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Water vapor emission mechanism for 67P/Churyumov-Gerasimenko

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Abstract

In this work we study the water vapor emission by the the comet 67P/CG, the target of Rosetta mission. In this work we investigate the physical conditions required to generate short-lived outbursts in cometary nuclei. We applied a thermo-physical model [1, 2, 3] in order to evaluate the temperature of surface and subsurface layers and the water flux. Cyclic sublimation and water condensation in the sub-surface layers, due to the change of the illumination condition on the surface, is a likely mechanism to explain part of the water outgassing [5].

1. Introduction and The Model

Comet 67P/Churyumov-Gerasimenko is the target of Rosetta, an ESA mission launched on March 2014. Observations from VIRTIS-Rosetta show water ice (whose stability depends on the local illumination condition) on the surface of the comet, which represents a localized source for short-lived outbursts [5].

The "Rome model" we applied [1, 2, 3] uses a quasi-3D approach, in which diurnal and latitudinal temperature variations are calculated by the insulation on the body. The numerical code computes the heat diffusion in the porous cometary material, leading to the water ice phase transition and sublimation of the volatile ices. The gas flux is controlled by a conservation mass equation, according to kinetic theory. The model takes into account the water ice amorphous-crystalline transition with the release of gases trapped in the amorphous ice, if present. A Crank-Nicholson implicit scheme is adopted. The code computes a " critical radius" representing the largest particle that is likely to leave the comet and compares it to the dust particle characteristics (mass and radius), in order to establish if a dust grain could or not leave the surface (and consequently form a crust). The model accounts for three different diffusion regimes comparing the mean free path and the pore diameters (Knudsen, viscous Stokes and transitional regimes). It assumes the comet as initially composed by a homogeneous mixture of water ice, silicatic and organics dust. The dust grains are distributed in different sizes classes, classes each of ones with their physical and thermal properties.

In Tab.1 we report the main physical parameters of our model.

Albedo	0.06	[4]
Dust (Silicates)/Ice	1.5	
Dust (Organics)/Ice	2.0	
Porosity	0.6	
Initial temperature	163	
Emissivity	0.9	[2]

Table 1: Main adopted physical parameters values in SI units.

2. Results

We study the surface and sub-surface layer temperature and also the water flux emission. In particular we focus on facet n°14083 of the shape (V4) as representative of the "neck" region [5] in order to study the sublimation and re-condensation effect. The facet examined experienced a "sudden shadow" during its regular day-night cycle: this introduces an inversion in the temperature profile vs depth as shown by Figs.1 and 2. We examined the case with and without self-heating, both with an ice's depth of 1 cm beneath the surface. Self-heating (due to the particular shape of the comet) has the effect to increase of about 10 K the temperature. The inversion of the temperature is present in the first layers of the comet and it is more evident after few minutes from the "sudden shadow". The thermal evolution of each facets is followed for several rotations at heliocentric distance of VIRTIS observations. In particular, we compare these observations with different theoretical curves, characterized by different ice depth and different initial thermal conductivity of the crust (see Fig.3). We focus on the facets n°120538-120542 of the shape (V5).

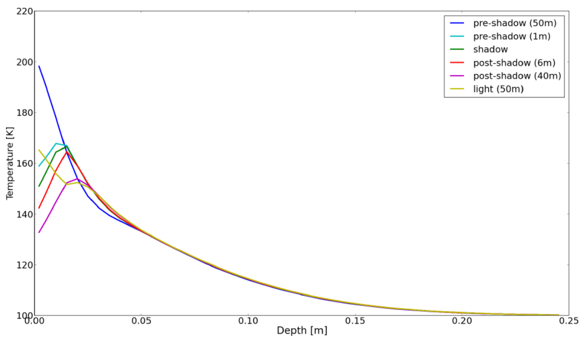

Figure 1: Temperature profile vs depth in case of ice 1cm deep (no self-heating)

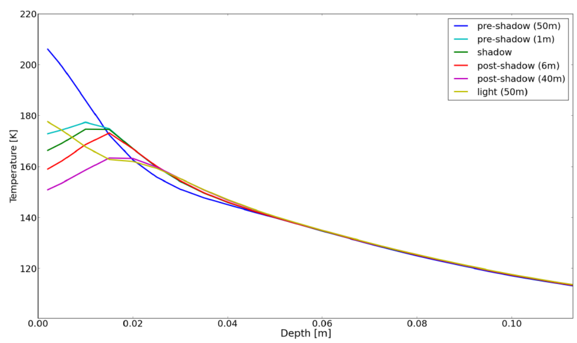

Figure 2: Temperature profile vs depth in case of ice 1cm deep (with self-heating)

3. Summary and Conclusions

Our simulations suggest that short-lived outbursts could be explained by the combined effects of sublimation and re-condensation. Ice that refreezes on subsurface layers due to change of the conditions of illumination on surface, could contribute to the water flux. Self-heating seems to be be required to fit with VIRTIS observations. We also observe that low thermal conductivity values lead to temperature profiles compatible with the observations. Surface roughness could increase the temperature of the comet.

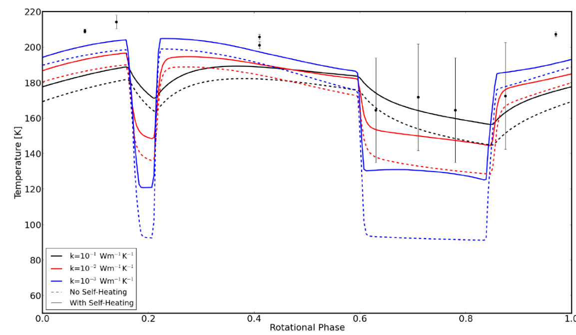

Figure 3: Temperature profile vs rotational phase for different values of thermal conductivity of the crust and with or not the effect of the self-heating. Black dots represent VIRTIS observations.

Acknowledgements

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