EPSC Abstracts
Vol. 6, EPSC-DPS2011-222-1, 2011
EPSC-DPS Joint Meeting 2011

Outgassing of icy bodies in the Solar System - The influence of surface dust layers on the sublimation of H_2O ice

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1. Introduction

The absorption of solar radiation by surface layers of icy bodies in the Solar System (such as icy satellites, Mars and comets) leads to a sublimation of the icy constituents and alters the surface properties. While the energy absorption and its distribution inside the surface layers are not fully understood in detail, there is observational evidence of the formation of non-volatile surface dust layers and sublimation beneath the residuals of the surface layers (Prialnik and Bar-Nun, 1988; Kömle, 1992; Sunshine et al., 2007). The formation of a non-volatile surface dust layer further decreases the sublimation rate of the icy constituents. Gas molecules escaping through the residuals are scattered by the dust particles, which can lead to a collimation of the gas flux. As a consequence, loose dust particles can be ejected by the gas drag of the outflowing gas.

2. Experimental Setup

We perform laboratory experiments in order to study the influence of dry dust layers on the sublimation of H_2O ice (see Fig. 1; Gundlach et al., 2011), which is the most abundant volatile material in the Solar System. Therefore, cylindrical ice-dust samples are positioned on a cold plate, which is cooled by liquid nitrogen. The experimental chamber can be evacuated to pressures below $\sim 10^{-5}\,\mathrm{mbar}$. The gas flux and the temperature of the ice-dust samples are continuously sampled during the measurements. To heat the ice-dust sample's surface by insolation, the pressure gauge can be replaced by a halogen lamp.

3. Results

The first measurements with this experimental setup were performed to investigate the reduction of the gas production rate of H_2O ice surfaces covered by a dry dust layer (see Fig. 2; Gundlach et al., 2011). A comparison of the obtained results with a theoretical model of the gas diffusion in random porous media (Skorov et al., 2011) yield a clear difference between theoretical and experimental data.

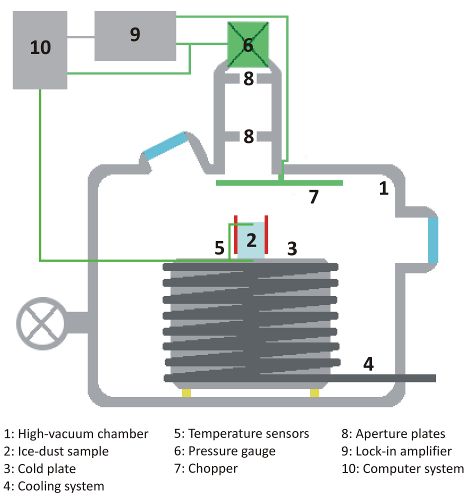

Figure 1: Schematic diagram of the experimental setup (Gundlach et al., 2011). Sublimated H_2O molecules from the sample's surface are detected using a pressure gauge together with a rotating chopper wheel.

Furthermore, the so-called sublimation coefficient, defined as the ratio between experimental and maximal sublimation rate (Isono and Iwai, 1969; Kossacki et al., 1999), was derived from these experiments (see Fig. 3). We conducted a systematic evaluation of the temperature dependence of the sublimation coefficient, which has a tremendous influence on the energy balance of sublimating ice surfaces and, therefore, on the thermal modeling of icy bodies in the Solar System.

Recent investigations of insolated ice-dust mixtures have shown that dust particle ejection can occur due to H_2O ice sublimation. The modification of the sample's surface by melting small channels into the ice leads to an increase of the activity at the location of the modifications.

During this conference, we will present our experimental results and their impact on current cometary research.

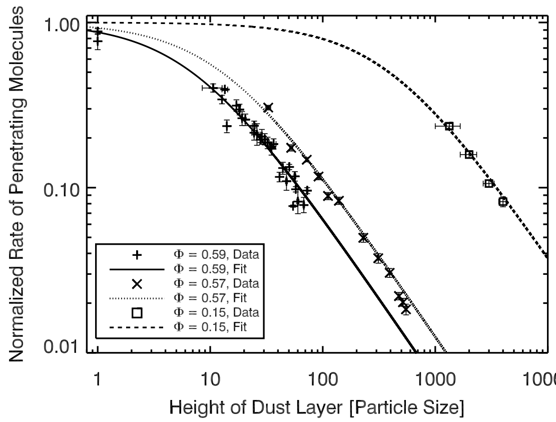

Figure 2: Reduction of the gas production rate of H_2O ice surfaces covered by a dry dust layer. ϕ is the volume filling factor of the dust layer. See Gundlach et al. (2011) for details.

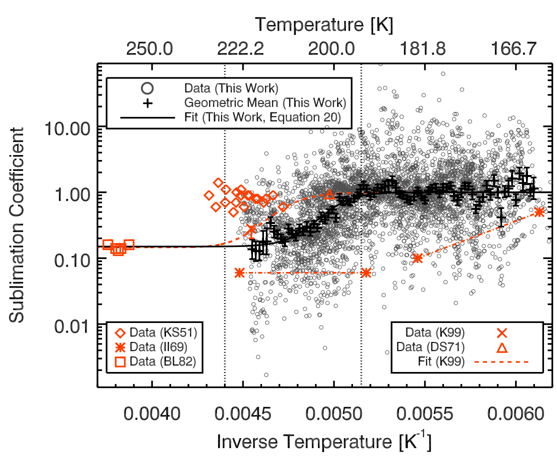

Figure 3: Temperature dependence of the sublimation coefficient (Gundlach et al., 2011). For comparison, the results of the following works are also visualized: Kramers and Stemerding (1951, diamonds), Isono and Iwai (1969, asterisks, red dash dotted curve), Beckmann and Lacmann (1982, squares), Davy and Samarjai (1971, triangle) and Kossacki et al. (1999, cross, dashed curve).

Acknowledgements

Yu. V. Skorov was supported by DFG under Grant BI 298/9-1.

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