A Tale of Two Sides: Pluto’s Opposition Surge in 2018 and 2019

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Near-opposition photometry employs remote sensing observations to reveal the microphysical properties of regolith-covered surfaces over a wide range of solar system bodies. When aligned directly opposite the Sun, objects exhibit an opposition effect, or surge, a dramatic, non-linear increase in reflectance seen with decreasing solar phase angle (the Sun-target-observer angle). This phenomenon is a consequence of both interparticle shadow hiding and a constructive interference phenomenon known as coherent backscatter [1-3]. While the size of the Earth’s orbit restricts observations of Pluto and its moons to solar phase angles no larger than α = 1.9°, the opposition surge, which occurs largely at α < 1°, can discriminate surface properties [4-6].

The smallest solar phase angles are attainable at node crossings when the Earth transits the solar disk as viewed from the object. In this configuration, a solar system body is at “true” opposition. When combined with observations acquired at larger phase angles, the resulting reflectance measurement can be related to the optical, structural, and thermal properties of the regolith and its inferred collisional history. The Pluto system was at true opposition when it crossed the line of nodes (Fig. 1) for the first time in 87 years in July 2018 [7], and, owing to the eccentricity of its orbit, it won’t be at true opposition again for another 161 years, in 2179. At the subsequent opposition in July 2019, Pluto was still observable at small phase angles and presented the opposite hemisphere to view.
In 2018, the sunlit portion of Pluto’s Charon-facing hemisphere, centered at longitude 30° E, was observable from Earth at a minimum phase angle $\alpha = 0.0049°$ (Fig. 2). In 2019, its anti-Charon hemisphere was visible at phase angles as small as $\alpha = 0.0131°$, centered at longitude 210° E, the same hemisphere viewed at high spatial resolution by the New Horizons spacecraft [8]. Since the sub-Earth latitudes were 55° and 56° N in 2018 and 2019, respectively, observations in both years include much of Lowell Regio, Pluto’s bright northern polar cap. Here we present and compare Hubble Space Telescope (HST) near-opposition solar phase curves (Fig. 3) of each of these hemispheres acquired between 2015 and 2019 with the Wide Field Planetary Camera 3 (WFC3) using the UVIS F555W filter (0.53 μm). Since Lowell Regio dominates 60% of the anti-Charon hemisphere and 80% of the Charon-facing hemisphere, the shapes of the two solar phase curves are similar; however, any differences in their shapes reveal differences in the scattering properties and physical surface characteristics of the terrains unique to each hemisphere. The New Horizons encounter (anti-Charon) hemisphere includes Tombaugh Regio and Sputnik Planitia and is ~0.1 magnitudes brighter than the Charon-facing hemisphere in the F555W filter. No part of Sputnik Planitia is visible in the Charon-facing hemisphere, so any differences between its solar phase curve and that of the anti-Charon hemisphere are mainly due to the scattering properties of Pluto’s darker equatorial regions. Preliminary results indicate that the slope of the anti-Charon hemisphere’s phase curve between phase angles 0.3° and 1° (0.025 mag/°) is shallower than that of the Charon-facing hemisphere (0.035 mag/°). When combined with New Horizons LORRI images acquired at higher phase angles, the quantitative analyses of the resulting solar phase curves reveal differences in the structure and texture of regolith particles on Tombaugh Regio and Sputnik Planitia and those on Pluto’s dark equatorial regions, including Cthulhu Macula.
Fig. 2. New Horizons LORRI composite images of Pluto showing the hemisphere visible at opposition in 2018 (left), centered at longitude 30° E, and 2019 (right), centered at 210° E. The bright, heart-shaped Tombaugh Regio and Sputnik Planitia, Pluto’s nitrogen ice glacier, dominate the view in 2019 but are not visible at the smallest phase angles in 2018. Red cross marks the approximate location of Pluto’s North Pole.
Fig 3. Preliminary near-opposition solar phase curves of Pluto's anti-Charon hemisphere (solid circles) and Charon-facing hemisphere (open circles) from HST WFC3 observations in the UVIS F555W filter (pivot wavelength 0.53 μm). Solid line is the fit to the Hapke 2012 photometric model [1, 8], globally averaged for Pluto, and offset by 0.1 magnitudes.

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References: