

Geology and Geophysics of 2014 MU69: New Horizons Flyby Results

John R. Spencer (1), Jeffrey M. Moore (2), William B. McKinnon (3), S. Alan Stern (1), Harold A. Weaver (4), Catherine B. Olkin (1), and the New Horizons Geology, Geophysics and Imaging Team. (1) Southwest Research Institute, Boulder, Colorado, USA (spencer@boulder.swri.edu) (2) NASA-Ames Research Center, Mountain View, California, USA (3) Washington University, St. Louis, Missouri, USA (4) Johns Hopkins University Applied Physics Laboratory, Laurel, Maryland, USA

Abstract

The New Horizons flyby of the small Kuiper Belt Object 2014 MU₆₉ provided the first look at the geology of a member of the Cold Classical Kuiper Belt, the most primitive known population of objects in the solar system. MU69 is a contact binary, and is unlike any object previously seen.

Introduction

At 05:33:22 UT on January 1st 2019, the New Horizons spacecraft passed 3538 km from Kuiper Belt object (KBO) 2014 MU₆₉, nicknamed “Ultima Thule”, giving us our first close-up look at a small KBO [5]. New Horizons data on MU69 achieved a best resolution of 33 m/pixel (though effective resolution was lower due to smear and low SNR). Extensive satellite and ring search data were also obtained.

Context

MU69 was discovered by the Hubble Space Telescope in June 2014, as part of a 4-year intensive search for New Horizons flyby targets beyond Pluto [4]. Based on its semi-major axis ($a = 44.2$ AU), low orbital eccentricity ($e = 0.038$), and low inclination ($i = 2.4^\circ$) [3], and its albedo and color (below), MU69 is almost certainly a member of the dynamically cold, non-resonant “cold classical” population of Kuiper Belt objects (CCKBOs), and probably a member of the tightest orbital clustering of CCKBOs known as the “kernel” [2]. Because there is no known mechanism for producing this cold orbital distribution after the dispersal of the protoplanetary nebula, and because of the low temperatures and low impact rates [1] in the Kuiper Belt, CCKBOs are thought to be the most dynamically and physically primitive known population of small bodies in the solar system.

Geology

Global Characteristics

MU69 is a contact binary, composed of two sharply distinct components which make contact at a bright, narrow, “neck” (Figure 1). The largest component is nicknamed “Ultima”, and the smaller one “Thule”. Both are flattened, with their smallest axes aligned, and their contact point is close to the longest axis of both bodies. This configuration strongly suggests that the two components formed independently, and orbited each other in a tidally-locked configuration before coming gently together. The current rotation period of 15.92 hours is slow enough that for reasonable densities, the two bodies must have lost significant angular momentum after contacting each other.

The rotational pole was oriented only 29 degrees from the sun and 39 degrees from New Horizons’ approach direction during the encounter, so only a little over one hemisphere was visible to the spacecraft during the flyby.

On both components, the surface is generally smooth, though pits are seen near the terminator, and bright spots away from the terminator may also be bright-floored pits. These features have a shallow size/frequency distribution similar to that of small craters in the Pluto system, and, if impact-generated, indicate a surface age of at least 4 Ga [1].

Ultima

Ultima is highly flattened, with approximate dimensions 20.6 x 19.9 x 9.4 km: the shortest dimension is the least certain. It appears to be divided into half a dozen similar-sized sub-units, distinguished by surface texture and/or separated by ~linear scarps or bright linear albedo features (Fig. 1).

Dark features that appear to be low hills and ridges are unevenly distributed across the surface. The sub-units may provide evidence for assembly of Ultima from smaller bodies, though the continuity of some surface texture units across some of the bounding linear features argues for some of the unit boundaries being relatively young rather than primordial.

Thule

Thule is closer to spherical than Ultima, with approximate dimensions 15.4 x 13.8 x 9.8 km (again, the shortest dimension is the least certain), and is markedly different in appearance (Fig. 1). It is dominated by a large depression, nicknamed “Maryland”, 7 km in diameter and 0.5 – 1.0 km deep, which is likely to be an impact feature. The rest of the surface is characterized by bright and dark albedo markings that often have strikingly sinuous boundaries, possibly due to sublimation erosion of variable-albedo thin surface layers.

Limits on Satellites and Rings

No satellites or rings were discovered during the flyby. At the time of writing, satellite searches excluded satellites > 150 meters diameter to radii of ~3,000 km, and > 3 km diameter out to the Hill sphere radius of ~40,000 km, assuming photometric properties comparable to MU69 itself. Rings with $I/F > 2 \times 10^{-7}$ in backscattered light and $> 10^{-6}$ in forward-scattered light, i.e. fainter than Jupiter’s main ring, were also excluded. No UV emission or absorption from molecular or atomic species, and no disturbance to the solar wind, was seen during the flyby, consistent with expectations for an object that has occupied a stable orbit for > 4 Ga.

Acknowledgements

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References

[1] Greenstreet, S., Gladman, B., McKinnon, W.B., Kavelaars, J.J., Singer, K.N.: Crater density predictions for New Horizons flyby target 2014 MU69, *Astrophys. J.* 872, L5, 2019.

[2] Petit, J.M., Kavelaars, J.J., Gladman, B.J., and 14 co-authors: The Canada-France Ecliptic Plane Survey- full

data release: The orbital structure of the Kuiper Belt, *Astron. J.* 142, 131, 2011.

[3] Porter, S.B., Buie, M.W., Parker, A.H. and 10 colleagues 2018. High-precision Orbit Fitting and Uncertainty Analysis of (486958) 2014 MU69. *Astron. J.* 156, 20.

[4] Spencer, J.R., Buie, M.W., Parker, A.H., and 17 coauthors: The Successful Search for a Post-Pluto KBO Flyby Target for New Horizons Using the Hubble Space Telescope, European Planet. Sci. Congress, EPSC2015–EPSC2417, 2015.

[5] Stern, S.A., Weaver, H.A., Spencer, J.R. and 200 co-authors: Initial results from the New Horizons exploration of 2014 MU69, a small Kuiper Belt Object, *Science*, in press, 2019.

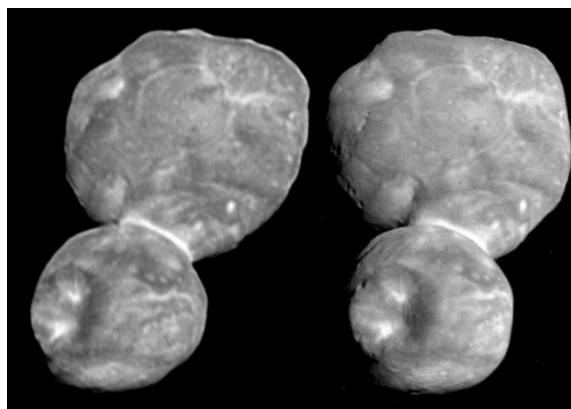


Figure 1. Cross-eyed stereo pair image of 2014 MU69, taken by the New Horizons Long-Range Reconnaissance Imager (LORRI). The “Ultima” component is at the top and the “Thule” component is at the bottom. Left image: Range = 27,860 km, phase = 12.9° , 138 m/pixel. Right image: Range = 6,650 km, phase = 32.5° , 33 m/pixel.