FORMATION OF COMETS : CONSTRAINTS FROM THE ABUNDANCE OF HYDROGEN SULFIDE AND OTHER SULFUR SPECIES

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Abstract. Recent determinations of H_2S and other sulfur compounds abundances in comets and in Orion KL bring new tests of the origin of cometary matter.

According to one of the two scenarios of cometary matter formation (Yamamoto 1991 ; Despois 1992), cometary composition should match closely the composition of interstellar medium (ISM). Recent observations of sulfur compounds provide new very useful tests ; sulfur, although not abundant, presents the advantage that most major S species are observed, whereas crucial C and N species like CH_4 and N_2 are at present still ill-known.

Comet results are summarized in Table I. Radio millimetric observations of the two bright comets Austin (1989c1) and Levy (1990c) have brought the first detection of H_2S (Colom et al. 1992 ; Crovisier et al. 1991). Optical observations of SO and SO_2 in Austin and other comets (Kim and A'Hearn 1991) have resulted in very low limits, corresponding to abundances lower than that of H_2S by 2 to 3 orders of magnitude. Also noticeable is the high variability of S_2 between comets - well detected in comet IRAS-Araki-Alcock (1983 VII), it is absent otherwise to very good limits (A'Hearn 1992) ; this contrasts with the limited variation encountered usually in mother molecules. CS_2 is the proposed parent for CS ; with H_2S this would be the main cometary sulfur species (Roettger 1991). The two last species are not well known : OCS limits need to be improved ; the lifetime of H_2CS is not constrained : if shorter than the assumed 3300 s at 1 AU, higher H_2CS abundances in the nucleus are possible.

Due to the paucity of available observation, the very complex Orion KL region is at present the main source of data for abundances ratios of S species in the ISM. It includes at least 4 (spatial as well as spectral) components : Hot Core, Plateau, Extended and Compact Ridges. Minh et al. (1990) have found very high H_2S abundances in both Hot Core and Plateau. However only in the Hot Core, where grain mantle evaporation has been suggested (e.g. Walmsley 1989), is H_2S much more abundant than sulfur oxides, whereas in the plateau, where shocks from outflows are believed to play an important role, their abundances are comparable. Regarding models of IS chemistry, the $[H_2S]/([SO]+[SO_2])$ ratio is usually between 0.1 and 10. Only grain surface chemistry models show a net tendancy for higher $[H_2S]$.

Is H_2S in other IS region frozen in grain mantles ? The tentative detection of solid H_2S towards W33A around 3.9 μ has raised some controversy as well on observational grounds (Smith 1991 ; Geballe 1991) as in the interpretation (Allamandola 1992). The level of present detection/upper limits is on the order of what is seen in comets, when compared to H_2O .

The resemblance of cometary and Hot Core ratios, together with results from state-of-the-art IS chemistry, tend to suggest a possible role of grain surface chemistry in the formation of cometary matter. A simple process could be the transformation of most atomic sulfur into H_2S when sticking on grains, through recombination with incoming H atoms ; atomic S is the dominant sulfur carrier in IS chemistry models (Millar and Herbst 1990).

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	S_2	H_2S	SO	SO_2	CS (CS_2)	OCS	H_2CS
Austin (1989c1)	<0.05	2.7	<0.05	<4	0.5	–	–
Levy (1990c)	–	2	–	<2.5	–	<2	<1
P/Halley	<0.3	–	<0.2	<0.02	0.3-2.5	<7	-
IRAS-A.-A. (1983 VII)	0.2	–	<0.005	<0.001	–	–	–
Others	–	–	<0.2	<0.01	1	–	–
Orion Hot core	–	1000-5000	<20	<24	–	–	–
Orion Plateau	–	1000-4000	520	520	22	52	–
Orion Compact Ridge	–	–	–	–	–	3.3	1.6
Orion Extended Ridge	–	1.5	<0.9	<3.3	2.5	–	–
TMC1	–	0.7	5	<1	10	2	3

TABLE I
Abundances of S species. Comets : relative production rate Q/Q_{H_2O} in units of 10^{-3}. See Crovisier et al. 1991 for references. ISM : relative column densities N/N_{H_2} in units of 10^{-9}. Data from Minh et al. 1990, Blake et al. 1987, Millar and Herbst 1990 ; see also Guélin et al. 1990, Turner 1991.

In addition to chemistry, the presence of H_2S provides constraints on the history of cometary matter through its low sublimation temperature. For pure H_2S, at the typical density of 10^{13}, it is about 57 K (Yamamoto 1985). H_2S and CO are thus the most volatile parent species directly identified in comets. It is very important to study the more realistic case of ice mixtures ; laboratory work should precise temperature constraints deduced from the presence of H_2S when sticked on other ices.

The study of sulfur bearing species bring thus several important new abundance ratios to test theories of the origin of cometary matter : H_2S/H_2O , H_2S /($SO+SO_2$), H_2S/CS. More data is clearly needed both in comets to improve the statistics and in interstellar space towards regions forming sun-like stars.

References

A'Hearn, M.F. 1992, these proceedings.
Allamandola, L.J. 1992, these proceedings.
Blake, G.A., Sutton, E.C., Masson, C.R., Phillips, T.G. 1987, Ap.J., 315, 621-645
Colom, P., Bockelee-Morvan, D., Crovisier, J., Despois, D.,Paubert, G. 1992, these proceedings.
Crovisier, J., Despois, D., Bockelée-Morvan, D., Colom, P., Paubert, G. 1991, Icarus, accepted.
Despois, D. 1992, these proceedings.
Geballe, T.R. 1991, M.N.R.A.S., 251, 24p-25p.
Guélin, M., Rist, C., Cernicharo, J. 1990, in Proc. 7th Manchester Astronomical Conference, Cambridge University Press, in press.
Kim, S.J., A'Hearn, M.F. 1991, Icarus, 90, 79-95.
Millar, T.J., Herbst, E. 1990, A.A. 231, 466-472.
Minh, Y.C., Ziurys, L.M., Irvine, W.M., McGonagle, D. 1990, Ap.J., 360, 136-141
Mumma, M.J., Stern, A., Weissman, P.R. 1992, in Protostars and Planets III, E.H. Levy, J.I. Lunine and M.S. Matthews eds., Univ. of Arizona Press: Tucson.
Roettger, E.E. 1991, Ph.D. dissertation, Johns Hopkins University.
Turner, B.E. 1991, Ap.J., 76, 617-686.
Smith, R.G. 1991, M.N.R.A.S., 249, 172-176.
Walmsley, C.M. 1989, in I.A.U. Symposium 135 : Interstellar Dust, eds. L.J. Allamandola and A.G.G.M.Tielens, 263-273.
Yamamoto, T. 1985, A.A., 142, 31-36.
Yamamoto, T. 1991, in Comets in the Post-Halley Era, eds. R.L. Newburn, Jr., M. Neugebauer, and J. Rahe, Kluwer : Dordrecht, 361-376.