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)…

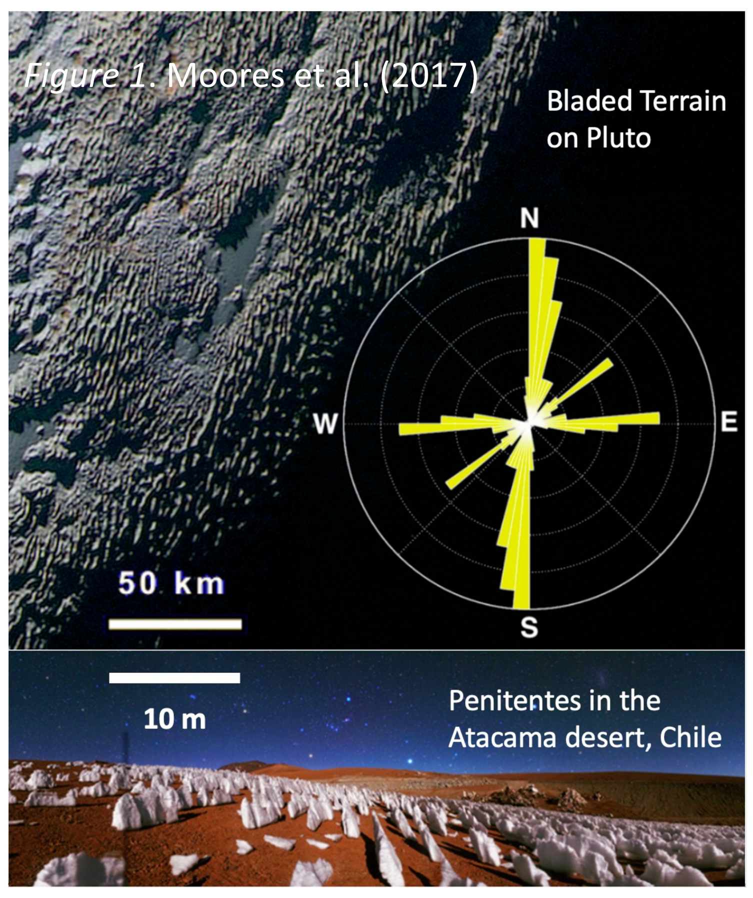


*Figure 1.* Moores et al. (2017)

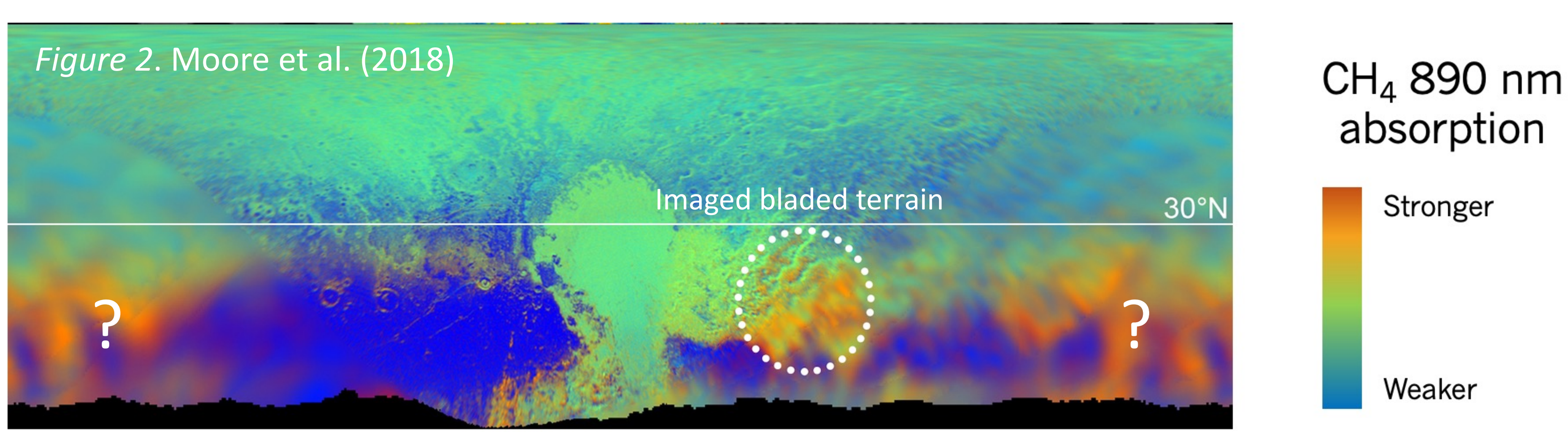


*Figure 2.* Moore et al. (2018)

## 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).

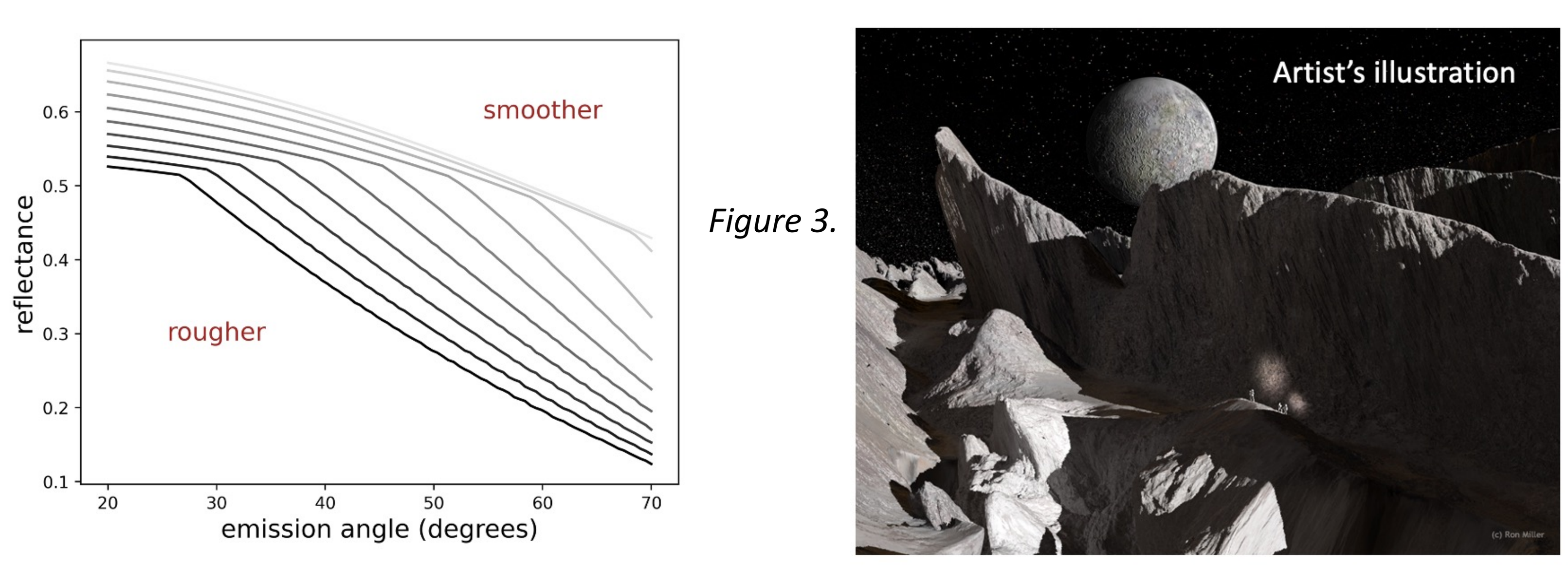


*Figure 3.*

***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.

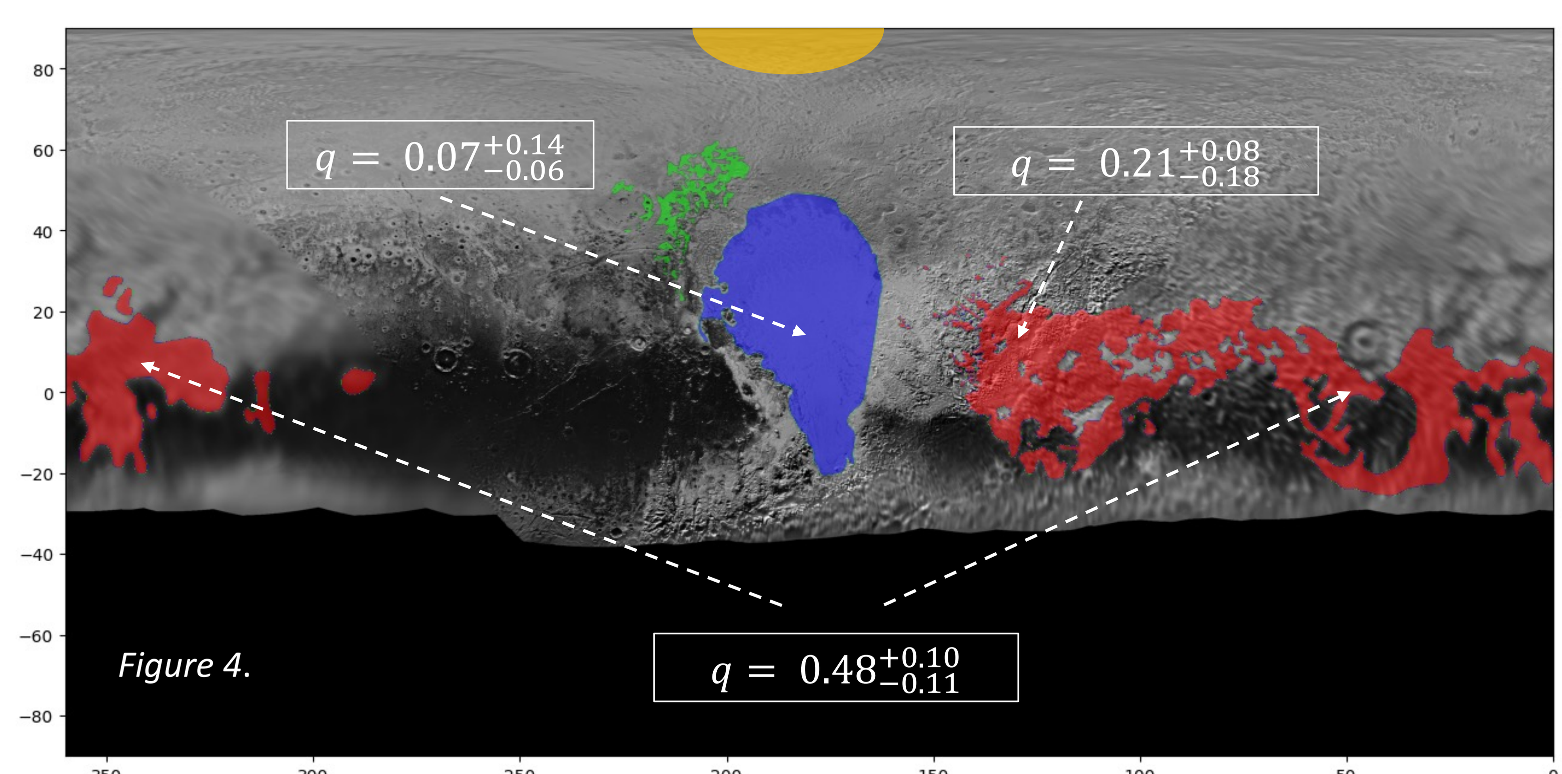


*Figure 4.*

## 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 a 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.


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## 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


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