

THERMAL-IR SPECTRAL ANALYSIS OF JUPITER'S TROJAN ASTEROIDS: DETECTING SILICATES. A. C. Martin¹, J. P. Emery¹, S. S. Lindsay², ¹The University of Tennessee Earth and Planetary Science Department, 1621 Cumberland Avenue, 602 Strong Hall, Knoxville TN, 37996, ²The University of Tennessee, Department of Physics, 1408 Circle Drive, Knoxville TN, 37996..

Introduction: Jupiter's Trojan asteroids (hereafter Trojans) populate Jupiter's L4 and L5 Lagrange points. The L4 and L5 points are dynamically stable over the lifetime of the Solar System, and, therefore, Trojans could have resided in the L4 and L5 regions for nearly 4.5 Gyr [1]. However, it is still uncertain where the Trojans formed and when they were captured. Asteroid origins provide an effective means of constraining the events that dynamically shaped the solar system. Trojans may help in determining the extent of radial mixing that occurred during giant planet migration.

Trojans are thought to have formed in one of two locations: (1) in their current position (~5.2 AU), or (2) in the primordial Kuiper belt (KB; ~15 – 30 AU) [2]. The surface composition of asteroids can be indicative of formation region [3]. Analysis of Trojans in the visible and near-infrared (VNIR; 0.8-4.0 μm) show Trojans have red or less-red sloped spectra, and likely contain anhydrous silicates [4], [5]. By determining the composition and silicate phase on Trojan surfaces with TIR spectra, we can place constraints on where Trojans accreted and thus further our understanding of the processes of small body formation.

Background: Trojan surface mineralogy provides a means to distinguish between a KB or *in situ* formation. If Trojans formed in or near the Main Belt (MB; 2-5 AU), close to their current position, they are expected to be made of similar material to Main Belt Asteroids (MBAs). The largest percentage of outer MBAs are likely made of hydrated silicates, carbon, and organic compounds and some anhydrous silicates (*e.g.*, [6], [7]). Common amongst these asteroid types is either carbonaceous, metallic, or siliceous material, primarily in crystalline or altered form (*i.e.*, aqueous or thermal alteration). Had Trojans formed in the outer MB it is expected that they are made of similar material that has been altered in a similar way.

The Nice Model predicts that Trojans are dynamically linked to KBOs as well as Jupiter Family Comets (JFCs) [2]. Therefore, if Trojans accreted in the primordial KB, they would have similar compositions to JFCs. Comets that pass near Earth have the advantage of high resolution spectral measurements as opposed to distant Trojans and KBOs. JFCs, such as 9P/Tempel, have a coma made primarily of CO₂, H₂O, and sub-micron sized silicate grains (*e.g.*, [8]). Typically, silicate-rich comae are dominated by amorphous phases [9], [10], though crystalline silicates have also been detected

(*e.g.*, [11],[8]). Had Trojans and JFCs formed in the same region, Trojans should have fine-grained silicates in primarily amorphous phases.

Analysis of TIR spectra by [12] shows that the surfaces of three Trojans (624 Hektor, 1172 Aneas, and 911 Agamemnon) have emissivity features similar to fine-grained silicates in comet comae. The TIR wavelength region is beneficial for silicate mineralogy detection because it contains fundamental Si-O molecular vibrations (stretching at 9 – 12 μm and bending at 14 – 25 μm ; [13]). Comets produce optically thin comae that result in strong 10- μm emission features when comprised of fine-grained (≤ 10 to 20 μm) dispersed silicates. Though Trojans do not have comae, the observed emissivity peaks could arise from a fluffy regolith of fine grain silicates, or silicates suspended in a transparent matrix [12], [14], [15].

Goals and Hypothesis: The goal of this research is to constrain the formation region of Trojans by analyzing silicate features in the TIR. Had Trojans formed in the main asteroid belt (near their current location), it is expected that they would be made of similar material as main belt asteroids. Had Trojans and Jupiter Family Comets (JFCs) formed in the same region, Trojans should have fine-grained silicates in primarily amorphous phases, similar to that of JFCs. We hypothesize Trojans are more consistent with silicates found on JFCs.

Methods: Mineralogical characteristics aid in constraining the origin of Trojans. The Fox and Enx value has been used in comet research to constrain the structure and evolution of circumstellar dust (*e.g.*, [16]). The trend is more Mg-rich crystalline silicates are found in the inner Solar System after condensation, and Fe-rich silicates to be found in the outer solar system.

For this study, we analyze Spitzer Space Telescope Infrared Spectrograph spectra of 11 Trojans: 4709 Ennomos, 3548 Eurybates, 1437 Diomedes, 588 Achilles, 617 Patroclus, 659 Nestor, 2797 Teucer, 1998 WD, 1998 XN77, 4060 Deipylos, and 1867 Deiphobus.

Emissivity peaks associated with olivine and pyroxene shift from shorter to longer wavelengths with decreasing Mg/(Mg+Fe) [17], [18], [19]. The exact location of the peak is used to determine the Mg/(Mg+Fe) value for each Trojan in this study (Figure 1).

We compare Trojan TIR spectra to TIR spectra of JFC comets such as 9P/Tempel, 29P/Schwassmann-

Wachmann, 73P/Schwassmann- Wachmann, 49P/Arend-Rigaux, and 36P/Whipple. We have used the list of features identified in [22] to compare Trojan spectral features to JFC spectral features. These features include a 15- and 20- μm minimum, a 28 – and 34 – μm maximum, and the presents and shapes of the 10 μm plateau.

Results: Olivine emission features in the 10- μm are consistent with a high iron content for 9 or the 11 Trojan spectra. The remaining three have a low signal to noise, so it could not be determined using this method. The pyroxene emission features in the 10- μm are consistent with a high iron content for up to 5 the 11 Trojan spectra, however these five need further analysis.

The comparison between Trojans and JFCs shows all Trojans have a 10- μm plateau. However most are round as opposed to the common trapezoid found in JFC spectra. Additionally, most Trojan spectra have 20- μm minima. Unlike JFCs, Trojan spectra tend to not have or have subtle 15- μm minima, 28- μm maxima, and 34- μm maxima. In general JFC spectra tend to be more pronounced and sharp.

Conclusion: Though Trojan emission features tend to have lower spectral contrast than those of JFCs, the mineralogical results partially suggest an outer solar system origin for Trojans. The sharpness of the features in comet spectra could be due to a higher ratio of crystalline to amorphous silica as compared to the Trojans or due to observations in two different scattering regimes.

More work needs to be done on analyzing the specific mineralogy evident in the Trojan spectra. This will be done using a Hapke-Mie radiative transfer code to determine the best fit combination of end-member minerals. Additionally, lab spectra of end member minerals and of meteorites will be used to compare to Trojan spectra.

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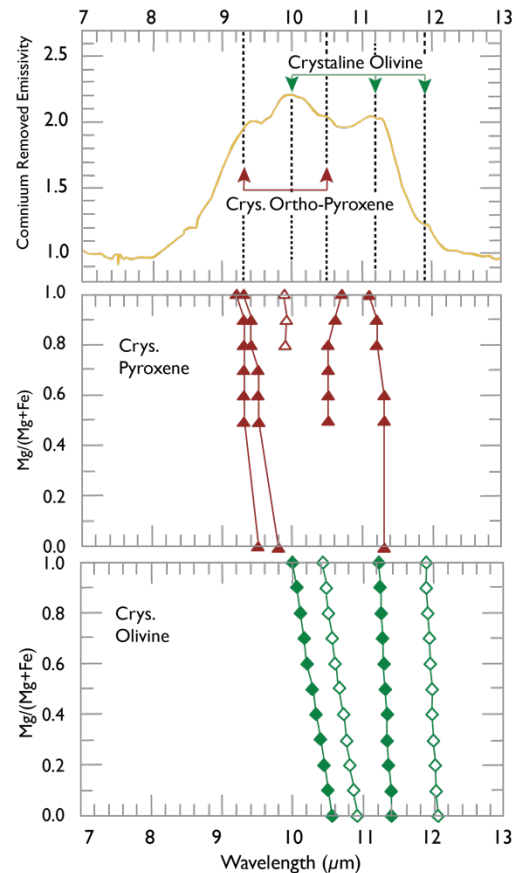


Figure 1: (a) TIR spectrum of 9P/Tempel 1 with dotted lines indicate crystalline olivine and pyroxene peaks determined from studies of comet C/1995 O1 Hale-Bopp. The variation of peak wavelength position with Mg content for crystalline orthopyroxene (b) and olivine (c) peaks observed around 10 μm . The filled symbols mark central wavelengths of strong silicate resonances and open symbols mark weaker silicate resonances. Modified from [10], [20], [21].