**Near-Infrared Spectroscopy of Trojan Asteroids: Evidence for Two Compositional Groups.** J. P. Emery[1], D. P. Cruikshank[2], and D. M. Burr[1]; [1] Earth and Planetary Science Dept & Planetary Geosciences Inst, University of Tennessee, Knoxville, TN (jemery2@utk.edu), [2]NASA Ames Research Center, Moffett Field, CA.

**Introduction:** Jupiter's Trojan asteroids occupy a unique location in the Solar System which places them at the crux of several of the most interesting outstanding issues regarding the formation and evolution of planetary systems. As primitive objects, their compositions conceal direct clues to the conditions of the nebula in the region in which they formed. At first glance, they seem to fit neatly into a paradigm in which macromolecular organic solids were a significant condensate in the middle part of the solar nebula and now darken the surfaces of distant asteroids, but no direct evidence for organics has yet been detected [1,2,3,4,5]. In fact, the only features detected in spectra of Trojan surfaces are due to fine-grained silicates, whose mineralogy may be closer to that of comet grains than typical asteroids [6]. Comparisons with comets and other outer Solar System bodies are not uncommon, given the similarly dark, spectrally red surfaces, but many low albedo Main Belt asteroids also exhibit many of the same spectral qualities.

Their orbits, librating around the stable Lagrange points (L4 and L5) of Jupiter at 5.2 AU, are stable over the age of the Solar System [7]. Recent dynamical work [8,9] has cast doubt on the traditional view that the Trojans formed near their present location at ~5 AU [10], predicting instead their origination from the Kuiper Belt. Compositions of Trojans have thereby become a key test of the dynamical evolution of the Solar System.

Unfortunately, compositional information on Trojan asteroids is hard to come by. Trojans have uniformly low albedos ($p_v$ ~ 0.03 to 0.07) [11,12,13] and reddish spectral slopes throughout the visible and NIR [e.g., 1-5,14-17], which allow various compositional interpretations. Although there is no correlation between size or any other physical parameter and spectral slope, [18] reported a correlation between visible colors (from Sloan Digital Sky Survey [SDSS] measurements) and orbital inclination for Trojans of both the leading and trailing swarms, as well as a bimodal distribution of spectral slopes. [19] note that whereas stable Trojans display a bi-modal H-distribution [see also 20], the distribution is uni-modal for unstable Trojans. [21] confirm the SDSS bimodal spectral slope distribution and find that a similar distribution is reproduced, in previously published visible spectra.

**Observations:** We have measured new near-infrared (0.8 - 2.5 μm) spectra of 71 Trojan asteroids using the SpeX instrument at NASA's Infrared Telescope Facility. The observations were carried out in April 2003, July 2006, March 2007, and September 2007. Expecting mostly featureless spectra, we took several steps to try to insure that spectral slopes would be as reliable as possible. The slit was aligned with the parallactic angle for all asteroid and star observations in order to reduce the possibility of light at shorter wavelengths (guiding was generally in K-band) falling out of the slit due to differential atmospheric refraction. Multiple solar analog stars were observed each night and every asteroid was reduced against several stars. This enabled us to identify mistaken analogs and characterize uncertainties in slope due to choice of standard and atmospheric variability. We made sure to remain well within the linear regime of the detector, never even approaching the suggested limit. Finally, several objects were observed multiple times to check the consistency of measured slopes.

**Results:** The new sample of NIR spectra of Trojans includes smaller objects than we previously observed. These smaller bodies are more likely to have suffered a surface-resetting impact recently, and may therefore show exposures of internal composition.

*Search for absorptions.* None of the objects we observed show any clear absorptions to within the level of noise in the data. Trojans are generally assumed to be ice and organic rich, but we see no evidence for these materials on the surface of any body that we observed. However, the goal of the observations was a broad survey of a large number of objects, so some of the spectra have relatively low S/N, especially in K-band, that could hide low levels of ices and/or organics. Thermal emission spectra have previously revealed the presence of fine-grained silicates on Trojan asteroids [6]. Nevertheless, the new NIR reflectance spectra show no indication of the 1- and 2-μm absorption bands characteristic of silicates. Spectra of a few objects appear to exhibit a broad but weak absorption around 2-μm that has been confirmed by repeat observations. In the absence of a corresponding 1-μm absorption, we have not yet found an explanation for this feature.

*Spectral slopes – bimodality.* As expected, spectral slopes of this sample of Trojans range from moderately to very red. Contrary to expectation, however, the distribution of spectral slopes is not continuous. The slopes fall into two groups with a distinct break between them (Fig. 1). The difference in slope is concentrated at the shorter end of the spectrum (λ<1.5μm); the distribution of H- and K-band slopes is unimodal. Although there is not a lot of overlap in the sample sets, there does appear to be a one-to-one correspondence between the visible color groups reported by [18,19,20] and the NIR spectral groups. The bimodality is present in both the L4 and L5 swarms. The average albedos of the two groups is identical (0.053). Our sample does not include many members of dynamical families, implying that the goupings are present among background objects, not necessarily due to family members. We can discern no correlation between spectral slope and size or any other physical or dynamical property, with one possible exception. A weak correlation between slope and inclination may be present, but the data could be interpreted as showing an absence of the redder objects at high inclinations.

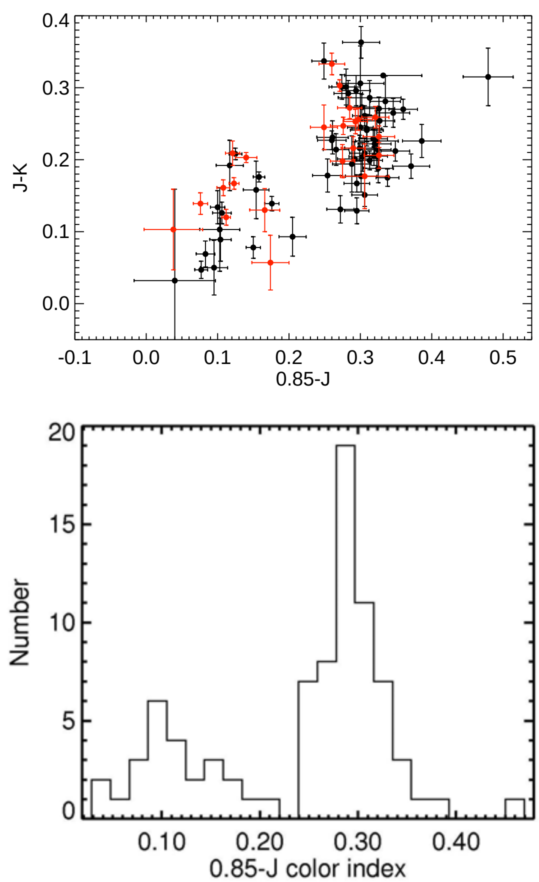


**Figure 1.** Color indices calculated from measured NIR spectra illustrate the spectral bimodality apparent among the Trojans. In the top plot, the black symbols are L4 Trojans and the red symbols are L5. The spectral difference occurs mainly at the shorter wavelengths, as expressed by the 0.85-J color index.

**Discussion:** Observational evidence from both the visible and NIR points to two distinct spectral groups among the Trojans. Both groups exhibit featureless spectra, with one group having steeper spectral slopes than the other. Mid-infrared emission spectra (unpublished) further support the presence of two groups, with the redder objects displaying larger 10-μm emissivity features than the less-red objects. The two Trojans with known densities are also distinct from one another: 617 Patroclus, with a less-red spectral slope, has a density of 1.05 g/cm$^3$ [22,23] and 624 Hektor, with a redder spectral slope, has a density of ~2.2 g/cm$^3$ [24,25].

These groups would be difficult to explain by evolutionary effects alone. It is more likely that they are indicative of two distinct compositional groups. Since there are two plausable scenarios for the formation of Trojan asteroids (one in which they formed at ~5AU and one in which they formed in the Kuiper Belt), a probable explanation for two compositional groups is that the present population contains members from both sources.

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