A Spitzer-based classification of TNOs

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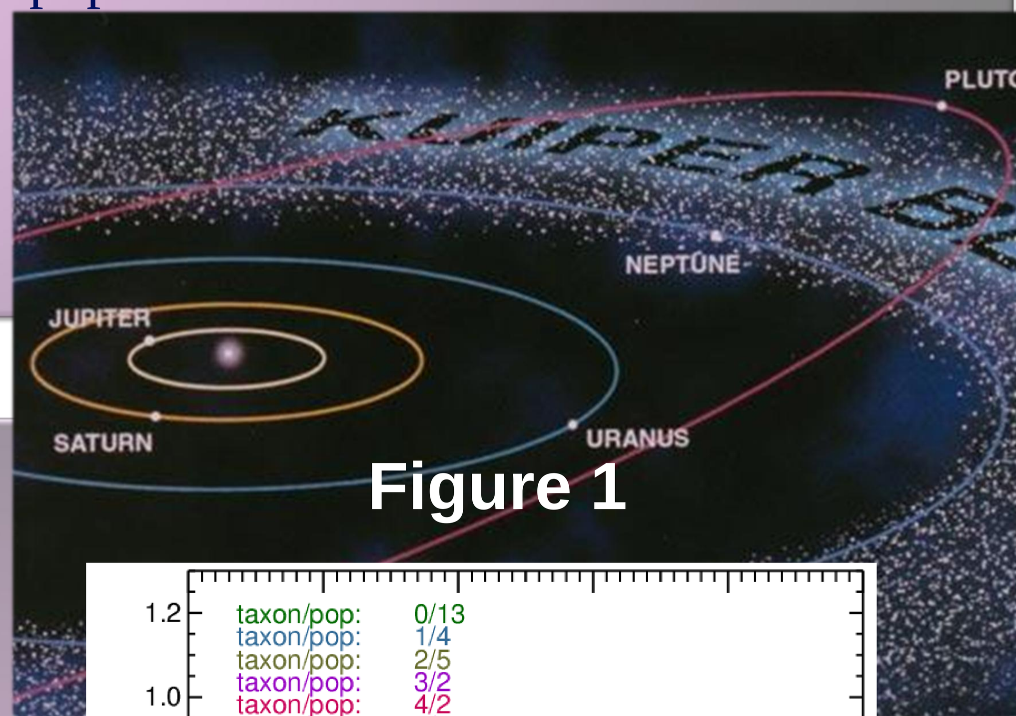
I. Introduction

The outer reaches of the Solar System are residence to the icy bodies known as trans-Neptunian objects (TNOs). Famous members include Pluto, Sedna, and Eris; all of these objects reside out past Neptune in a region known as the Kuiper Belt. A database of 48 objects was used by Fulchignoni et al. [1] to cluster and analyze the various spectra into classified taxa. The dataset adopted by that group [1] was used as a baseline for photometric colors to which Dalle Ore et al. [2] provided the significance of adding albedo measurements taken from Stansberry et al. [3]. To further the classification accuracy, two near-infrared color bands from the Spitzer Space Telescope were supplemented with the previous 7-filter photometry in our study. We present a redefined taxonomy that may uncover clues to evolutionary trends of the TNO population.



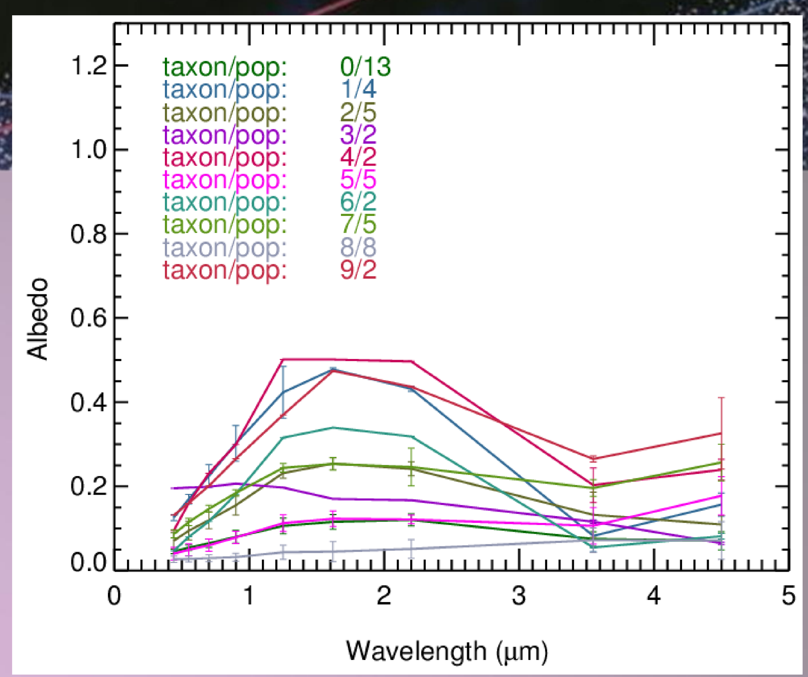


Figure 1:Albedo vs Wavelength for the dataset. Error bars show the spread of each taxon. Taxa 3 (purple) and 8 (grey) do not follow the common shape of the dataset. This may be due to compositional differences in the surface of the objects.

II. Data

We analyze a sample of 48 objects; each TNO has 9 geometric albedo wavelengths denoted as B, V, R, I, J, H, K, S1, and S2 (centered at 0.44, 0.55, 0.7, 0.9, 1.25, 1.62, 2.2, 3.55, and 4.5 μm, respectively).

IIi. Clustering & Plotting

Analysis of the data was completed through a clustering technique making use of a K-means partitioning algorithm developed by Marzo et al. [4][5][6]. The best-fit number of clusters for the data is 10 as shown in Figure 1; prior studies involving a smaller number of wavelengths and slightly larger datasets yielded fewer taxa, such as [1] which presented 4 and [2] that reproduced 7.

Taxa 3 and 8 each emerge with a distinguished shape; the first is composed of one object, (90482) Orcus, with 2 separate Spitzer observations. DeMeo et al. [7] confirmed the presence of H_2O ice, which supports the elevated albedo at shorter wavelengths for taxon 3. Taxon 8 contains 4 objects with 2 Spitzer observations each. The members are (15784), a scattered-disk object, (19308), (52872), a Jupiter-coupled object that does not contain water ice [7] and (54598) Bienor, a Centaur. The only distinguishable correlation that can be determined at this time is that the albedo is low at all wavelengths for this taxon.

Another notable taxon is number 4; this is TNO (90377) Sedna. Emery et al. [8] established the presence of CH_4 ice and proposed further inspection for H_2O ice, indicating the presence of organic materials on the surface. The presence of ices might be the cause of the large albedo values between 1 and 3 μm in Figure 1.

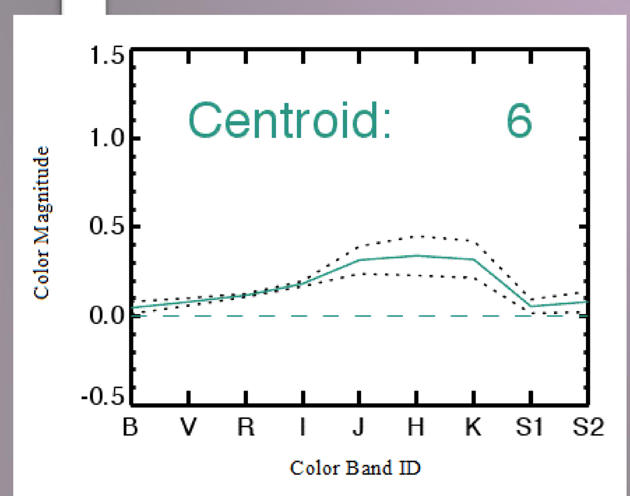
IIii. Preliminary Modeling Results

The clustering tool produces a centroid for each taxon that represents the average spectra of the objects. Combinations of H_20, amorphous C, CH_4, olivine, serpentine, ice tholin II, hydrogenated amorphous C, Triton tholin, Titan tholin, and pyroxene produce models that can be fitted to each taxon, shown below in Figure 2 for two of the taxa.

Taxon 4 has 274 possible models that are comprised of 6 different mixtures of H_20, CH_4, Triton and Titan tholins, and amorphous C; this is in agreement with [8]. However, the spread of the centroid is unusually large when compared to others within this taxonomy; this may be due in part to the variability in Sedna's spectra that were classified into the taxa. Therefore, more models can fit into the dotted line envelope.

Occasionally, taxa cannot be modeled with the aforementioned compounds. This is exemplified in taxon 6 in Figure 2; it is also present in centroid models for taxa 0, 1, 7, and 9. In order to fit all taxa, the currently available database will have to be expanded, models of different compounds will have to be completed and then further research on our taxa can be accomplished.

Taxon 3, which is composed solely of Orcus, has a significant amount of water ice in each of the 134 models; this is in accordance with [7]. Finally, taxon 8, which had a peculiar collection of objects, produced 1120 models in 5 mixtures. Amorphous C and various tholins create some of these combinations; these 2 categories of compounds vary in color from a red hue to darker tones due to the irradiation of the ices as discussed in [2]. Therefore, the geometric albedo will be lower as seen in Figure 1.



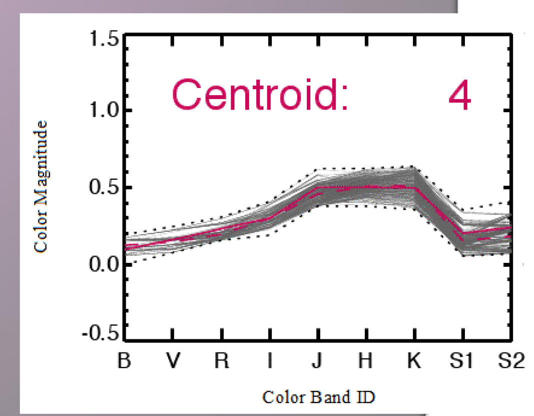


Figure 2: Models for taxa 4 (right) and 6 (left) are shown. Dotted lines outline the spread for each taxon and the solid color line is the average spectral line from the taxonomy plot. The grey lines shown only in the graph at the right represent the 274 models for the specific taxon. The flat dashed line at a color magnitude of 0 in the left graph highlights the lack of models in the database that can fit the taxon.

III. Conclusions

With the inclusion of 2 Spitzer bands, an increased number of classes are defined within our adopted population of 48 objects and allow us to introduce a revised TNO taxonomy. A few of the taxa are comparable to previous publications of specific objects. The modeling resulted in 5 taxa with compositional representations and 5 that were left without. However, the lack of modeling only is an indication of our need to further develop our data-base of geometric albedos.

At this time, our results are very preliminary, but confirm that there is much more to be studied about TNOs, both from the theoretical and the observational standpoint.

IV. Acknowledgments

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V. References

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