Hot Organic Chemistry in the Inner Part of Protoplanetary Disks

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HOT ORGANIC CHEMISTRY IN THE INNER PART OF PROTOPLANETARY DISKS. F. Lahuis, E.F. van Dishoeck, K.M. Pontoppidan, D. Lommen, M.R. Hogerheijde, *Leiden Observatory, P.O. Box 9513, 2300 RA Leiden, The Netherlands (ewine@strw.leidenuniv.nl)*, A.C.A. Boogert, G.A. Blake, *California Institute of Technology, Pasadena, CA 91125, USA*, C.P. Dullemond, *Max-Planck Institut für Astronomie, Heidelberg, Germany*, J.K. Jørgensen, D. Wilner, *Center for Astrophysics, Cambridge, MA 01238, USA*, J. Kessler-Silacci, C. Knez, N.J. Evans, *Dept. of Astronomy, University of Texas, Austin, TX 78712, USA*.

Sensitive medium-resolution spectra of the Class I source IRS 46 in Ophiuchus, obtained with the InfraRed Spectrograph on board of the Spitzer Space Telescope, reveal strong vibration-rotation absorption bands of gaseous C_2H_2, HCN and CO_2 (see Figure 1) [1]. This is the first time these features are seen in the spectrum of a low mass young stellar object (YSO). Moreover, IRS 46 is only source in our spectroscopic survey within the Spitzer "Cores to Disks" (c2d) legacy program [2] which shows strong gas-phase absorption bands. High excitation temperatures of ≥ 300 K and abundances of $10^{-6} - 10^{-5}$ with respect to H_2 are derived, reminiscent of high temperature chemistry previously seen toward the warm inner regions of high mass YSO's [3,4].

In spite of this high abundance, the HCN J=4–3 line is barely detected with the James Clerk Maxwell Telescope, indicating a source size less than 20 AU. The 850μm continuum maps obtained with the JCMT and the Smithsonian Millimeter Array, together with the absence of scattered light in near-infrared images, put stringent limits on the mass and extent of any circumstellar envelope. A compact dense envelope is unable to explain the high excitation temperatures. Two possible explanations for the origin of this hot gas are considered: (i) the inner regions of a nearly edge-on disk; and (ii) a small blob of dense hot gas in the outflow.

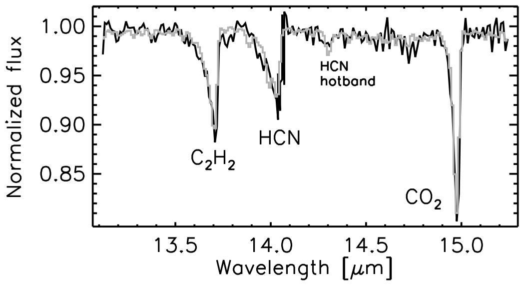

Figure 1: Blow-up of the normalized Spitzer-IRS spectrum toward IRS 46 covering the $\nu_5 = 1-0$ vibration-rotation band of C_2H_2, the $\nu_2 = 1-0$ band of HCN and the $\nu_2 = 1-0$ band of CO_2. Included in grey is the best fit synthetic spectrum. The most prominent HCN $\nu_2 = 2-1$ hot band is indicated.

A model for a nearly edge-on self-shadowed flaring disk has been constructed to fit the observed spectral energy distribution in a manner similar to that for CRBR 2422.8-3423 [5]. The 3-D axisymmetric Monte Carlo radiative transfer code of Dullemond & Dominik is used [6]. Figure 2 shows the temperature and density structure of the hot inner part of the disk. The disk radius is ~ 60 AU, the inclination is $\sim 75^\circ$ and the mass of the disk is $\sim 0.03\ M_\odot$. The disk has a puffed-up inner rim in order to reproduce the near- and mid-IR emission.

To test the plausibility that the observed columns of hot gas originate from the inner disk, the column and average temperature in the line of sight through the disk have been calculated up to the photosphere where the continuum at 14 μm reaches $\tau = 1$. A sufficiently large column density ($\sim 10^{22}$ cm^{-2}) of hot ($400 - 900$ K) dense gas can be reached in absorption toward the hot background of the inner rim and against the inner rim on the far side of the star.

High resolution L- and M-band spectroscopy with Keck-NIRSPEC at 3 and 4.7 μm shows that most of the hot HCN and CO gas toward IRS 46 is blue-shifted by 25 km/s. While this could point to the presence of an outflow, there are various arguments against this interpretation. In particular, it is unclear how a such small, few AU size blob could retain its high densities and molecular abundances given the large internal velocities of $\sim$10 km/s and the harsh stellar UV radiation field. We are exploring if dynamics within the disk can explain the velocity shift.

In summary, it is possible that the molecular absorption bands observed here are direct probes of hot organic chemistry in the inner few AU of the planet forming zone of a circumstellar disk. This work illustrates the power of medium- and high-resolution mid-infrared spectroscopy for studying protoplanetary disks.

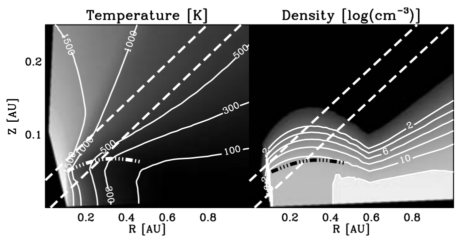

Figure 2: 2-D distribution of the temperature (left) and density (right) in the inner disk of IRS 46. Included are the $\tau = 1$ photosphere at 14 μm (dot-dashed curves) and two example lines of sight at an inclination of 75° (dashed lines) along which the absorption is assumed to be observed. The outer line of sight is toward the photosphere in the warm inner rim whereas the inner line of sight is toward the hot (1500 K) inner rim on the opposite side of the star.

References: [1] Lahuis, F., Boogert, A.C.A., van Dishoeck, E.F., et al. 2005, ApJ, submitted. [2] Evans, N.J., Allen, L.E., Blake, G.A., et al. 2003, PASP, *115*, 965. [3] Lahuis, F., & van Dishoeck, E.F. 2000, A&A, *355*, 699. [4] Boonman, A.M.S., van Dishoeck, E.F, Lahuis, F., & Doty, S. D. 2003, A&A, *399*, 1063. [5] Pontoppidan, K.M., Dullemond, C.P., Dishoeck, E.F., et al. 2005, ApJ, *622*, 463. [6] Dullemond, C.P., & Dominik, C. 2004, A&A, *417*, 159.