Shape Of 2014 MU69: Contact Binary From Low Speed Merger?, A.F. Cheng[1], H.A. Weaver[1], S.A. Stern[2], W.B. McKinnon[5], J.M. Moore[3], K.D. Runyon[1], W. Grundy[4,] C.B. Olkin[2], J.R. Spencer[2], A. J. Verbiscer[7], J.W. Parker[2], C. M. Lisse[1]and the New Horizons GGI Team. [1]Johns Hopkins Applied Physics Laboratory, Laurel, MD 20723,[2]Southwest Research Institute, 1050 Walnut St. Suite 300, Boulder, CO 80302 (astern@boulder.swri.edu), [3]NASA Ames Research Center, Moffett Field, CA 94035. [4]Lowell Observatory, 1400 West Mars Hill Road, Flagstaff, AZ 86001, [5]Dept. Earth and Planetary Sciences, Washington University, St. Louis, MO 63130, [7]Department of Astronomy, University of Virginia, Charlottesville, VA 22904.

Introduction. On 1 January 2019, the New Horizons mission encountered the cold classical Kuiper Belt Object (KBO) 2014 MU69 (hereafter MU69), nicknamed Ultima Thule [1]. From early image returns, MU69 appears to be a contact binary, with the two nearly spherical lobes having roughly spherical diameters of ~19.5 km and ~14.2 km [2,3,4], where the larger and smaller lobes are nicknamed Ultima and Thule respectively. This shape suggests that MU69 the result of a low velocity merger of two primordial planetesimals [4,5]. A digital shape model has been produced based on the early images [6] and is used here to examine the volume and the gravity field for the contact binary shape. Based upon the volume deficit between the contact binary shape versus the two spheres individually, it is suggested that the merger speed was on the order of 1 m/s.

Dynamical Considerations. The shape model consists of 6058 vertices and 9999 facets with a triangular tessellation of the surface. The two lobes lie along the x-axis which is the axis of the bi-lobed shape. The z-axis is the rotation axis. The origin is at the center of mass assuming a constant density for the shape. The overall extent of the body in the x dimension is 33.5 km. This model is not well constrained by the returned images in dimensions along the viewing directions from New Horizons, but it is a reasonable three dimensional extrapolation assuming that MU69 is formed as two nearly spherical lobes joined by a narrow neck.

The gravitational potential is calculated from this digital shape model using the methods described by [7]. Figure 1 shows a scatter plot of facet locations which outline the two lobes of MU69. Specifically it shows cylindrical radius measured from the x-axis versus x.

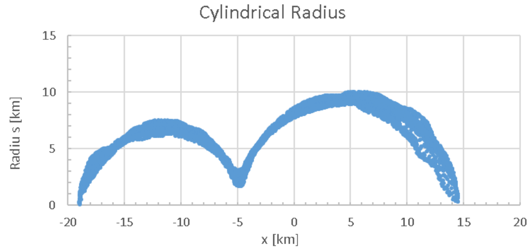

Figure 1 Shape model cylindrical radius versus x

The neck, the narrow region between the two lobes, is at x=-5 km. The radius of the body at the neck is 2.7 km based upon the model. The effective gravitational potential, is also calculated assuming a constant density of 0.5 gm/cc (a typical value for cometary nuclei [Y]) and a rotation period of 15.3 hr [Z]. Fig 2 is a scatter plot of the effective potential at the same facet locations versus x.

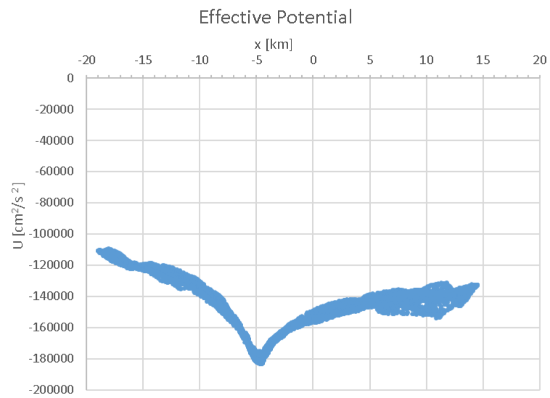

Figure 2Effective potential versus x

The neck region is a gravitational low and is at the lowest effective potential across the entire surface. Table 1 summarizes parameters of the shape model.

Table 1. Summary of MU69 shape model

Extent in x	33.5 km
Volume	4739.8 km^3
Assumed density	0.5 gm/cc
Rotation period	15.3 hr

Two mascon model. A two mascon model of the gravitational potential is fitted to the potentials calculated for the shape model. In this mascon model, two point masses placed on the x-axis, one representing Ultima and one representing Thule. The two mascon model is summarized in Table 2.

Table 2 Two mascon model for MU69 shape model

	Mass kg	**X km**
For Ultima	1.70199 e 15 kg	4.5353 km
For Thule	6.6676e14 kg	-11.5768 km

The potential of the shape model is very well fitted by the potential of this two mascon model. The rms fractional deviation between the two potential models, for the full set of facet locations, is 1.2e-4

Merger conjectures. If MU69 is the product of a low speed merger between two nearly spherical objects, then we conjecture that these bodies had radii of 7km and 9.3 km just before the merger (see Fig. 1). The combined volume of these two spheres is 4806 km^3, slightly exceeding the volume of the shape model (Table 1). If we suppose that this volume change resulted from deformations in the merger, we estimate the relative speed of the merger collision, by equating the relative kinetic energy (0.5 gm/cc density for both bodies) with the resisting stress multiplied by volume change. The deformation involves both crushing and shearing motions, so this is a very rough estimate, but the resulting merger speed is$v = 0.5 \left(\frac{P}{1\,kPa}\right)^{1/2}$ m/s.

For a resisting stress of 1 kPa, similar to reported strengths for Comet 67P, the merger would involve relative speeds of the order of 1 m/s.

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