Constraining Hydrogen Abundance on Asteroid (16) Psyche. V. Reddy[1], D. J. Lawrence[2], L. Elkins-Tanton[3], and D. Takir[4], [1]Lunar and Planetary Laboratory, University of Arizona, 1629 E University Blvd, Tucson, AZ 85721-0092, [2]Johns Hopkins University Applied Physics Laboratory, Laurel, Maryland, School of Earth and Space Exploration, Arizona State University, Tempe, Arizona, [4]SETI Institute, Mountain View, California.

Introduction: Constraining the abundance of hydrogen on the surface of small bodies enables us to understand its surface geology, impact history, interaction with space environment and resource potential. Main belt asteroid (16) Psyche is the target of a NASA Discovery mission that would arrive at the target in 2026 [1]. Psyche is interesting because it is thought to be the remnant core of a differentiated planetesimal that survived a hit-and-run collision [2]. This hypothesis is surported by Psyche's high radar albedo, suggesting a high metal content in its near surface.

Psyche was the focus of an intense multi-wavelength ground-based observational campaign during its 2015 opposition [3-6]. These observations showed surface veriegation in metal-slicate ratio, a hemispherical albedo dichotomy, and the presence of a hydration feature suggesting volatiles are present on the surface. Forward modeling the lightcurve using the radar-derived shape model [3] showed that 3/4th of Psyche's surface was covered with a low albedo material. Coupled with the detection of the (OH/H_2O) hydration feature by [4], it is likely that Psyche's surface is covered with low-albedo carbonaceous impactor material rich in volatiles.

NASA's Dawn spacecraft Framing Camera (FC) observations of asteroid (4) Vesta have shown that its surface is contaminated with low-albedo exogenic carbonaceous impactors. This hypothesis is strengthened by the detection of hydrogen [7] and hydration features on Vesta not only by the Dawn spectrometer [8] but also by ground based telescopic observations [9].

In this abstract we propose a method to constrain the hydrogen abundance on asteroid (16) Psyche using the 3-micron hydration feature detected by [4]. We created an absorption band (%) depth vs. hydrogen abundance (micrograms per gram) calibration using telescopic, Dawn visible and infrared spectrometer (VIR) and Gamma-Ray and Neutron Detector (GRaND) observations of Vesta.

Vesta Observations: Ground-based near-IR observations of Vesta by [9] suggested the presence of a weak absorption band at 3-microns between longitudes 155 degrees and 195 degrees in the [10] coordinate system (Fig. 1-2). [9] concluded that carbonaceous impactors could be the source of this putative 3-micron feature. This was supported by previous laboratory study of HED meteorites that showed carbonaceous xenoliths in brecciated howardites [11]. The location of the ground-based detection of the 3-micron feature by [9] corresponds to region east of Marcia crater (330 to 60 deg longitude) in Claudia system that is used by the Dawn science team [12] (red box in Fig. 3).

The band depth of the 3-micron feature on Vesta from Dawn VIR spectrometer observations [13] ranges between 1-4% for the entire surface (Fig. 4). The band depth of the 3-micron feature (1%) observed by [9] is also consistent with Dawn observations at similar longitudes [13] (red box in Fig. 4).

Psyche Observations: [4] obtained rotationally resolved 3-micron spectra of asteroid (16) Psyche using the NASA IRTF. These observations showed variation in the depth of the absorption band (-3%) as a function of longitude (Fig. 5). [4] attributed this feature to OH- or water-bearing clay minerals in the surface. Similar to Vesta, they postulated that these clay minerals might be in remnant carbonaceous chondrite impactors that have coated the surface of Psyche with the exogenic material.

Constraining Hydrogen on Psyche: Ground-based spectra and Dawn spacecraft spectral and gamma-ray and neutron observations provide us with a first-order relationship between 3-micron band depth (%) and hydrogen abundance (micrograms per gram). [7] puts a range of hydrogen abundance on Vesta for the region observed by [9] and [13] (shown in red boxes) between 100-150 micrograms of hydrogen per gram of surface material (Fig. 6). This would suggest that a 1% band depth of the 3-micron absorption feature observed by both ground-based telescopes [9] and Dawn VIR spectrometer [13] corresponds to 100-150 micrograms of hydrogen per gram of surface material. Using this calibration, we estimate that the 2-3% 3-micron absorption band depth on Psyche would correspond to a hydrogen abundance of 200-300 micrograms per gram of Psyche regolith.

References: [1] Elkins-Tanton, L. T. et al. (2014) LPSC 1253. [2] Asphaug, E. et al. (2006) Nature 439-155. [3] Shepard, M. K. et al. (2017) Icarus 281-388. [4] Takir, D. et al. (2016) AJ 153:1. [5] Sanchez, J. A. et al. (2016) AJ 153:1. [6] Drummond et al. (2018) Icarus (In Press). [7] Prettyman, T. H. et al. (2012) Science 338:6104. [8] McCord T. B. et al. (2012) Nature 491, 83-86. [9] Hasegawa, S. et al. (2003) GRL 30:21. [10] Thomas, P. C. et al. (1997) Icarus 128, 88-94. [11] Zolensky, M. E. et al. (1997) MAPS 31:518-537. [12] Reddy, V. et al. (2012) Icarus 226:1103-1114. [13] De Sanctis, C. et al. (2012) ApJL 758:2.

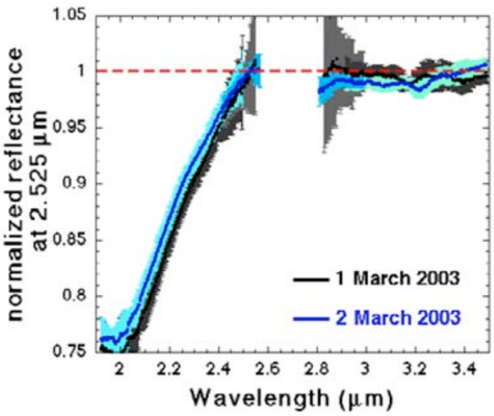

Figure 1. Ground-based mid-IR spectra of Vesta from Hasegawa et al. (2003) showing a weak absorption band at 2.8 microns.

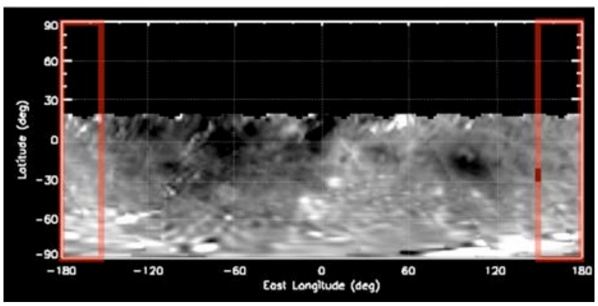

Figure 2. Dawn RC1 map of Vesta showing the longitudnal range (red boxes) where Hasegawa et al. (2003) detected the 2.8 micron feature with ground-based telescopes. The map is in the Thomas et al. (1997) coordinate system.

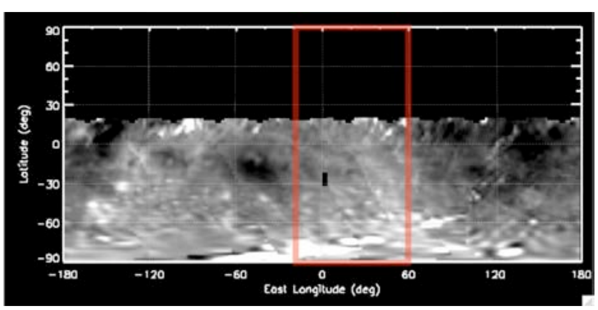

Figure 3. Dawn RC1 map of Vesta showing the longitudnal range (red boxes) where Hasegawa et al. (2003) detected the 2.8 micron feature with ground-based telescopes. The map is in the Claudia coordinate system used by the Dawn mission.

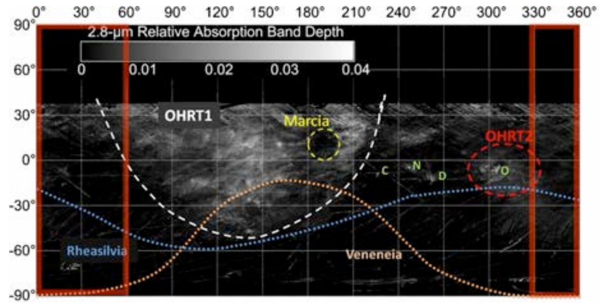

Figure 4. Dawn 2.8-micron band depth map of Vesta from De Sanctis et al. (2012) showing the longitudnal range (red boxes) where Hasegawa et al. (2003) detected the 2.8 micron feature with ground-based telescopes. The map is in the Claudia coordinate system.

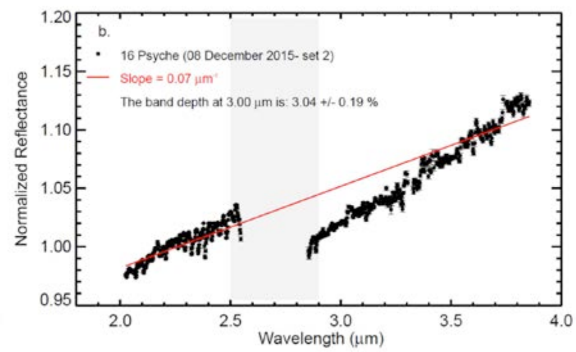

Figure 5. Ground-based mid-IR spectrum of asteroid (16) Psyche (red) from Takir et al. (2017) showing an absorption feature around 2.8 microns. This feature has been interpreted to be due to remnant carbonaceous impactors on the surface of the asteroid.

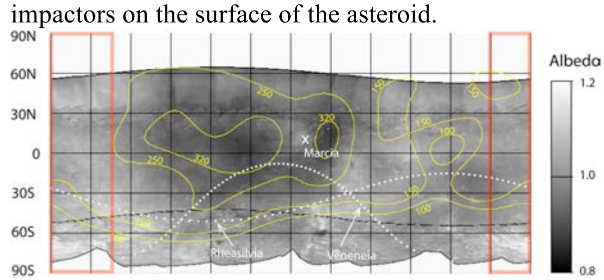

Figure 6. Dawn hydrogen map of Vesta from Prettyman et al. (2012) showing the longitudinal range (red boxes) where Hasegawa et al. (2003) detected the 2.8 micron feature with ground-based telescopes. The map is in the Claudia coordinate system.