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Simulations of water sublimation and surface temperatures: the case of asteroid (1) Ceres

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Abstract

Ceres is one of the most interesting object of main belt, since it represents the link between rocky asteroids and ice satellites: through his study it is possible to reconstruct the water history of the solar system. Water vapour presence has been recently reported by [1] and it was suggested for the first time in [2] through a marginal detection of the photodissociation product. We applied a "cometary-like" sublimation model described in [3],[4] and [5] to simulate the termal surface properties and water flux in order to give a theoretical support to Dawn NASA mission [6]. The arrival at Ceres of Dawn spacecraft is planned in spring 2015.

1. Introduction and Description of the model

Asteroid (1) Ceres is the biggest object of main belt and it is also the most massive one. Theoretical simulations suggest that Ceres is differentiated and consists in a silicate core (with a weak metallic presence) with an icy mantle [7], [8] and [9] and hydrated minerals on its surface [10]. Recently, Herschel observations revealed the presence of water vapour around Ceres, suggesting a flux of at least 10^{26} molecules for second, from (probably) localized sources. The variability of the water emission could led to suppose to be in presence of a "cometary-like" sublimation, but in principle cryovolcanism can not be excluded. Such a process needs an internal heat source that could be represented by long-lived radionuclides, while we can reasonably neglect tidal forces dissipation as possible candidate for the water emission.

The model we applied to study thermal properties of the surface and water vapour activity uses a 3D-approach, since it calculates diurnal and latitudinal temperature variations by the insolation on the surface. The surface is covered by a mesh of quadrilaters.

We assume Ceres as a spherical body and made of a homogeneous mixture of dust, organic materials and water ice in specified proportions. Each dust distribution has different physical and thermal properties and the dust grains are distributed in different size classes ([4],[5]).

The code solves the heat diffusion equation taking into account the terms linked to the energy gained/lost by sublimation and recondensation of water ice and to the energy relased during the transition from amorphous to crystalline ice. The mass conservation equation controls the gas flow through the pore system. The surface temperature results from the balance of solar input and the energy re-emitted in space, conducted in the interior and used to sublimate ices. Surface and internal temperatures are computed for each facets of the grid, providing thermal maps at the surface and at depth.

Table 1: The cases we explored

Case	Ice depth
A	0.25 m
B	0.35 m
C	0.50 m
D	1.00 m
E	10.00 m
F	100.00 m

2. Summary and Conclusions

We have developed several cases in which the water ice is at different depth from the surface (see Tab.1). Typical results of surface temperature and flux of water vapour are reported in Figs.1-5. The heliocentric distance we considered are 2.72 (pre-perihelion) and 2.90 (post-perihelion) AU. The first distance is linked to the first water line detection [2], the second to the Dawn's arrival at Ceres. Supposing a cometary-like behavior for Ceres, from a first analysis it seems that ice has to be close to the surface in order to have a relatively high flux compatible with the measurements provided by [1]. Therefore, cases A, B and C seem to be the most plausible, as we can see in Figs.2 and 3, where case A is shown, at 2.72 and 2.90 AU, respectively. We observe that, if the ice layer is located very deep inside the body (≥100 m below the surface, case F), a considerable decrease in the flux occurs (Figs.4 and 5).

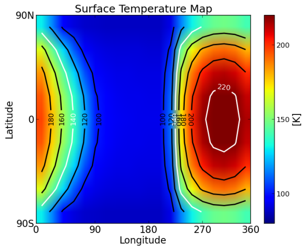

Figure 1: A typical example of surface temperature.

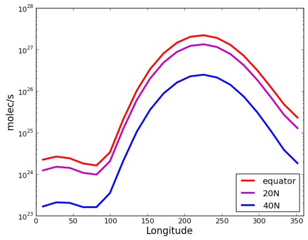

Figure 2: Case A at 2.72 AU.

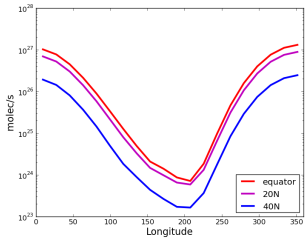

Figure 3: Case A at 2.90 AU.

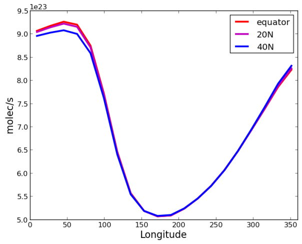

Figure 4: Case F at 2.72 AU.

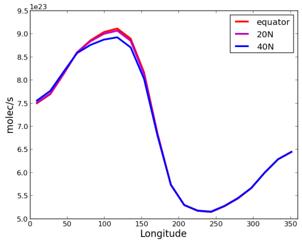

Figure 5: Case F at 2.90 AU.

Acknowledgements

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