Water and Organic Volatiles in Protoplanetary Disks: The Case of GV Tau N

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Abstract

How water and volatiles are distributed through protoplanetary disks around young stars is of astrobiological interest, particularly as it relates to the question of how terrestrial planets in our solar system acquired water and organics. We present high-resolution (λ/Δλ~25,000), near-infrared spectroscopic L-band observations toward T Tauri star GV Tau N. The data were acquired in 2010 with the NIRSPEC instrument on Keck II, located on Mauna Kea, HI as part of a spectral survey. We detected strong absorption due to several molecules, including several bands of water, HCN, and C_2H_2 that we interpret to be located in the warm molecular layer of the nearly edge-on protoplanetary disk.

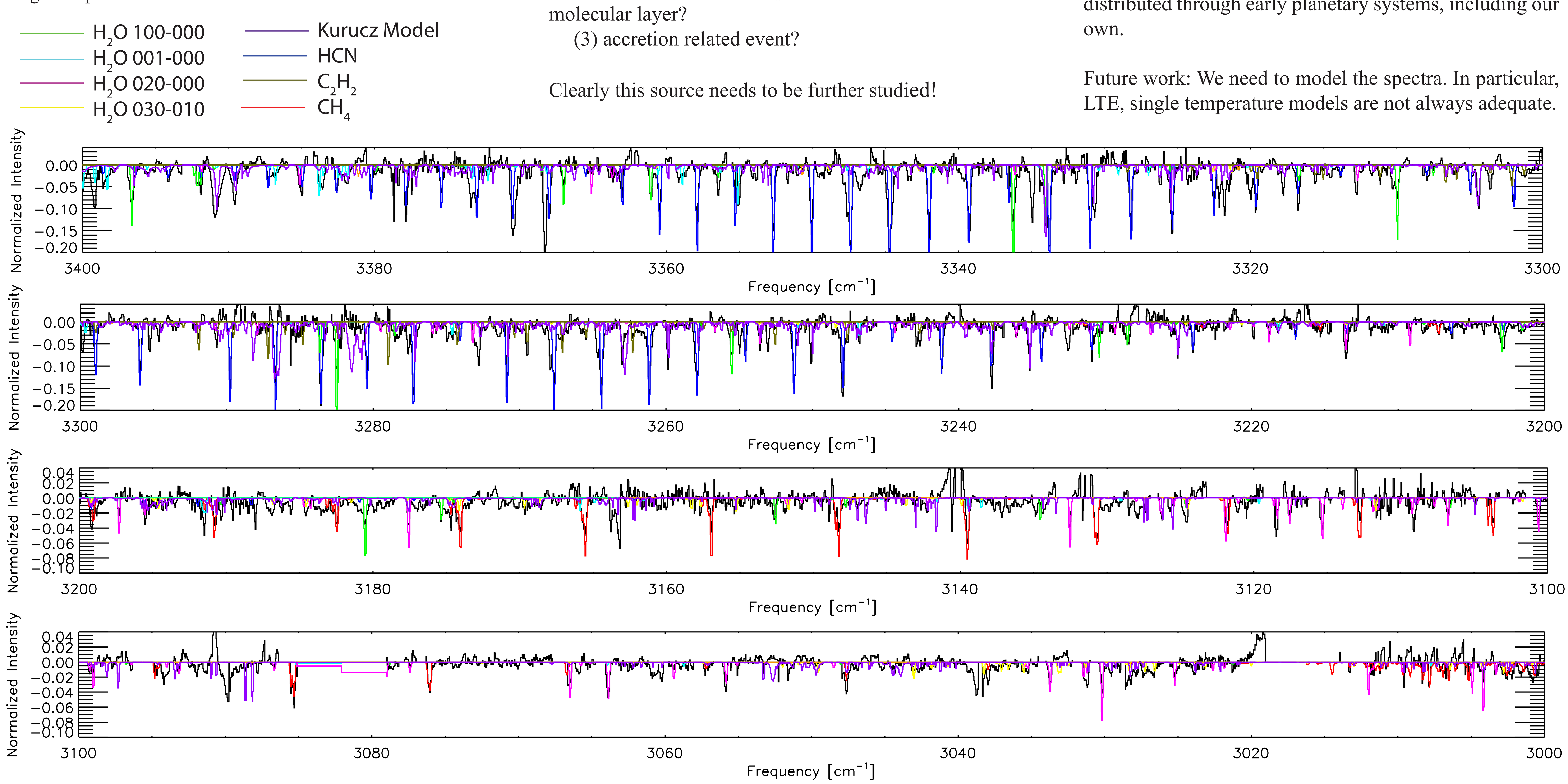
Data Analysis

Data were reduced using standard methodology:
- Flatfielding/dark subtraction
- Straightening in spectral and spatial dimensions
- LBLRTM model used for wavelength calibration

Low mass T Tauri stars have many photospheric absorption lines in the near-IR, so we fit a Kurucz model to our data (purple line in spectra below) to account for photospheric absorption.

Then we fit LTE single temperature (generally 600-900 K) model synthetic spectra to the resulting residuals. With the exception of water, such models adequately reproduce the observations.

Figure 2: Residual spectra of GV Tau N. Overplotted are a synthetic photospheric model (purple) and synthetic models for HCN (red), several bands of H_2O (green, teal, yellow, magenta, orange), C_2H_2, (olive) and CH_4 (red). All models were generated assuming LTE and a single temperature.



Anatomy of a Disk

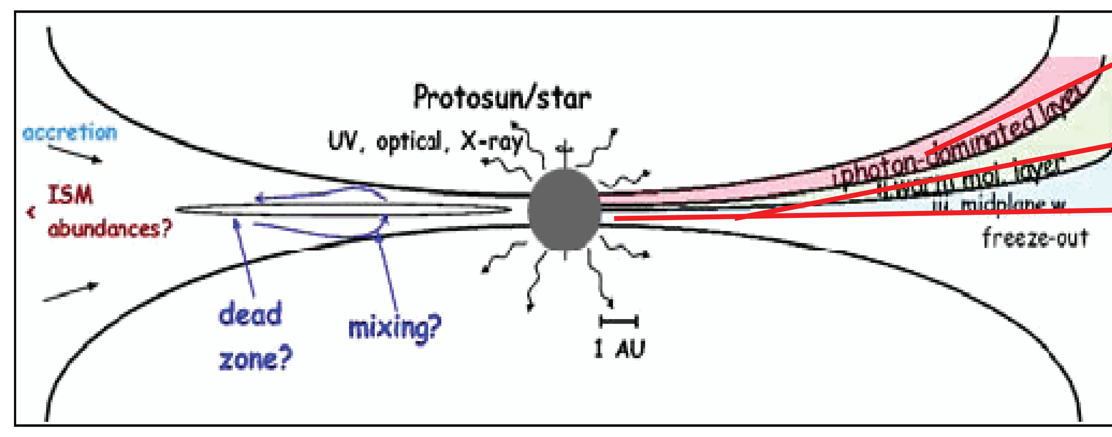


Figure 1: Illustration of processed occurring in a circumstellar disk (left) and the chemically distinct regions (right).
From: "FIRI -- a Far-Infrared Interferometer" ESA Mission Proposal by Helmich, F. with R. Ivison, arXiv.org, 13 July 2007

- Disk atmosphere, observe emission lines, dominated by ions, radicals, some molecules (i.e. CO, H_2O)
- Warm molecular layer, observe: absorption lines due to simple molecules (HCN, C_2H_2, H_2CO, CH_3OH, etc).
- Midplane: too optically thick, molecules predominantly in ice phase...comets?

In general, the vertical structure of disks can be divided into 3 chemically distinct regions (see Fig 1):

(1) a **cool midplane** where solid material sediments and forms planetesimals, and volatiles freeze onto dust grains beyond the snow line (defined as the distance where water will be found in the solid form, ~5 AU in our solar system).

(2) the **disk surface**, which flares upward and is exposed to stellar and interstellar radiation, particularly UV and X-rays, giving rise to a photon-dominated region characterized by ionization and dissociation products.

(3) between these two layers is a **warm molecular layer** where a rich molecular chemistry is predicted to occur.

To sample region (3) the disk must be close to edge-on.What we can sample regarding composition of a disk depends strongly on orientation. To test models, we need objects with a variety of orientations.

To sample the warm molecular layer requires just the right orientation: GV Tau N!

GV Tau - the Warm Molecular Layer

GV Tau (Haro 6-10) is a T Tauri binary system in L1524. The system is highly variable, particularly in the NIR (Leinert et al. 2001; Koresko et al. 1999).

We acquired spectra of GV Tau N. They changed significantly between 2006 (Gibb et al. 2007) and 2010 (this work).

In general:
(1) narrow organic absorption lines got deeper
(2) some broad asorptions got shallower
(3) other features remained unchanged
Also, the source was much fainter in 2010.

Expanded spectral coverage in 2010 shows high J HCN lines in absorption, indicating higher T_{rot} than reported earlier.

What causes the variability? Things to investigate:
(1) clumpy circumbinary material (increased veiling)
(2) warped disk exposing a different level of the warm molecular layer?
(3) accretion related event?

Clearly this source needs to be further studied!

Discussion

Through a combination of infrared and radio observations, we are beginning to probe the different chemical layers of disks. We have samples of the disk atmosphere, the warm molecular layer, and (through comets) the midplane. This will help us understand how volatiles were distributed through early planetary systems, including our own.

Future work: We need to model the spectra. In particular, LTE, single temperature models are not always adequate.

References

Gibb et al. 2007, ApJ, 660, 1572
Koresko et al. 1999, ApJ, 525, L49
Leinert et al. 2001, A&A, 369, 215

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