Mapping the Surface of Dwarf Planet Candidate 2007 OR10 with K2

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The Kuiper belt is composed of icy planetesimals left over from planet formation orbiting beyond Neptune. Except for the handful of dwarf planet Pluto-sized bodies, most Kuiper belt objects (KBOs) have surfaces devoid of volatile ices (methane, nitrogen, and carbon monoxide). Schaller & Brown (2007b) proposed a simple model that appears to explain the observed surface compositions (see Figure 1). They assume each KBO originally formed with a cometary abundance of volatiles scaled appropriately to the size of the body with only jeans escape acting over the age of the Solar System. According to their model, most KBOs are simply too hot or too small to hold on to any of their primordial inventory volatile ices, meanwhile the large dwarf planets residing in the Kuiper belt are able to retain some portion of methane, nitrogen, or carbon monoxide as ices.

Though we now have some understanding of which bodies in the Kuiper belt are capable of retaining volatile ices on their surfaces, there is much to still be learned about the processes modifying the surfaces of the dwarf planets. It is likely that the volatile escape and processing for the large KBOs is more complex, particularly in this transition region from volatile rich to poor. A crucial test of this model is 2007 OR10, which after assuming reasonable values for surface albedo is in the volatile transition region. As one of the faintest dwarf planets known, at 21.5 magnitude, even with 6-10m telescopes it is difficult or nearly impossible to get a high signal-to-noise spectrum to identify the near-infrared absorptions from methane on 2007 OR10. Its extreme red color with a solid detection of broad water ice features in near infrared spectra suggests that 2007 OR10 is holding on to the last gasps of methane as expected from Schaller & Brown (2007b) (Brown et al 2011). Photoprocessing of methane into higher order hydrocarbons or 'tholins' by solar ultraviolet irradiation darkens it to a red color. If there is no replenishment of the exposed methane ice, a red tholin crust should form on the objects in the transition region, and this has been the explanation used for the red optical colors of Quaoar where the presence of methane has been confirmed by high-resolution near-infrared spectroscopy (Schaller & Brown 2007a).

K2 provides a unique opportunity to study dwarf planet-sized 2007 OR10 in Campaign 3, by mapping its albedo distribution and indirectly the surface composition. For spherical surfaces like that expected for 2007 OR10, albedo changes will be the dominant determinant of the rotational light curve. Amplitudes of expected are < 0.15 mag. To date, ground-based efforts have failed to measure a rotation period (e.g. Benecchi et al 2013) either because the rotation period is too long or the amplitude is too low to be measured by 2-4-meter telescopes, but which space-based telescopes such as Kepler can detect. For a 21st V magnitude object, a single 30-minute exposure with K2 in fine guiding mode is estimated to achieve a few percent photometric accuracy (according to the Guest Observer Office). 2007 OR10 will be on silicon (predicted by JPL Horizons to a positional uncertainty less than an 1'' in both RA and Dec) over a 56-day period, requiring a pixel mask that covers the total region 2007 OR10 will fall on during Campaign 3. Typical KBO rotation periods are a few hours to days. Even if individual measurement errors are higher than predicted, the shear number of K2 observations will be sufficient to uniquely identify a rotational period in a folded light curve search.

A K2 light curve will help explore how patchy the tholins are on the surface of 2007 OR10. We may never again have this opportunity to obtain such a high cadence and precision light curve of 2007 OR10. By studying the surface now, we can produce a baseline of observations that can be used to track the evolution of 2007 OR10's surface albedo over the next several decades as the body currently near aphelion moves closer to the Sun. As it does, any remaining pure methane frost may sublimate and reveal the surface, underneath causing changes to the amplitude and shape of the rotational light curve.

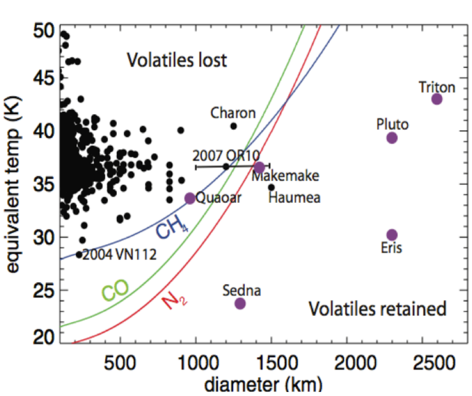

Figure 1: Figure taken from Brown et al 2011. Schaller & Brown (2007b) Jeans escape model predictions for KBO volatile ice loss and retention, updated to include 2007 OR10. Objects to the right of the line are expected to retain volatile ices. Transition zone from volatile rich to volatile poor is between the blue and red lines. Note: only size uncertainty error bars are included for 2007 OR10.

References: Benecchi, S. & Sheppard, S. 2013, AJ, 145, 124, Brown, M. E., Burgasser, A. J., & Fraser, W. C. 2011a, ApJ, 738, L26+Schaller, E. L., & Brown, M. E. 2007a, ApJ, 670, L49, Schaller, E. L., & Brown, M. E. 2007b, ApJ, 659, L61