SPECTRAL PROPERTIES OF 486958 2014MU$_{69}$ (ULTIMA THULE) VERSUS 67P/CHURYUMOV-GERASIMENKO.

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Introduction: 486958 2014 MU$_{69}$, nicknamed Ultima Thule (hereafter UT), was surveyed by the New Horizons spacecraft on 1st January 2019 [1-5]. This small cold classical Kuiper Belt Object (KBO) ~ 33 km across has a bilobed shape, and consists of two nearly spherical icy planetesimals (r ~ 9.7 and 7.1 km). UT might have formed through a slow velocity collision in the outer region of the proto-solar disk, and remained there for 4.55 Gyrs. In this respect, it never approached the sun, might have preserved its superficial icy surface and might provide insights into the ice/dust mass ratio, the physical state of water ice (amorphous vs. crystalline) or the ice composition and mixing state with refractory dust.

Within this framework, an interesting issue is the comparison of UT with comets [6-8], and 67P/Churyumov-Gerasimenko (67P/CG) in particular. This short-period comet has been explored thoroughly by the Rosetta spacecraft and its surface has been scrutinized by the VIRTIS-M imaging spectrometer in the range 0.4-4 µm. Unlike KBOs, 67P/CG's surface is dominated by refractory and semi-volatile components, and is basically devoid of ice (except in collapsing cliffs and localized shadowed region favoring recondensation). The surface of 67P/CG thus appears as a valuable proxy for understanding UT's surface composition, provided the reasonable assumption that their refractory components are very similar. Indeed, the analysis of stratospheric IDPs, AMMs and STARDUST grains emphasize intense radial mixing in the protosolar disk.

Here, we report on a preliminary comparison of the spectral data collected by the LEISA/MVIC polychromatic imager with 3 visible filters and by the LEISA/RALPH imaging spectrometer operating in the range 1.25-2.5 µm ($\lambda/\Delta\lambda$ =240) with those of 67P/CG VIRTIS-M/Rosetta [5,9-11]. UT spectra have been compared to modeled spectra of 67P/CG dust mixed up with volatile species, and impact on reflectance and spectral slopes have been investigated. The presence of possibly newly identified molecules is also discussed with respect to the volatile composition of 67P/CG.

Composition and spectral properties of 67P:

Comet 67P/CG is composed of three main components [12]: (1) volatiles, i.e. gas generated by ice sublimation, dominated by H_2O, CO and CO_2; (2) semi-volatile species, as ammonium ions and low weight molecules; (3) refractory dust, comprising silicates, opaque minerals (e.g. sulfides) and refractory organic matter. The VNIR mapping of the nucleus reveals a homogeneous surface, and three main features as a low reflectance level (reflectance factor REFF and I/F of 1-4 %), red slopes in the visible and near-infrared ranges and a 3.2 µm broad absorption band [11]. The low reflectance is mostly controlled by the presence of opaque minerals, however the carrier of the reddish slopes has not been identified yet.

Preliminary comparison: The UT radiance factor I/F in the visible range averages at ~ 0.08, and at 0.18 ± 0.02 in the 1.2-2.5 µm range [9]. These I/F values are higher than those measured for 67P by a factor of ~ 3.

Calculations were run for mixtures of water ice and 67P refractory refractory, using a simple Hapke model (no multiple scattering and opposition effect) and the photometric model of 67P surface of [11] (Fig. 1).

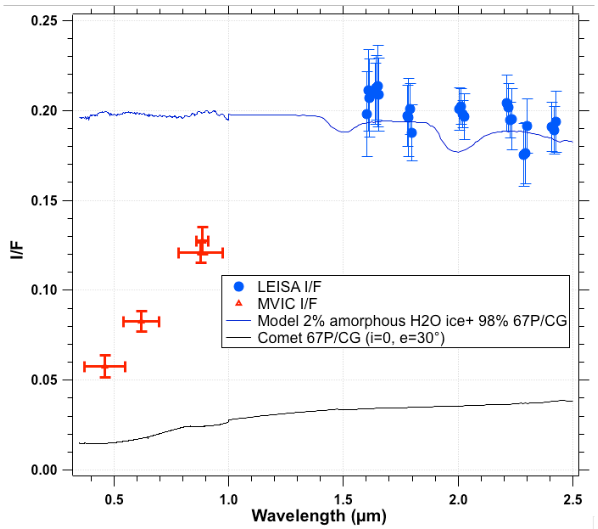

Figure 1: I/F values of Ultima Thule 67P/CG compared with 67P/CG spectra (blue) and modeled spectrum calculated for a mixture made of 67P/CG refractory materials mixed with amorphous water ice (2 vol%).

Assuming a granular mixture of both these components, modeled spectra display a higher I/F ratio consistent with UT, but with a neutral slope, whatever grains sizes and mixing ratio combination. The surface of UT then appears difficult to simulate with a simple granular mixture and thus questions the carrier of UT red color, which might be different than 67P/CG. A major difference between the two objects is the young surface of 67P/CG, renewed at each perihelion due to cometary activity. In contrast, surface aging might be very significant in the case of UT, possibly controlled by GCR irradiation. Unsaturated organic compounds may be present at UT surface, and their nature will be investigated through laboratory experiments [13].

At the time of writing, the full set of RALPH data is not available, and only 25 wavelengths have been downloaded and analyzed. The recovery of the full set of data, in particular LEISA spectra, will help constrain further potential links between UT and 67P. In particular, firm conclusion on the presence/absence of water ice bands is expected.

References:

[1] Stern et al. (2019) LPSC presentation.[2] Schenk et al. (2019) LPSC presentation. [3] Porter et al. (2019) LPSC presentation.[4] McKinnon et al. (2019) LPSC presentation. [5] Grundy et al. et al. (2019) LPSC presentation. [6] Protopapa et al. (2019) LPSC presentation. [7] Weaver et al. (2019) LPSC presentation. [8] Lisse et al. (2019) LPSC presentation. [9] Howett et al. (2019) LPSC presentation. [10] Cook et al. (2019) LPSC presentation. [11] Ciarniello et al. (2015) A&A, 583, A31. [12] Quirico et al. (2016) Icarus 272, 32-47. [13] Cruikshank et al. (2019) LPSC presentation.

Acknowledgements. We thank NASA, the Deep Space Network, JPL, KinetX Aerospace, the entire present and past New Horizons team, and the Gaia and HST missions for making the flyby of MU69 successful. E. Quirico, B. Schmitt and L. Gabasova acknowledge for support from CNES and ANR grant ANR-17-CE31- 0004.