THE EFFECT OF CHANGING VIEWING GEOMETRY ON PYROXENE AND EUCRITE REFLECTANCE SPECTRA.

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Introduction: In July of 2011, the Dawn spacecraft is scheduled to go into orbit around the second largest main belt asteroid, 4 Vesta [1]. Dawn will spend ~ 1 year orbiting Vesta, obtaining ≥10,000 spectral frames of the surface at wavelengths of 0.25 µm – 5 µm. [2]. These spectral images will be acquired at varying angles of incidence and emission resulting in a variety of phase angles. The project results reported here are designed to understand how the reflectance spectra of Vesta-relevant materials change as a function of incidence, emission and phase angles.

Spectral Data: Diffuse reflectance spectra were collected at the University of Winnipeg Planetary Spectrophotometer Facility (UWPSF) using an ASD FieldSpec Pro HR spectrometer over the wavelength range of 0.35 to 2.5 µm. Two samples have been analyzed to date, the first being the Moama eucrite believed to have derived from Vesta [3]. The second sample is an Fe-rich orthopyroxene (OPX) from Ekersund, Norway (Fs42 En54 Wo4) which serves as an analogue for diogenites. Their grain sizes were <150 and <45 µm, respectively.

Reflectance spectra were acquired relative to Spectralon measured at i=13° and e=0°. Ten sets of measurements were obtained for each sample resulting in three emission angles (e=0, 30, 60°), four incidence angles (i=0, 13, 30, 60°) and five different phase angles ranging from 13° - 120°.

Results: The data set was sorted three ways for comparative analysis.

Fixed phase angle. With the OPX sample, for phase angles up to 90°, band I and II depths vary slightly, from 46 - 41% and 35 - 30% reflectance, respectively. Somewhere between a phase angle of 90° and 120°, band depths drop significantly to 36% and 26%. The same trend (significant changes for phase angles >90º) was observed when looking at band I and II areas and band area ratio (BAR). The lowest values for band depth, band area, and BAR for both samples were all found for the 120° phase angle measurements.

Fixed incidence angle. The slope of the OPX spectra (as measured by the reflectance ratio of the peak near 1.4 µm to the peak near 0.7 µm) became redder as the emission angle increased. This was also the case with the eucrite when i= 30° and i= 60° but a decreasing blue slope was observe when the incidence angle was 0° (Fig. 1).

For both the OPX and the eucrite, reflectance at 0.56 µm decreased with increasing emission angle. However, at an incidence angle of 60°, this trend reverts to increasing reflectance as the emission angle increases.

Band center positions after continuum removal were found to vary somewhat as the emission angle increased. Eucrite band I shifted to shorter wavelengths by 9 nm between i= 0° and i=60°, and had a 15 nm difference between the highest and lowest values for the total set of phase angle measurements. Band II center shifted 18 nm between its two most extreme points. For the OPX, band I center position moves slightly shortward as emission angle increases but only by 4 nm. Band II had a much greater change in position (16 nm) but no systematic trends were found within the data.

Fixed emission angle. No systematic correlation was found for the slope of the pyroxene spectra as a function of increasing incidence angle. However, for the eucrite, the slope became bluer when the emission angle was 0° but became redder at an emission angle ≥ 30°.

Band center position changes with changes in incidence angle were non-systematic. When the emission angle is 0°, band II center of the eucrite shifts shortward by 22 nm as incidence increases from 13° – 60°. A maximum difference of 15 nm was detected for band I, but no systematic trends were found. The pyroxene sample did not exhibit as great of change as the eucrite on band I, only moving 4 nm, but band II showed a difference 16 nm.

Although patterns were found when changes in band depth were analyzed, these patterns are not consistently systematic. At an emission angle of 30°, band I of the pyroxene became shallower with increasing incidence angle (Fig. 2) whereas the depth of band II of the eucrite deepened. Pyroxene band II depth also dropped but only at an emission angle of 60° (Fig. 3).

The most obvious and direct change observed was reflectance at 0.56 µm. For both samples and at all emission angles, reflectance dropped as the incidence angle and therefore phase angle increased. This trend held throughout the data set except for one outlier at an emission angle of 60°. The eucrite's reflectance for incidence of 30° and 60° was essentially the same with the 30° incidence angle measurement being only 0.22% brighter.

Conclusions: We have found that the effects of changing angles of incidence and emission can affect pyroxene and eucrite diffuse reflectance spectra. Furthermore, as the phase angle increases to higher angles (90 to 120°), variations increase. The majority of our outlier data points were collected when i= 60° and e= 60°. These influences affecting band center positions, depth, area, absolute reflectance, and spectral slope may cause misinterpretation of the true nature of Vesta's surface. Band center position is used to determine pyroxene Fe content and a variance of 16 nm translates into a difference of ~20% Fe content [4]. The band area ratio for the 1 and 2 µm absorption bands is a sensitive indicator of the olivine-orthopyroxene abundance. A difference in BAR of 0.22 observed for the pyroxene translates into a difference of ~15% OPX [5]. With the spectrum-altering effects of phase angle sometimes being different for orthopyroxenes versus eucrites, the potential compositional diversity across Vesta may not be amenable to robust determinations, unless phase angle effects are carefully corrected for.

Additional phase angle measurements, as well as expanding our sample suite to include additional materials relevant to Vesta , are being undertaken, so that the nature of phase angle effects on interpretation of reflectance spectra for Vesta can be better understood.

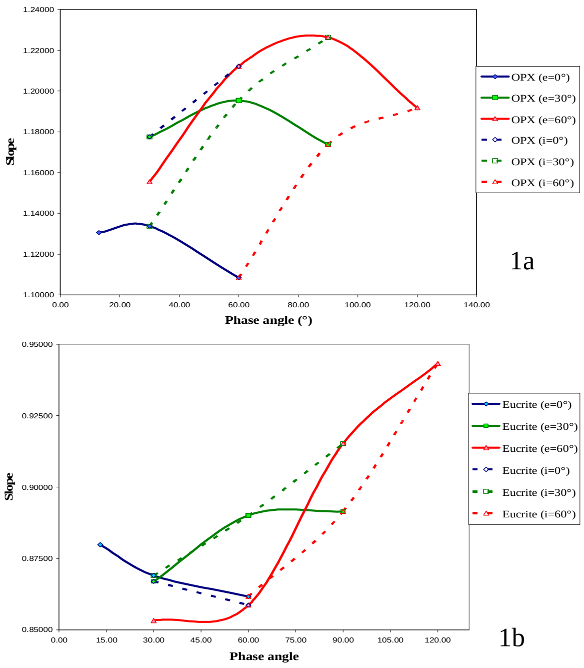

Fig. 1. Spectral slope measured as reflectance ratio of the peak near 1.4 µm to the peak near 0.7 µm vs. phase angle. (1a - OPX, 1b - eucrite)

References: [1] The Planetary Society (http://www.planetary.org/explore/topics/dawn). [2] Rayman M. D. et al. (2006) *Acta Astronautica*, *58*, 605-616. [3] Kelly M. S. et al. (2003) *Icarus*, *165*, 215. [4] Cloutis E. A. and Gaffey M. J. (1991) *JGR*, *96*, 22,809-22,826. [5] Cloutis E. A. et al. (1986) *JGR*, *91*, 11,641-11,653.

Acknowledgments: This study was supported with grants from the Canadian Space Agency, NSERC, and the University of Winnipeg. The Planetary Spectrophotometer Facility was established with support from the Canada Foundation for Innovation, the Manitoba Research Innovations Fund, and the Canadian Space Agency.

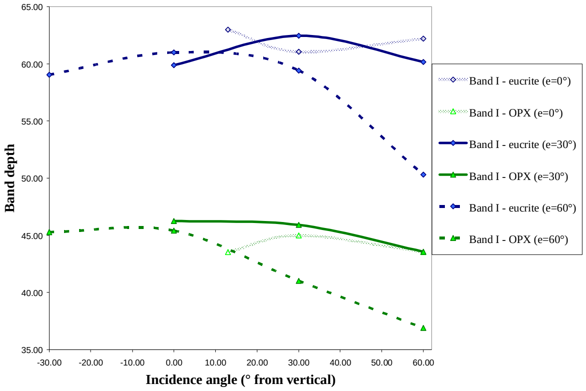

Fig. 2. Band I depths of eucrite and OPX vs. phase angle.

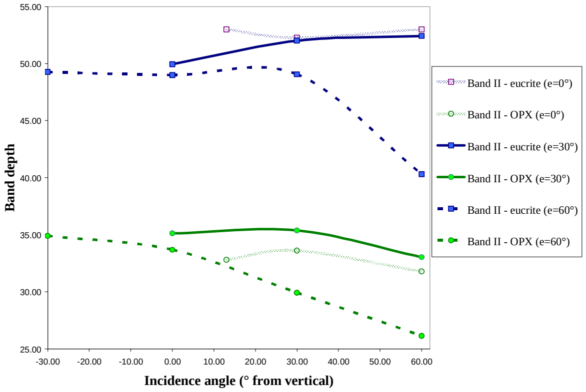

Fig. 3. Band II depths of eucrite and OPX vs. phase angle.