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Simulation of 67P/Churyumov-Gerasimenko during the Rosetta mission phases

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Abstract

We discuss the results of cometary subsurface numerical model applied to predict the evolution and activity of 67P/Churyumov-Gerasimenko during the most critical times of the Rosetta mission. Here we focus our study mainly on the close approach phase (3.7 AU from the Sun) to lander delivery phase (3 AU).

1. Introduction

Active cometary nuclei are icy remnants of the outer solar system formation, which have been drifting towards the inner solar system in recent times. ROSETTA space mission is the planetarycornerstone of the European Space Agency (ESA) long-term programme Horizon 2000. ROSETTA is designed to rendezvous comet 67P/Churyumov-Gerasimenko in May 2014 at about 4 AU of the Sun and approach the comet gradually over three months during which its distance to the comet will be reduced to about few cometary radii and it will map the surface of the nucleus. We applied the model described in [1,2,3] to the case of the 67P/Churyumov-Gerasimenko comet nucleus in its current orbit. This numerical model is based on the resolution of the coupled heat and vapour transfer equations by a Crank-Nicholson implicit scheme (described in [4]) with surface conditions defined by a grid with variable shape and illumination conditions.

2. Simulation for the Close approach phase

The simulations of the comet activity, surface properties and internal differentiation are studied from 3.9 AU to 3 AU, at the time of the arrival of Rosetta near the nucleus with global mapping activity and preparation for the Lander delivery.

Here we describe the case of an ellipsoidal nucleus covered by a dust mantle (fig.1). The ellipsoid has semi-major axes a, b, c equal to 2.686 km, 2.125 km, 1.704 km respectively with aspect ratios a/b=1.26 and a/c=1.57.

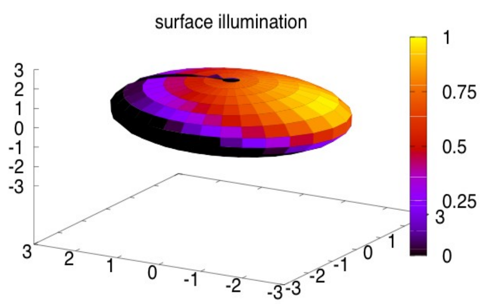
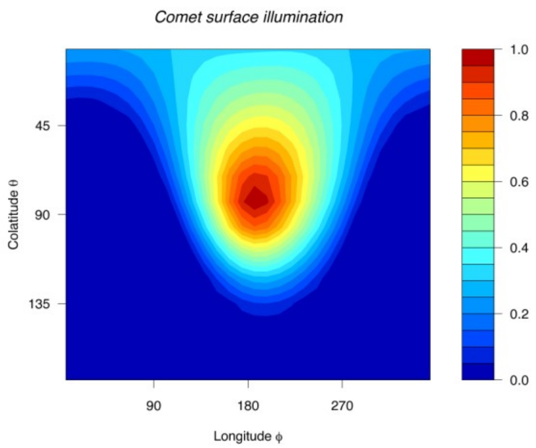


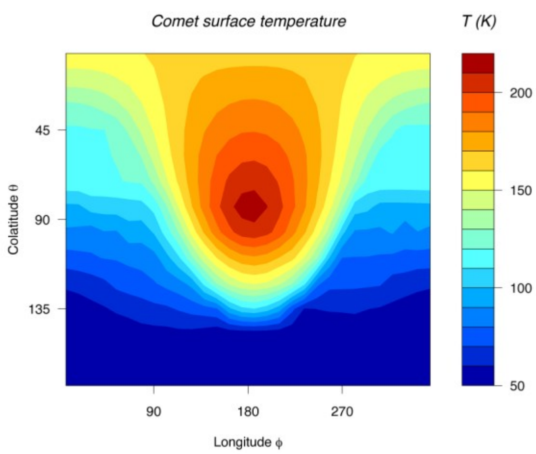
Figure 1: Shape considered to describe the nucleus of 67P/C-G. Illumination corresponds to 45◦ obliquity near aphelion. x, y and z scales are in km, color scale corresponds to the cosine of the local normal and the direction to the Sun.

With the orientation chosen for the calculations presented here, the comet nucleus is practically illuminated perpendicular to its rotation axis at about 3 AU. This means that we are almost at an equinox orientation.

Fig. 2 represents the Mercator projections of the illumination and temperature at the surface of comet nucleus we consider. The South pole is not illuminated and stays at the coldest temperature (50 K). The highest temperature is about 220K when the dust crust coverage is global. This leads to 150-180K temperature differences between various locations on the surface of the comet.



a



b

Figure 2: Mercator projections of the comet surface illumination (a) and temperature (b) at 3 AU from the Sun.

The numerical simulations also give us the surface activity of the comet nucleus, which depend directly from the illumination of the nucleus, its rotation period and the propagation of the heat wave in the comet nucleus material and the surface properties of the comet nucleus.

The sublimation of ices lead to the ejection of gases: water gas ejection is mostly located in the northern hemisphere, with some more diffuse ejection near the North pole when a global dust coverage is present. The CO_2 and CO fluxes are more diffuse and originate mostly from the northern hemisphere of the comet. The Southern hemisphere of the comet generally remains free of most gas ejection.

Such asymmetry in the H_2O and CO_2 coma is coherent with behaviour exhibited by comet 9P/Tempel 1 observed by Deep Impact [5] or more recently detected for comet 103P/Hartley 2 [6]. Taking into account the peculiar light curve observed for 67P activity [7], it is most probable that such asymmetry will also be observed

4. Summary and Conclusions

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.

Acknowledgements

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