COMETARY MATTER IN OBSERVATION AND SIMULATION EXPERIMENTS

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Comet nucleus simulation experiments serve a twofold purpose: to interpret the data from ground based observations and the recent ones from Halley space missions and to prepare future comet nucleus sample return missions. Information on the nucleus was obtained by direct observation (size, albedo, gas jets, surface structure and - in combination with astronomical data - density). The interpretation of the gas phase composition leads to models for the composition of the nucleus. The nature of the crystalline matter was evaluated from dust particle impact mass analysis. Fred Whipple's concept of a dirty snowball, containing icy and mineral components, was widely approved.
First experiments to simulate the ice-mineral matter of comets were performed from 1967 on by Russian groups in Dushanbe (Tadjik SSR) and Leningrad on relatively small samples of ice with admixtures of NH_3, CO_2, mineral grains, organic compounds, metal powders, etc. at temperatures slightly over 77 K in vacuum with light and heat sources. A second major attempt was that of Saunders et al. 1986, who prepared fine ice grains by spraying an emulsion of water-montmorillonite clay particles into liquid nitrogen. After evaporation of the water component fluffy clusters of the minerals remained. The experiments performed by the COSI team (Comet Simulation) in DFVLR Köln-Wahn and KFA-Jülich started with samples prepared from slurries of water, 2-5 µm minerals (olivine, montmorillonite, kaolinite, etc.) and carbon grains (2-10 µm) by the spraying method of Saunders. Fluffy ice-dust grains of 5-20 µm diameter were formed with densities about 300-500 kg M^{-3}. For a review, cf. [1]. Future development of sample preparation has to concentrate on simulation of a) general structure and morphology and b) chemical composition.
The problems of the general structure include those of the morphology of the ice (snow, fluffy grains, blocks), its crystalline structure (amorphous, cubic, hexagonal), the kind, size and structure of the minerals and carbon additives, and the dust-ice mixing ratio. These are important for thermal dynamics, evaporation rates, dust emission, formation and destruction of residues and crusts, etc. Among the chemical problems range: the kind and amount of NH_3, CO_2, CO, CH_4 admixtures, their crystalline or complex state, the role of organic components such as CH_2O, CH_3OH, etc. They are important for gas release, explosive evaporation events, heat transfer inside the ice, organic compound formation, build-up of crusts and refractories, etc. Temperature conditions are linked to those of composition and morphology [2].

Fig. 1 reports briefly the four methods which are checked or prepared by the COSI team at present: a) spraying into liquid

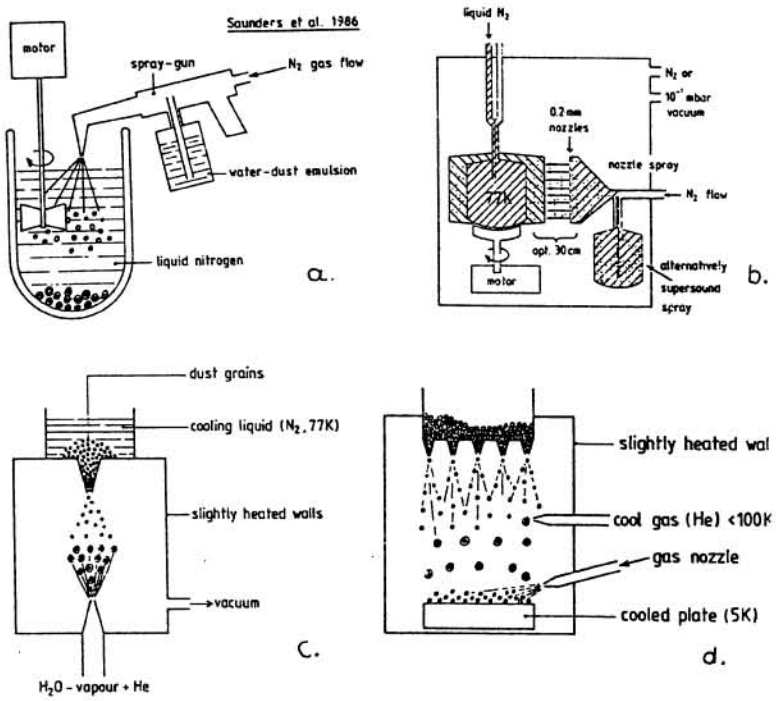

Fig. 1 Four methods to produce matter for comet nucleus simulation experiments.

nitrogen, b) spraying of dust-water emulsions through nozzles onto cold walls (which results in fluffy layers of ice with a good thermal contact to the cold surface), c) a whirlpool procedure in gas or vacuum, where the cold mineral grains are covered with H_2O, NH_3, CO_2, etc. layers, and d) the injection of grains into a layer growing by condensation in the vacuum. Condensation experiments are performed in cryostates with binary and ternary gas mixtures containing H_2O at 77 K and 5 K. The build-up of a representative cometary matter sample includes many side investigations of the latter kind, and will be realized step by step, taking into account the technical facilities of the chambers and the diagnosis methods. The size of the sample and its position relative to the cold walls is important for scaling up to true cometary conditions. It seems that the sample of the preliminary experiments with 30 cm diameter has almost the final size for regular experiments in the space simulator.
The problems of sample preparation are intimely related to those of sample transport, removal of probes, storage, conservation and handling. Double containment and cryostat techniques are developed. Glove boxes (with He or N_2 purge gas) and cold chambers (-40 °C) are prepared for the diagnosis of the samples. These technical developments are undertaken also in view of the return and handling of icy space samples.

[1] Grün, E., Kochan, H. Roessler, K. and Stöffler, D., Diversity and Similarity of Comets, ESA-SP-278 (1987) 501/8
[2] Roessler, K., ibidem, 509/13