Color and Albedo of Ultima Thule: a Comparison to TNOs and Centaurs. C. M. Dalle Ore[1], D. P. Cruikshank[2], F. Scipioni[1], R. J. Cartwright[1], R. P. Binzel[3], A. M. Earle[3], J.J. Kavelaars[4], S. Protopapa[5], J. C. Cook[6], C. B. Olkin[5], W. M. Grundy[7], C. J. A. Howett[5], A. H. Parker[5], D. T. Britt[8], S. A. Stern[5], J. R. Spencer[5], H. A. Weaver[9], J. Wm. Parker[5], A. J. Verbiscer[10] and the New Horizons Composition Team [1]SETI Institute, Mountain View, CA (cmdalleore@gmail.com), [2]NASA Ames Research Center, Moffett Field, CA (Dale.P.Cruikshank@nasa.gov), [3]MIT, Cambridge, MA, [4]National Research Council of Canada, Victoria BC & Department of Physics and Astronomy, University of Victoria, (Victoria, BC), [5]Southwest Research Institute, Boulder, CO, [6]Pinhead Institute, Telluride, CO, [7]Lowell Observatory, Flagstaff, AZ, [8]University of Central Florida, [9]Space Exploration Sector, Johns Hopkins University Applied Physics Laboratory, Laurel, MD, [10]University of Virginia, Charlottesville, VA.

Introduction: The Kuiper Belt region that extends beyond Neptune, often called the Third Zone of our Solar System, has offered powerful insights into the origin and history of our planetary system. The objects that occupy this region, the trans-Neptunian population, are extremely diverse, ranging from geologically-evolved, volatile-dominated dwarf planets to small, volatile-poor and extremely primitive planetesimals. Their dynamical properties also vary and are tied to their evolution as part of the Solar System [1].

Apart from Pluto, our knowledge of this part of the Solar System derives mostly from a growing number of ground-based observations of the transneptunian objects (TNOs), Centaurs, comets observations and exploration. For the smaller, very far objects only photometric observations have been possible until now. The farthest objects are those that have been subjected to the least amounts of solar irradiation and are therefore considered to be among the most pristine ones.

Not as far as the TNOs but as intriguing is the dynamical class of the Centaurs. These are bodies that are believed to have migrated closer to the Sun after originating in the outer regions occupied by the TNOs. If this is indeed the correct scenario than Centaurs are expected to show the most processed materials particularly for those that have been in closer orbits for a long time.

Some of the TNOs are thought to have been captured by the outer planets and are now satellites. Prominent examples are Phoebe and Triton, Saturn's and Neptune's satellites respectively.

Furthermore, comets are objects that are believed to have originated in the outer regions of the Solar System and have been exposed to heavy processing by solar irradiation during their passages near the Sun.

Ultimately, processing of some of the volatile original icy component is known from laboratory experiment to yield the colored refractory material that seems to be a common constituent of many of the bodies belonging to the Third Zone of the Solar System [2].

The January 1st 2019 New Horizons flyby has finally provided us with a set of data for the object known unofficially as Ultima Thule (486958 2014 MU_{69}, or UT), one of the smaller and very far objects that until recently could only be detected by the Hubble Space Telescope. This body is the most pristine small body yet to be explored by a spacecraft and can shed some light on the composition of the primordial nebula as well as gauge our understanding of other populations in the Solar System.

As part of this work we present a comparison of the broad band photometry obtained from New Horizons data of UT to that of other objects observed from the ground and belonging to or thought to have originated from the Third Zone. The methodology is similar to that adopted by [3]. UT's spectral signature was also compared to that of the small satellites of Pluto, comparable in size to this object by [4]. A color comparison of Ultima Thule with some of the outer Solar System satellites has been explored by [5]. Finally, comparisons of Ultima Thule's spectral signature with that of comet 67P/Churyumov-Gerasimenko and of comets in general are presented by [6, 7] respectively.

Data Analysis: The New Horizon's data used for this study consist of hyperspectral cubes obtained with Linear Etalon Imaging Spectral Array (LEISA) [8]. The spatial resolution of our best data ranges between ~1.8km/px and ~4km/px, depending on the chosen scan. At the time of this abstract writing it is projected that both scans will have been downloaded in time to be analyzed for the meeting allowing a detailed spatial investigation. The spectra cover the range between ~1.2 and 2.5 µm, sufficient to include J, H, and K photometric bands. Furthermore, the New Horizons flyby has provided UT data in the visible by means of the Multi-spectral Visible Imaging Camera (MVIC) [8]. These data consist of broad band filter photometry roughly corresponding to the B, V, and I bands.

The J, H, and K band photometry was ultimately obtained by convolving UT spectral data obtained with LEISA by the filter response functions for the individual bands. The spectra corresponding to selected areas representative of different terrains on UT were grouped by means of an unsupervised classification tool, which selects spectra that are similar and averages them. The MVIC data was analogously clustered yielding representative color measurements in the B, V, and I bands for the different terrains.

We present a preliminary visual comparison of the resulting broad band photometry of Ultima Thule's compositionally diverse regions to that of previously observed TNOs following [3].

From the flyby data we also deduce a taxonomic class for UT following [9, 10].

Initial results: The broad band photometry obtained for UT is limited in the number of colors as the spectral coverage of New Horizons extends only to 2.5 µm. However, the limited range covers a very important part of the spectrum allowing us to investigate the surface coloration in the visible part of the spectrum with respect to that of other TNOs belonging to different dynamical classes. Recent work from the Colours for OSSOS project [12] suggest that the cold classical objects exhibit a variation in g/r/z color space that is unique and the MVIC filters, when transformed to this space, will help further connect the surface properties of MU_{69} to the bulk of the cold classical population. Furthermore, the close range flyby has provided us with spatially resolved data. A first examination of MVIC data (0.4-~1.0µm) from a partial cube observed before the flyby has already shown at least two different colors for the neck and the rest of the object supporting the idea that the composition and/or grain size of the surface material might vary across the surface. In general, the comparison of UT broad band photometry can offer another glimpse at the history of this object with respect to that of similarly sized but closer ones. In turn this comparison can shed light on the question of the nature and distribution in the Solar System of the colored material and whether it is a product of nature or nurture of the system [11].

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