A MUTUAL EVENT LIGHTCRUVE MODEL FOR BINARY TRANSNEPTUNIAN OBJCETS: APPLICATION TO (79360) SILA-NUNAM. S. D. Benecchi[1], W. M. Grundy[2], A. Thirouin[2], A. J. Verbiscer[3], and D. L. Rabinowitz[4], [1]Planetary Science Institute, 1700 E. Fort Lowell, Suite 106, Tucson, AZ 85719 (susank@psi.edu), [2]Lowell Observatory, [3]University of Virginia, [4]Yale University,

Introduction: Lightcurves are powerful tools for investigating the spin rates and gross shapes of bodies throughout the Solar System, providing insights on the physical make-up of bodies without visits by spacecraft. However, in the Kuiper Belt, observational geometry, in particular the fact that these objects take 200+ years to orbit the Sun and only reach phase angles of ≤2° from Earth, means that there are often degenerate interpretations for the physical characteristics of an object. Mutual events – eclipses and occultations – of binary bodies are doubly powerful in that they directly measure the object shapes and sizes and place added precision on their mutual orbit configurations because of their changing and interacting geometrical map. With datasets spanning growing observing time baselines the phase space of possibilities converges, and with observations in multiple filters the distribution of surface ices can also be traced. However, interpretation of these datasets also requires modeling of both object interactions due to the individual object geometry, our Earth-based perspective, as well as the nature of the objects themselves.

Observations: From 2010-2017 we collected 22 observational datasets on the transneptunian binary (79360) Sila-Nunam using a combination of facilities including the Apache Point Astrophysical Research Consortium 3.5m, Gemini North and South, the Irénée duPont at Las Campanas Observatory, NASA's IRTF, the Perkins and Discovery Channel telescopes at Lowell Observatory, SMARTS, SOAR, and the VATT, both inside and outside of mutual events to test the robustness of our model and to fully interpret this Cold Classical transneptunian object.

Computational Model: We developed a "generic" binary model that attempts to determine the physical parameters of the two bodies within a binary system based on a combination of orbital and photometric properties. The code is built as a set of modules which are then combined together to form a larger conceptual model that is used to build the final output. The model takes a set of input parameters and forward constructs output lightcurves based on those values. It produces a 3D rendering of the objects and uses a Modified Whitted's ray-tracing method to create each surface pixel. It includes shadow-casting, bi-directional reflectance based on Hapke's model and an optimization for the generated shapes. The Hapke parameters offer a way to investigate the actual surface properties of each object including single scattering albedos, the amplitude of the opposition surge, a compaction value, a surface roughness, and phase angle.

One starts with a set of generalized, though reasonable guesses for the object sizes, shape (sphere or ellipsoid), Hapke parameters, spin information (pole, rotation rate and amplitude) as well as the mutual binary orbit and primary heliocentric orbit information. Each one of these parameters or set of parameters can then be fixed or set to iterate between a specified range to produce a measure of the object luminosity at each measurement step for comparison with actual data (Sample output in Figure 1). The model parameters are then iterated until the best match is found, or some limit on the number of iterative steps has been reached.

We also explore the predictive nature of the model for planning future observations of binary systems based on limited initial inputs.

The combination of modeling and observations is a powerful tool for better understanding the environment in the current Kuiper Belt. Some example results from this technique include (79360) Sila-Nunam [1], (385446) Manwë-Thorondor [2], and (486958) Arrokoth [3].

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References: [1] Benecchi, S. D., et al. (2014) *Icarus, 229, 423*. [2] Rabinowitz, D. L., Benecchi, S. D., Grundy, W. M., Verbiscer, A. J., & Thirouin, A. (2020) *AJ., 159, 27*. [3] Buie et al. (2020) *AJ,* 159, 130.

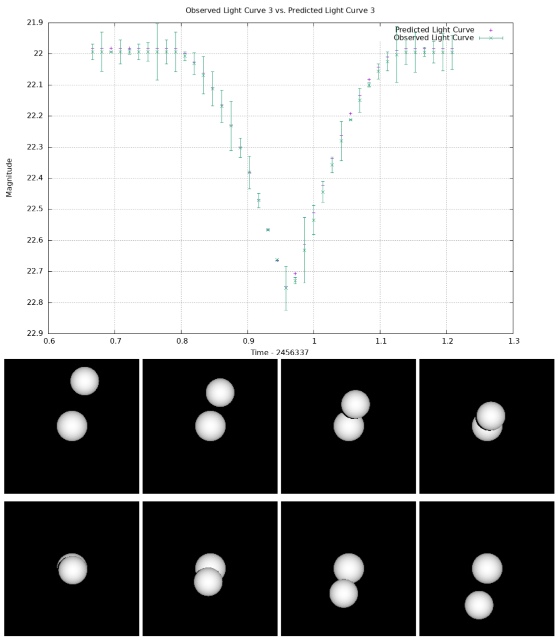

Figure 1: (Top) Sample dataset and model comparison lightcurve. Each pixel from the output code is the ratio of light that should be reflected from the object for the given model. (Bottom) Sample model renderings at timesteps of 5 points for the lightcurve model shown.