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Quasi 3-D approach for thermal evolution of non-spherically shaped comet nuclei

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Abstract

Comet nuclei are considered as the most pristine bodies of the solar system and their study sheds an important light on the processes occurring during the initial stages of the solar system formation. Predictive models of the thermal evolution and differentiation of a cometary nucleus are needed to understand the nature of the comet nuclei in terms of composition, structure and physical properties, to understand the physical phenomena that can occur in comet nuclei and foresee cometary activity. The recent in situ images of cometary nuclei have shown typical non-spherical shape and particular topography.

We have developed a new quasi three-dimensional approach for non-spherically shaped cometary nuclei [1, 2], 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.

Introduction

Cometary nuclei observed in situ are typically non-spherical and present a variety of terrains. This work analyzes the results of a quasi three-dimensional approach for irregularly shaped cometary nuclei [1], 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.

Model description

Compositions and internal structure of comet nuclei are poorly known, and cannot be easily determined from ground observations. The shape of the comet is described by a two-dimensional mesh of quadrilaterals. The position of the point located at the center of each quadrilateral is given by its colatitude (latitude counted from the North pole) and longitude. 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. Figure 1 shows examples of spheroidal and irregular comet nucleus shapes with their illumination.

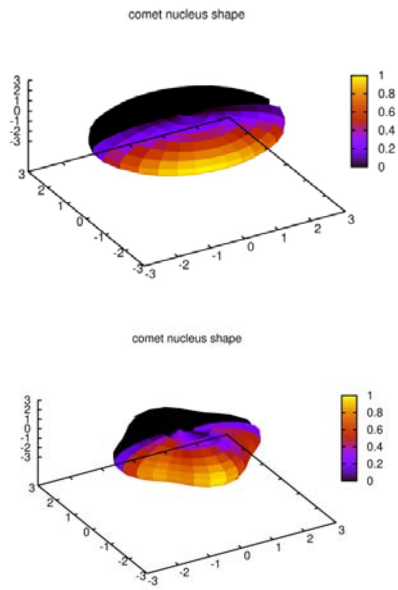

Figure 1: Irregularly shaped comet nuclei and their calculated illumination.

Thermal evolution

The thermal evolution of each mesh domain 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.

The model takes into account the amorphous-crystalline transition of water ice, as well as the thermodynamical release of gases (CO, CO_2) trapped in the amorphous water ice. 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

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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, 3, 4, 5, 6].

Results and Conclusion

The model is applied to differently shaped nuclei. The results show that differently shaped nuclei can have different internal structures leading to different activity patterns and behaviours (fig.2).

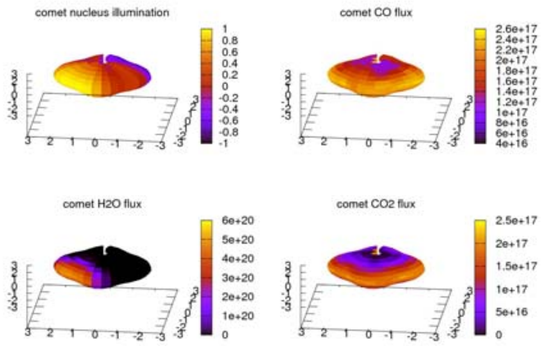

Figure 2: Illumination, H_2O, CO and CO_2 fluxes ($mol.s^{-1}$) for an irregular shape. Obliquity = 0º.

The investigated shapes influence the general behaviour of the comet in terms of production rates, spatial distribution of the gas fluxes, internal stratigraphy and surface temperature. However, there are also common features arising from these different models such as formation of the dust crust when the nucleus is far from the Sun.

The distribution of the water flux is the one most influenced by the shape, being directly linked with the illumination: shadowing effects due to the shape can be seen in its pattern. Water activity shows not only diurnal variations but also changes of intensity linked to the shadows on the comet.

Irregular shapes can have large shadowing effects that can results in very diverse activity patterns on the comet surface. Moreover, when the dust mantle is present, the water flux comes prevalently from those regions not covered by dust that can be defined as "active regions".

The fluxes of the minor species are less influenced by the illumination condition on the surface, but they depend on the location of the sublimation fronts inside the cometary nucleus.

In general, local variations in the dust and gas fluxes can be induced by the nucleus shape. The distribution of "active" areas is different with different shapes, reflecting the illumination conditions on the surface.

The shape influences the spatial distributions of the volatile ices resulting in different patterns in the comet interior (different stratigraphy).

We can expect that comets with different shapes have different internal stratigraphy, even if they share common dynamical and compositional properties.

References

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