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# Albedo Map of Kuiper Belt Object 2014 MU69 and Comparison with Cognate Solar System Objects

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## Abstract

An albedo map of KBO 2014 MU69 is presented. The similar albedo of MU69's two lobes suggests co-formation and co-evolution. MU69's surface is representative of cold classical KBOs.

## 1. Introduction

Normal reflectance (also called albedo) and Bond albedo are important properties of a planetary surface. Most variations of the observed brightness of a surface are not intrinsic, but rather due to changes in the incident, emission, and solar phase angles. Normal reflectance, the reflectance or I/F when the incident, emission, and solar phase angles are all zero degrees, is a measure of the intrinsic surface brightness and yields clues to the physical properties of a surface and its geology. Bond albedo is the ratio of the total scattered to incident power on a planetary surface and is crucial for understanding the thermal evolution of the surface.

On January 1st, 2019 the New Horizons spacecraft flew by the cold classical Kuiper belt object (KBO) 2014 MU69 (informally named Ultima Thule) [1]. MU69 is the first cold classical Kuiper belt object to be explored by a spacecraft and the flyby results have important implications for planetary formation and evolution. MU69 was discovered to be a bilobate object, the larger and smaller lobes are informally named Ultima and Thule respectively.

## 2. Albedo Map of 2014 MU69

Figure 1 is a preliminary normal reflectance map of MU69. The New Horizons LORRI image called CA04-MAP with a pixel scale of ≈140 m was used to generate the map. The LORRI instrument has a pivot wavelength of 610 nm [2]. The I/F was calibrated using a 50% Pluto plus 50% Pholus spectrum [1], and photometrically corrected to normal reflectance using a lunar (Lommel-Seeliger) function [3]. A histogram of the normal reflectance values is shown in Figure 2.

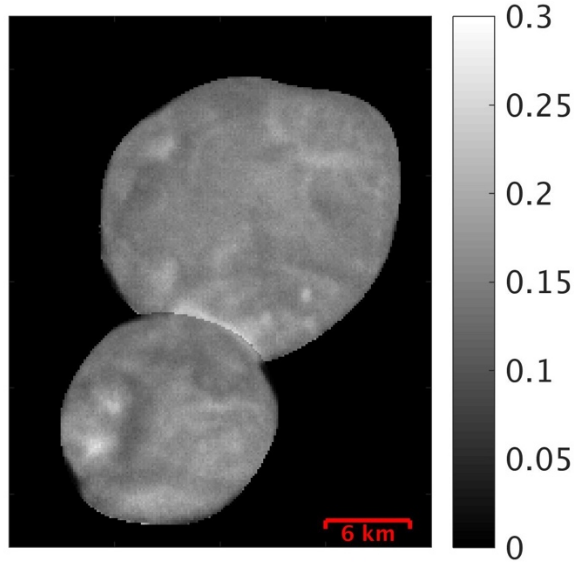


Figure 1: Normal reflectance (albedo) map of KBO 2014 MU69.

The modal normal reflectance of MU69 is 0.16; for a lunar photometric function, the geometric albedo is equal to the normal reflectance so the geometric albedo of MU69 is 0.16. The normal reflectance distributions of MU69's two lobes have approximately the same mode. The distribution of the Ultima lobe, however, has a sharper peak and is more symmetrical. The neck connecting the two lobes and the large depression in the Thule lobe have the highest normal reflectance. The intrinsically darkest surface is in the large depression in the Thule lobe.

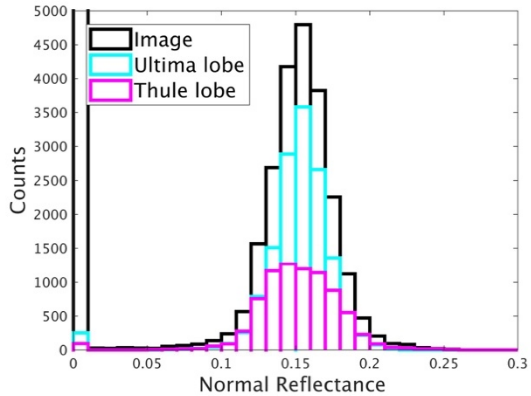


Figure 2: Histogram of normal reflectance values of KBO 2014 MU69.

## 3. Comparison with Cognate Objects

The cold classical KBOs, of which MU69 is one example, range in geometric albedo from 0.09 – 0.23 with a median of 0.15 at an effective wavelength of 550 nm [4]. The similarity in geometric albedo between MU69 and the median of the cold classical KBOs suggests that MU69 may be a typical cold classical KBO. This is an important result as it implies that the formation and evolution of MU69 reflects that of the cold classical Kuiper belt in general.

Aside from MU69, the only other KBOs to be explored by a spacecraft are Pluto and its satellites. Pluto has a mean geometric albedo of 0.62 at the LORRI pivot wavelength of 610 nm [5], far brighter than MU69. Cthulhu Regio, the most extensive region of Pluto's dark equatorial terrains, however, has a normal reflectance mode of 0.16 at 610 nm. The similar normal reflectance of Cthulhu Regio to that of MU69 suggests that Cthulhu Regio's surface and evolution within the Kuiper belt are also similar to MU69's. Cthulhu Regio also has a similar red color to MU69 [1]. Charon has a geometric albedo of 0.41 at 610 nm and its darkest observed terrain, Mordor Macula, generally has normal reflectances > 0.2 [5]. The small satellites in the Pluto system have greater geometric albedos than MU69, likely due to formation from a giant impact [6]. Thus, the satellites of the Pluto system are not similar in albedo to MU69.

Jupiter family comets likely formed in the Kuiper belt but have a mean geometric albedo of ≈0.04 at 550 nm effective wavelength [7]. 67P/Churyumov–Gerasimenko is the best explored Jupiter family comet and has a geometric albedo of 0.06 at 550 nm [8]. The darker geometric albedos of 67P/Churyumov–Gerasimenko and Jupiter family comets in general compared to that of MU69 and other cold classical KBOs suggests that these comets have evolved since they the departed the Kuiper belt or that they formed from a different family of objects. Saturn's satellite Phoebe is hypothesized to be a captured KBO [9]; it has a mean normal reflectance of 0.08 at 1000 nm and approximately constant geometric albedo from 340-1000 nm [10]. Thus, it is also significantly darker than MU69.

## 4. Ongoing Work

To improve the measurement of the normal reflectance, a photometric model that is the superposition of lunar and lambert functions will be used in future work. The Bond albedo is calculated by multiplying the normal reflectance by the phase integral. New Horizons imaged 2014 MU69 at solar phase angles from ≈10-140 degrees, so the phase integral can be determined. A Bond albedo map at the LORRI pivot wavelength of 610 nm will be generated.

## 5. Summary and Conclusions

1. The two lobes of MU69 have very similar normal reflectance modes suggesting that they co-formed and co-evolved.

2. MU69's albedo is consistent with other cold classical KBOs suggesting it is a typical cold classical KBO.

## References


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