EPSC Abstracts
Vol. 6, EPSC-DPS2011-44, 2011
EPSC-DPS Joint Meeting 2011
© Author(s) 2011

A compositional interpretation of TNOs taxonomy

C. M. Dalle Ore (1,2), D. P. Cruikshank (1), T. L. Roush (1) and J. P. Emery (3)
(1) NASA Ames Research Center, California, 94035, USA, (2) SETI Institute, Sunnyvale, California, 94043, USA (Cristina.M.DalleOre@nasa.gov / Fax: +1 650 604 6779) (3) Earth and Planetary Sciences Dept, University of Tennessee, Knoxville, TN 37919, USA

Abstract

Trans-Neptunian objects (TNOs) are believed to be key to understanding the evolution of the outer Solar System. Compositional and dynamical information are needed in order to decipher their history. We present a new TNOs taxonomy based on colors and visible albedo measurements from the literature. The new taxonomy is calculated from a photometric database and obtained with a clustering tool analogous to the ones used in the past. The addition of albedo, however, shows dramatically different results, substantiated by modeling of the independent taxa. We present the new taxonomy and its composition deduced from modeling. We discuss the implications for the history of the outer Solar System.

1. Introduction

TNOs, are small icy bodies orbiting at the edge of the Solar System. According to dynamical models, e.g. [11; 9; 8; 4; 10], they are likely remnant planetesimals that were scattered across the Solar System as a consequence of the migration of the giant planets. Thus, they can be key to unraveling the history of the outer Solar System.

A number of studies have yielded a classification scheme that discriminates the TNOs based on their current orbital properties. The main accepted dynamical classes are: the classical Kuiper Belt, which consists of a group of objects with orbits resonant with Neptune and a group that have non-resonant orbits (all in heliocentric orbits of ~30-50 AU), and Scattered Disk objects having greater heliocentric orbits and with generally high eccentricity and inclination. Centaurs are objects that originated as TNOs, whose orbits cross those of the giant planets.

The TNOs' compositions, and ensuing implications for their history, are not as clearly defined as their dynamical properties. This is because TNOs are small and distant, making spectral observations difficult for all but the largest and closest ones. Colors are available for a large number of TNOs and have been statistically analyzed to yield a taxonomy [7]. Unfortunately, the taxonomy does not appear to correlate with either dynamical or physical properties (i.e., albedo and size) of the objects. This, along with the scarcity of spectral observations, has impaired progress in linking dynamical theories with compositional evidence.

2. Data analysis and modeling

Fulchignoni et al. used photometric colors and a g-mode statistical analysis to define the existing TNO taxonomy [7]. We use the same colors and a K-means statistical analysis, modified to be unsupervised [12], to classify TNOs. These initial results established a consistency between the g-mode and K-means approaches. We performed an independent K-means analysis on the photometric colors that are scaled using the individual V-band (0.55 μm) geometric albedos, thus representing an absolute reflectance for each object. The albedo-based analysis reveals seven groups, two of which contain a single high albedo object (Haumea and Eris respectively). We focus our compositional analysis on the remaining five groups with lower albedo.

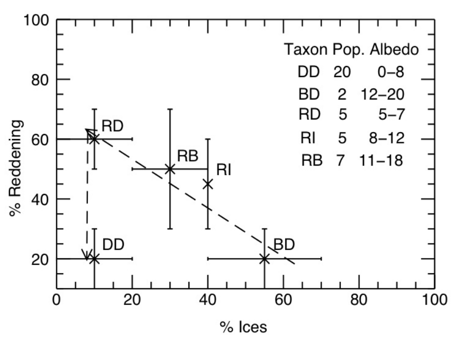
In order to thoroughly investigate the compositional implications of the individual groups determined by the statistical analysis, we computed a series of spectral models to represent potential surface compositions. We calculated synthetic spectra based on the approach presented by Shkuratov [13]. We created a database of more than $2x10^5$ synthetic spectra for simple mixtures, and the associated relative colors. We relied upon materials used in previous compositional studies of TNOs, e.g. [5; 3; 2; 1; 6]. These included reddening (tholins, minerals) and darkening (amorphous carbon, hydrogenated amorphous carbon) materials, and various ices (H_2O, CH_4, N_2). The models were computed varying the relative amounts and grain sizes of the components.

Each group in the TNO albedo-based taxonomy was then compared to the models in the database using an automatic procedure that matches all models that were within the statistical uncertainty of each group. The output was a family of models and their associated physical parameters for each group. The, compositional information is a plausible range of components, and the associated physical information includes the grain sizes, and mixing configurations for each group in the albedo-based taxonomy.

3. Results

Making use of our clustering tool we obtained seven independent classes that define the new 'albedo' taxonomy, of which only five are analyzed at this time. Figure 1 shows that in the compositional parameter space, each albedo-based group occupies a unique location. The lack of overlap between classes is evidence of the uniqueness of the solutions and therefore of the effectiveness of the technique at constraining the composition of the groups. Furthermore, the albedo-based groups describe a pattern that may be indicative of the evolution of the TNO surfaces, representing an important step in improving our understanding of their history.

Figure 1: Ices and reddening content in each TNO albedo-based taxon, from the database of synthetic spectral models incorporating ices, tholins, carbons, and minerals. Error bars are ranges of acceptable values. Taxa are; DD (dark-dark), BD (blue-dark), RD (red-dark), RI (red-intermediate), RB (red-bright). The number of objects and range of geometric albedo (%) for each taxon are given in the legend.



4. Summary and Conclusions

We present a new albedo-based taxonomy for TNOs that makes use of absolute reflectances and albedos. We compare each group identified in the taxonomy to synthetic models to provide compositional and physical constraints. We find that each group can be associated with unique constraints on composition. Furthermore, a clear trend emerges when compositions and taxonomy are considered together. We will discuss the implications of this trend outlining the evolution of these pristine surfaces.

References

[1] Barkume, K. M., Brown, M. E., & Schaller, E. L. 2008, AJ, 135, 55.

[2] Barucci, M. A., Cruikshank, D. P., Dotto, E., et al. 2005, A&A, 439, L1

[3] Barucci, M.A., Merlin, F., Dotto, E., et al. 2006, A&A, 455, 725.

[4] Charnoz, S., & Morbidelli, A. 2007, Icarus, 188, 468.

[5] Cruikshank, D. P., & Dalle Ore, C. M. 2003, Earth Moon and Planets, 92, 315.

[6] Emery, J. P., Dalle Ore, C. M., Cruikshank, D. P., et al. 2007, A&A, 466, 395.

[7] Fulchignoni, M., Belskaya, I., Barucci, M.A., et al. 2008, The Solar System Beyond Neptune, 181.

[8] Gladman, B. 2005. Science 307, 71-75.

[9] Levison, H. F., & Morbidelli, A. 2003, Nature, 426, 419

[10] Lykawka, P.S. and Mukai, T. 2007. Icarus 189, 213-232.

[11] Malhotra, R. 1995. AJ 110, 420- 429.

[12] Marzo, G. A.; Roush, T. L.; Blanco, A.; et al. 2006. Journal of Geophysical Research, 111, CiteID E03002

[13] Shkuratov, Y., Starukhina, L., Hoffmann, H., Arnold, G. 1999, Icarus, 137, 235.