HIGHLY LOCALIZED SEASONAL COLD-TRAPPING IN THE NECK OF 2014 MU69 'ULTIMA THULE'.

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Introduction: On January 1, 2019 NASA's New Horizons spacecraft flew past the cold classical trans-neptunian object (486958) 2014 MU69 nicknamed "Ultima Thule" (herein "UT") at a distance of 3500 km [1]. A distinct surface feature recorded by both the LORRI [2] panchromatic narrow-angle camera and the Ralph [3] wide-angle color camera is a brighter (less dark) and less-red narrow "collar" present in the neck region of the bi-lobed overall body of UT. The origin of this "collar" is one of the many mysteries of UT's surface morphology that offers a challenge for interpretation. Here we hypothesize whether highly localized seasonal shadowing effects arising from UT's bilobate shape and its nearly in-plane spin vector orientation might play a role in creating and maintaining such a distinctly delineated feature.

Shadows at the Neck: Shadows on airless bodies create sharp boundaries - leading to the thought that shadowing effects (and hence low temperatures or temperature cycling) play a role in creating a sharply delineated feature such as the "collar." Time series imaging data and lack of a significant detectable light curve on the inbound trajectory of the New Horizons spacecraft indicates the spin vector of UT lies nearly within its orbital plane [4]. At the time of the encounter, UT consistently presented one hemisphere bathed in constant sunlight with its pole pointed toward the Sun. Thus we can deduce at the current epoch the subsolar point on UT is maintained at high latitude values over the course of each rotation. With this knowledge for the pole orientation for UT, we can deduce that for orbital epochs located 90 degrees and 270 degrees away from the current position, the spin vector for UT will be nearly orthogonal to the Sun, placing the subsolar point near UT's equator throughout each rotation. Interestingly at these near-equatorial sub-solar epochs for UT, the bi-lobed shape will effectively keep the neck region in nearly constant shadow over the course of each rotation. A consequence of this orientation and deep shadow epoch for the neck region is to create a highly localized cold trap very close to the base of the crevasse at the juncture between the two lobes.

Volatiles in Search of a Cold Trap: We do not propose that volatiles are currently present in the neck region of UT. Rather we suggest that this region is the most likely location for any freely released volatiles to have taken up temporary residence during any interval they survive on the surface. In this presentation we evaluate the extent to which, over the course of UT's ~298 year orbit, a highly localized deep shadow and cold trap may be optimally receptive in the tightly defined crevasse region at the base of the neck. A nominal guess is that this may favorably be the case for about 50% of each orbit. Scenarios for liberating volatiles that become available for cold-trapping need ongoing consideration. Impacts excavating subsurface volatiles is one contender [5]. Tectonic stresses (creating 'grinding') or thermal cycling stresses focused right at that interface could produce a very convenient local source of freely moving volatiles right at the localized region for cold-trapping [6,7]. Impacts or other stresses may occur at any point in UT's orbit, and at times such as the current epoch, an entire anti-sun hemisphere (also in a long continuous orbital season shadow) is available to trap any released volatiles that do not successfully escape into to space. An important consideration may be that with an entire hemisphere available as a cold trap, the coating depth of any available volatiles might be thinly distributed. In contrast, the epochs during which the base of the neck region is available as a cold-trap have an advantage toward building up a thicker layer because for a fixed amount of available volatiles, the sharply defined narrow band having near-continuous deep shadow (and therefore the coldest band anywhere on the surface) will have much more limited surface area for deposition.

Brighter Albedo and Less Red Color: It may not necessarily be the case that volatiles trapped in the highly localized "collar" of UT are currently present and detectable [7, 8]. Instead, for any interval when volatiles can be present on the surface, those volatiles become subjected to bombardment by galactic cosmic rays that begin to create residual non-volatile organics typically referred to as tholins [9]. These tholins may dominate the entire surface of UT and account for its generally similar color to the Cthulu region of Pluto [10]. The difference for the less dark albedo and less red color in the "collar" [7] could be that this process of creating tholins therein has been "reset" to a more recent time than the presumed ~4.56 billion year age of UT. The timing for creating the 'not as old' tholins in the "collar" corresponds to the most recent time that a sufficiently large crater excavation or other volatile release event occurred at a favorable orbital epoch when that highly localized cold trap was "ready to rexceive." The timing of such an event (or events) is poorly constrained. The shorter total time for the tholin processing of these volatiles will allow them to be sless dark and less red than the overall surface, as shown by current measurements. The "collar" material being a younger tholin residue or other more recently recycled surface structure, rather than a fresh volatile, gives it a long life that does not require any special timing for discovery during a brief flyby encounter.

Predictable Structure: If this hypothesis has merit, higher resolution imaging of the "collar" structure may show a relatively distinct boundary corresponding to the sharp boundaries that can be created by shadowing geometry. Local variations along the boundary, i.e. concavities along the edges that are most effective in creating permanent shadows over all rotation angles, could create rough edges. Similarly, the thickness and overall outline of the "collar" might correlate with the gross topographic silhouette of the "Thule" lobe that creates the limiting edges of the diurnal shadow. Multiple volatile release events might be evidenced by distinct layers or color boundaries corresponding to different epochs of volatile deposition. Collar structure that is broken or muted toward the equator could result from sunlight being able to "peek" into the bottom of the neck crevasse at local noon during the equator-on solar aspects - times when lobe shadowing is otherwise most effectively creating a highly localized cold trap. Forthcoming data should be able to support or refute these suppositions.

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