Astrochemistry: Recent Successes and Current Challenges
Poster Book IAU Symposium No. 231, 2005
A. J. Markwick-Kemper, ed.

DOI: 00.0000/X000000000000000X

The chemical structure of the inner 200 AU of protostellar envelopes and disks

Jes K. Jørgensen[1], Tyler L. Bourke[1], Philip C. Myers[1], Fredrik L. Schöier[2], Ewine F. van Dishoeck[3], David J. Wilner[1], and the PROSAC team†

[1]Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, MS42, Cambridge, MA 02138, USA (e-mail: jjorgensen@cfa.harvard.edu).

[2]Stockholm Observatory, AlbaNova, SE-106 91, Stockholm, Sweden

[3]Leiden Observatory, PO Box 9513, NL-2300 RA Leiden, The Netherlands

Abstract. We present high angular resolution (1″; 200 AU) observations from a large program studying low-mass protostars with the Submillimeter Array. Here we focus on the object, NGC 1333-IRAS2: continuum emission at submillimeter wavelengths resolve its circumstellar disk with a size of about 300 AU. High excitation lines of a number of molecular species, i.p., complex organic molecules including CH_3OH and CH_3OCH_3, are detected on these scales. We present an interpretation of the chemistry in which the circumstellar disk is the main reservoir of the complex organic species.

Keywords. astrochemistry, stars: formation, ISM: abundances, ISM: molecules, Stars: individual (NGC 1333-IRAS2A)

With the Submillimeter Array a new window has opened to study the innermost (∼100 AU), warm and dense regions of the envelopes and disks around deeply embedded protostars. The advantages of the SMA for studying the physics and chemistry of deeply embedded protostars are:

• **Submillimeter wavelengths:** Studies based on observations of lower excitation lines may be complicated as these lines are sensitive to the chemistry of the outer cold regions of the envelopes. In the 325-365 GHz window a wealth of molecular rotational transitions constrain the chemistry in the dense ($\sim 10^7 - 10^8$ cm^{-3}) and warm (~ 100 K) material in the envelope. Likewise since the dust continuum flux scales with frequency as ν^2 or steeper, submillimeter observations are well suited for probing the dust in protostellar disks.

• **High angular resolution:** The innermost regions of the envelopes where the temperature increases above 100 K are heavily diluted in a single-dish beam ($< 2''$ size compared to typical single-dish beam sizes of 10-20″). Interpretation of the line emission from these regions relies on extrapolation of the density and temperature distribution from observations on larger scales. Typical SMA observations resolve the emission down to these scales and make it possible to disentangle the emission from the envelope and circumstellar disk.

All in all, studies of the continuum and line emission with the SMA provide a unique possibility to probe the warm and dense gas and dust on small scales of protostellar envelopes and provide detailed constraints on the physical and chemical properties of disks in these deeply embedded stages.

† James Di Francesco (Herzberg Inst. of Astrophysics), Chin-Fei Lee, Shigehisa Takakuwa (CfA/SMA), Nagayoshi Ohashi (ASIAA) & Qizhou Zhang (CfA).

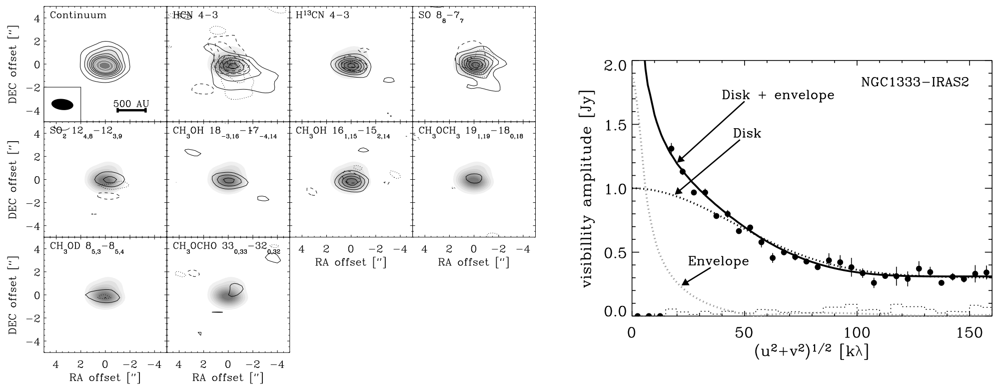

Figure 1. NGC 1333-IRAS2A observed with the SMA. *Left:* detection of high excitation molecular line emission. The contours are given in steps of 3σ. *Right:* The presence of the circumstellar disk inferred from 850 μm continuum observations by a combination of an extended envelope and a 300 AU circumstellar disk. From Jørgensen et al. (2005).

We have undertaken a survey of a large sample of deeply embedded protostars with the Submillimeter Array, "Protostellar Submillimeter Array Campaign (PROSAC)". A sample of 9 sources have been observed systematically in a wide range of lines at 218-355 GHz. The sources were selected from a large survey by Jørgensen et al. (2002) for which detailed line and continuum radiative transfer models exist constrained by single-dish observations.

As an example of the potential of the program, Fig. 1 shows the detection of continuum and high excitation transitions toward the class 0 object, NGC 1333-IRAS2A. The continuum is clearly resolved: in addition to the extended envelope, also observed with single-dish telescopes, a compact but resolved disk structure is seen. The size of this disk is about 300 AU. Such a disk structure would suggest that circumstellar disks rapidly build up in the protostellar stages and that an inner cavity exists in the envelope with a size determined by the rotation the protostellar core. With a cavity at least of the same size as the disk, the temperature in the envelope does not exceed 70–90 K. Given the disk mass, $\sim$a few$\times$0.01-0.1 $M_\odot$, inferred from the continuum emission, this component will provide a significant contribution to the observed emission in the interferometer beam and will in fact dominate the column density of a potential hot core. A likely explanation for the observed emission from the complex organic molecules is that these species reside in this circumstellar disk.

Acknowledgements

This research was supported by NASA Origins of Solar Systems Grant NAG5-13050. The Submillimeter Array is a joint project between the Smithsonian Astrophysical Observatory and the Academia Sinica Institute of Astronomy and Astrophysics, and is funded by the Smithsonian Institution and the Academia Sinica.

References

Jørgensen, J. K., Bourke, T. L., Myers, P. C., Schöier, F. L., van Dishoeck, E. F., & Wilner, D. J. 2005, ApJ, submitted

Jørgensen, J. K., Schöier, F. L., & van Dishoeck, E. F. 2002, A&A, 389, 908