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VEGA-GIOTTO FLYBY MISSIONS AND COMETARY COSMOGONY

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1. INTRODUCTION. The opportunity to absorb the results of the in-situ measurements as made on the board of the spacecrafts is for cometary cosmogony the most important implication of the Vega/Giotto flyby missions to Halley. Unfortunately the exploration of matter identified as ejecta from the nucleus proved its inability to define unambiguously the very chemical-mineralogical nature of the nucleus - to provide information comparable with expected from a sample return mission. However, incapable to offer an adequate empirical firm basis for a scenario describing formation of a cometary body the obtained results are significant enough to affect and to re-direct the cosmogonical thinking.

Accordingly, the understanding is to be modified of the dichotomy of cometary matter as deduced from the distinction of water-dominated volatiles and silicate-based non-volatiles. Organic carbon compounds emerged as a major constituent of cometary matter. Their discovery enabled not only to correct the views on the supposed chemical nature of the nucleus but it stimulated a search for a signature of a chemical activity accompanying ejection of matter from cometary nuclei [see, e.g., Combi and Delsemme,1986; Combi, 1987]. At the moment with all the respect to the work of Whipple [1950, 1963, 1976, 1984] it is likely that the revision of his classic concept of the icy conglomerate cannot be avoided.

Affected by the Vega/Giotto flyby missions to Halley cometary cosmogony seems to enter its new conceptual period. Of basic importance appeared the results of the in-situ measurements - mass-spectrometric, UV- and IR-spectroscopic. Chemistry has been called to explain the occurrence inside the nuclei of the variety of species as inferred from the mass-spectrometric data and to predict the results of the processes possibly involved. Cosmochemical factor has been postulated to operate behind the observed cometary phenomena.
The chemistry of the interstellar medium, covering the circumstellar and interstellar dust became a natural ally of the advances in cometary cosmogony.

2. COMETARY MATTER: GENERAL. Cometary nucleus is so far inaccessible. Inaccessible in-situ is the cometary matter filling the nucleus. Far from perihelium, at temperatures as low as 20 - 30 K, or less, the nucleus is an assemblage of solids. They appear to make (on large scale) continuum that can be defined as monolithic [cf. Brandt, 1987]. However, the low bulk density of cometary nuclei- although estimated from astronomical data with rather poor precision (e.g. for Halley Rickman [1986] found 100 - 300 kg/cu.m, while Sagdeev et al. [1988] 600 (+900,-600) kg/cu.m - can be explained only with abundant microscopic pores and void spaces corresponding with chemical-mineralogical features of the microstructure.

Of particular importance for understanding the nucleus is the exploration of the ejecta. In the past the attention to the ejecta was focused on the gaseous products of sublimation of cometary ices as exposed to solar radiation while believed to be responsible for the observed cometary phenomena.

Accordingly chemistry used for explanation of cometary ejecta has been reduced to dealing with simple phase transition. In terms of such an approach generation of ejecta was viewed as a transfer of material from the interior of the nucleus to the surrounding halo or coma without any significant chemical change. The process of transfer was tacitly assumed chemically indifferent. The transferred material of the nucleus has been supposed to be aggregated in analogy with aggregation of planetary matter [cf. Donn, 1988].

The outcomes of the in-situ measurements invalidated the assumption of chemical passivity as attributed to cometary nuclei. In contrast with such a passivity is the abundance of the organic carbon compounds varying appreciably in chemical reactivity and stability while contributing in organic mantles of grains. There is no reason to refer the gaseous ejecta to cometary ices only. A need arises for a model of the cometary nucleus with cosmochemical signature consistent with a multidisciplinary approach.

3. THE EJECTA. The results of the exploration of the ejecta were recently summarized by Jessberger et al.[1988b] using an extensive reference list. The major element composition of the Halley dust was considered as a part of this summary [Jessberger et al.,1988a]. The discussed below pre-requisites of a re-orientation of cometary

cosmogony were inspired by the work of Kissel and Krueger [see Kissel et al., 1986a, b; Kissel and Krueger, 1987a, b; Krueger, 1988] involving the dust particles.

To understand the results for the dust let us look at the gaseous ejecta [Encrenaz, 1987]. Overdominant was found the contribution of water as high as 80%. Relative to water other abundances are: CO: 5 - 7%, CO2: 1.5 - 3.5%, CH4: 2 - 7%, saturated hydrocarbons: 1%, HCN: 0.1%, NH3: <10%, N: 2%. Such a composition of the ejecta hardly can be recognized as involving species previously incorporated into the nucleus. It has been believed to be converted into a mixture frozen but chemically unchanged.

The results of the chemical identification covered 20 elements distributed among 5 major (H,C,N,O,S), 7 minor (O, Mg, Al, Si, (S), Ca, Fe), and 8 trace elements (Li, B, Ti, Cr, Mn, Co, Ni, Ca). The occurrence of further 9 elements was found highly uncertain.

Among identified molecular species organic carbon compounds play a special most important role. They have been subdivided into two categories according to the level of reliability of their identifcation. Chemically they form four groups specified as CH, CNH, COH and CHON compounds. Each group consists approximately of two types of compounds: highly unsaturated ones with one triple or two double C-C bonds in 4 - 5-membered chains coexisting with cyclic unsaturated, aromatic or heterocyclic partners. The probability of the occurrence of COH is claimed to be not high. There is no doubt that the carbon compounds need a special insight and careful consideration. One can suspect that the grouped compounds resemble homologous series and probably could be derived from few initial molecules or radicals like CO, HCN, C2 - typical astrophysical species. Interacting on the surfaces of grains encrusted with various metals active as catalysts with hydrogen and other molecules such species could initiate reaction sequences leading to synthesis of polymeric carbon chains of various length, their branching and cross-linking.

It is not excluded that a computer search for an adequate chemical network would be reasonable and fruitful. The context of the interstellar chemistry seems to be both attractive and promising.

4. COMETARY ICES - WATER. If water has been brought into cometary nucleus together with grains as their component claimed to contribute in the supposed mantle then it should be regarded as endogenous i.e. to enter the basic material. However, facing the abundance of icy-rocky objects in the solar system we cannot exclude the occurrence of exogenous water in cometary nuclei - water that joined the nucleus during an episode preceding the ultimate formation of a cometary body. One can hypothesize that such an episode would include a kind of a "snowfall": condensation of water-dominated mixture of gases of composition close to the supposed cometary one. Expelled from the central warmer regions towards the colder periphery of the planetary system it would traverse the circumsolar region of swarming grains - precursors to cometary bodies. This exogenous water could penetrate a swarm of grains to condense into a dendritic structure leading to a low average density as featuring cometary bodies.

Another peculiar source of water was considered too [Krueger, 1988]: water from chemical reaction of the synthesis gas $CO + H_2$: its occurrence is highly probable, while the presence of a metal catalyst (Fe, Ni, Co) not excluded. So we arrived at the Fischer-Tropsch catalytic reduction-polymerization leading to formation of water:

$$(CO + 2 H_2)^* n = (C_nH_{2n} + n H_2O)$$

However, the deep difference between the known laboratory conditions and those governing in the solar/galactic medium (extremely low temperatures and concentrations of reactants, variability of occurrence of catalysts) suggests a reasonable reservation.

5. COMETARY NUCLEUS AS ASSEMBLAGE OF SOLIDS. Far from the Sun cometary nuclei are composed of solids. The features echoing with their very nature are preserved only in the dust particles. The latter have been shown to be aggregates of coalesced submicron grains. Their mass distribution is ranging 6 orders of magnitude - down to 10^{-19} kg. In terms of this finding aggregation of grains preceded their swarming. It is hypothesized that nucleation and initial rise of aggregates were made possible due to supply of chemical-mineralogical material of circumstellar and interstellar origin. The high

efficiency of aggregation as demonstrated by the span of the size distribution is attributed to local conditions inside eddies produced by turbulence supposed to operate at the periphery of the solar nebula under the impact of a convective instability [cf.,e.g.,Cabot et al.,1987]. The flux of gases streaming outwards the solar system was considered by many authors [see e.g.Cameron,1984; Vityazev and Pechernikova, 1986; Rawlings et al., 1988].

The growth of the dust particles was probably close to diffusion-limited aggregation (DLA) of Witten and Sander [1983] or cluster-cluster aggregation of Meakin [1983] leading to fractal structures [Donn, 1987; Hughes, 1987].

6. CONCLUSION. The offered very fragmentary scenario is based on assumed distinct origin of cometary solids. It predicts incorporation of grains of galactic origin as aggregates evolved from smaller interstellar particles into a mass of condensate. The latter is supposed to be obtained during an episodic snowfall producing the matrix material filling the cometary nucleus.

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