National Aeronautics and Space Administration

Investigating the extent of bladed terrain on Pluto via photometric surface roughness

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Context

- NASA's *New Horizons*, that flew by Pluto in 2015, observed fields or landscapes of roughly evenly spaced, often sub-parallel sets of steep ridges situated on high ground, in the eastern portion of the encounter hemisphere. This landform has been labelled as '*bladed terrain*' (Fig. 1).
- Bladed terrain is thought to be formed via sublimational erosion of massive deposits of methane (CH_4) ice, akin to penitentes of water ice in high-altitude deserts on Earth (Fig. 1).
- Since *New Horizons* collected high resolution images of only one hemisphere, we don't know if bladed terrain exists on the far-side of Pluto. But, CH_4 signatures on the far-side of Pluto hint at a possibility (Fig. 2)…

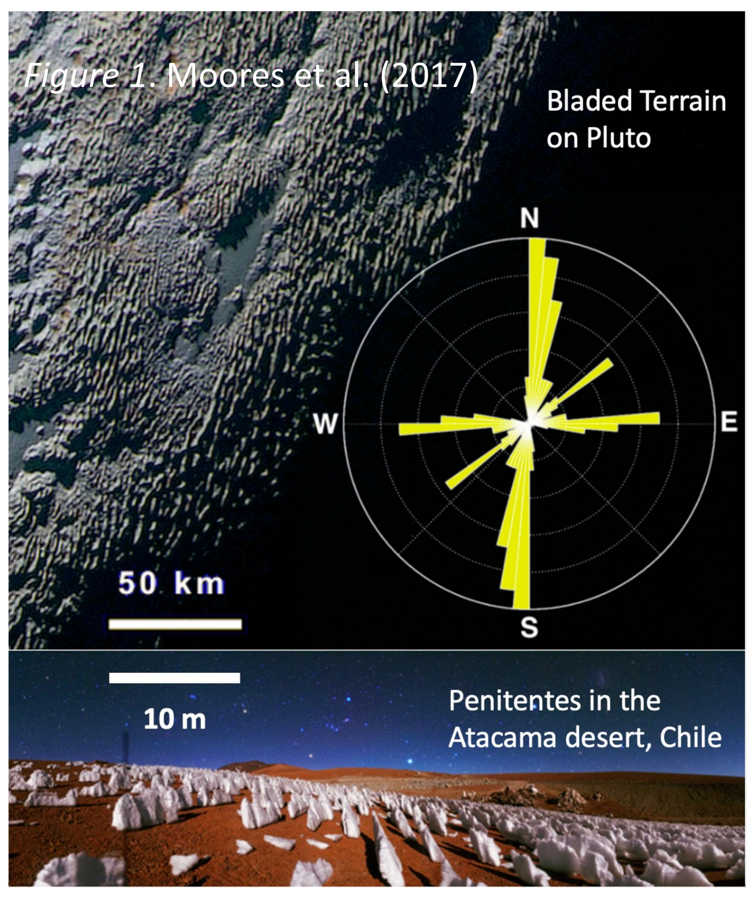

Figure 1. Moores et al. (2017)

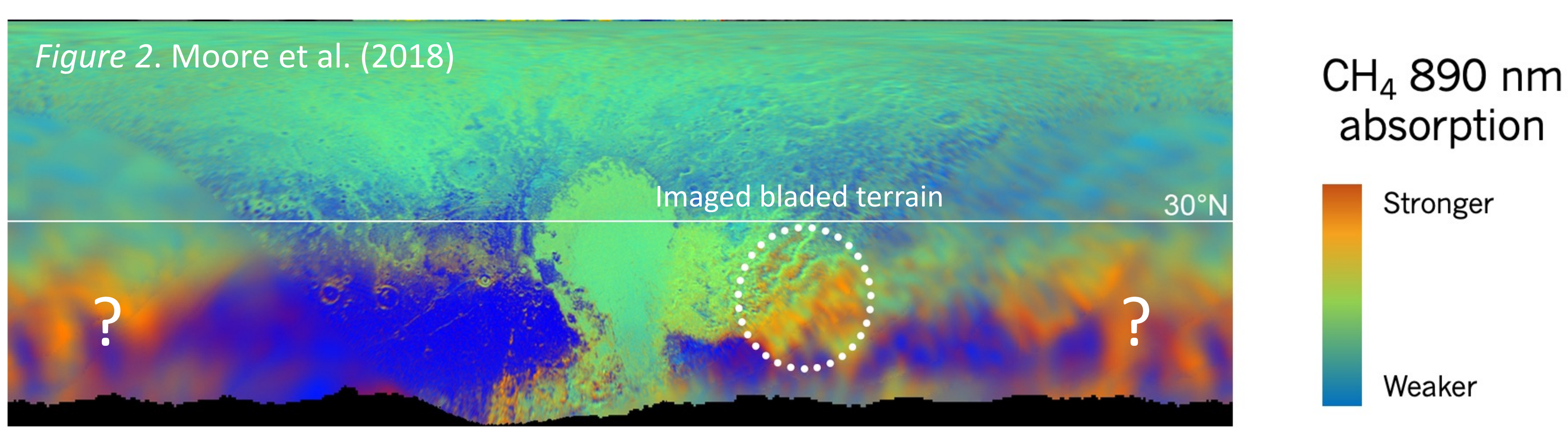

Figure 2. Moore et al. (2018)

Objectives

- While we lack high-resolution images of the far-side of Pluto to investigate the presence of possible bladed terrain, *photometry* – the study of how light is scattered from a planetary surface as a function of observation geometry - provides a way to peer below the resolution limit of the camera.
- The macroscopic 'texture' of a surface (whether its smooth or rough) affects the amount of sunlight that is reflected in two ways: by changing the local incidence and emission angles, and by removing light from the scene by casting shadows (Fig. 3).

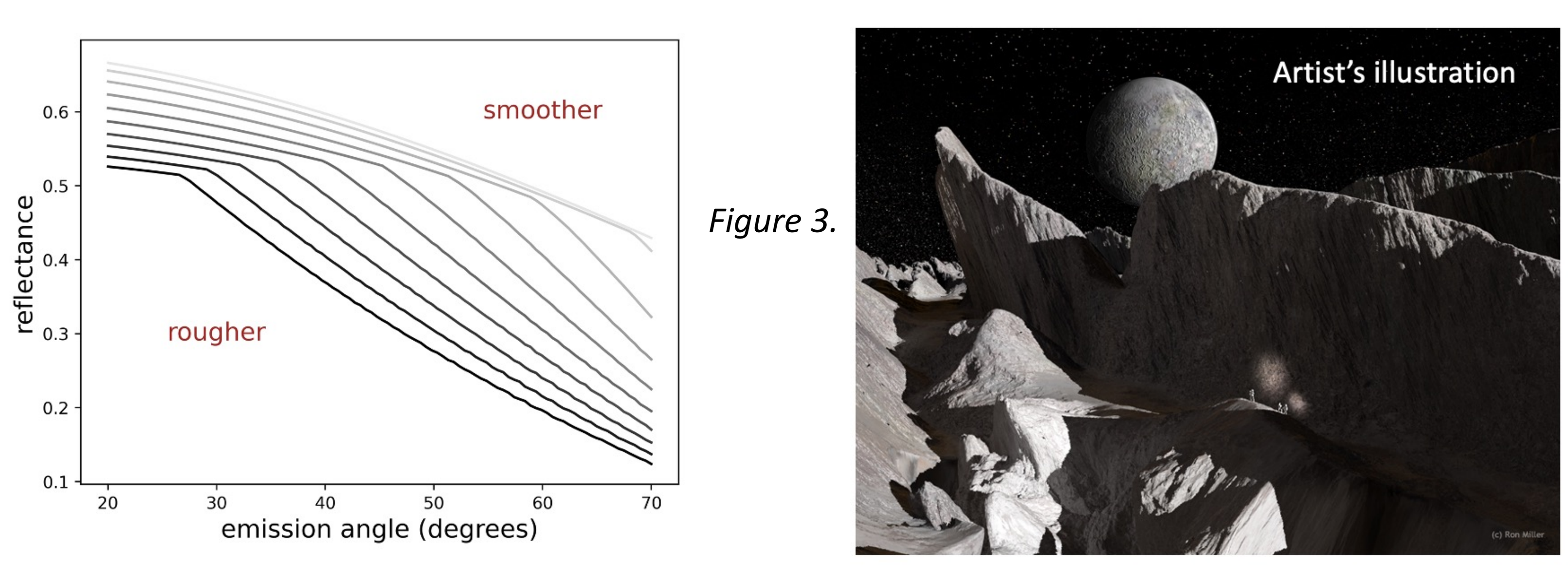

Figure 3.

Research question: What is the photometric roughness of the hypothesized bladed terrain regions on the non-encounter hemisphere of Pluto?

Method

- We extracted reflectance profiles of certain regions from *New Horizons* images of the near-side bladed terrain regions on Pluto, the methane rich regions (where bladed terrain is hypothesized) on the far-side of Pluto, and Sputnik Planitia, the visibly smooth glacial deposit region (or 'heart') of Pluto, to provide a point of comparison.
- These reflectance curves were fit with a photometric model that calculates reflectance of a surface full of idealized craters. The roughness of this surface is characterized by the depth-to-radius (q) ratio for these craters. **Higher q → higher roughness**
- We employ Bayesian inference for this fitting exercise, as it provides rigorous uncertainties of the estimated parameters and accounts for their degeneracies.

Results

- Our estimates for the roughness parameter q are presented in Fig. 4. **We find that the methane rich regions on the far-side of Pluto, where bladed terrain is hypothesized to exist, are indeed very rough**, while the Sputnik Planitia region is smooth, in line with our expectations.
- The bladed terrain on the near-side of Pluto are rougher than Sputnik Planitia, but not as rough as the far-side hypothesized bladed terrain regions.
- We think this disparity could be attributed to the role of multiply scattered photons in the inherently brighter near-side of Pluto, which could be diluting shadows cast by bladed terrain like rough features, reducing their apparent roughness.

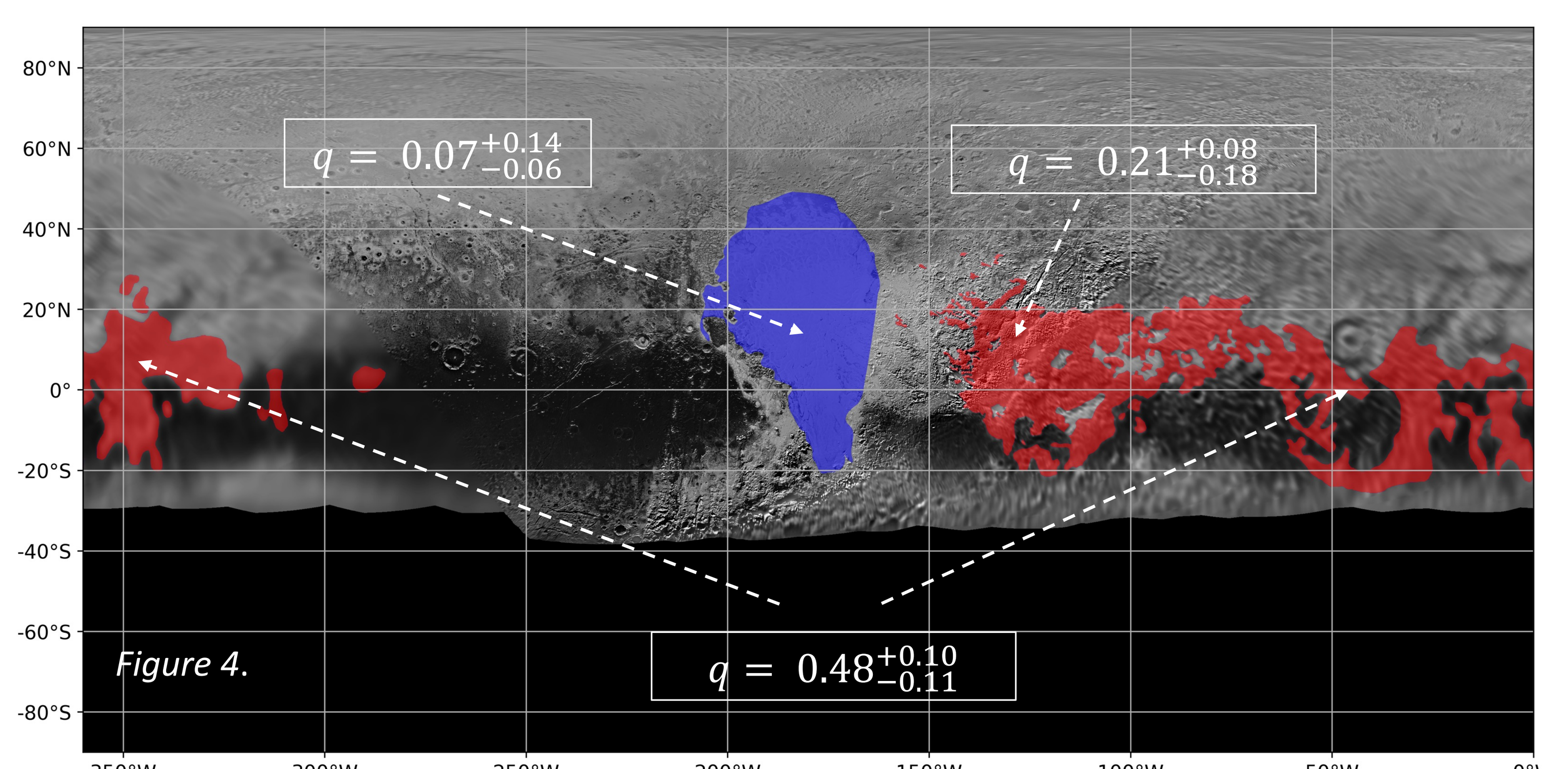

Figure 4.

Significance of Results and Future Work

- We provide a method to gain fundamental insights into the physical nature of planetary surfaces by studying how they reflect light as a function of observation geometry, especially the surface roughness.
- This approach is especially useful when high resolution images are not available, which is the case for the majority of planetary bodies in the solar system.
- Next, *we plan to apply this methodology to infer roughness of various terrains of Europa*, especially focusing on regions where penitente-like features were recently hypothesized to exist. Our work will be foundational to future exploration and hypothesis-testing by JPL's *Europa Clipper,* and for landing-site assessment for future landers for Europa and other icy moons in the solar system, which are a crucial part of JPL's long-term vision.

National Aeronautics and Space Administration

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California Institute of Technology
Pasadena, California

www.nasa.gov

Clearance Number: CL#23-6197

Poster Number: PRD-P-024

Publications and Acknowledgements:

Mishra et al., Investigating the extent of bladed terrain on Pluto via photometric surface roughness, *Geophysical Research Letters*, 2023 (submitted)

Mishra et al., Bayesian analysis of Juno/JIRAM's NIR observations of Europa, *Icarus*, 2021, 357

This research was funded by the New Horizons Project, and carried out at the Jet Propulsion Laboratory, California Institute of Technology, under contract to the National Aeronautics and Space Administration.

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