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Ceres: ice stability and water emission

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Abstract

Recent observations of H_2O vapor plumes in localized regions [1] suggest the presence of ice on surface and/or on sub-surface regions of asteroid Ceres. In the hypothesis of a cometary-like emission mechanism (as already suggested by [2]), we performed several simulations in order to establish what are the likely physical conditions (in particular ice depth and thermal conductivity of crust) to fit Herschel observations [1].

1. Introduction

Ceres, target of NASA Dawn mission, is the link between outer ice satellites and inner rocky asteroid of our solar system. Recently, Herschel observed the presence of water vapor emission around Ceres, suggesting a flux of at least 10^{26} molecules for second from well localized regions, at mid-latitude [1]. This phenomenon could be explained in two main ways: the first mechanism involves the presence of long-lived radionuclides as internal heat source (as expected by theoretical models, i.e. [3, 4]); the second one requires a cometary-like behavior [2]. It was observed a certain variability of emission with the heliocentric distance [1]: this suggests that water emission could be driven by a cometary-like sublimation, due to the increase of temperature during the approach of the perihelion. So we applied a cometary model, developed by [5, 6, 7], and we studied the temperature of the first layers and the water emission.

2. The Model

The model assumes Ceres as spherical body made of a homogeneous mixture of dust and ices in well-defined proportions. At surface, the balance among solar input, energy re-emitted in space, conducted in the interior and used to sublimate ices determine the temperature. 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 ices. The gas flow through the pore system is described by the mass conservation equation.

In Table 1 we report the main physical parameters of our model.

Albedo	0.09
Dust/ice ratio on surface	2.5
Porosity	0.4
Initial temperature	163
Crust thermal conductivity	$10^{-3}, 10^{-2}$
Emissivity	0.8
Ice depth	0, 0.02, 0.05, 0.50

Table 1: Main adopted physical parameters values in SI units.

In the assumption of a “cometary-like” behavior (valid for the external layers), we performed several simulations in order to study the effects of the different parameters on temperature and on sublimation. We explored the case of emissivity equal to 0.8 in order to simulate a “moderately-rougher” surface. Thermal conductivity values used in our model are 10^{-3} and 10^{-2} (in SI units), since they lead to “reasonable” values of thermal inertia. In fact, it is expected that Ceres could have low/medium values of thermal inertia: some studies suggest values of 15-38 (in SI units) [10, 11], others higher values, i.e. 80 [12]. We study as ice’s depth influences the water emission, by setting ice front at different depth from the surface (see Table 1).

3. Summary and Conclusions

The maximum temperatures achieved are consistent with VIR measurements (Tosi et al., in preparation) and with the temperature of the warmest area (235±4K, [8]) for low values of thermal conductivity, if ice is within few cm from the surface (see Fig.1). Since the ice on surface at the equator is stable for very few orbits (as suggested by [9]) (see Fig.2), in order to fit Herschel observations (10^{26} mol/sec), we need an emitting area of about 1km^2 in agreement with

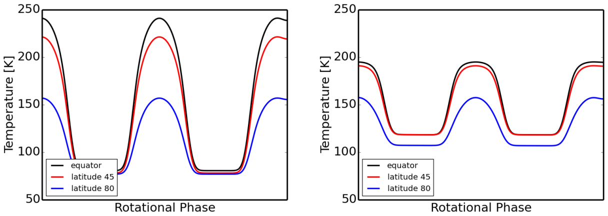

Figure 1: Temperature vs rotational phase for two different thermal conductivity values, 10^{-3} (left) and 10^{-2} (right) (in SI units), with ice at 5 cm beneath the surface.

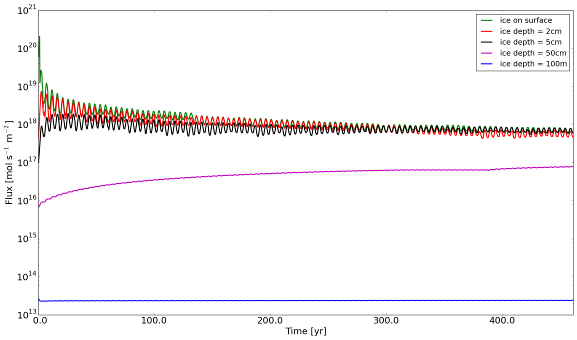

Figure 2: Flux vs time for different ice's depth at equatorial latitude, with thermal conductivity of 10^{-3} [SI].

[1] and also a continuous replenishment of water on the surface. For this purpose, an area of 1km^2 is expected to be activated every 1400-7700 years, with an excavated depth of about 200-250 m (the uncertainty depends on physical properties of the terrain). The activation rate is calculated by impact cratering (the frequency of formation of crater with at least 1 km in diameter is 4.5×10^{-11} - 2.5×10^{-10} km^{-2}yr^{-1}). If ice is below the surface of several tens of cm, water ice is stable for very long time (see Fig.2): in this case, an emitting area of 10^4 km^2 is required. If ice is very far below the surface (i.e. 100 m), an emitting area of 10^7km^2 is required, which is greater than the overall area of Ceres, so impossible. Fluxes from polar regions are very small compared to Herschel observations. The water emission could lead to a transient atmosphere around Ceres, as suggested by Magni et al. (in preparation), by applying a smoothed-particle hydrodynamic code.

Acknowledgements

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