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Temperature and emissivity of specific regions of interest on Ceres

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Abstract

We describe the thermal behavior of some notable features, investigated by the Dawn spacecraft on the dwarf planet Ceres, using thermal infrared data acquired by the Visible and InfraRed mapping spectrometer (VIR), and comparing them with the local geology and mineralogy of those areas. Based on experience gained at Vesta, thermal information at unprecedented spatial resolution is useful in constraining thermophysical properties, which ultimately allow a comprehensive interpretation of the observed features.

In this paper we summarize the most salient results concerning the thermal analysis of Ceres, and we will present preliminary results of the thermal analysis obtained for the latest VIR data obtained during Dawn's second extended mission (XM2).

1. Introduction

The NASA Dawn spacecraft entered orbit around the dwarf planet Ceres in March 2015, where it is currently approaching its end-of-mission. In the mission phases that have been planned, the VIR imaging spectrometer aboard Dawn acquired a large amount of hyperspectral data of the surface, to map the surface composition and to retrieve surface temperatures on the dayside of the target.

The infrared range longward of ~3.5 µm is crucial to reveal the thermal emission of Ceres on its dayside, which can be used to map surface temperature across different orbits and local solar times (LST), and therefore constrain thermal properties at different spatial scales.

To derive surface temperature, we rely on a Bayeasian approach to nonlinear inversion that was applied to different datasets: 1) Dawn/VIR data acquired during the orbital phase at asteroid Vesta in 2011-2012 [1], 2) Rosetta/VIRTIS data obtained during the close flyby of asteroid 21 Lutetia in 2010 [2], and 3) Rosetta/VIRTIS data acquired at comet 67P/Churyumov-Gerasimenko in the two-year period 2014-2015 [3]. Compared to other methods, this approach allows simultaneous retrieval of surface temperature and emissivity in the 4.5-5.1 µm range.

2. Results

On Ceres, the feature displaying the largest thermal contrast, both on a regional and local scale, is the 34-km crater Haulani, located in the equatorial region and close to the prime meridian. Its central mountainous ridge, its floor, rim and its nearest ejecta appear cooler than surrounding terrains observed under similar illumination conditions and LST [4]. While Haulani is one of the youngest surface features of Ceres (< 6 Myr), its thermal contrast is not as distinct as in other young craters like Oxo, Juling and Kupalo, difficult to be explained with space weathering. Rather, the characteristics of the impact event that formed crater Haulani, also triggering hydrothermal activity in the shallow subsurface, could have exposed material with higher density or different thermal conductivity compared to other similar young impact features. An accurate thermophysical modeling of Haulani will allow one to identify the main cause of the thermal signature that is unique to crater Haulani [5].

Bright material units were discovered on Ceres by the Dawn spacecraft during approach in early 2015.

The brightest cluster of spots is found in the 92-km complex Occator crater. VIR data acquired in the near infrared revealed that Cerealia Facula (the brightest spot) is made up of an outcrop of anhydrous sodium carbonate, which is the solid residue of crystallization of brines erupted from below. Despite their compositional uniqueness on Ceres, Occator's faculae do not show substantial thermal contrast at spatial resolutions of kilometers down to a few hundreds of meters, suggesting that albedo does not strongly constrain surface temperature on Ceres.

Dawn/VIR spectra allowed a safe identification of water ice-rich materials on the surface of Ceres. Starting from the 10-km crater Oxo [6], a total of about ten ice-rich units were discovered in as many craters located poleward of 30°. These units are favored by peculiar local topography, which allows ice to be shielded from direct sunlight for most of the Cerean day, or are the result of recent impacts or recent landslide activities [7]. In this respect, crater Juling is particularly interesting since the extension of its ice-rich unit has been discovered to change with time, suggesting a potential connection with the sporadic variations of water and hydroxyl observed from space [8]. Because pure surficial H2O ice would sublime under current thermal conditions on Ceres, where daytime surface temperatures span the range 180-245 K, direct thermal mapping enabled by VIR infrared data can put constraints on the ice loss rate of ice-rich materials, helping us to constrain their formation and retention mechanism.

With an average height of about 4 km, Ahuna Mons is the highest mountain discovered on Ceres. A thermal analysis of Ahuna Mons carried out with VIR highlights that the northern flank and the summit of Ahuna could be inherently cooler than the surrounding regions observed at the same local time [9]. Ahuna is hypothesized to be cryovolcanic in origin, and its sodium carbonate-rich mineralogy and morphologically fresh features support a relatively young age of this particular area though the formation age of the Mons is ~200 Ma [10]. This evidence of younger age and the association with thermal anomaly could be related to a different compactness of the surface regolith.

In addition to presenting a summary of the main discoveries made by Dawn/VIR in the thermal mapping of Ceres, here we will also present preliminary results related to the spectral emissivity retrieved for the main structures previously discussed. Because Dawn's second extended mission (XM2) is carried out on an elliptical orbit that provides the opportunity to overfly features of interest such as craters Juling, Occator and Haulani with unprecedented pixel resolution, we will attempt a thermal analysis of those data.

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