Photometric Study of the Macroscopic Roughness of Pluto

A *New Horizons* Study

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Abstract: **Pluto is a fascinating distant Kuiper Belt Object (KBO), sitting approximately 7.5 billion kilometers from Earth. The exploration of the Dwarf Planet in July of 2015 by the *New Horizons* spacecraft represents a unique opportunity to study the processes and properties of the body of Pluto. This paper will use *New Horizons* data to apply photometric techniques to explore the macroscopic roughness of two terrain types on Pluto: C'thulhu Regio and Sputnik Planitia. These two surfaces exhibit starkly contrasting albedos and relatively smooth surfaces compared to other icy bodies in The Solar System.**

1.) Introduction

Changes in topography on icy bodies can represent different terrain features. These can range from hills, valley, ridges, and impact craters. Different terrain features will exhibit different photometric properties when looking at them in terms of macroscopic roughness. To examine how roughness behaves on surfaces using photometry, it is key to look at changes in the local incidence and emission angles. The variations in these values as a surface varies represents alterations in the intensity in light from the sun that is scattered on the surface.

Using the Crater Roughness Model developed by [1] Buratti et al. 1985 and other techniques discussed below, we are able to ingest New Horizons data in such a way that we are able to extract the local albedo and photometric angles for each pixel as observed by *New Horizons*

2.) Methods

The instrument used for the dataset for this study was the Ralph Telescope. Specifically, the Multispectral Visible Imaging Camera (MVIC) was the primary imager for the Pluto data collected here. MVIC was selected due to the field of view of Pluto that allowed for wide-spans in emission angle in a single image.

Images were selected based upon the criteria of having Solar phase angles higher than 30° due to known desirability to stray from the opposition effect and have surfaces properly illuminated to survey macroscopic roughness. Additionally, it is necessary to have the desired terrain be at emission angles > 60 ° due to the need for the more dramatic shifts in albedo as observer approaches the limb.

Images are then processed using the United States Geological Survey's Integrated Software for Imagers and Spectrometers (ISIS). ISIS is an enabler to process spacecraft images to render the images with multiple bands of information for each pixel. These new images are referred to as 'cubes' as they have multiple layers.

Images are processed with ISIS to have bands for latitude and longitude (IAU), Solar phase angle, emission angle, incidence angle, and I/F. I/F, Irradiance/Solar Flux, is a dimensionless value representing radiance properties of a surface. An I/F value of 0 is a black body and an I/F of 1 is a perfectly reflective surface.

ISIS is then used to render multiple iterations of the same ‘cube’ such that one iteration for each band mentioned above is opened and then spatially synchronized to allow for measurements to be taken for different values, but of the same physical terrain. A line extraction tool is used to take a measurement of pixel values and then plot them into an ASCII formatted table that can be processed into the Crater Model.

The Crater Roughness Model places paraboloidal craters (not necessarily meaning impact-craters) across a surface based upon variances in local I/F, Emission, and Incidence angles. These craters are defined by a depth-to-diameter ratio (d/D). This model also will generate mean slope of a surface from these parameters.

3.) Results

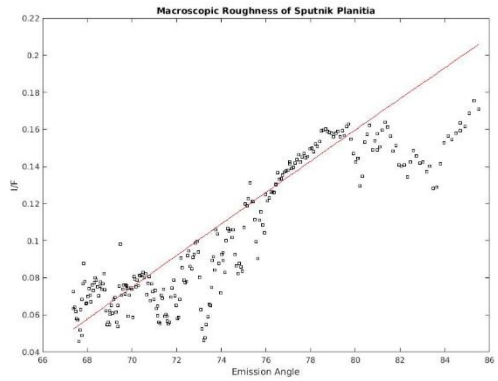

Figure 1: The best-fit crater roughness model (red) against I/F vs. emission angle values taken from Sputnik Planitia

Sputnik Planitia displays a remarkably smooth surface. With mean slopes of less than 1° and a best-fit (d/D) of 0.016 ± 0.001. This collaborates with theories that explain Sputnik Planitia to be a relatively young surface on Pluto.

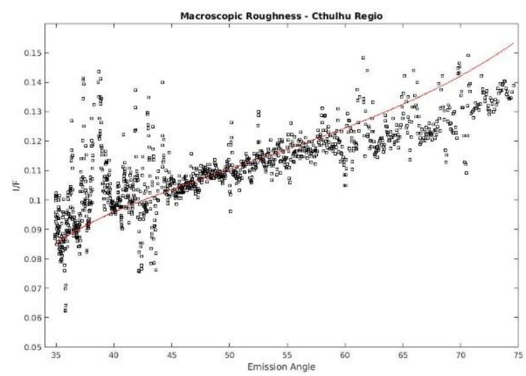

Figure 2: The best-fit crater roughness model (red) against I/F vs. emission angle values taken from C’thulhu Regio

C’thulhu Regio’s dark albedo smooth was also considerably smooth. A best-fit (d/D) of 0.04 ± 0.01 was calculated. This accompanied by a mean slope of 2° shows a dark surface that has an infall process that is having a smoothening affect.

4.) Discussion

Sputnik Planitia(SP) exhibits a bright and smooth surface. With albedos as high as 1.0 [2](Buratti et al. 2017), a smooth surface visibly clean from impact craters (S.A. Stern et al. 2015), there is some sort of resurfacing process ongoing that makes SP a comparatively younger surface on Pluto, that of darker, more cratered regions.

Figure 3: Sputnik Planitia is displayed prominently in this MVIC image. Note the high albedo surface and apparent lack of impact craters.

SP is a collection of bright icy plains that appear to comprised mostly of nitrogen ice. [3](Grundy et al. 2016) The reportedly smooth surface from modeling in this study adds evidence to the young age of SP. The infill process of nitrogen is causing SP to be smooth not just compared to other surfaces on Pluto, but also to other icy surfaces in the outer Solar System.

The high albedo regions on Titan were observed with Cassini to have an average (d/D) of 0.50 and a mean slope of 34°. Meanwhile, Europa, another fairly high albedo body in The Solar System, was reported to have a (d/D) of 0.30 and a mean slope of 22°.[4](Buratti et al. 2006)

The dramatic contrast in comparative roughness's of these bodies indicates a divergence in geological processes in both of their histories and possibly what activates ongoing are shaping the surface.

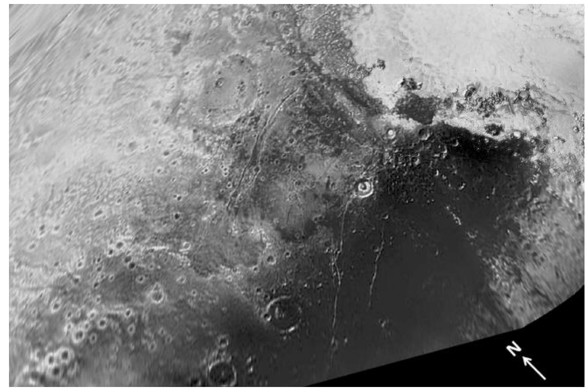

Figure 4: C'thulhu Regio is shown with its blanket like coating of exogenic tholins.

C'thulhu Regio's dark albedo (as low as .08 [2]) surface is thought to have an ongoing process of atmospheric depositing of tholin-like hydrocarbons [5] (Grundy et al. 2017). From a roughness standpoint, atmospheric depositing is evidenced by comparison to another dark albedo surface, Iapetus. From Cassini observations in [6](Lee et a. 2010) a coating of exogenic dust is thought to collect on the dark hemisphere of the body. The reported roughness of that surface from similar modeling shows an average (d/D) of 0.084 and a mean slope of 6°.The similar roughness of terrains on both bodies shows evidence for an infall process ongoing that puts organics on an otherwise rough and dark icy body.

5.) Follow-On Research

This model would have useful applications when applied to Pluto's other differentiated terrain types, namely the polar caps.

Further comparison of solar system bodies, namely Kuiper Belt Objects, applying this model would help gain insight into the formative and ongoing processes in the Solar System's 'Third Zone'

6.) References

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