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Ceres and Vesta mineralogy determined by VIR on Dawn

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Abstract

The Dawn spacecraft [1] arrived at Ceres in early 2015, the second of its targets, and performed a detailed study of its surface and internal properties. Previously, it performed a detailed orbiting campaign at Vesta. Ceres together with Vesta represent the key to understand some important points relative to the role of the protoplanet size and the water content in determining the evolution of protoplanets and minor bodies. Dawn is equipped with a Visible and InfraRed Mapping Spectrometer (VIR) [2] to study the surface composition of the Dawn targets. Here we report about the main VIR results at Ceres and Vesta.

1. Introduction

VIR is an imaging spectrometer coupling high spectral and spatial resolution in the VIS (0.25-1.0 μm) and IR (0.95-5.0 μm) spectral ranges [2]. VIR acquired data during Approach, Survey, High Altitude Mapping (HAMO) and Low Altitude Mapping (LAMO) orbits that provided very good coverage of the surface of Ceres and Vesta. The bodies' surfaces ware mapped with increasing spatial resolution from Survey (CSS) to LAMO orbits (CSL), but this increase was at the expense of coverage.

2. Result

Ceres

The VIR instrument observed Ceres' surface at different spatial resolutions and revealed a nearly uniform global distribution of surface mineralogy. The average thermally-corrected reflectance spectrum of Ceres (Fig. 1) is almost flat in the spectral region below 2.6 μm, but it shows several bands in the 2.6-4.2 μm wavelength region (Fig. 1), at 2.72, 3.05-3.1, 3.3-3.5, and 3.95 μm. The most prominent is a strong and narrow absorption centred at 2.72-2.73 μm indicative of OH-bearing silicates. The other bands indicate the presence of ammonia bearing species and carbonates [3-7].

Clearly, Ceres experienced extensive water-related processes and chemical differentiation. The surface is mainly composed of a dark and spectrally neutral component (carbon, magnetite), Mg-phyllosilicates, ammoniated clays, carbonates and salts. The observed species suggest endogenous, global-scale aqueous alteration [7].

While mostly uniform at regional scale, Ceres' surface shows small localized areas with different species and/or variations in abundances. Water ice has been detected in localized small patches especially at high latitudes [8] in the North hemisphere but also in a crater not far from the equator in the southern hemisphere [9]. Sodium carbonates have been identified in several areas on the surface, notably in Occator bright faculae [10,4] and many of the bright areas that punctuate the surface of Ceres are compatible with the presence of sodium carbonates. Organic matter has been discovered in several places, most conspicuously in a large area close to Ernutet crater [11]. The signature is associated to aliphatic organics.

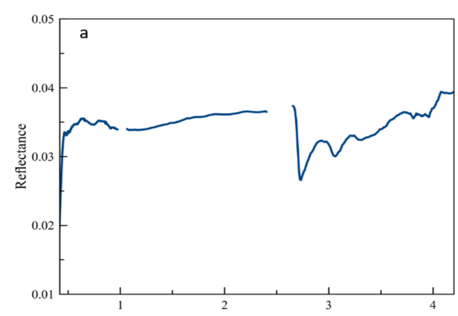

Fig.1 Thermally corrected average spectrum of Ceres in the spectral range 0.4-4.2 μm.

Vesta

Vesta spectra are characterized by pyroxene absorptions at 0.9 and 1.9 µm and spectrally different regions of Vesta have been identified (fig.2). They are characterized by distinctly different band depths, widths, shapes and centers [12], suggestive of different HED lithologies. Although almost all of the surface materials exhibit howardite-like spectra, some large units can be interpreted to be material richer in diogenite (based on pyroxenes band centers) and some others like eucrite-rich howardite units[12,13]. The Rheasilvia basin has its own spectral characteristics: deeper and wider bands, average band centers at shorter wavelengths. These spectral behaviors indicate the presence of Mg-pyroxene-rich (diogenite-rich) terrains in Rheasilvia. Vesta's surface shows considerable diversity at local scales, in terms of spectral reflectance and emission, band depths, centers and spectral slopes. Many bright and dark areas were identified on Vesta from VIR and FC. Bright material is the best example of Vesta endogenous material while dark material is due to contamination by infall carbonaceous chondrites [14,15], also identified as the main carrier of the hydration band at 2.8 micron identified on Vesta. Olivine has been identified on Vesta in different regions [16] and its distribution is compatible with both the main differentiation models (magma ocean and localized plutons).

3. Conclusions

Ceres shows mineralogy and geology dominated by the action of water and other volatile ices mixed with rocks. The surface displays clearly the products of aqueous alteration and ice on the surface [3-11] and subsurface. Moreover, Ceres shows clear sign of "recent" hydrothermal activity [4]. The presence of ammonia in phyllosilicates and salts [3,4,5] indicates the accretion of volatiles, such as ammonia in the original material from which Ceres formed, suggesting a cold formation environment. Moreover, the presence of organic species on Ceres, mixed with minerals formed by water alteration and hydrothermal processes, suggest a favourable environment for the developing of molecules precursor of biological molecules.

Conversely, Vesta shows records of different, less wet, primordial processes that took place at the origin of the solar system. It is basaltic, indicating that internal heat was sufficient to fully differentiate the body, but the surface shows signatures of endogenous OH, delivered by ancient impactors or dust.

Dawn observed two dramatically different objects, relicts of the primordial solar System and prototypes of the terrestrial planets (Vesta) and bodies of the outer solar system (Ceres).

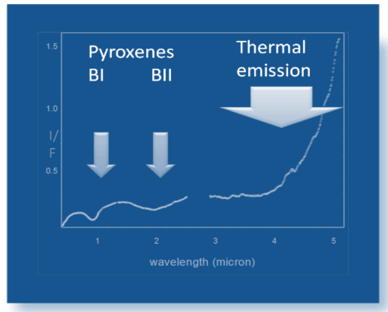

Fig.2 Average Vesta spectrum acquired by VIR.

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