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Comet 67P/Churyumov-Gerasimenko surface changes triggered by amorphous ice transformation

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Abstract

Instruments on board the Rosetta spacecraft monitored the comet 67P/Churyumov-Gerasimenko (67P) during its last two-year journey through the inner solar system and mapped the surface of the nucleus at high resolution. Upon approaching the Sun, the nucleus heats up, frozen volatiles sublimate together with water and dust into the tail region. The 67P Comet activity was observed from the whole surface combined with jets from distinct sources. Our experimental study of gas-laden amorphous ice can explain gas release and jets during the heating process of the ice and the changes on the surface.

1. Introduction

The Rosetta mission findings on comet 67P/Churyumov-Gerasimenko (67P) provided the most accurate information on the composition and morphology of the nucleus. For the first time in comet research, the ROSINA instrument on board the Rosetta spacecraft, detected O_2, N_2 [2], [9] and also noble gases: Ar, Kr and Xe [7]. Our experimental studies on cometary gas-laden amorphous ice fit the direct measurements of gas release upon heating.

2. Experimental

The experiments presented in this study were performed using the experimental set-up described in [6]. The test chamber and its pump consisted of two 10 in. cryogenic pumps. The water-vapor and gas mixtures were prepared in a 2-L glass bulb. The mixtures were flowed onto a 17 cm^2 cold plate at a pressure of 10^{-6} torr and temperatures between 30-60 K. Ice layers about 50-100 µm thick were deposited during time periods of 45 min. The ice sample was warmed at a rate of 1 K min^{-1} and the gases were monitored by a quadrupole mass spectrometer.

3. Results

In this experimental study of gas-laden amorphous ice containing O_2, N_2 and Ar, were formed. Upon heating, all the gases are released from the ice together, in several temperature ranges: during the annealing process (60-100 K), the transformation to cubic ice (~140 K), the transformation to hexagonal ice (~160 K) and together with water sublimation (>160 K), (Fig. 1), as observed with gas mixtures of CO, CH_4 and Ar [1]. Two types of gas release from the ice were observed depending on the gas content in the mixture and the formation pressure: constant gas flow and jets forming "craters" and cracks in the ice layer [5]. The gas release in different temperature ranges can explain the measured heterogeneity in the coma of comet 67P [4].

Exothermic crystallization of amorphous ices could have triggered higher rates of activity on the surface of the nucleus in the past [3], [8].

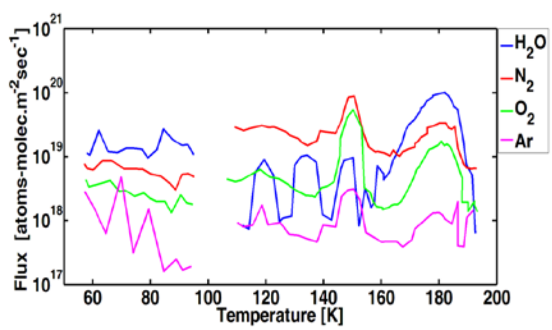

Figure 1: Gas release upon heating of O_2, N_2 and Ar from amorphous ice. Most of the gas is released during the transformation of the ice to cubic form at 140 K.

[1] Deceased, Jerusalem, 25 January 2017

4. Summary and Conclusions

Gas release form the ice rules the comet activity and surface morphology depending on the illumination conditions. The gases are released from the ice continuously and also as jets changing the nucleus surface. The gas release from amorphous ice can explain the heterogeneous coma of comet 67P/Churyumov-Gerasimenko and the surface activity as measured by ROSINA.

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