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MODIFICATIONS OF COMET MATERIALS BY THE SUBLIMATION PROCESS: RESULTS FROM SIMULATION EXPERIMENTS; E. Grün* and KOSI-team†, *Heidelberg, FRG

An active comet like comet Halley loses by sublimation a surface layer of the order of 1 m thickness per perihelion passage. In situ measurements (1) showed that water ice is the main constituent which contributes to the gas emission although even more volatile species (CO,NH_3,CH_4,CO_2 etc.) have been identified. Dust particles which were embedded in the ices are carried by the sublimating gases. Measurements of the chemical composition of cometary grains indicate that they are composed of silicates of approximate chondritic composition (2) and refractory carbonaceous material (3).

In the past there have been several attempts to experimentally study the sublimation process of mixtures of ices, minerals and carbonaceous compounds. Extensive work was carried out by Soviet groups in Dushanbe and Leningrad, who heated up ice samples electrically or irradiated them with light sources inside a cold chamber (4,5). Among the interesting findings was the formation and ablation of dust mantles during the sublimation process. In another approach (6,7), silicate minerals and organic compounds covered with water ice were exposed in a vacuum chamber. After sublimation of the water ice highly porous filamentary sublimate residues were found for some classes of phyllosilicate minerals or in cases when organic compounds (tar) were present.

The approach by the KOSI-team (8-10) focuses on the investigation of cometary processes at relevant scales. The scale of the simulation experiments is determined by the scale for the heat transport into the interior (diurnal thermal skin depth) and the scale of the gas interaction (mean free path length) above the surface which are both of the order of 10 cm. Comet simulation experiments are performed in the big Space Simulator of DFVLR, Cologne, which allows the study of samples of up to one meter dimensions.

Initial experiments were performed with porous water ice-mineral mixtures of 0.4 g/cm^3 bulk density which were irradiated at about 1 solar constant intensity for several hours. Representative temperature profiles taken at different times are displayed in Fig. 1. The temperature near the upper surface of the ice reached > 200 K at which significant sublimation occurred. With time the temperature profiles became flat near the surface. The layer of low temperature gradient was observed to grow in thickness during the course of the experiment. At the end of irradiation the investigation of the sample showed three distinct layers: A mantle of mineral dust of 5 to 10 mm thickness covered a several cm thick shell of hard but porous ice and dust. The layer below this shell was obviously in its original unconsolidated state.

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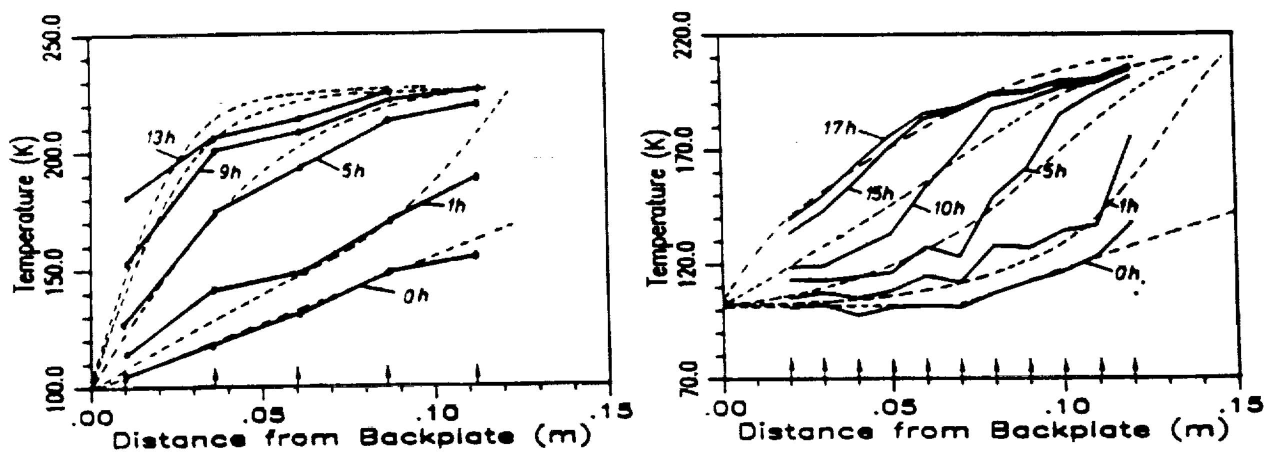

Fig. 1: Temperature profiles recorded during two simulation experiments (flat lines) and calculated from a thermal model (broken lines) at various times after the start of irradiation (10).

Both the temperature profile and the metamorphosis of the ice can be explained if we postulate that heat is advected towards the interior rather than conducted. The porosity of the sample allowed for water vapor to flow inwards driven by the difference in vapor pressure between the sublimating surface layer of ice and the cold interior. Model calculations (10) suggest that the vapor flow carried heat at a rate of about 60% of the heat input at the top surface of the ice. Recondensation of the vapor onto the original fluffy ice formed the hard icy shell.

Comet simulation experiments show that significant modifications of cometary materials occur due to sublimation process in near surface layers which have to be taken into account in order to derive the original state of this material.

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