

## OH and H<sub>2</sub>O on Vesta under the moonlight

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### Abstract

The search for OH and H<sub>2</sub>O at the surface of Vesta is underway using the visible and infrared mapping spectrometer in orbit onboard the Dawn spacecraft. To understand the origin of the OH detected on Vesta, the approach is 1) to analyze any correlation as function of composition, local time of day, latitude, and morphological features, and 2) to compare those findings under the light of previous detections of OH and H<sub>2</sub>O on the Moon, which has also a basaltic composition.

### 1. Introduction and background

Searching for OH and H<sub>2</sub>O on Vesta is key [1] because the presence of these molecules at the surface of objects in the inner solar system is fundamental for understanding the formation of water in the early history of the solar system, as well as its implications on the mineralogical, thermodynamical, and geological evolution of the planets [2, 3]. Vesta is the second largest object in the main asteroid belt, and is understood as a protoplanet: It is a celestial body that is mineralogically differentiated – and water may have played a role here –, more evolved than a most of the asteroids, but not as much as a planet [4, 5].

Vesta is located in the inner part of the main asteroid belt: Signatures of hydration in the 3-μm region have been reported from some telescopic observations [6], but not confirmed by others; [7], and no absorption could specifically be detected at 2.8 μm,

Objects rich in hydrated minerals and water ice have been detected in the mid outer part of the main asteroid belt [8, 9] and beyond, however, despite the relatively small distances, the resonance gap between the two parts of the belt makes them dynamically

distant, which explains the compositional dichotomy associated to this resonance gap.

The pyroxene-rich surface of Vesta [10, 11, 12] shares some similarities with the surface of the Moon, where OH and H<sub>2</sub>O have been detected by imaging spectroscopy in the near-infrared [13, 14, 15], and for which various mechanisms have been suggested [16].

Those recent results from the lunar surface have led to establish a few hypotheses about the origin of OH, both on the surface and in the interior. Because Vesta is in many ways similar to the Moon, in that it is an airless, differentiated, basaltic body in the inner Solar System, some of the same processes should have operated [1]. OH can come from three sources which may all coexist (See [17] and [18] for background and reviews): 1) indigenous from the original material forming the object, 2) in-fall of meteorite and cometary material containing water or hydroxyl, and 3) from processes associated with the solar wind irradiating the surface material that can actually produce such compounds.

The Dawn spacecraft is in orbit around Vesta since July 2011. The search for OH and H<sub>2</sub>O is underway using reflectance spectra between 0.25 and 5.1 μm from Dawn's Visible and Infrared Mapping Spectrometer (VIR) [19]. VIR has detected a weak but significant absorption band at 2.8 μm that is attributed to OH [20, 21]. The nature and origin of OH is investigated by way of comparing the distribution of the 2.8-μm band depth with morphological features, mineralogical composition and temporal variations. Comparisons obtained with lunar observations are used to determine possible differences in the processes of formation of OH.

## 2. Analysis of VIR spectra

A global average reflectance spectrum for Vesta from the Dawn Survey orbit phase is shown in Fig.1. Molecular absorptions from OH and H<sub>2</sub>O exist in the near-infrared between 2.8 and 3.5- $\mu$ m. Some weak spectral structure exists in this range in the global average I/F spectrum [McCord et al., 2011 EPSC]. The spectral domain near the short wavelength edge of the OH-H<sub>2</sub>O region is also affected by incomplete calibration. However, no artifact is visible in the 2.4-2.9- $\mu$ m range on ratioed spectra, suggesting the instrument is responding linearly, and that a simple correction of the response function is appropriate to recover the signal.

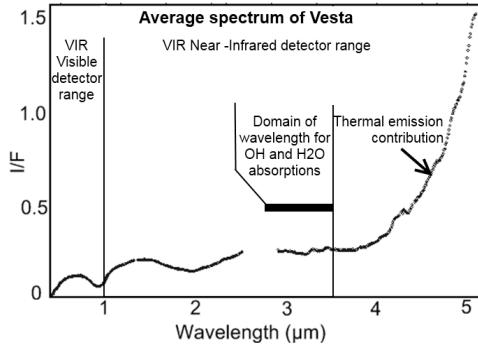


Figure 1: VIR average spectrum of Vesta.

Based on this first analysis, and in the absence of robust reference spectrum of the surface of Vesta in the entire VIR NIR range of wavelength, we are taking a step by step approach based on empirical calibration correction. We are now using ratioed spectra against telescopic measurements from Hasegawa et al. (2003, 2004). Although ground-based telescopic spectra have a gap between 2.5 and 2.9  $\mu$ m due to atmospheric water vapor absorption bands, they are the only reference available for Vesta. For the correction, the reflectance in this gap is assumed to be featureless.

## 3. Analysis of absorptions at 2.8- $\mu$ m

Spectral variations at 2.8  $\mu$ m across the surface of Vesta suggest the presence of an absorption band due to OH. Areas defined by a stronger band form coherent spatial units. Multiple observations of the same area provide similar spatial distribution.

While the strengths and locations of these spectral variations are being better defined, a search is also underway to identify the sources and processes responsible. Associations with surface morphological features observed at high spatial resolution with the Framing Camera (FC) are proving complex. No significant correlation with temperature, also retrieved by VIR or with illumination suggest that the formation of OH is not likely due to short-term surface processes, as might be the case on the Moon [13, 16]. The final objective will be to derive abundance estimates for OH and H<sub>2</sub>O at the surface of Vesta, and to compare them with abundances found on the Moon. On the Moon, feldspathic areas such as highlands show stronger absorption bands of OH and H<sub>2</sub>O. Vesta is less feldspathic than the Moon. The strong pyroxene absorption bands in VIR data indicate that Vesta surface particles are more crystalline. The crystal structure of Vesta's soils may have fewer defects than lunar soils, which is less favorable to proton implantation. Analysis of incoming data is underway, with more spatial coverage, higher spatial resolution and improved calibration.

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## References

- [1] Pieters et al., 2011, Space Science Rev. 163. [2] Cyr et al., 1998, Icarus 135. [3] Encrenaz et al., 2008, Ann Rev 46. [4] Russell et al., 2007, Earth Moon Planets 101. [5] Russell et al., 2012, Science 336. [6] Hasegawa et al., 2003, Geophys. Res.Let. 30. [7] Rivkin et al., 2006, Icarus 180. [8] Rivkin and Emery, 2010, Nature 464. [9] Campins et al., 2010, Nature 464. [10] McCord et al., 1970, Science 168. [11] Gaffey et al., 1997, Icarus 127. [12] De Sanctis M.C. et al., Science, 336, 697, 2012. [13] Pieters et al., 2009, Science 286. [14] Sunshine et al., 2009, Science 286. [15] Clark et al., 2009, Science 286. [16] McCord et al., 2011, J. Geophys. Res. 116. [17] Lucey, 2009, Science 286. [18] Lucey et al., 2006, Rev. Mineral. Geochem., 60. [19] De Sanctis et al., 2010, Space Science Rev 163. [20] McCord et al., 2011, EPSC-DPS ,abstract 567 [21] Combe J.-Ph. et al., 2012, LPSC, 2643.