# Thermal Model of Comet Nuclei: Implications for Rosetta

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We investigate the effect of shape, orbital history, obliquity and dust covering on the thermal properties and the activity of comet 67P/Churyumov-Gerasimenko. Implications for the Rosetta mission timeline are derived.

### Background

Rosetta will rendezvous comet 67P/Churyumov-Gerasimenko in 2014 to study in details its nucleus and its activity from ∼3.5 AU to its perihelion (∼1.3 AU). Moreover, a lander will be sent to the surface of the comet for in situ study of the near sub-surface properties. This work analyzes the results of quasi three-dimensional thermal models for irregularly shaped cometary nuclei, which has been developed to interpret the current activity of comets in terms of initial characteristics, and to predict shape and internal stratification evolution of the nucleus [1, 2]. Our model has been applied to the specific orbital parameters of comet 67P/Churyumov-Gerasimenko: semi-major axis of 3.51 AU, eccentricity of 0.63 and obliquity of $\sim 45°$.

### Methodology

Compositions and internal structure of comet nuclei are poorly known, and cannot be easily determined from ground observations. Parameters used in our simulations are derived from the observations of 67P/Churyumov-Gerasimenko when available, or otherwise chosen among those that are considered typical for comets [3]. A mesh of quadrilaterals describes the comet shape. The illumination over the surface circumscribed by the four faces of the quadrilateral is calculated by the angle between the local normal and the direction to the Sun. Fig. 1 shows an example of a spheroidal comet nucleus shape with its illumination.

The thermal evolution of each grid surface is calculated by taking into account the solar illumination and the properties of the material beneath the surface. The heat diffusion through the porous mixture of ice and dust is computed, determining the water ice phase transition and the sublimation rate of the volatile ices. After several orbits, the comet nucleus, initially homogeneous, exhibits a layered structure near the surface where sublimation fronts constitute the boundary between different layers. The flow of matter through the pore system is calculated determining whether it recondensates if it reaches colder parts of the nucleus or whether it escapes from the surface. The dust particles dragged by the escaping gas can be either blown off or deposited and accumulated on the surface to form a dust mantle. The matter sublimated and ejected determines the surface erosion. A detailed description of the code is given in [1, 2, 4].

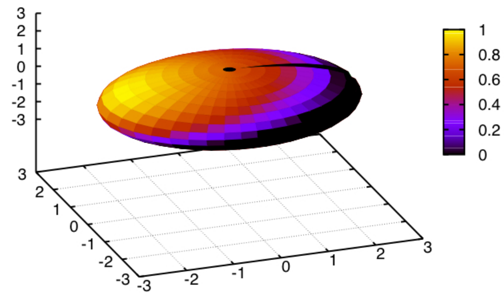


Figure 1: Spheroidal shape of the comet nucleus with illumination expressed as the cosine between local normal and direction to the Sun in color scale to show the influence of obliquity.

### Results and Future Work

From the simulations developed, we have seen that 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 different shaped and inclined comet nuclei, especially in terms of local activity, surface and subsurface characteristics and properties.

Fig. 2 compares the water ejection rate of a simulated spherical comet nucleus on the orbit of comet 67P/C-G with (SD, SD0) or without (S, S0) dust mantle on the surface and with or without obliquity (obl). The models

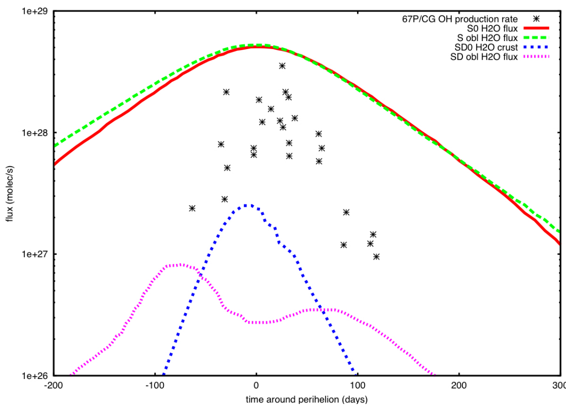


Figure 2: Comparison of the water ejection rate from a spherical comet nucleus with the activity observed for 67P/C-G near perihelion.

usually present a pre-post perihelion asymmetric behavior reminiscent of the observations. The obliquity influences the ejection rate mainly far from the Sun, while the presence of a dust mantle quenches the water activity, especially near perihelion. The values obtained in both cases (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 [5].

Fig. 3 shows the surface temperature and different gases ejection rates for a spheroidal nucleus without obliquity on the orbit of 67P/C-G at the time of Rosetta far approach phase. The maximal temperature without dust mantling can reach 180K, while the presence of a thin dust mantle increases the temperature (200K and more). The ejection rates of the different gases have the same order of magnitude if no dust mantle is present, but with a strong local ejection of water on the subsolar region of the illuminated comet nucleus. The presence of a dust mantle quenches significantly the ejection rate of water, while at the same time diffusing the local ejection towards the higher latitudes. At a smaller scale, similar tendencies are seen on the distribution of CO and $CO_2$ ejection rates.

The quantification of such results for the various timelines of the Rosetta mission will allow us to define the comet nucleus properties (temperature, ejection of matter …) and environment at the time of the Rosetta Rendezvous to prepare the safe landing of Philae and make adequate observations.

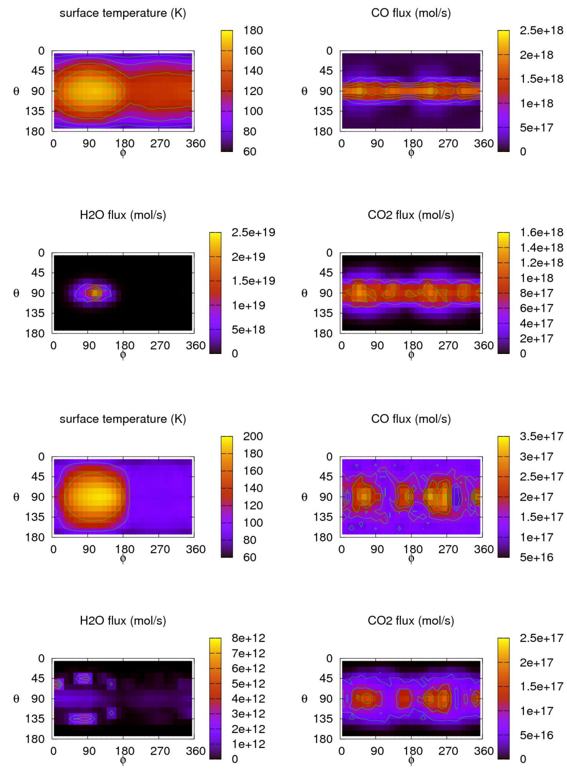


Figure 3: State of a spheroidal nucleus comet model without (four top panels) and with (four lower panels) a dust crust at the time of the far approach phase of Rosetta (06/2014 at ∼3.8 AU from the Sun).

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## References

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