ultraviolet flux is high enough to desorb the water molecules. High above the disk midplane, water will be dissociated by full force of the stellar ultraviolter or X-ray radiation.

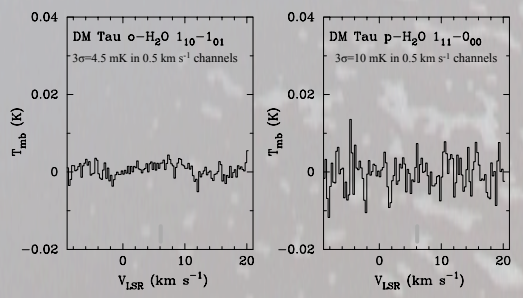
Water vapor is therefore expected to exhibit an enormous range of abundance throughout the disk, from nearly absent in the cold and dense midplane ($\ll 10^{-12}$ w.r.t. H_2), to being the dominant oxygen baring molecule in warm (>200 K) gas near the star.

We aim to detect the ground-state emission lines of water vapor in a representative sample of gas-rich protoplanetary disks, or place stringent upper limits on the strengths of these lines.

Observational setup

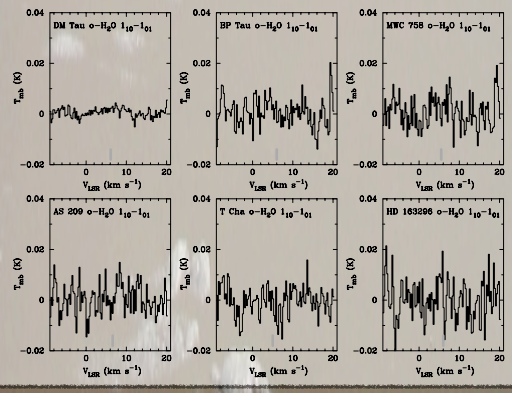
- 4 deep targets and 8 shallow targets
  - deep: DM Tau✓, TW Hya, LkCa 15, MWC480
  - shallow: HD163296✓, BP Tau✓, GG Tau, GM Aur, T Cha✓, MWC725✓, AS209✓, IM Lup (✓=data obtained)
- double beam swicth observations
- ortho-H_2O 1_{10}-1_{01} at 557 GHz
  - deep: t_{int}=7 hr, giving 3σ=4.5 mK in a 0.5 km s^{-1} channel
  - shallow: t_{int}=35 min, giving 3σ=15 mK in 0.5 km s^{-1}
- para-H_2O 1_{11}-0_{00} at 1113 GHz
  - deep: t_{int}=14 hr, giving 3σ=12 mK in 0.5 km s^{-1}
  - shallow: t_{int}=1 hr, giving 3σ=44 mK in 0.5 km s^{-1}

Results



Results

3σ=4.5 mK and 12–17 mK in 0.5 km s^{-1} channels



Discussion / comparison to models

- Models predict very different line strengths.
- Depending on the relative locations of the dust photosphere and where the H_2O line reach τ~3, lines may be in emission or absorption.

➡Some models are ruled out

Conclusions

- No ground-state water vapor emission detected, down several mK
- Different models predict line strengths (in emission and/or absorption) of several tens of hundreds of mK
- Our observations rule out these models, and place an upper limit on the *disk-averaged* water vapor abundance of $<10^{-10}$
- The expected line strengths sensitively depend on parameters such as the dust settling, and the relative locations of dust and water vapor in general.
- We plan to complete our study by observing the 3_{12}-3_{03} line, tracing ~300 K gas, and probing a different regime of excitation.

Brinch et al. (in prep)