Extra-red transneptunian objects and Centaurs: Composition and chemical history

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We present the results of a systematic analysis of the surface composition of ten of the reddest transneptunian objects (TNOs). The goal of the analysis is to determine the current chemical compositions of these extra-red objects and investigate possible paths of chemical evolution since formation. The sample consists of six objects from the classical and resonant populations, one detached object, and three Centaurs. The classical and resonant objects are expected to be similar to each other in composition, while the surfaces of the three Centaurs could have been significantly modified as their orbits evolved. Furthermore, Brown et al. (Brown, M.E., Schaller, E.L., & Fraser, W.C., 2011. A Hypothesis for the Color Diversity of the Kuiper Belt. ApJL, 739, L60) propose that objects with red color are rich in methanol.

The available data consist of broad-band photometric measurements in the wavelength range between 0.3 and 4.5 µm. The photometric measurements are scaled to the albedo at 0.55 µm to yield an approximation of the spectral shape of each object that is then compared to a library of synthetic spectra of mixtures of materials known to be present on the surfaces of TNOs. Errors as well as phase-angle differences are taken into account as part of the fitting uncertainty.

For each object, we obtain a range of compositions that match their spectral distribution within the estimated errors. This yields the likelihood for the various materials to be present on the surface as well as a rough measure of the uncertainty of the estimate. All objects show presence of methanol and/or methane on their surface, supporting the Brown et al. (2011) hypothesis. To further analyze our results, ices are grouped into 'stable' (H_2O), 'partially stable' (CH_3OH, CO_2), and 'volatile' (CH_4, CO, N_2).

Our results show some difference in the amount of 'volatile' and 'partially stable' ices among the classical and resonant objects. A trend in the sense of less ice present on closer and smaller objects is apparent, possibly related to the objects' ability to retain those ices and to the ices available in the solar nebula at those distances at the time of formation. Pholus, one of the Centaurs, exhibits a lower abundance of 'volatile' ices and enhancement of organic and carbonaceous material with respect to the other Centaurs. Since Centaurs are believed to originate from TNOs captured into fairly short-lived orbits closer to the Sun, our findings are consistent with the idea that Pholus has recently lost to sublimation some of its 'volatile' ice reservoir, exposing more of its native organic material.

A similar behavior is visible for the classical and resonant objects, although the trend is very weak when the carbonaceous material is not taken into account. This hints at the possibility that irradiation weathering might be acting on the closer objects, actively transforming red organic into dark carbonaceous material. More distant objects, on the other hand, might still be pristine in their composition, suggesting that their organic component might have originated in the early stages of their accretion to planetesimals or even before as chemical changes in the solar nebula.

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