

**TESTING GRAIN-SURFACE CHEMISTRY IN HOT CORE REGIONS.** Suzanne E. Bisschop, Ewine F. van Dishoeck, *Leiden Observatory, Postbus 9513, 2300 RA Leiden, Netherlands, (bisschop@strw.leidenuniv.nl)*, Jes K. Jørgensen, *Harvard-Smithsonian Center for Astrophysics, 60 Garden Street MS42, Cambridge, MA 02138, USA.*

Many complex organic molecules have been detected in star-forming regions, like  $\text{CH}_3\text{OH}$ ,  $\text{CH}_3\text{OCH}_3$  and  $\text{CH}_3\text{CH}_2\text{CN}$ . Studying their chemistry is important, since these species may eventually be incorporated into circumstellar disks and thus become part of the material from which future planetary systems are made. Two scenarios for their formation have been proposed: grain-surface formation and high-temperature gas-phase reactions (van Dishoeck & Hogerheijde, 1999). In the former case, grain-surface reactions during the cold pre-stellar and protostellar phases are thought to lead to the formation of hydrogenated molecules, which subsequently evaporate into the gas when the young star heats its surroundings. In the latter scenario, high-temperature gas-phase reactions involving evaporated molecules (primarily  $\text{CH}_3\text{OH}$ ) produce complex organic species like  $\text{CH}_3\text{OCH}_3$  (Charnley et al., 1992). The resulting molecules from these two schemes are also known as “first generation” and “second generation” species, respectively. Currently, it is very difficult to distinguish between these two scenarios since the rates of even some of the most basic surface reactions are not known. Accordingly, we have started a combined laboratory and observational program to test the scenarios.

The basic scheme for grain surface chemistry has been outlined by Tielens & Hagen (1982) and Tielens & Charnley (1997). The first step is hydrogenation of the main species that accrete from the gas onto the grains, i.e., C, N, O and CO, leading to  $\text{CH}_4$ ,  $\text{NH}_3$ ,  $\text{H}_2\text{O}$ ,  $\text{H}_2\text{CO}$  and  $\text{CH}_3\text{OH}$ . These molecules can react further in the ice with C, H, N, and O creating several more complicated species. In the warm regions close to the protostars the grain mantles can evaporate, returning many of the “first generation” molecules into the gas phase.

Deep searches for a set of molecules have been performed for 7 high mass and 1 low mass young stellar objects with the James Clerk Maxwell Telescope. The focus is on relatively nearby sources with narrow line widths to avoid confusion. The molecules studied are HCO,  $\text{H}_2\text{CO}$ ,  $\text{CH}_3\text{OH}$ ,  $\text{CH}_2\text{CO}$ ,  $\text{CH}_3\text{CHO}$ ,  $\text{C}_2\text{H}_5\text{OH}$ , HNC and  $\text{NH}_2\text{CHO}$ . As an example Figure 1 shows the detection of  $\text{C}_2\text{H}_5\text{OH}$  toward N7538IRS1. Several of these molecules have been detected for most or all sources, with a few exceptions:  $\text{NH}_2\text{CHO}$ ,  $\text{CH}_2\text{CO}$  and HCOOH are only detected for a few sources and HCO and  $\text{CH}_3\text{CHO}$  not at all. For HCO the reason for the non-detection

is likely its low intrinsic line strength.  $\text{CH}_3\text{CHO}$  has previously been detected by Ikeda et al. (2002) with rotational temperatures of only 20-30 K, much lower than the lowest rotational transition that can be probed with the JCMT whose energy level lies at 71 K.

Correlations between the abundances of these species with respect to CO have been studied. The correlation is found to be strong for  $\text{CH}_3\text{OH}$ ,  $\text{H}_2\text{CO}$ ,  $\text{C}_2\text{H}_5\text{OH}$ , and HNC (see for example Figure 1 for HNC and  $\text{C}_2\text{H}_5\text{OH}$ ), whereas no clear trends are yet found for the abundances of HCOOH,  $\text{NH}_2\text{CHO}$ , and  $\text{CH}_2\text{CO}$ . The strong trends found for four of these molecules indicate that they are either present in the same environment or share a common formation mechanism. The resulting branching ratios can be compared with various models. For example, pure gas-phase models by Lee et al. (1996) predict  $\text{CH}_2\text{CO}/\text{CH}_3\text{CHO}/\text{CH}_3\text{CH}_2\text{OH}$  ratios of  $\sim 1 : 10^{-3} : 10^{-5}$ , whereas grain-surface chemistry predicts ratios much closer to unity (Tielens & Charnley, 1997). Our inferred branching ratios are found to be much closer to the latter values, indicating that grain-chemistry plays an important role.

A more complete analysis based on detailed radiative transfer models is in progress and first results will be presented in the poster.

## References

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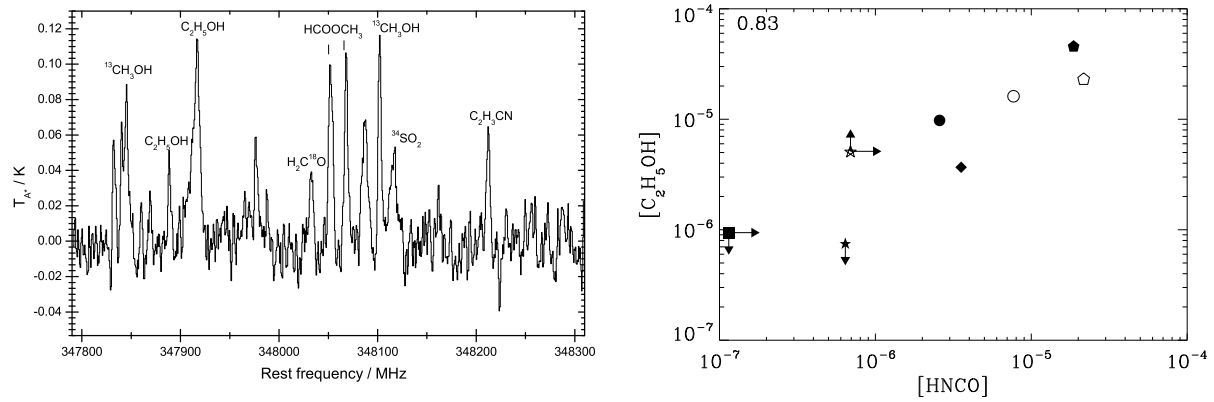


Figure 1: Left: The 348.05 GHz setting observed for N7538IRS1. This setting contains lines of  $^{13}\text{CH}_3\text{OH}$ ,  $\text{C}_2\text{H}_5\text{OH}$ ,  $\text{H}_2\text{C}^{18}\text{O}$ ,  $\text{HCOOCH}_3$ ,  $^{34}\text{SO}_2$  and  $\text{C}_2\text{H}_3\text{CN}$ . Right: Comparison between abundances of  $\text{C}_2\text{H}_5\text{OH}$  and  $\text{HNCO}$  for the 8 observed sources.