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Centaur-Sized KBOs Also Show Bimodal Colors

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Abstract

Since the first color measurements of the surfaces of Centaurs and Kuiper Belt Objects (KBOs) their color distributions have been puzzling. Centaurs became known for splitting in two distinct color groups, whereas KBOs presented a rather continuous distribution of colors [Peixinho et al. 2003, A&A 410, L29-L32]. Two decades after the discovery of the Kuiper Belt the mechanism responsible for the aforementioned distinct behavior remains unanswered.

We have compiled a database of visible surface colors for 253 of these objects, of which 10 are new measurements, and analyzed the color distribution of Centaurs and KBOs as function of their absolute magnitudes, or size. We find evidence that Centaur-sized KBOs also exhibit two color groups. Such suggests that the 'color bimodality problem' is a size related phenomenon, shared both by Centaurs and KBOs of similar sizes, instead of a phenomenon related with dynamical class. We will also discuss other patterns seen among KBOs and the relations between spectral features and visible surface colors.

1. Introduction

KBOs — also known as Trans-Neptunian Objects (TNOs) — located in a disk-like region beyond Neptune, are expected to be well-preserved icy fossil remnants of the Solar System formation. Those which dynamically evolve to become Comets form a transient population, with short-lived chaotic orbits between Jupiter and Neptune, denominated by Centaurs [1, 2]. Centaurs show two distinct color groups, one with neutral solar-like colors, and another with very red colors, whereas KBOs seem to exhibit a broad continuous color distribution [3]. The dynamical link between Centaurs and KBOs has lead to the concept that their surface properties are distinct due to some surface evolution processes that altered them differently and several models have been proposed [4, 5, 6]. Regardless, none has been able to adequately reproduce the observations [6, 7, 8, 9].

2. Data Analysis

We address the puzzling problem of the color distributions of Centaurs and KBOs using a new compilation of 253 published $B-R$ colors — of which 10 are new measurements obtained using 8m Subaru telescope and UH2.2m telescope — and available absolute magnitude non-corrected from phase angle effects $m_R(1,1)$, or $H_R(\alpha)$, along with some identified spectral features which are known for 48 of these objects. We take absolute magnitude as a proxy for size and analyze the statistical evidences for the existence of color groups as a function of size regardless of dynamical family (see Fig. 1)

3. Interpretation and Conclusions

Small objects, including both KBOs and Centaurs, display a bimodal structure of visible $B-R$ colors at 0.1% significance level (i.e. objects with absolute magnitude $H_R \geq 6.8$, or $D_{km} \leq 165$, assuming $p_R = 0.09$). Large objects evidence also for a bimodal structure, with a different color 'gap' than the previous one, with significance of 0.9% ($H_R \leq 5.0$, or $D_{km} \geq 380$), but seems induced by the presence of 'Haumea collisional family' objects. On the other hand, intermediate sized objects appear to be continuous in colors ($6.8 > H_R > 5.0$, or $165 \leq D_{km} \leq 380$). Confronting data on near-infrared spectral properties with data on colors does not suggest the existence of any clear link between them. Even though a collisional family with distinct colors than its parent body is known to exist among large objects these might be too scarce and peculiar to allow for any gen-

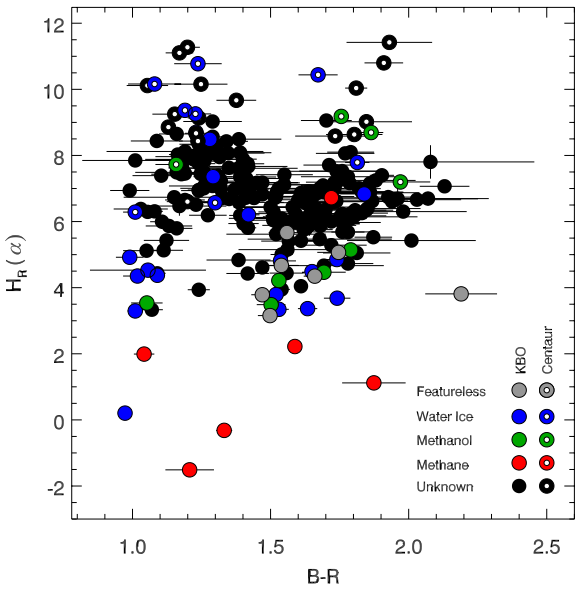

Figure 1: $B-R$ versus $H_R(\alpha)$ plot of all 253 objects. KBOs are represented by solid circles and Centaurs by white dotted solid circles. Objects with $H_R \geq 6.8$ separate into two color groups. Objects with $H_R \leq 5.0$ also separate in two colors groups but are possibly a mere feature induced by the 'Haumea collisional family'. Objects with intermediate H_R values do not evidence for any separate groups. Objects' spectra with known features of water ice, methane, methanol, and featureless spectra, are coded using colors as described in the legend. There is no clear connection between $B-R$ colors and the presence of any particular spectral features.

eralization. On the other hand, as probable remnants from disruptive collisions, small objects seem ideal targets to test and study the catastrophic collisional models. Intermediate objects, too large to be remnants from disruptive collisions and too small to hold cryovolcanic activity, might be the best targets to test and study combined effects of different regions of formation in the protoplanetary disk, different space weathering effects, and different thermal processing. Further studies are to be encouraged.

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