The Photometric and Spectral Properties of Vestoids: Preparations for the *Dawn* Encounter at Vesta. M. D. Hicks[1], B. J. Buratti[1], V. Reddy[2], K. J. Lawrence[1], [1]Jet Propulsion Laboratory California Inst. of Technology, 4800 Oak Grove Dr. 183-401, Pasadena, CA 91109, Michael.D.Hicks@jpl.nasa.gov. [2]University of N. Dakota.

Introduction: The *Dawn* Mission is part of NASA's Discovery Program. Launched in 2007, the spacecraft will begin the first detailed study of a Main Belt asteroid, 4 Vesta, in August 2011 and continue its orbital mission for nine months. The main goals of Dawn's in-depth study are to understand the evolution of this protoplanet and the role of water in its history; to derive Vesta's bulk properties; to model its surface composition and geologic landforms, and to understand its relationship with the terrestrial HED meteorites and the near-Earth vestoids, both of which are believed to originate on Vesta. In preparation for the encounter in August, an observing campaign to study the spectrophotometric properties of vestoids is underway. One important component of this program is the gathering of photometric observations of vestoids over a complete range in solar phase angles. Because Vesta is in the Main Belt, the maximum excursion in solar phase angle is limited to ~25º. The vast bulk of the observations to be obtained by *Dawn* are at larger solar phase angles. No project data products or scientific results – mosaics for both public consumption and for geophysical studies, composition based on spectroscopic band identifications, topographic analysis based on photoclinometry, shape models, etc. – can be of very high fidelity without careful photometric modeling and correction. The goal of this study is to derive a surface phase function for Vesta and vestoids that will be in place at the start of the nominal mapping mission. A subsidiary goal is to derive fundamental photometric values (geometric albedos, phase integrals, and Bond albedos) that will enable more efficient spacecraft operations, and physical photometric properties such as roughness and surface directional scattering properties. Finally, our study will result in a comprehensive photometric survey of vestoids that will serve to show their relationships to Vesta and other classes of asteroids. From these studies we can better understand the origin and dynamical history of the Near Earth Objects and the terrestrial meteorites.

Observations of Vestoids: A number of vestoids have well-placed apparitions before the August encounter. For example, from JPL's Table Mountain Observatory (TMO), four vestoids can be studied over a large excursion in solar phase angle; when these photometric data are combined together and with additional data of Vesta at smaller solar phase angles (<25º) a full solar phase curve can be obtained (see Table 1). From these measurements, and if one assumes a Lommel-Seeliger (lunar-like) photometric scattering law, surface phase functions for constructing mosaics and for deriving accurate instrument integration times can be derived [1].

Table 1 - **– Future observational circumstances for high phase V-type asteroids before *Dawn* Vesta encounter.**

Object	a (AU)	H_v	Bright-est	Phase angles (º)	Nights
1998 VO33	1.25	13.1	2/6/11	25-96	52
1981 Midas	1.78	15.5	2/16/11	46-75	32
2003 YT1	1.11	16.2	5/09/11	67-101	47
1992 FE	0.93	16.4	5/25/11	62-97	41

Observations of 4055 Magellan in 2010. In 2010, we gathered photometric measurements at TMO of the vestoid 4055 Magellan. We obtained enough photometric data to determine a rotational light curve and a disk integrated brightness at 55º, more than doubling the excursion in solar phase angle for Vesta, as shown in Figure 1 .

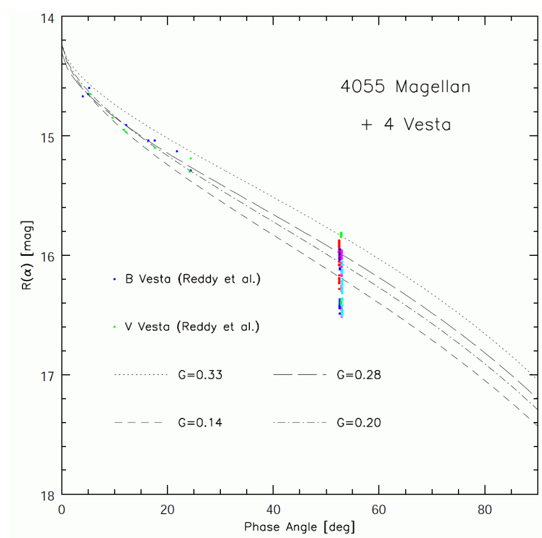

Figure 1: Observations of 4055 Magellan obtained at JPL's Table Mountain Observatory in 2010 with previous observations of 4 Vesta [2]. Colors distinguish different nights within the TMO observing run. The four curves are model phase curves using the standard IAU asteroid photometric model (H-G model).

For a large lightcurve amplitude object such as Magellan, the surface slope distribution is a better approximation of a sphere at maximum lightcurve brightness (an assumption implicit to the H-G model). Our estimated phase parameter of Magellan (g=0.30±0.02) is indistinguishable to that of Vesta (g=0.322), giving us confidence in using NEO vestoids as photometric analogs. Using Russell's Rule [1], one can estimate the

Bond Albedo of Vesta. The Bond albedo is the product of the geometric albedo (p) times the phase integral (q), which can be estimated by Russell's Rule:

$$q = 2.17x\ \Phi(54^o)$$

where Φ is the disk integrated brightness normalized to unity at 0º. Figure 1 shows that Vesta's phase integral in the R-filter is about 0.19. With a visible geometric albedo of 0.42 [3] we find a Bond albeo of 0.08. (Our estimate does not take into account differences in the phase curves between the R and V filters.)

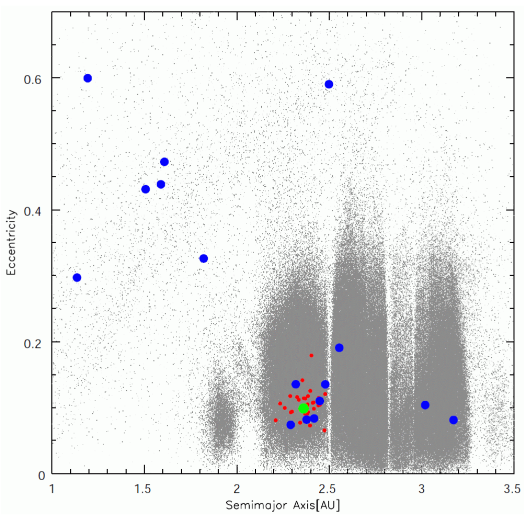

Figure 2: Osculating elements for the V-type asteroids observed at Palomar (blue), archived V-type asteroids in the SMASSII database (red) and Vesta (green) [4] .

Spectroscopic observations. Low-resolution CCD spectra of V-type asteroids have been obtained at the 200-inch telescope on Palomar Mountain (P200). Our sixteen P200 vestoids include NEOs observed during our ongoing survey of radar targets and PHAs (2005 GC120, 1999 VO6, 2003 EF54, 1996 EN, 2004 FG11, 2010 MF1, 4055 Magellan), main-belt objects near Vesta (1999 LH13, 2004 LV3, 1991 CD, 6093 Makota, 2247 Hiroshima, 1998 FL71, 12073 Larimer) and two outer main belt objects (7472 Kumakiri and 1991 SG1). The main-belt vestoids were targeted due to their suggestive SDSS colors. The osculating elements of the P200 vestoids and the V-type asteroids archived in the SMASS II dataset [4] are plotted in Figure 2.

For our spectra we quantified a pseudo-band depth, (maximum reflectance - 0.85 µm reflectance)/maximum reflectance. We also measured the spectral slope from 0.6 µm to 0.7 µm in units of percent change per 0.1 µm. These quantities are plotted up in Figure 3. Panel A suggests that there is no significant difference between the P200 and SMASS II vestoids. The remaining panels explore how these two spectral features trend as a function of perihelion distance and size. There is no clear correlation of either parameter with size nor perihelion distance. One would have expected a notable shift in color with size and perihelion distance: larger objects have longer collisional lifetimes and the V-type NEOs are susceptible to the "gravitational shaking" due to close approached with the Earth and should, in general, exhibit younger surfaces.

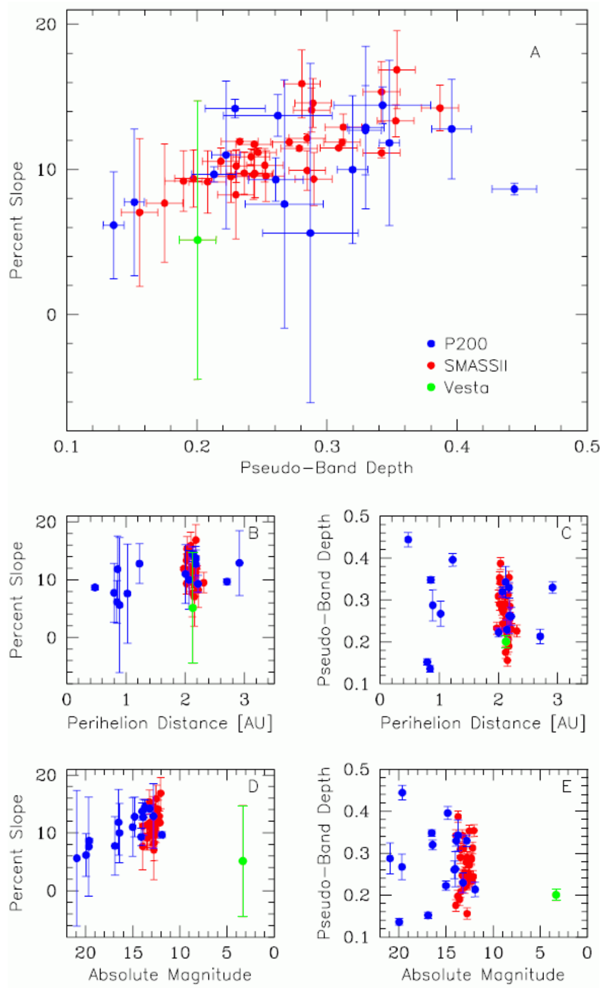

Figure 3: Spectral slope and pseudo-band depth for P200 and SMASSII vestoids. There is no clear spectral difference between main-belt and NEO vestoids.

References: [1] Buratti, B. J. and Veverka, J. (1983) Icarus **55**, 93-110. [2] Reddy, V. et al. 2010. *B.A.A.S.* **42**, 1033. [3] Tedesco, E. F. et al. 2004. NASA PDS, IRAS-A-FPA-3-RDR-IMPS-v6.0. [4]Bus, S. J. and Binzel, R. P. (2002) Icarus **158** 146-177.

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