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The True Colors of KBOs

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Abstract. The existence of a population of large planetoids outside the orbit of Neptune predicted by GP Kuiper, KE Edgeworth and JA Fernandez has been confirmed by ground-based observations.The physical properties of these Kuiper Belt Objects (KBOs) remain elusive. Photometric measurements have indicated that they have diverse color variations. A theoretical model is formulated to simulate the evolution of the surface materials of the KBOs under the influence of cosmic ray irradiation and meteoroid impacts. The long-term goal is to couple this theoretical model to observations and laboratory experiments such as LARA (Laboratory Astrochemistry and Astrophysics).

1. KBOs in the Trans-Neptunian Region

Since the first discovery of QB1 by David Jewitt and Jane Luu in 1992, ground-based observations have now discovered nearly four hundred KBOs with sizes ranging between 100 km and a few hundred km. Pluto is the largest object in this trans-neptunian population. It has been estimated that there should be about 70,000 objects with diameters larger than 100 km.The KBOs are believed to be remnants from the accretional process of Uranus and Neptune. They are also the main supplier of short-period comets. Investigation of the KBO population is therefore essential to our understanding of the solar system origin.

2. Surface Irradiation History

The chemical composition of the KBOs is most likely a mixture of water ice, organic matter of hydrocarbon nature and rocky material. The exposure of the surface material to cosmic rays and solar radiation could lead to the build up of a crust of dark matter with very low albedo. It is known from laboratory experiments that organic material made up of complex polymers could change its color from being reddish red to darkest dark by energetic irradiation. On the other hand, occasional impact collision with other small bodies could lead to the formation of craters or gardening (re-surfacing) of the subsurface material. This stochastic bombardment effect would hence produce layers of icy material of different cosmic-ray exposure ages on top of the old surface (Luu and Jewitt, 1996). It is perhaps for this reason that photometric and spectral measurements have indicated a wide range of surface colors and chemical compositions of the KBOs (Luu and Jewitt, 1996; Tegler and Romanishin,1998).

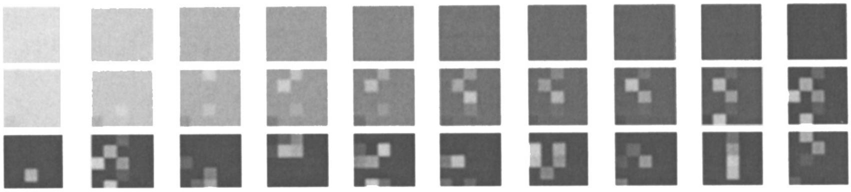

Figure 1. Schematic illustration of the surface color variations of KBOs: (a)upper row: a KBO without impact; (b)middle row: a KBO with impacts; (c)lower row: ten different KBOs. Figure courtesy of Z.W.Zhang.

3. Stochastic Impact Model

In order to trace the surface "weathering" process of the KBOs so that their evolutionary history might be eventually deciphered, a theoretical model is being developed to simulate the cumulative effect of cosmic ray exposure and random meteoroid impacts. The basic principle of our model can be demonstrated by considering the addition of patches of resurfaced material at different times of the solar system history. Figure 1 illustrates the time evolution of the surface color of a KBO in 10 time steps. It can be seen that the general area not subjected to impact cratering will have its color turning from bright to dark. On the other hand, localized regions rejuvenated by meteoroid collisions will first regain their bright color while turning to a darker color at a later time. It is in this manner that the KBOs could have gained such a diverse range of surface reflectance spectra and colors.

4. Future Work

(1) The size distribution of the interplanetary meteoroids
(2) The size distribution of the impact craters and possible overlapping
(3) The orbital evolution of KBOs (i.e., classical KBOs vs. scattered KBOs)
(4) A comparison with spectroscopic and photometric observations
(5) The inputs from laboratory experiments of ice irradiation

References

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