ULTRAVIOLET SPECTROSCOPY OF THE LUCY MISSION TARGETS WITH THE HUBBLE SPACE TELESCOPE O. A. Humes[1], C. A. Thomas[1], J. P. Emery[1], W. M. Grundy[1,2], [1] Department of Astronomy and Planetary Science, Northern Arizona University, Flagstaff, AZ 86011, USA, [2] Lowell Observatory, Flagstaff, AZ 86001, USA

Introduction: The recently launched Lucy spacecraft [1] will fly by a number of Jupiter Trojan asteroids within the next decade. The Trojan asteroids are of particular interest as their gravitational relationship to Jupiter links the histories of these bodies to the history of giant planet migration in the early solar system [eg. 2, 3, 4, 5]. As primitive asteroids [6], the Jupiter Trojans are thought to have undergone little geological processing since their formation and emplacement at Jupiter's L4 and L5 Lagrange points. Thus, an understanding of the compositions of these asteroids will constrain our understanding of conditions in the earliest eras of planetary formation. However, determining the compositions of Trojan asteroids using remote sensing techniques is complicated by the relatively featureless spectra of Trojan asteroids in the visible and near infrared (VNIR) [7]. In the VNIR, Trojan asteroids tend to have low albedos and neutral to moderately red slopes. Trojans are classified into two groups based on the magnitude of their VNIR slopes: the less-red (LR) and red (R) groups [8, 9].

With so few constraints on the composition of Trojan surfaces provided by VNIR spectroscopy, other regions of the electromagnetic spectrum, including the mid-infrared (MIR) and ultraviolet (UV), are used to study Trojans. In the infrared, Trojan spectra display 10- and 20- micron emission features attributed to fine grained silicates suspended in a transparent matrix or fairy castle structure [10, 11]. In the LR population, a feature at 3.1 microns has been attributed to absorption from either very fine grained water frosts or the N-H stretch [12]. In the near-UV, absorption features have been suggested by ground based spectrophotometry [13, 14]. More recently, spectroscopy using the Hubble Space Telescope (HST) has suggested that UV slopes are linked to VNIR slopes, with R group Trojans having generally shallower slopes than LR group Trojans in the UV [15].

Observations:

Methods. We obtained ultraviolet spectra of Lucy mission targets Eurybates, Leucus, Orus, and the Patroclus-Menoetius binary using the Wide Field Camera 3 (WFC3) G280 grism with contemporaneous F300X imagery. Our spectra were reduced using the aXe-WFC3 siltless spectroscopy pipeline [16] with slight modifications to account for the motion of non-sidereal targets. The datasets for each object were filtered for outliers, fitted for subpixel shifts to the solar spectrum and divided by the solar standard [17] and combined to produce an average reflectance spectrum for each individual target. We then produced geometric albedo for Orus and Patroclus-Menoetius by scaling to literature values of visible geometric albedo [7, 18].

Results. See Figure 1 for the observed reflectance spectra of Orus, Patroclus-Menoetius, Eurybates, and Leucus. We do not observe absorptions features in the UV for these targets, and instead a local reflectance minimum at 0.4 microns followed by an increase in reflectance from 0.35 – 0.3 microns in the spectra of Orus and Patroclus-Menoetius. We attempt to model this "bump" feature as a Rayleigh peak caused by scattering from submicroscopic particles.

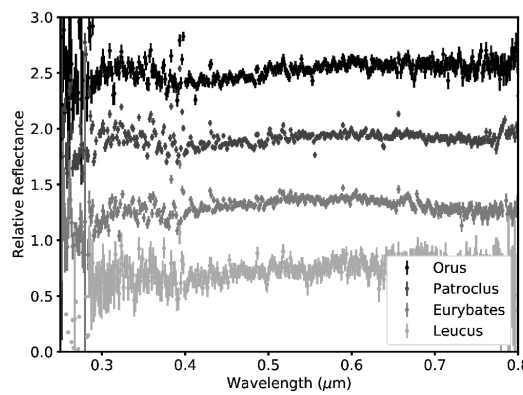

Figure 1. Ultraviolet reflectance spectra of Lucy mission targets Orus, the Patroclus-Menoetius, Eurybates, and Leucus, normalized to 0.5 microns, offset for clarity.

Hapke Modeling:

Methods. We used a Hapke optical model [19] to explore possible compositions for Orus and Patroclus-Menoetius. Our optical model incorporated both geometric optics for particles that are large compared to the wavelength of light and Rayleigh scattering for particles small compared to the wavelength of light to compute geometric albedo. We drew initial starting compositions from previous literature on optical models of Trojans [7, 20] and added a scattering component in order to account for an observed rise in reflectivity in the near-UV spectra of Orus and Patroclus-Menoetius. We tested two different classes of scatterers: ices (H_2O, CO_2, and NH_3) and opaques (iron, graphite, and amorphous carbon). These initial starting compositions were refined using a χ^2 minimization routine to find the parameters corresponding to the best fit grain sizes and mixing ratios. We also used the χ^2 metric as a comparative metric to evaluate the relative goodness of fits of different models.

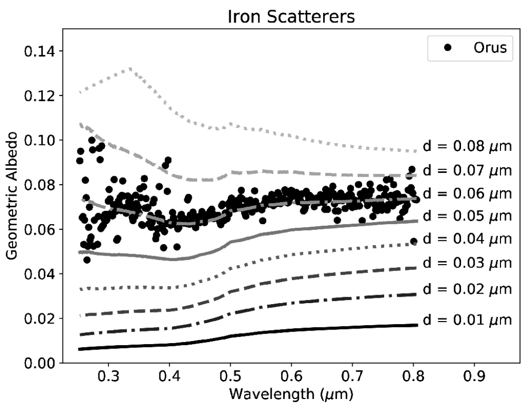

Figure 2. The effect of changing the grain size of iron scatterers in the best fit model for Orus (spectrum shown without error bars for clarity). The grain size of the iron determines the onset and spectral contrast of the "bump" feature.

Results. All five of our best fit models for Orus and Patroclus-Menoetius as evaluated by the χ^2 metric contain silicates, darkening agents (such as iron, carbon, or an additional silicate), and an opaque scattering component. We find that all scatterer compositions among the opaque compositions tested (iron, amorphous carbon, and graphite) provide a reasonably good fit: our results do not distinguish between opaque compositions, but do rule out the transparent icy scatterers due to their high albedo. While all of our best fit models contain pyroxenes as the primary silicate component, substituting pyroxenes for olivines still provides a reasonably good fit to the data. As in [7], we find that the moderately red slopes of Trojans in our sample can be explained by the presence of silicates, without needing to invoke organics (such as tholins). The grain sizes of the opaque scatterers are responsible for determining the wavelength at which the bump feature begins to appear, as well as its spectral contrast. The grain sizes of the opaque scatters range in size from 20-80 nm in our five best fit models.

Discussion:

As with previous optical modeling studies [7, 20] of Trojans, we find that a combination of silicates and darkening agents provide a good match to the red slopes and low albedos of Trojans. We also report a new feature in the near-UV spectra of the Trojans Orus and Patroclus-Menoetius. The presence of this feature does not appear to correspond to VNIR slopes, as it is present in both Orus (R group) and Patroclus-Menoetius (LR group), and absent in the spectrum of Leucus (R group) and the more neutral-toned Eurybates [21]. Our optical modeling results indicate that this feature is consistent with Rayleigh scattering due to dark opaques in the 20-80 nm size range. Particles in this size range are referred to in the planetary literature as submicroscopic particles, and have been implicated in spectral darkening in space weathering processes [22, references therein]. Submicroscopic opaques may be responsible for space weathering on the Trojans, but additional data is needed to understand the mechanism for space weathering on D & P type asteroids.

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