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The Pluto System at True Opposition

Anne Verbiscer (1), Mark Showalter (2), Paul Helfenstein (3), and Marc Buie (4)
(1) University of Virginia, Charlottesville, Virginia, USA (verbiscer@virginia.edu) (2) SETI Institute, Mountain View, California, USA, (3) Cornell University, Ithaca, New York, USA, (4) Southwest Research Institute, Boulder, Colorado, USA.

Abstract

During its 2018 opposition, the Pluto system was visible from Earth at the smallest solar phase angles in 87 years as it crossed the line of nodes. The system was at "true" opposition on 12 July 2018 when, as seen from Pluto, the Earth transited the solar disk. Such rare planetary alignments of inclined, outer Solar System objects enable the characterization of their global small-scale surface texture and porosity as well as the direct measurement of their geometric albedos, rather than estimations of those values based on interpolation of photometric models. Here we report the results of a Hubble Space Telescope (HST) program to observe the Pluto system at true opposition and characterize the phase curves of Pluto and its moons, Charon, Nix, Hydra, Styx, and Kerberos at small phase angles using the Hapke 2012 photometric model [1].

1. Background

The phase functions of most particulate surfaces and planetary rings exhibit a dramatic, non-linear increase in reflectance as the solar phase angle α decreases to 0°. This phenomenon is the opposition effect, or surge, a consequence of both interparticle shadow hiding (SH) and a constructive interference phenomenon known as coherent backscatter (CB) [1-3]. Although the size of the Earth's orbit restricts observations of the phase function of Pluto and its moons to phase angles no larger than α = 1.8°, this opposition surge, which occurs largely at angles of less than a degree (Fig. 1), can discriminate surface properties [4-6].

The complete characterization of surface properties from photometric analysis requires observations at all phase angles, from α = 0° to 180°. During its July 2015 flyby of the Pluto system, NASA's New Horizons spacecraft did not observe any Pluto system objects at phase angles smaller than α = 8° [7]; yet small phase angle observations are critical to the derivation of small-scale surface properties and the interpretation of near-infrared spectra from the analysis of absorption band depths [8]. Therefore, the HST observations acquired at true opposition contain information about the physical properties and scattering behavior of surfaces on Pluto and its satellites needed to interpret New Horizons data acquired at higher phase angles.

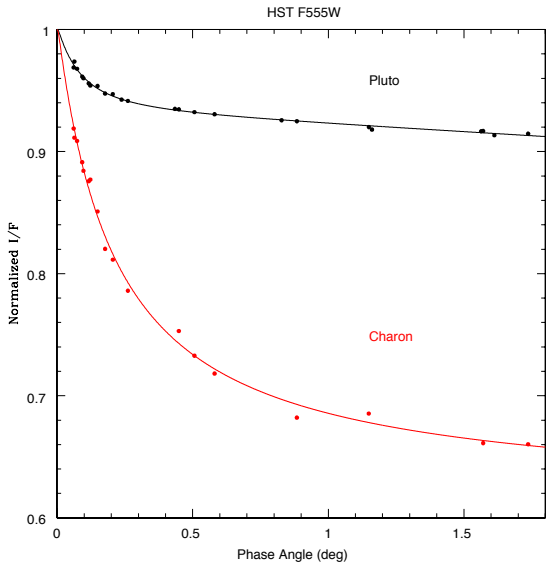

Figure 1: Disk-integrated solar phase curves of Pluto (black) and Charon (red) from HST WFC3 observations in the F555W filter (peak wavelength 0.54 μm) normalized to I/F = 1 at α = 0° (HST Program 13667, M. Buie, PI). All observations have been corrected for variation in reflectance with longitude (lightcurve). Solid lines are fits to the Hapke 2012 photometric model using the parameters in Table 1. Charon has a much stronger opposition surge than Pluto.

Table 1: Preliminary Hapke Parameters for Pluto and Charon at 0.55 μm (HST WFC3 F555W filter)

Hapke 2012 Parameter	Pluto	Charon
Single Scattering Albedo ω_o	0.528	0.633
Macroscopic Roughness $\bar{\theta}$	20°	5°
Henyey-Greenstein g	-0.36	-0.29
SHOE Amplitude B_{oS}	0.307	0.74
SHOE Angular Width h_S	0.206	0.0019
CBOE Amplitude B_{oC}	0.074	0.01
CBOE Angular Width h_C	0.0017	0.0059

2. Observations

Using HST's Wide Field Camera 3 (WFC3) during 13 orbits in Cycle 25, we acquired multi-wavelength observations of the Pluto system at phase angles as small as α=0.005°. Since the Sun is not a point source, no planetary body can be observed at precisely α = 0°, and the smallest possible phase angle at which Pluto and its moons can be observed is defined by the angular radius of the Sun seen from Pluto's heliocentric distance.

We will present solar phase curves and rotation light curves for Pluto system surfaces including fits to the Hapke 2012 photometric model [1], described by seven parameters: the single scattering albedo ω_o, macroscopic roughness $\bar{\theta}$, the single particle scattering function, the shadow hiding opposition effect (SHOE) amplitude B_{oS} and angular width h_S, and the coherent backscatter opposition effect (CBOE) amplitude B_{oC} and angular width h_C.

3. Summary

Preliminary fits of the Hapke 2012 model (Table 1) to solar phase curves of Pluto and Charon (Fig. 1) demonstrate that the two surfaces do not share scattering properties.

Acknowledgements

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References

[1] Hapke, B. Theory of Reflectance and Emittance Spectroscopy. Cambridge University Press, 2012.

[2] Shkuratov, Yu. and Helfenstein, P.: The opposition effect and quasi-fractal structure of regolith: 1. Theory. Icarus 152, 96-116, 2001.

[3] Hapke, B. Bidirectional reflectance spectroscopy. 5. The coherent backscatter opposition effect and anisotropic scattering. Icarus 157, 523-534, 2002.

[4] Nelson, R. et al.: Photometric properties of candidate planetary surface regolith materials at small phase angle: Relevance to small bodies in the outer solar system. LPSC 46, 2584, 2015.

[5] Verbiscer, A. et al.: Surface properties of Saturn's icy moons from optical remote sensing. In Enceladus and the Icy Moons of Saturn, P. Schenk et al., Eds. University of Arizona Press, Tucson, p. 323-341, 2018.

[6] Helfenstein, P. and Shepard, M.: Testing the Hapke photometric model: Improved inversion and the porosity correction. Icarus 215, 83-100, 2011.

[7] Verbiscer, A. et al.: Phase curves of Nix and Hydra from the New Horizons Imaging Cameras. Astrophysical Journal Letters 852, L35, 2018.

[8] Verbiscer, A. et al.: Near-infrared spectra of the leading and trailing hemispheres of Enceladus. Icarus 182, 211-223, 2006.