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The Compositional Classes of the Kuiper Belt

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Abstract

Here we present the observations of the centaurs and low-perihelion Kuiper belt objects targeted by the H/WTSOSS survey. With the multi-colour spectro-photometry, we show how the surfaces of Centaurs clearly divide into two unique compositional classes, each of which exhibits correlated optical and NIR colours. We show how this bifurcation continues into low-perihelia scattered disk and resonant objects. We discuss possible causes of the observed colours and show how the colours are best explained by an intimate mixture of a neutral and red component, the neutral component of which is common between both classes. Using the presented observations along with available albedos measurements, we constrain possible candidate materials for the neutral component. Likely candidates include silicate materials observed on the irregular satellites of the gas-giants and the Jupiter Trojans.

1. Introduction

It has long been known that the Centaurs – those objects with perihelia, q<25 AU, which originated from the Kuiper belt – exhibit bifurcated optical colours [3]. Despite extensive spectroscopic efforts, this confusing property of the Centaurs has eluded explanation. Here we present spectro-photometric observations of the centaurs and low-perihelion objects observed as part of the large program, the Hubble/WFC3 Test of Surfaces in the Outer Solar System (H/WTSOSS), a survey that was designed to provide new understanding about this and other enigmatic properties of surfaces in the Kuiper belt.

2. Observations

All targets were observed in the F606w, F814w, F139m, and F154m filters available to the WFC3 which are comparable to ground-based R, I, and J filters, along with a narrow band filter sensitive to the water-ice absorption feature at ~1.6 µm. Each target was observed with identical exposure patterns and times providing a very uniform set of measurements. The three colour results of all targets with q<35 AU are presented in Figure 1.

3. Compositional Classes

As can be seen from Figure 1, the low-q objects fall into two distinct classes. The correlated optical and NIR colours exhibited by each class are a distinct signature of related compositions amongst a class' members and can be explained by a geographic mixture of a neutral and red component. This explanation however, is unattractive as it requires a different neutral and red component for each class. An alternate explanation is one in which all class' members share identical compositions and differ in a manner which affects their reflective properties. Variations in grain-size could produce the observed colours, but would cause a variation in albedo of at least a factor of 5 which is not detected on these objects (see Figure 2). The simplest explanation is one in which the colours are a result of intimate mixtures of a red component unique to that class, and a neutral component common amongst all classes (see Figure 1). This attractive scenario suggests that the colours of each class are inherently primordial resultant from the material from which each class accreted. This suggests that the neutral component was ubiquitous throughout the outer primordial disk.

The observations we present place some constraint on the colour of the neutral component. A material with nearly neutral optical and NIR colours is required. Likely candidates include phyllosilicates and olivines inferred to exist on other objects which likely originated in the outer Solar system [2,3]. Most silicate materials are too reflective to be compatible with available albedo measurements (see Figure 2). Rather, it must be that if the neutral component is indeed silicate in nature, it must be partially darkened by a darkening agent such as carbon.

Acknowledgements

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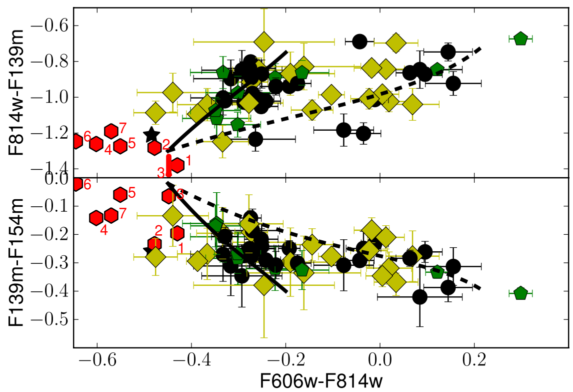

Figure 1. Observed colours of H/WTSOSS targets with with q<35 AU. Centaurs (black circles), resonant (yellow diamonds) and scattered objects (green pentagons) are shown. Solar colours are shown as a black star. Model intimate mixture models are shown as solid and dashed lines. Red hexagons are the colours of candidate silicate minerals. 1, 2 – chlorites, 3, 4 – serpentines, 5, 6 – olivines, 7 – magnetite.

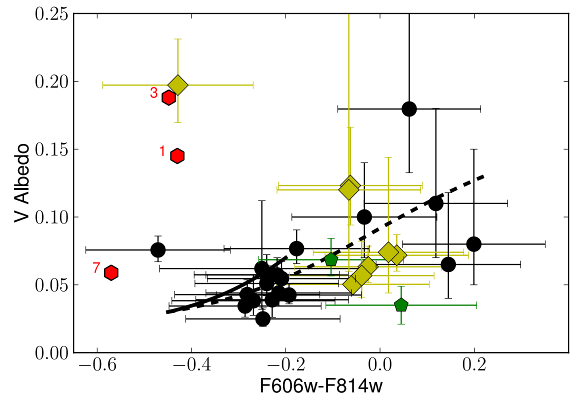

Figure 2. V-band geometric albedo vs. simulated WFC3 colours from ground-based observations along with predicted albedos from intimate mixture models. Albedos and colours of minerals shown. Points and lines as above.