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The Geophysical Environment of (486958) 2014 MU_{69}

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Abstract

On 1 January 2019, NASA's *New Horizons* spacecraft performed the first flyby of a small Kuiper Belt Object, (486958) 2014 MU_{69} (henceforth "MU69"). *New Horizons* revealed a fascinating bilobed contact binary that likely records some of the earliest epochs of solar system history [1].

The irregular shape of MU69 yields an unusual and potentially unintuitive geophysical environment. Understanding the shape, moments of inertia, gravity field, rotation, and surface slopes are of primary importance. These physical characteristics control a wide array of geologic phenomena—from mass-wasting to tectonics. In this work, I will present new models for the geophysical environment of MU69.

1. The Shape, Spin, and Density of MU69

At the time of writing this abstract, there are two shape models of MU69. The first is a low-resolution, global model, determined by fitting all available *New Horizons* images with a forward model consisting of a parametric contact-binary shape model, a given rotation state, and rough photometric model [2]. The second is a high-resolution "skin" derived by stereo photogrammetry analysis of *New Horizons* image pairs [3,4]. These two analyses provide complimentary information about the shape of MU69. However, at present, these two shape models have not been merged into a single, self-consistent shape model. In this work, we focus on analysis of the low-resolution model.

The rotation rate and spin-pole of MU69 has been well-characterized by analysis of the entire sequence of *New Horizons* approach images. The rotation rate is 15.918 hours, and the obliquity is 99.3° [2]. This high obliquity has interesting consequences for the thermal environment on MU69 [5,6]. There is no evidence for non-principal axis rotation of MU69. In this work, we assume that MU69 is in the lowest-energy, principal axis rotation state—with the rotation axis aligned with the maximum principal axis of inertia, and going through the center of mass.

In the absence of gravity measurements, or detected satellites, the density of MU69 remains largely unconstrained. If MU69 has no tensile strength, the density must be >290 kg/m^3, else the rotation would overwhelm the mutual gravity of the two lobes and cause them to separate. An analysis of the distribution of slopes as a function of density [7] suggests a very low density of ~300 kg/m^3. In this work, we assume a fiducial bulk density of 500 kg/m^3 based on the average densities of cometary nuclei [8].

2. The Geophysical Environment of MU69

Fig. 1 shows the derived geophysical quantities for MU69. Fig. 1B shows the geopotential altitude. The geopotential is the sum of the gravitational and rotational potentials in a body-fixed reference frame [9]. The geopotential altitude is a measure of elevation with respect to a chosen geopotential surface (in this case, the minimum in MU69's neck), and is more geophysically meaningful than the radius. The geopotential is highest at the distal ends of MU69 and along the equators of each lobe. The geopotential decreases with increasing latitude on each lobe, and ultimately reaches a global minimum in the neck. This means that if material can flow downslope, then it will naturally move to higher latitude and into the neck region. The slopes on MU69 are generally gentle (<20°; Fig. 1C). While this model shows steep slopes in the neck, preliminary analysis of the stereo-derived shape model indicates this region may be smoother than expected—plausibly indicating that mass wasting has already partly filled the neck.

The two lobes of MU69 are well-aligned (Fig. 1D), meaning the corresponding principal axes of the two lobes are nearly parallel. The total misalignment of the principal axes is <10°, which is unlikely by chance. This may hint at the formation and evolution of MU69.

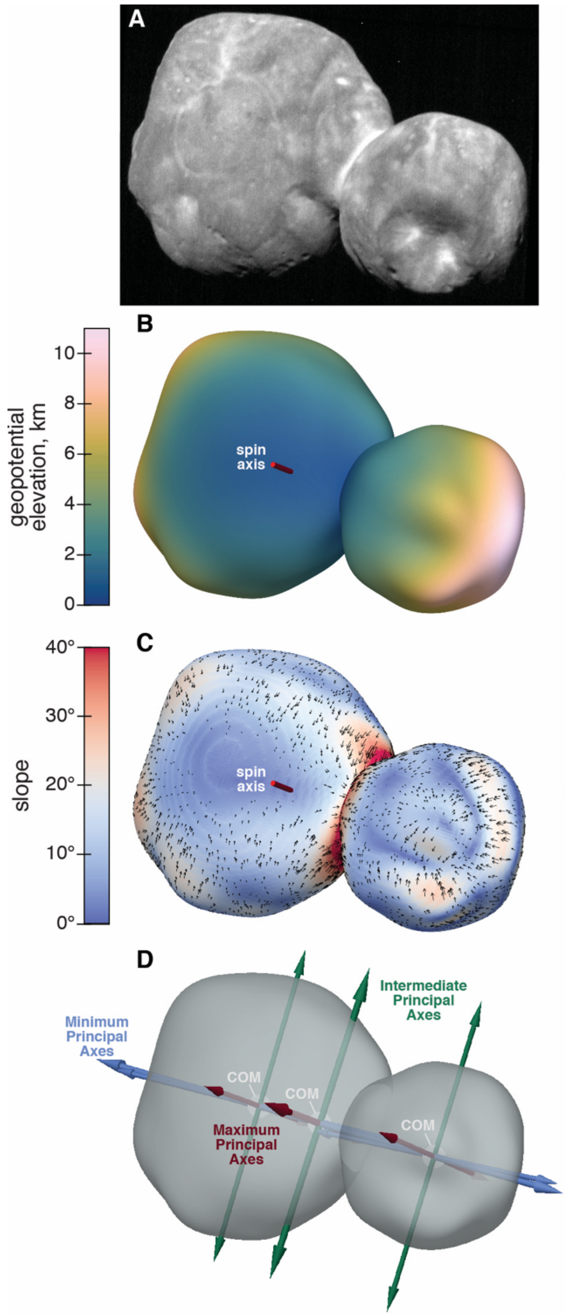

Figure 1: Geophysical properties of 2014 MU_{69}. (A) *New Horizons* CA06 LORRI image. (B) Geopotential altitude. (C) Slopes. (D) Principal axes of inertia of each lobe (thin vectors) and the entire object (thick vectors) and their respective centres of mass (white circles).

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