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Observations of deuterated formaldehyde and methanol in low-mass protostars. Evidence for grain surface chemistry ?

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Abstract. We present observations of deuterated formaldehyde (HDCO and D_2CO), methanol (CH_2DOH and CH_3OD) as well as doubly-deuterated methanol CHD_2OH towards a sample of low-mass protostars. Such multi-isotope study provides strong constraints on grain chemistry models that propose to explain methanol formation. Our observations point to the formation of methanol on the grain surfaces, while formaldehyde formation may be dominated by gas-phase reactions and/or strongly affected by abstraction reactions on grains.

Keywords. Low-mass protostars, deuterium, grain, chemistry

1. Observations

Using the IRAM 30-meter telescope (Pico Veleta, Spain), we observed the five deuterated species HDCO, D_2CO, CH_2DOH, CH_3OD and CHD_2OH towards the seven low-mass protostars IRAS16293−2422, NGC1333−IRAS4A, −IRAS4B, −IRAS2, L1448N, L1448mm and L1157mm. We also present observations of deuterated formaldehyde (HDCO and D_2CO) towards L1527.

We detected the two deuterated formaldehyde isotopes (HDCO and D_2CO) towards all the sources of our sample. Regarding methanol, only the four sources IRAS16293−2422, NGC1333−IRAS4A, −IRAS4B and −IRAS2 have good detections. This is consistent with the study by Maret et al. (2005) that shows that these three sources are indeed the brightest ones for CH_3OH emission. CH_2DOH was detected in all sources it was searched for, but only the low-lying transition was detected in the case of L1448N, L1448mm and L1157mm. CH_3OD was detected only towards IRAS16293, IRAS4A, IRAS4B, L1448mm and L1157mm, with only one transition detected in the two last sources. Finally, doubly-deuterated methanol was detected towards IRAS16293, IRAS4A, IRAS4B and IRAS2. Upper limits were derived for the other sources.

2. Analysis - Comparison to grain chemistry models

We computed all column densities of the different isotopes using the population diagrams method, assuming a source size of $10''$. H_2CO and CH_3OH column densities were recomputed by the same method from the data from Maret et al. 2004 and Maret et al. 2005, correcting for the the opacities whenever the ^{13}C transitions had been observed.

Methanol is thought to be formed on the grains by successive hydrogenations of CO.

An intermediate product of these reactions is formaldehyde. Deuterium fractionation studies of formaldehyde and methanol thus provide a useful tool for confirming the grain chemistry scenario. To understand if formaldehyde and methanol are formed simultanuously on the grains, and to unveil a possible contribution of gas-phase processes in the formation of formaldehyde, we compared the observed fractionations to the predictions of the grain chemistry model from Stantcheva et al. (2003), which only considers successive hydrogenations/deuterations but no abstraction reactions (such as $H_2CO + H \rightarrow HCO$).

Fig. 1 presents, in dashed lines, the HDCO, D_2CO, CH_2DOH, CH_3OD et CHD_2OH fractionations predicted by the grain model, as a function of the gas-phase atomic D/H ratio at the time of mantle formation. The observed fractionations with their error bars have been superimposed for each source. This allows to infer the required D/H ratio required for the formation of each molecule.

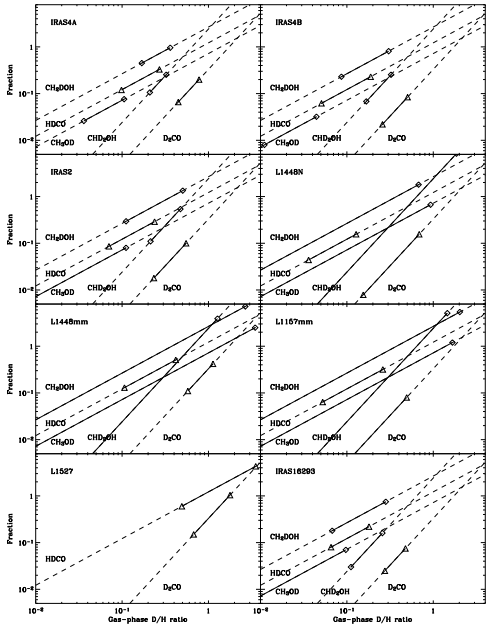

Figure 1. Comparison between the observed fractionations (triangles are for formaldehyde species whereas diamonds are for methanol species) towards the eight sources of our sample (solid lines) and the predictions of the grain model (dashed lines, Stantcheva et al. 2003).

Methanol fractionation appears to be consistent with the formation on the surface of dust grains (Parise et al. 2002, 2004). However, HDCO and D_2CO are not consistent with a common D/H value. This might point to the fact that either gas-phase production of formaldehyde is an important path, either that abstraction reactions are playing a role on the grain surfaces, enhancing the most deuterated isotopomers.

References

Maret, S. et al. 2004, *A&A* 416, 577
Maret, S. et al. 2005, *A&A* accepted
Parise, S. et al. 2002, *A&A* 393, L49
Parise, B. et al. 2004, *A&A* 416, 159
Stantcheva T. et al. 2003, *MNRAS* 340, 983