Simulation of Ceres water sublimation and thermal state

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The dwarf planet Ceres is the largest of the minor bodies and is located in the main asteroid belt with a semimajor axis of 2.77 au. The current observational evidence shows that the boundary between rocky bodies and icy bodies is probably within the asteroid belt or a little further, and Ceres is a key object to understand the story of water in the solar system. Ceres represents the key, together with Vesta, to answer some important questions relative to the role of protoplanet sizes and water content in determining their subsequent evolution. Ceres is thought to be differentiated into a silicate core with an icy mantle [1,2,3], and hydrated minerals were found on its surface [4]. Moreover, the presence of water vapour around Ceres has been recently reported by [5] from Herschel observations. Water outgassing was also suggested by a marginal detection of the photodissociation product OH [6]. The recent observations suggest a flux of water vapour from Ceres of at least 10^{26} molecules/s. Moreover, it seems that the flux is originating from localized sources. The variation of the detected activity along the Ceres' orbit could suggest a cometary-like sublimation [5], but cryovolcanism cannot be excluded. Here we applied a ”cometary-like” sublimation model [7,8] to simulate the thermal properties and the water flux of Ceres in the light of the NASA Dawn mission [9], planned to arrive at Ceres in spring 2015. In the literature, there are several works dedicated to the study of this asteroid [1,3], but they are mainly devoted to simulate the thermal evolution of the body since its formation. The current work, conversely, uses a quasi-3D approach, derived from the thermal evolution models of cometary nuclei, to study the thermal properties of the surface and to investigate the conditions for the observed water activity. The model assumes Ceres to be a spherical body with a fixed radius and made of a homogeneous mixture of dust and ices in different proportions. The body is composed of water ice, dust, and organic materials, in specified proportions. Each dust distribution has different physical and thermal properties and the dust grains are distributed in different size classes. The surface temperature is derived from the balance among solar input, energy re-emitted in space, conducted in the interior and used to sublimate ices. A mesh of quadrilaterals describes the shape. The illumination for each of the facets making up the full shape is calculated by the angle between the local normal and the direction to the Sun. The thermal evolution of each grid surface is calculated by taking into account the solar illumination and the properties of the material on and 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 ices. The temperature is also computed for each element, providing thermal maps at the surface and at depth. We have developed several geophysical and thermal scenarios, changing the proportion of ice and dust, surface albedo, and the presence and absence of ice on (and below) the surface. From this first analysis, it seems that water ice layers located very deep inside the body (>100s meters below the surface) cannot account for such a relatively high flux. For having the water flux seen by [5], the icy layers must be much closer to the surface. The output of the different models is discussed.

Acknowledgements: This work was supported by an ASI grant.

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