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FORMALDEHYDE EMISSION FROM LOW MASS PROTOSTARS

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Abstract. We present a survey of the formaldehyde emission in nine class 0 protostars obtained with the IRAM 30m and the JCMT millimeter telescopes. Using a detailed radiative transfer code of the envelopes surrounding the protostars, we show that all but one of the observed objects show an inner warm evaporation region where the formaldehyde is much more abundant (up to three orders of magnitude) than in the outer cold part. The largest inner formaldehyde abundances are associated with the sources having the lowest submillimetric to bolometric luminosity ratio, i.e. with sources closer to the class I border. These abundances are compared with predictions from recent models of hot core chemistry.

1 Introduction

Formaldehyde is, after water and carbon monoxyde, one of the main component of ices in grains mantles. Recently, Ceccarelli et al. (2000a,b), Maret et al. (2002) and Schöier et al (2002) have shown that in the inner parts of protostellar envelopes, grains mantles evaporate, releasing the ices components into the gas phase, and, among them, formaldehyde. Observations of formaldehyde transitions can be therefore used to determine the physical and chemical conditions, namely density, temperature and chemical abundances, in the inner part of protostellar envelopes (Ceccarelli et al. 2003, Maret et al. 2003).

The most accepted scenario predict that formaldehyde is formed on grain surfaces, by successive hydrogenation of CO. The measure of the formaldehyde abundance in the gaseous phases of the inner part of the envelopes gives some hints on the composition of the grain mantles, and in turn on the grain surface chemistry. Moreover, chemistry models predict that, once in the gas phase, formaldehyde can rapidly form complex molecules, by the so called *hot core* chemistry (Charnley et al. 1992). This chemistry was thought to exist only in high mass protostars, where the gas temperature and density are high enough to trigger endothermic reactions between species. The very recent detection of O and N bearing complexes molecules towards IRAS16293-2422, typical of massive hot cores (Cazaux et al. 2003), emphasizes the chemical similarity that may exist between low and high mass protostars.

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In order to determine if IRAS16293-2422 is representative of low mass protostars, or rather a peculiar case, one needs to measure the formaldehyde abundance in a larger sample of protostars. In this contribution, we present the results of a survey of the formaldehyde emission towards a sample of low mass, Class 0 protostars.

2 Observations

A sample of eight Class 0 protostars, located in the Perseus, ρ-Ophiuchus and Taurus complexes, were observed using the James Clerk Maxwell Telescope and the Institut de Radio Astronomie 30 meter telescope. Eight formaldehyde transitions were selected, three ortho and five para, ranging from 140 to 364 GHz. The transitions between 140 GHz and 280 GHz were observed with the IRAM-30m telescope, while transitions at higher frequencies were observed using the JCMT. The choice of these two instruments allow a nearly constant beam size over frequencies. The transitions were chosen to cover a large range of upper energies, from 20 to 100 cm^{-1}, in order to probe the physical conditions in the different part of the envelope. The corresponding $H_2^{13}CO$ transitions were also observed to determine the opacity of the lines.

Fig. 1 shows a typical example of lines observed towards NGC1333-IRAS4A. The lines are relatively narrow, with a contribution of the wings extending at larger velocities. Some of the lines show self-absorption and/or absorption by the foreground material.

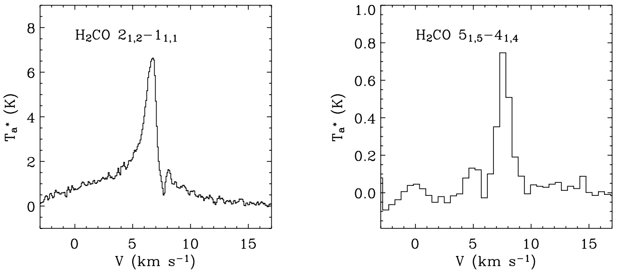

Fig. 1. Typical exemple of formaldehyde lines observed towards NGC1333-IRAS4A

3 Model

The formaldehyde emission was modeled using a 1D spherical radiative code. The density and dust temperature profiles determined by Jørgensen (2002), from the simultaneous modeling of the continuum emission at 450 and 850 μm and the spectral energy distribution, were adopted. The gas temperature was computed by solving the thermal balance in the envelope (Ceccarelli et al. 1996).

Finally, because of the importance of evaporation in the inner parts of the envelope, the formaldehyde abundance has been approximated by a step function: $X_{\rm out}$ in the outer part of the envelope where the dust temperature $T_{\rm dust}$ is lower than 100 K, and $X_{\rm in}$ in the inner parts of the envelope where $T_{\rm dust} > 100$K. These abundances have been determined by a χ^2 analysis. Fig. 2 show the χ^2 contours has a function of

Table 1. Derived formaldehyde abundances, radius and density where $T_{\rm dust} = 100\,{\rm K}$ and $L_{\rm smm}/L_{\rm bol}$ ratio.

Source	$L_{\rm smm}/L_{\rm bol}$[a] (%)	$R_{\rm 100K}$ (AU)	$n_{\rm 100K}$ ($\rm cm^{-3}$)	$X_{\rm out}$	$X_{\rm in}$
NGC1333-IRAS4A	5	53	2×10^{9}	2×10^{-10}	2×10^{-8}
NGC1333-IRAS4B	3	27	2×10^{8}	5×10^{-10}	3×10^{-6}
NGC1333-IRAS2	≤ 1	47	3×10^{8}	3×10^{-10}	2×10^{-7}
L1448-MM	2	20	2×10^{8}	7×10^{-10}	6×10^{-7}
L1448-N	3	20	1×10^{8}	3×10^{-10}	1×10^{-6}
L1157-MM	5	40	8×10^{8}	8×10^{-11}	1×10^{-8}
L1527	20	0.7	3×10^{6}	3×10^{-10}	6×10^{-6}
VLA1623	0.2	13	2×10^{8}	8×10^{-10}	-
IRAS16293-2422[b]	2	133	1×10^{8}	1×10^{-9}	1×10^{-7}

[a] From André et al. (2000).

[b] From Ceccarelli et al. (2000b).

$X_{\rm in}$ and $X_{\rm out}$ for two sources of the sample. Table 1 presents the derived abundances in all sources.

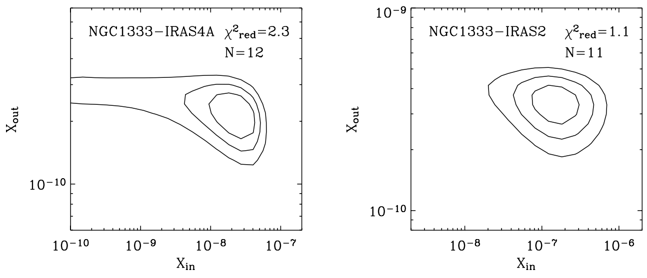

Fig. 2. χ^2 as a function of $X_{\rm in}$ and $X_{\rm out}$ for NGC1333-IRAS4A and NGC1333-IRAS2. The contour levels show the 1, 2 and 3 σ confidence level respectively.

In all the sources but VLA1623, the observations are only reproduced if there is a jump in the formaldehyde abundance, between 2 and 3 orders of magnitude. The position of this jump is not well constrained by our observations, but is consistent with the radius where grain mantle evaporates in the inner part of the envelope.

It is interesting to note that the higher inner formaldehyde abundances are observed in the older, namely having the lowest $L_{\rm smm}/L_{\rm bol}$ ratio, border class I source, L1527. *A contrario* the lowest abundances are observed towards NGC1333-IRAS4A and B, and no jump is observed on the youngest source of our sample, VLA1623. This result is certainly surprising, as chemical models predicts that once on the gas phase, formaldehyde will be rapidly destroyed by endothermic reactions, on a time scale of 10^4 yr (Rodgers &

Charnley 2003). On the other hand, if the $L_{\rm smm}/L_{\rm bol}$ is not a evolutionary tracer, but a parameter affected by the initial conditions of the pre-stellar core from which the protostar forms (Jayawardhana 2001), the differences in the values of $X_{\rm in}$ may simply reflect different efficiencies in the formation of H_2CO. Observations on a larger sample of protostars are needed to answer this question.

4 Conclusions

We presented a survey of the formaldehyde emission of a sample of class 0 protostars. The data have been modeled with a 1D spherical radiative transfer code. Our model shows that the formaldehyde abundance is enhanced between two and three orders of magnitude in the inner part of the envelope, where the dust temperature reaches 100 K. In this region, the grain mantle evaporates, releasing the ices components, and among them, formaldehyde. The different abundances observed from one source to the other may reflect different efficiencies on the formation of H_2CO on grain mantles, but other observations on a larger sample are needed to answer this question.

References

André, P., Ward-Thompson, D., & Barsony, M. 2000, Protostars and Planets IV, 59+

Ceccarelli, C., Castets, A., Caux, E., et al. 2000a, A&A, 355, 1129

Ceccarelli, C., Hollenbach , D.J, & Tielens, A.G.G.M.

Ceccarelli, C., Loinard, L., Castets, A. et al. 2000b, A&A, 362, 1122

Ceccarelli, C., Maret, S., Tielens, A.G.G.M, Castets, A., & Caux, E. 2003, A&A, in press

Charnley, S.B., Tielens, A.G.G.M, & Millar, T.J. 1992, ApJ, 389, L71

Jayawardhana, R., Hartmann, L., & Calvet, N. 2001, ApJ, 548, 310

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

Maret, S., Ceccarelli, C., Caux, E. Tielens, A.G.G.M, & Castets, A. 2002, A&A, 395, 573

Maret, S., Ceccarelli, C., Caux, E. et al. 2003, A&A, in press

Rodgers, S.D. & Charnley, S.B. 2003, ApJ, 585, 355

Schöier, F.L., Jørgensen, J.K., van Dishoeck, E.F., & Blake, G.A. 2002, A&A, 390, 1001