Dissociative Recombination and the build-up of complex molecules in the Interstellar Medium

W. D. Geppert,[1] M. Hamberg[1], E. Vigren[1], R. D. Thomas[1], V. Zhaunerchyk[1], E. S. Wirström[2], C. M. Persson2[b], T. J. Millar[3], J. Semaniak[4] M. Kamińska[4], F. Österdahl[1], J. H. Black[2], Å. Hjalmarson[2], P. Bergman[2], M. Holmgren[2], F. Hellberg[5], and M. Larsson[1]

[1]Stockholm University, Department of Physics, Roslagstullbacken 21, SE-10691 Stockholm, Sweden
[2]Onsala Space Observatory, SE-439 92 Onsala, Sweden
[3]Queen's University Belfast, University Road, Belfast, BT7 1NN, UK
[4]Institute of Physics, Świętokrzyska Academy, PL-25406, Kielce, Poland
[5]Manne Siegbahn Laboratory, Frescativägen 24, SE-104 05 Stockholm, Sweden

methanol, ethanol, dimethyl ether and formic acid are produced in the gas-phase or on grain surfaces. As gas-gas production pathways very often ion-neutral reactions leading to the protonated form of the species followed by dissociative recombination to yield the final product have been invoked.

In the case of methanol, a feasible gas-phase production process is unlikely. The rate of radiative association of CH_3^+ and H_2O leading to $CH_3OH_2^+$ has been found to be far to low to explain the observed methanol abundances [1] and, on top of that, only a minor fraction of methanol (3 %) is produced in the dissociative recombination of the latter ion [2]. Introduction of these new findings into state-of-the art model calculations of dark clouds yielded that the proposed gas-phase mechanism is by far insufficient to explain the observed methanol abundances. On the other hand, successive hydrogenation of CO on icy grain surface by H atoms has been found to produce methanol [3].

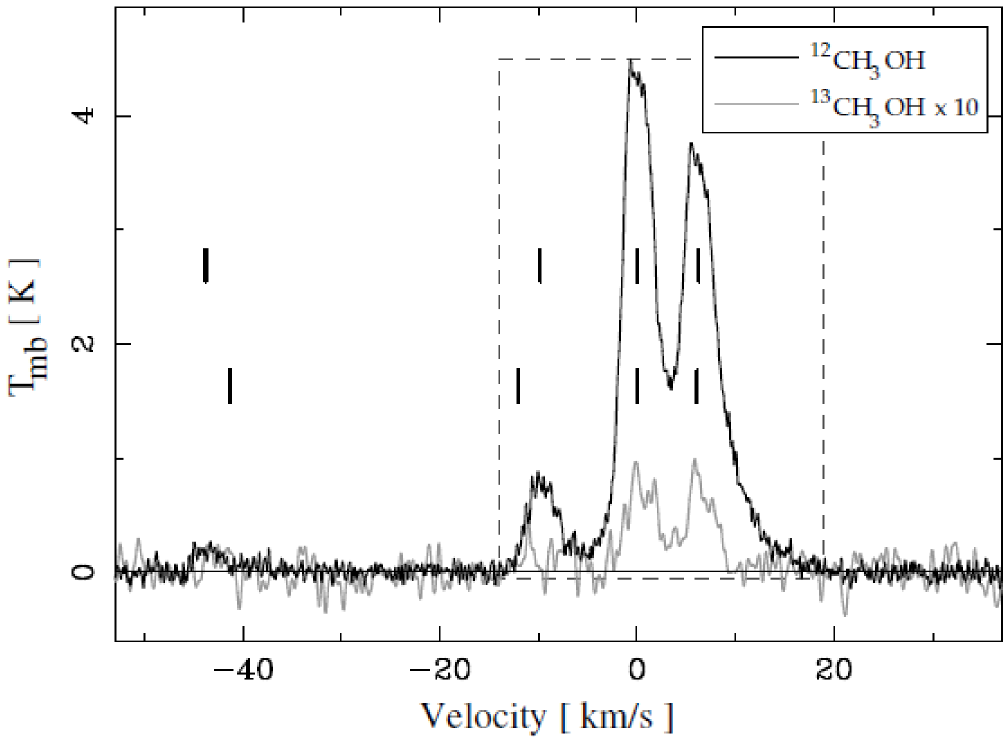

Figure 1: Spectra of the 2-1 rotational line group of $^{13}CH_3OH$ (black) and $^{12}CH_3OH$ (gray) around 96 GHz

It now remains to be proven by direct observation that interstellar methanol really originates from grain surfaces. This can be done by the so-called, isotope labelling a posteriori, which was first suggested by Charnley et al. [4]. The method is based on the fact that ^{13}C is preferably accumulated in CO at low temperature, which in turn results in a ^{13}C deficiency in other molecules forming from ion-neutral reactions in the gas-phase [5]). Assuming that this selective fractionation remains unaltered by the processes of adsorption and desorption, the $^{12}C/^{13}C$ ratio in various molecules could be used to distinguish between formation from CO on cold grains and gas-phase formation.

We therefore performed observations of the $^{12}C/^{13}C$ ratio for $C^{18}O$ and methanol in several massive young stellar objects, one pair of compact HII regions and one source hosting several young stellar objects. The 2-1 rotational line groups of the 2 isotopomers around 96 GHz were observed using the 20m telescope at Onsala Space Observatory. (see Fig. 1). With one exception (where the ^{12}C molecule lines are very probably optically thick) the agreement of the $^{12}C/^{13}C$ ratio on the two compounds is excellent. This points to a surface origin of interstellar methanol, which is also corroborated by the fact that a strong correlation of abundances between methanol and formaldehyde has been found in several star-forming regions [6].

Furthermore, the role of dissociative recombination in the formation of other, more complex molecules detected in star-forming regions like ethanol, dimethyl ether and ethanol will be discussed.

References

[1] D. Gerlich, and M. Smith, 2006, Phys. Scripta, 73,
[2] W. D. Geppert et al., 2006, Faraday Discuss. 133, 177H. Shimauma, K. Pingu, & S. Miyauchi, 2008, ApJ 575, 1100 .
[3] Fuchs, G. W. et al. 2009, A & A 505, 629
[4] S. B. Charnley et al., 2004, MNRAS 347, 157
[5] W. D. Langer, T. E.Graedel, M. A Frerking & P. B. Armentrout, 1984, Ap J., 277, 581
[6] Bisschop, S. E. Ph. D. thesis, Leiden University 2007