CHEMICAL EVOLUTION OF INTERSTELLAR DUST INTO PLANETARY MATERIALS; M. N. Fomenkova and S. Chang, NASA Ames Research Center

Comets are believed to retain some interstellar materials, stored in fairly pristine conditions since their formation [1]. The composition and properties of cometary dust grains should reflect those of grains in the outer part of the protosolar nebula which, at least in part, were inherited from the presolar molecular cloud [2]. However, infrared emission features in comets differ from their interstellar counterparts [3]. These differences imply processing of interstellar material on its way to incorporation in comets, but C and N appear to be retained. Overall dust evolution from the interstellar medium (ISM) to planetary materials is accompanied by an increase in proportion of complex organics and a decrease in pure carbon phases.

The composition of cometary dust grains was measured *in situ* during fly-by missions to comet Halley in 1986 [4]. The mass spectra of about 5000 cometary dust grains with masses of $5x10^{-17}$-$5x10^{-12}$ g [5] provide data about the presence and relative abundances of the major elements H, C, N, O, Na, Mg, Al, Si, S, Cl, K, Ca, Ti, Cr, Fe, Ni. The bulk abundances of major rock-forming elements integrated over all spectra were found to be solar within a factor of 2 [6], while the volatile elements H, C, N, O in dust are depleted in respect to their total cosmic abundances (see Figure).

The abundances of C and N in comet dust are much closer to interstellar than to meteoritic and are higher than those of dust in the diffuse ISM. In dense molecular clouds dust grains are covered by icy mantles, the average composition of which is estimated to be H:C:N:O ≅ 96:14:1:34 [7]. Up to 40% of elemental C and O may be sequestered in mantles [7]. If we use this upper limit to add H, C, N and O as icy mantle material to the abundances residing in dust in the diffuse ISM, then the resulting values for H, C, and N match cometary abundances. Thus, ice mantles undergoing chemical evolution on grains in the dense ISM appear to have been transformed into less volatile and more complex organic residues [8] wherein the H, C and N are largely retained and ultimately accreted in cometary dust.

The abundance of O is about the same for cometary dust, meteorites and interstellar dust. In all these samples, most of O in a solid phase is bonded to silicates. In dense molecular clouds, the abundance of O in dust+mantles is significantly higher then in cometary dust. This difference may reflect the greater lability of oxygenated species toward astrophysical processing. Laboratory studies show that O-bearing functional groups in organic compounds tend to be relatively easily removed by heating and/or UV and particle irradiation [8]. In Halley's coma, O-containing organic grains, being unstable, were located closest to the nucleus [9]. The decomposition of the organic grain component in the coma provided a significant extended source contribution to O-containing gaseous species such as CO and H_2CO [10].

Carbon is present in the comet Halley grains in three major forms: (i) complex organic (CHON) material of highly variable composition; (ii) carbon grains, consisting mainly of C with minor (~1%) amounts of other elements; and (iii) carbonates. Possible organic components are aromatic and aliphatic hydrocarbons, aromatic heterocycles, amino-, hydroxy- and polycarboxylic acids, aromatic ketones, etc. [11]. Similar compounds identified in meteorites have anomalously high D/H ratio signifying their interstellar origin [12]. The proportion of C bound in the

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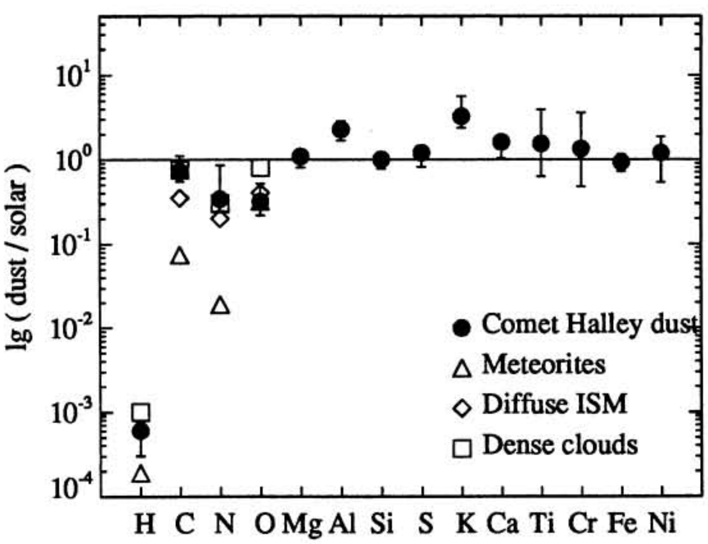
form of complex organic material appears to increase with increasing degree of processing: up to 50% in interstellar grains, 70-80% in comet dust, and 90-95% in meteorites. The opposite trend exists for the proportion of C in carbon phases in the space materials: up to 50% in interstellar grains, ~8-10% in comet dust, ~2% in meteorites. Sub-micron carbon grains in meteorites may be destroyed by processing on the parent body or in the laboratory (or both).

All cometary [C]-grains contain minor abundances of rock-forming elements. These grains are predominant among small particles 10^{-17}-10^{-15}g [9] and the presence of even smaller (10^{-21}-10^{-18}g) carbonaceous grains in the coma of comet Halley has been suggested [13]. The occurrence of [C]-grains in the coma does not correlate with that of any other groups of particles or with the distance from the nucleus [9]. Therefore, they appear to be primary grains coming from the nucleus rather than products of decomposition of other classes of organic particles. We surmise that the size, properties and appearance of [C]-grains in comet Halley are consistent with the hypothesized properties of circumstellar grains originating in stellar outflows from carbon stars. The circumstellar origin seems to be more likely than carbonization of interstellar ice mantles by irradiation in the ISM. Laboratory irradiation of ice analogs results in loss of ~80% of the H, N, and O, but a significant fraction of these elements remains in an organic residue [8]. This is inconsistent with the observed composition of [C]-grains in Halley. Furthermore, the only reliably evidence of a strong isotopic anomaly in carbon, $^{12}C/^{13}C \sim 5000$ [14] occurs in the spectrum of a typical carbon grain. Such strong isotopic anomalies have been observed in meteoritic carbon grains [15] and attributed to stellar birth sites.



Bulk abundances of major volatile and rock-forming elements in the dust component of comet Halley (•), carbonaceous meteorites (Δ), the diffuse ISM (◇), and dense molecular clouds (□). Error bars for Halley data reflect maximum errors due to either error of measurement or scattering of values between two instruments.

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