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Experiments on cometary activity: ejection of dust aggregates from an evaporating water-ice surface

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Abstract

For a better understanding of cometary activity, comet-simulation experiments are necessary. In our experiments we study the ejection of dust aggregates caused by the sublimation of water ice under cometary-like conditions. We find that dust ejection exactly occurs when the pressure of the water vapor in the ice-dust interface exceeds the tensile strength plus the gravitational load of the covering dust layer. Furthermore, we analyzed the trajectories of emitted dust and the size of ejected aggregate clusters depending on the dust layer thickness.

1. Introduction

The gas-driven dust activity of comets is still an unresolved question in cometary science. In the past, it was believed that comets are dirty snowballs and that the dust is ejected when the ice retreats. However, thanks to various space missions to comets, it has become evident that comets have a much higher dust-to-ice ratio than previously thought and that most of the dust mass is ejected in large particles. Because of the very low albedo of comets [1], they are among the darkest objects in the Solar System. Hence, the solar radiation can effectively heat the surface of the cometary nucleus, which leads to the evaporation of the volatile constituents and, therewith, to the ejection of the surface material. Dust-aggregate release from the surface is possible, if the gas pressure underneath the dust cover is sufficient to overcome the sum of the gravitational stress exerted by and the tensile strength of the dust-aggregate layer. The gas pressure can be approximated by the sublimation pressure and by taking the influence of the dust layer on the diffusing molecules into account [4].

With this work, we intend to establish a new series of comet simulation experiments, focusing on the investigation of the gas-driven dust activity by starting as simple as possible. Thus, we use a solid block of water ice and dust aggregates placed on top of this ice block.

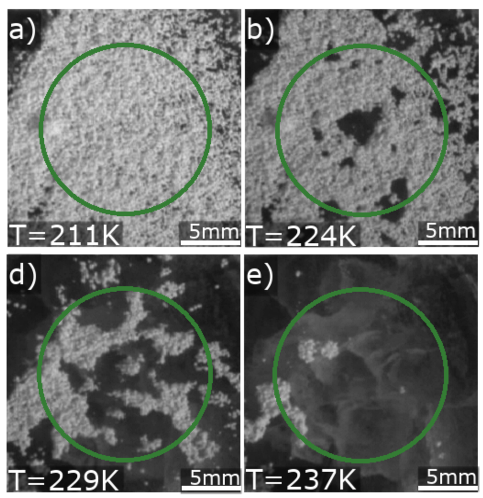

Figure 1: Temperature-dependent evolution of an ice-dust sample from a top view. The dust aggregates appear white and the water ice black. The green circle shows the area in which the fractional dust-cover data was acquired.

2. Experimental

The experiments were performed inside a vacuum chamber to ensure cometary-like conditions. Two cameras were used to monitor the surface evolution of the dust-covered water ice from top and from the side. The samples were produced inside the sample holder, a cylindrical copper block. A heater was inserted in order to heat the sample from $\sim 180\,\mathrm{K}$ to $\sim$

250 K. As cometary dust analogues, we chose aggregates, consisting of irregular silica (SiO_2) monomers, which were sieved into different size ranges, between $\sim 50\ \mu\mathrm{m}$ and $\sim 500\ \mu\mathrm{m}$ in diameter onto the water ice.

3. Results

When the surface of the ice had reached a certain temperature, the dust layer visibly began to erode, due to the ejection of dust aggregates. The temperature-dependent evolution is shown in Figure 1). We define the activity temperature T_A as the temperature at which 50 % of the dust layer within the green circle in Figure 1 was ejected. From this temperature and from the estimated layer thickness, we derived the water-vapor pressure below the dust cover. The water-vapor pressure has to exceed the tensile strength of the material plus the gravitational load of the dust layers to be able to eject the dust aggregates. For the derivation of the tensile strength, we used the model developed in Ref. [6] and the data show a good match to the predictions. This means that our approach is a reasonable approximation for the ice-evaporation-driven dust activity.

Additionally, we observed that mostly clusters of dust aggregates were ejected by the outgassing water-ice surface. Those sizes we determined for different layer thicknesses, but for a fixed dust-aggregate diameter. From this analysis, we derived the median value of the cluster size as a function of the layer thickness. This means: the thicker the layer, the lager the clusters are.

The side view of the samples allowed us to observe the trajectories of single aggregates or clusters when ejected by the outflowing water molecules. In total, the trajectories of eight particles were recorded and fitted by parabolic functions to derive the initial velocity and mean accelerations of the aggregates.

4. Implications for comets and summary

With this work, we will present our first comet-simulation experiments on the ejection of dust aggregates from an evaporating water-ice surface. The experimental results provide three major implications for our understanding of cometary activity, namely, the observed emission of dust aggregates can be explained by our assumptions, the dust layer thickness has an important influence on the size of ejected clusters and most of the ejected dust aggregates have an initial starting velocity exceeding zero. Details can be found in our upcoming paper [2].

Acknowledgements

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References

[1] A'Hearn, M. F.; Belton, M.; Delamere, W.; Kissel, J.; Klaasen, K.; McFadden, L.; Meech, K.; Melosh, H.; Schultz, P.; Sunshine, J. & others: Deep impact: excavating comet Tempel 1, Science, American Association for the Advancement of Science, Vol. 310, pp. 258-264, 2005.

[2] Bischoff, D.; Gundlach, B.; Neuhaus, M. & Blum, J.: Experiments on cometary activity: ejection of dust aggregates from an evaporating water-ice surface, submitted to MNRAS, 2018.

[3] Blum, J.; Gundlach, B.; Krause, M.; Fulle, M.; Johansen, A.; Agarwal, J.; von Borstel, I.; Shi, X.; Hu, X.; Bentley, M.; & others: Evidence for the formation of comet 67P/Churyumov-Gerasimenko through gravitational instability of a pebble cloud, Monthly Notices of Royal Astronomical Society, 2017.

[4] Gundlach, B.; Skorov, Y. & Blum, J.: Outgassing of icy bodies in the Solar System - I. The sublimation of hexagonal water ice through dust layers, Icarus, Vol. 213, pp. 710-719, 2011.

[5] Gundlach, B.; Blum, J.; Keller, H. & Skorov, Y.: What drives the dust activity of comet 67P/Churyumov-Gerasimenko, Astronomy and Astrophysics, 2015.

[6] Skorov, Y. & Blum, J.: Dust release and tensile strength of the non-volatile layer of cometary nuclei, Icarus, Vol. 221, pp. 1-11, 2012.