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Col-OSSOS: A Compositional Interpretation of Kuiper Belt Spectra

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1. Introduction

It is generally accepted that the Solar System underwent a large reorganization after the epoch of formation, which was responsible for the outward spread of the gas-giant planets, and the dispersal of the proto-planetesimal disk. The strongest evidence for this reorganization comes from the dynamical structure of the outer Solar System (eg. [1]). Further evidence of the dispersal has been presented, including similarities in the size distributions of seemingly unrelated planetesimal populations [2], and contamination of the outer Solar System planetesimal reservoirs by objects with asteroidal compositions [3].

Spectral surveys of the outer Solar System have revealed the signatures of the dispersal in the compositional-dynamical structure of the current planetesimal populations. The distribution of the known surface types of Kuiper Belt Objects (KBOs) are now being used to infer the compositional structure of the protoplanetesimal disk itself. This is the main idea behind the Colours of the Outer Solar System Origins Survey (Col-OSSOS) which is gathering ugrzJ broadband colours of a brightness limited sample of KBOs. These observations have been designed to detect the number of KBO compositional classes, and map the distribution of taxons throughout the outer Solar System [4]. We present the current Col-OSSOS colours sample in Figure 1.

Beyond their cosmogonic usefulness, the Col-OSSOS sample has enabled a new compositional interpretation which can explain the observed colour distributions of the three KBO compositional classes, all while tying in the known outliers, and the spectrum of the irregular satellite, Phoebe, purported to be a captured KBO.

2. A Compositional Interpretation

We present a new idea regarding the compositional properties of KBOs, that is predicated on the correlated optical-NIR colours of the two compositional classes [5], and the assertion that nearly neutral coloured KBOs share origins with the carbonaceous asteroids (see presentation by Schwamb et al). The latter assertion can only be true if the majority carbonaceous objects that were emplaced in the Kuiper Belt are reddened, and possess significantly higher concentrations of water-ice compared to their asteroidal counterparts.

The reddening agent must be similar in spectral behavior to many laboratory organic materials such as tholins. An additional neutral coloured material, with nearly linear spectrum through the optical-NIR range, must be responsible for the correlated colours of KBOs, with each KBO exhibiting a unique mixture of carbonaceous material, the reddening agent, and the nearly linear material. Increasing concentrations of the later material not only increase the optical spectral slopes, but increasingly mask the presence of the absorption features common to carbonaceous asteroids, which are seen on only the most neutral coloured KBOs, hence resulting in the nearly linear spectra that have been observed. Within this model, Phoebe occupies a special category, possessing a high concentration of water-ice, which is stable at the Saturnian distance, but is completely devoid of the reddening agent, which was presumably collisional stripped, or destroyed through irradiation processes. We present an example of this idea of reddening of carbonaceous material in Figure 2.

If this model is true, it follows that the neutral class of KBOs are cosmogonically related to certain classes of carbonaceous asteroids, and likely shared a similar origin within the protoplanetesimal disk as their asteroidal counterparts. As the Kuiper Belt is dominated by mass from the neutral class, our model implies that the majority of KBOs are simply reddened carbonaceous asteroids. Confirmation of this idea will come from the identification of the absorption features common to the carbonaceous asteroids, which much

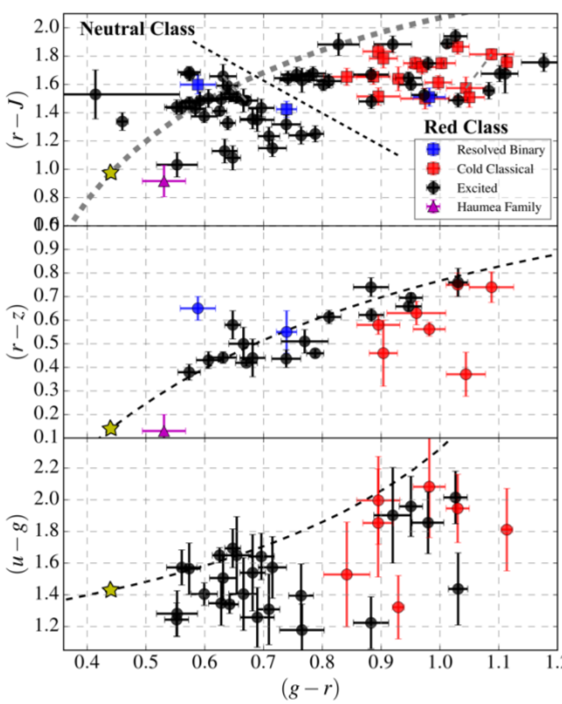

Figure 1: Broadband colours of Col-OSSOS observations. Dynamical class is shown by point colour. The dashed line in the top panel marks the division between the neutral and red classes of dynamically hot objects. Solar colours are shown by the yellow star.

also be common to most small KBOs, albeit with a more modest presence.

3. References

[1] Nesvorny, D., Evidence for the Slow Migration of Neptune from the Inclination Distribution of Kuiper Belt Objects, 2015, ApJ , 150, 73

[2] Fraser, W., et al., The Absolute Magnitude Distribution of Kuiper Belt Objects, 2015, ApJ, 782, 100.

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[4] Schwamb et al., Col-OSSOS: The Outer Solar System Origins Survey, accepted for publication in AJ.

[5] Fraser and Brown, The Hubble Wide Field Camera 3 Test of Surfaces in the Outer Solar System, 2012, ApJ, 749, 33

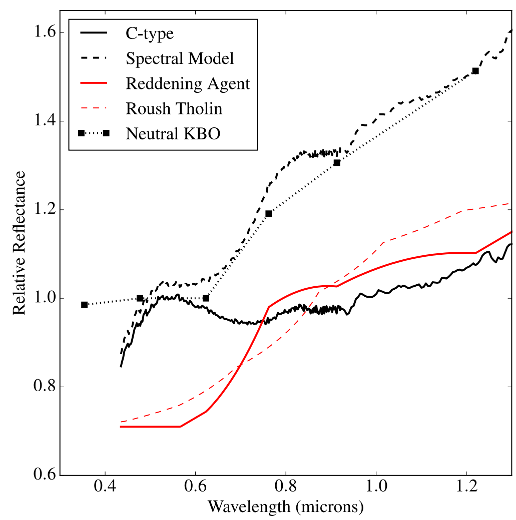

Figure 2: Example spectral modelling of a neutral class object. The KBO spectrum extracted from the Col-OSSOS colours is shown by the dotted line and square boxes. The model spectrum, shown by the dashed curve, is a geometric sum of the C-type spectrum (solid black line) and the model reddening agent (red solid line). The reddening agent broadly matches the behaviour of some laboratory organic materials, including the Roush Titan tholin shown by the dashed red line.