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The Kuiper belt vs the asteroid belt: Insights from the New Horizons mission results

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Abstract

New Horizons' tour of the Kuiper belt continues to produce new insights into the formation and evolution of the objects in it [1, 2]. Starting with the flyby of the Pluto-system in 2015, and continuing with close flyby of the cold classical KBO 2014 MU69 (nicknamed Ultima Thule) in 2019, clues to the collisional history of the Kuiper belt are being revealed through the data returned by New Horizons. From the objects sampled by New Horizons, the evidence points to fewer small objects (less than ~1 km in diameter) and fewer collisions in the Kuiper belt than in the asteroid belt.

1. Impact craters on KBOs

Images returned by New Horizons are the first to show cratered surfaces on objects located in the Kuiper belt today. By examining the record of impacts on the surfaces of these objects, we are able to learn about the size-frequency distribution (SFD) of the Kuiper belt at small sizes that are not easily observed from current ground- or space-based telescopes. The craters observed on Pluto and Charon represent impacts by other KBOs [3, 4] ranging in size from ~40 kilometers to ~300 meters [5] in diameter.

The crater data displays a distinct break in slope; for craters smaller than about 10-15 km in diameter (or impactors smaller than ~1-2 km in diameter) the size distribution breaks to a shallow slope (Figure 1). The SFD slope seen for the smaller craters/impactors is shallower than ~1.7 differential slope (or 0.7 cumulative) for all observed distributions [5]. This produces is a relative deficit of small craters which cannot be explained solely by geological resurfacing. This implies a deficit of small KBOs (≲1 to 2 kilometers in diameter). Some surfaces on Pluto and Charon are likely ≳4 billion years old, thus the crater record provides key information on the SFD of KBOs at the end of the accretionary and rearrangement epochs of the early solar system.

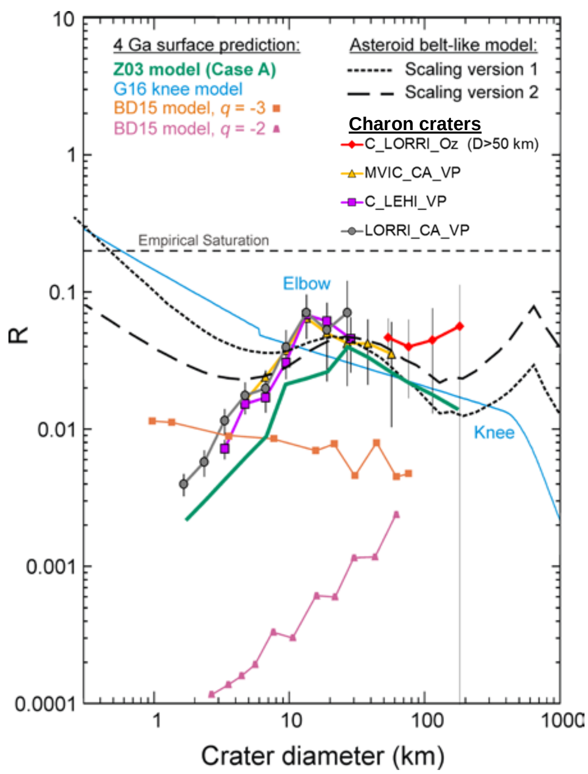

Figure 1: Impact crater size-frequency distribution R-plot of Charon craters shown with four models of impactor flux onto Charon from Z03 [6], G16 [3, 4] and BD15 [7], all for a 4 Ga old surface. Also shown

are two different scalings of a collisional evolution model of the asteroid belt [8, 9]. The crater data do not match the slopes predicted from collisional evolution models (in which collisions between KBOs would produce copious fragments) and do not resemble the asteroid belt at small sizes. The Z03 model, based on craters on the young surfaces of Europa and Ganymede [6], is the closest match to the Charon craters (D < 10 km) over the entire data range. See [5] for more details.

The preliminary results for the impact craters on 2014 MU69 are consistent with a lack of small craters [10]. The potential craters on 2014 MU69 are all in the size range where the shallow SFD slope would be expected. Although the lighting geometry is not ideal for observing topography over some of the surface, the overall surface is relatively lightly cratered (far from saturation; Figure 2). There are regions on MU69 where small craters should be visible and only a few are seen. The SFD slopes from the possible craters across MU69 are similar to the shallow slopes on Pluto and Charon. The surface of 2014 MU69 is also estimated to be quite old. See [10] for more details.

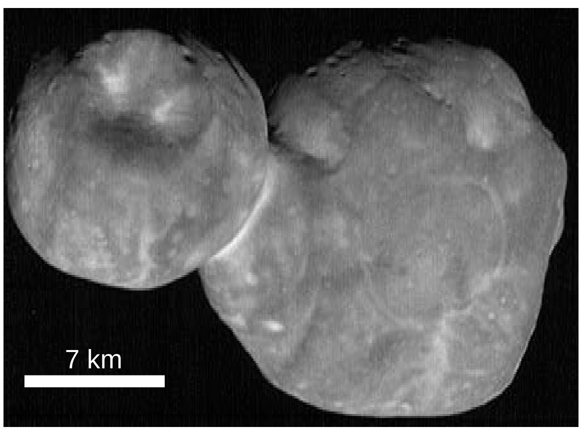

Figure 2: The cold classical KBO 2014 MU69 as seen by New Horizons in the highest resolution image sequence (CA06 observation, ground scale 33 m px^{-1}, effective resolution ~70 m, phase angle 32°).

2. The shape of 2014 MU69

The overall shape and morphology of 2014 MU69 (Figure 2) indicates it has not experienced catastrophic collisions since the formation of the “contact binary” shape early in solar system history [1, 11]. This indicates a relatively benign collisional environment at least for cold classical KBOs. See [1, 11] for more on this topic.

3. The big picture

In this presentation we will give an overview of the differences between the Kuiper belt and the asteroid belt. We compare the New Horizons data to other observational datasets and models of both initial formation and subsequent collisional evolution [5]. We will discuss the implications for different populations of solar system bodies, both in the inner and outer solar system.

Acknowledgements

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