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Thermal state of comet 67P during the Rosetta mission

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Abstract

Shape, orbital parameters, and dust properties are taken into account to determine the thermal state and probable near-surface activity of comet 67P/Churyumov-Gerasimenko during the nominal Rosetta mission.

1. Introduction

In 2014, the European space mission Rosetta will rendez-vous comet 67P/Churyumov-Gerasimenko (hereafter 67P) and study in situ its nucleus properties and activity variations from ~3.71 AU from the Sun to ~1.24 AU (see Tab. 1). We use the results from quasi three-dimensional thermal models of irregular small bodies [1, 2, 3] applied to the case of 67P to make predictions on the probable thermal state and activity of the comet during the Rosetta mission. The specific orbital parameters of comet 67P (semi-major axis of 3.51 AU, eccentricity of 0.63 and obliquity of $\sim 45°$), leading to significant seasonal effect by exposure of the South pole towards the Sun mainly around the perihelion passage, have been taken into account in the calculations.

Table 1: Brief description of Rosetta timeline.

Phase	Start date	Sun dist. (AU)
Close approach	17 Jul. 2014	3.71
Global mapping	17 Aug. 2014	3.54
Close observation	25 Aug. 2014	3.49
Lander delivery	10 Nov. 2014	3
Comet escort	16 Nov. 2014	2.97
Perihelion passage	13 Aug. 2015	1.24
End of mission	Dec. 2015	1.8 – 2

2. Numerical simulations

A detailed description of the code is given in [1, 5]. When possible, parameters derived from observations of 67P have been used in the simulations. Some parameters on the composition and internal structure of comet nuclei are taken from values considered typical of comet nuclei [4]. A quadrilateral mesh is used to describe the comet shape and determine its illumination from the Sun. From these parameters and the state of the material beneath the surface, the thermal state of each grid surface is calculated. We compute the heat diffusion through the porous mixture of ice and dust, the sublimation rate of ices (H_2O, CO_2 and CO) and the phase transition between amorphous and crystalline water ice. The transport of gas towards the interior of the comet nucleus leads to its condensation in the pores, while the gas reaching the surface escapes the nucleus. It can drag small dust particles with it, while larger dust grains are deposited and accumulate on the surface to form a dust mantle.

3. Results and discussion

From the simulations developed, the cometary nucleus shape influences the structure of the inner coma (ejection rate near the surface). The obliquity has a strong influence on the local activity, surface and subsurface characteristics and properties. In general, the models with inclined spin axis show a strong asymmetric erosion with respect to those not inclined. Also the internal stratigraphy is mainly influenced by the obliquity of the comet: different comet behaviors can arise from differently shaped and inclined comet nuclei, especially in terms of local activity, surface and subsurface characteristics and properties [3]. The values obtained when the comet nucleus is covered with a dust mantle or not (activity about 5 times larger than the observations for the case without dust mantling) suggests that the comet nucleus must be mostly covered by a dust mantle with a fraction of active surface similar to the one suggested by [6].

We expect the initially homogeneous comet nuclei to present a layered structure after several orbits close to the Sun. The most eroded parts of the comet are located near the South pole which is mostly illuminated near perihelion due to the orientation of 67P. This could lead to the presence of volatile pristine material (CO_2 and amorphous water ice) not too deep below the surface of the South pole and up to 20 cm of dust coverage around that area [2]. The northern hemisphere is less eroded and should possess a thinner dust cover (couple of cms). At the time of lander delivery, near 3 AU from the Sun, the gas fluxes near the surface of the comet will be strongly located in the northern hemisphere of the comet, with the strongest amplitude variations in the water ice flux (up to 3.5×10^{18}) as illustrated by Fig. 1a. The dust coverage of the comet together with the specific illumination at that time, will lead to high temperatures (up to $\sim$ 300 K) and extreme temperature variations (up to 150K) around the equator of the comet nucleus as illustrated in Fig 1b. We would conclude from these results that the southern hemisphere area of the comet nucleus promises to present a safe landing site (low temperature variations, minimal gas and dust fluxes and good dust coverage) together with a highly eroded terrain and the potential for pristine material presence not too deep below the surface.

The quantification of our results will allow us to define the comet nucleus properties (temperature, gas ejection) in more details for the various timelines of the Rosetta mission in order to help the safe landing of Philae and prepare adequate observations.

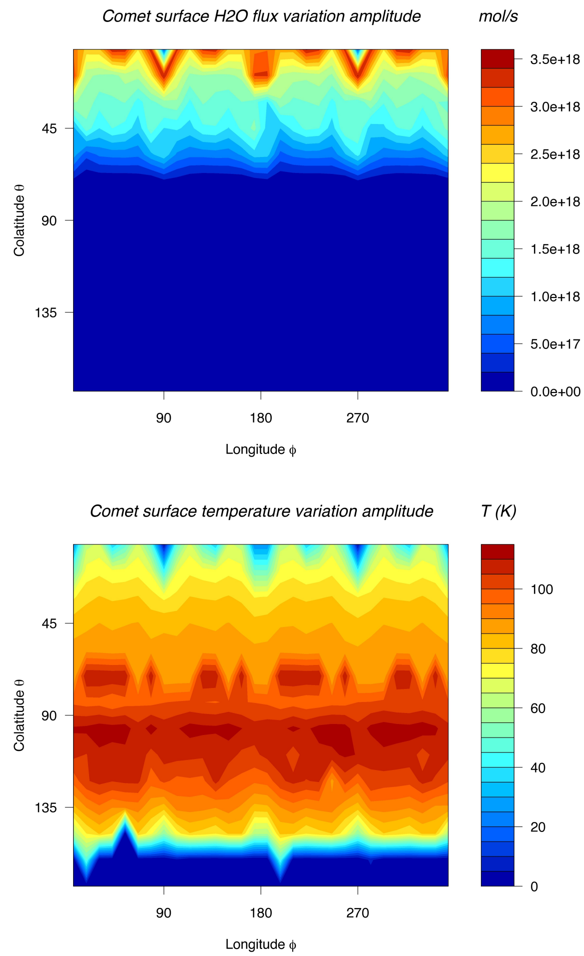

Figure 1: Surface temperature and water flux variations amplitude near 3 AU from the Sun without dust mantling.

4. Acknowledgments

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