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Observations of Trans-Neptunian Objects at True Opposition

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Abstract

With observations at true opposition and at larger solar phase angles, we measure the opposition surge of several TNOs in multiple bandpasses including *R*, *I*, and occasionally *V*. Our survey includes binary TNOs as well as those not currently known to have multiple components, from a variety of dynamical classes. We test the hypothesis that ejecta exchange [7] enhances the opposition surge of binary TNOs [5] by creating a surface with a complex microtexture conducive to the constructive interference which produces the effect at the smallest phase angles.

1. Introduction

Most airless, particulate surfaces exhibit a dramatic, non-linear increase in reflectance as the solar phase angle decreases to zero. This is the opposition effect, or surge, a consequence of both interparticle shadow hiding and a constructive interference phenomenon known as coherent backscatter. [2] [3] [4] [6]

When observed at opposition, the large heliocentric distances of trans-neptunian objects (TNOs) present unique opportunities to probe regions of the phase function inaccessible to objects closer to the Sun. Since the Sun is not a point source, even the most distant TNOs cannot be observed at solar phase angle $\alpha = 0°$. The angular size of the solar radius seen from the TNO establishes the minimum phase angle at which the object can be observed from Earth. Seen from the TNO, the Earth transits the solar disk, and in this configuration, the TNO is at "true" opposition. This precise alignment enables the measurement of its reflectance at the smallest solar phase angles for any body in the Solar System, down to $\alpha \simeq 0.003°$ for the outermost objects. When combined with additional photometric observations at larger phase angles, we can measure the opposition surge slope (magnitudes/degree) which is a potential classifier of dynamical class and as such can relate the evolution of a TNO to its physical surface properties.

2. Observations

Our survey includes several classical, resonant, detached, and scattered objects [1] as well as Centaurs. We measure the opposition surge at multiple bandpasses to investigate any wavelength dependence of surge characteristics such as amplitude and angular width. Fig. 1 shows the near opposition R band phase curves of three binary TNOs: 1995 TL_8, 1997 CS_{29}, and 2000 YW_{134}. Two of these, 1997 CS_{29} and 2000 YW_{134} exhibit remarkably strong opposition surges, with slopes of 2 magnitudes/degree out to $\alpha = 1°$. The other, 1995 TL_8, shows a strong spike (1 magnitude/degree) between true opposition (the minimum phase angle) and $\alpha = 0.1°$, but then flattens considerably to only 0.1 magnitude/degree between phase angles 0.1° and 0.7°. Although each of these objects comes from a different dynamical class, 1997 CS_{29} and 2000 YW_{134} have secondaries with comparable semi-major axes, 2300 and 1900 km, respectively, while 1995 TL_8 is a much closer binary with only 420 km separating the primary and secondary.

3. Conclusion

If ejecta exchange plays a role in enhancing the opposition surge of a TNO binary, the effect is larger for separations of ~ 2000 km than it is for the more tightly bound components; however, in order to confirm any relationship between opposition surge strength, binarity, and hence semi-major axis, more observations are required.

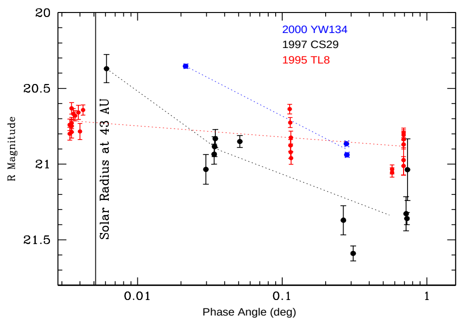

Figure 1: The near-opposition solar phase curves (R-band) of three binary TNOs: 1995 TL_8 (red), 1997 CS_{29} (black), and 2000 YW_{134} (blue). The phase curve for 1995 TL_8, a detached object, is flatter than that of classical TNO 1997 CS_{29} and 2000 YW_{134} from the scattered disk. Dotted lines link averages of observations on single nights; no corrections for rotational lightcurves are shown. Observations at true opposition appear to the left of the vertical solid line, the angular size of the Sun's radius at 43 AU, the average heliocentric distance of these TNOs at the time of observation.

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