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Comparing KBO (486958) MU_{69} to JFC Nuclei

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Abstract

On 1 January 2019, NASA's New Horizons mission conducted a close flyby (3540 km closest approach distance) of the cold classical Kuiper Belt Object (KBO) (486958) 2014 MU_{69} (hereafter MU69) [8]. Since the vast majority of the Jupiter Family Comets (JFCs) also came from the Kuiper belt, where they were originally members of the scattered KBO population whose orbits are strongly perturbed by gravitational interactions with Neptune, comparisons of MU69 and JFC nuclei provide an opportunity to compare objects from two different KBO families, as well as constrain how solar heating modifies the nascent stage of cometary nuclei. Here we compare the physical properties, color, and composition of MU69 and the nuclei of the Jupiter Family Comets (JFCs) that have been studied by flyby or rendezvous spacecraft missions.

1. Physical Properties

Five JFC nuclei have been studied at close range by spacecraft: 9P/Tempel by Deep Impact [1] and Stardust NExT [10], 19P/Borrelly by Deep Space 1 [7], 81P/Wild by Stardust [3], 67P/Churyumov-Gerasimenko by Rosetta [6], and 103P/Hartley by EPOXI [2]. These JFC nuclei have diverse shapes and surfaces (Fig. 1).

The JFC nuclei are significantly smaller than MU69, and MU69's volume exceeds that of the JFC nuclei by factors of $30-6000$. Comets 19P, 67P, and 103P appear to be highly elongated bilobate objects,

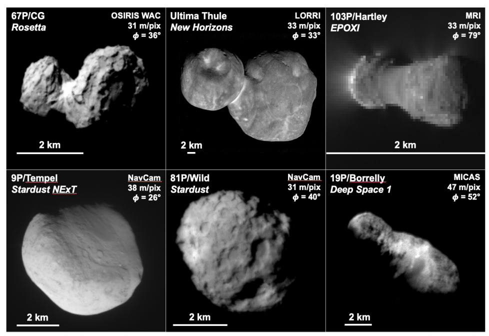

Figure 1: The images of JFC nuclei shown here have spatial resolutions and phase angles similar to those of the highest resolution image of MU69, except that 103P was only observed at much higher phase angles.

suggesting the merger of two distinct bodies, as has been proposed for MU69 [8]. Except for 67P, whose bulk density is 533 ± 6 kg m^{-3} [5], the densities of the other JFC nuclei discussed here are generally uncertain by a factor of two or more, but all are consistent with $\sim$500 kg m^{-3}, which implies average bulk porosities of $\sim$50-80%. Various arguments [8] also suggest that MU69's density might be $\sim$500 kg m^3, implying that its two lobes have porosities similar to those of JFC nuclei. The rotational period of Ultima Thule (15.9 hr) is comparable to those measured for 67P and 103P and falls well within the range measured for the JFC population [4].

The JFC nuclei discussed here are much darker than

MU69, with 2-3 times smaller geometric albedos. If the JFC nuclei once had higher albedos in their nascent state in the Kuiper belt, then the darkening of their surfaces might be associated with cometary activity when the JFCs entered the inner solar system. Indeed, most of the surface features on the JFC nuclei have been attributed to cometary activity. The surfaces of JFC nuclei can be divided into "smooth" and "rough" (or "mottled") regions, with the rough terrains associated with a preponderance of pits/depressions or mounds/hills [9]. The smooth regions of JFCs are generally brighter than average and are often associated with gravitational lows, perhaps suggesting accumulation by small grains that scatter light more efficiently than the average surface. Bright areas on MU69, especially in the neck region between the two lobes, are also usually associated with gravitational lows [8]. While outgassing and subsequent fallback to the surface provides a natural mechanism for moving grains across the surfaces of cometary nuclei, grain transport across MU69's surface likely requires a different process. Although many pits have been identified on the surfaces of both JFC nuclei and MU69, determining whether any of them are associated with impact events has been problematic. Pits on comets are usually attributed to activity; whether the pits on MU69 could be produced by volatile sublimation processes is an open question.

2. Color and Composition

New Horizons photometry of MU69 at visible wavelengths shows strong reddening ($\sim$28% per 100 nm) across the surfaces of both lobes with very little difference in colors between the two lobes. MU69's neck region, and the other bright regions on MU69's surface, are slightly less red than the rest of the surface. MU69's optical colors are typical of the cold classical KBOs, which are among the reddest objects in the solar system (Fig. 2). Cometary nuclei typically have red optical colors as well, but the reddening is usually $\sim$3 times smaller compared to MU69.

MU69's albedo spectrum flattens to approximately neutral at infrared wavelengths ($1.2-2.5$ μm), whereas cometary nuclei generally continue the reddening trend to at least 3 μm. MU69's infrared spectrum has several absorptions features, with the strongest one tentatively attributed to methanol (CH_3OH) ice and a weaker one possibly associated with water (H_2O) ice. If these identifications are correct, they indicate that MU69's entire surface is likely covered with methanol ice (given that MU69 was barely resolved spatially

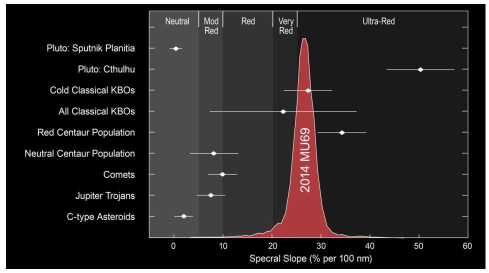

Figure 2: MU69's surface color is very red, relative to solar color, and falls squarely in the range measured for other cold classical KBOs. The surfaces of cometary nuclei are also generally red, but much less so than MU69

during the LEISA observations) with a CH_3OH/H_2O abundance ratio perhaps 100 times larger than the ratio measured in cometary comae. No absorption by methanol ice has ever been detected on the surface of a comet nucleus. Some Rosetta/VIRTIS spectra of 67P showed ice absorptions from H_2O and CO_2, but only with very high spatial resolution and observing under very special conditions (e.g., at the dawn terminator, or at the base of cliffs where sublimation-driven activity was detected).

Acknowledgements

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