MULTIBAND PHOTOMETRY OF RSL AND DUST-DEVIL TRACKS FROM CaSSIS COLOR IMAGES

G. Munaretto[a,b], M. Pajola[a], A. Lucchetti[a], G. Cremonese[a], E. Simioni[a], C. Re[a], S. Bertoli[a,c], L. Tornabene [d], A. S. McEwen[e], P. Becerra[f], V. G. Rangarajan [d], A..Valantinas [f], G. Portyankina[g], N. Thomas[f]

[a]INAF, Osservatorio Astronomico di Padova, Padova, Italy (giovanni.munaretto@hotmail.it); [b]Department of Physics and Astronomy "G. Galilei", University of Padova, Padova, Italy,[c]Center of Studies and Activities for Space "G. Colombo" (CISAS), Padova. [d]Inst. Space & Earth Exploration, Dept. Earth Sci., Western University, London, Canada [e]Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ, USA, [f]Physikalisches Institut Universitat Bern, Switzerland,[g]University of Colorado, Boulder, CO

Introduction: Recurring Slope Lineae (RSL) are narrow dark streaks that incrementally lengthen down Martian warm steep slopes [1]. On first approximation, they appear and elongate during the Martian summer, disappear completely in winter and recur annually. This temperature dependence suggested that RSL may be related to flows of liquid water or brines [1-5], possibly fed by groundwater sources [6, 7] or from the deliquescence of hygroscopic salts [8]. Alternatively, RSL have been interpreted as dry granular flows [9, 10, 11, 12], possibly related to aeolian processes [13, 14]. Among the evidence that supports the latter is that, in Tivat crater, RSL and dust-devil tracks faded simultaneously due to the widespread removal of dust from both [11]. More importantly, RSL were much more abundant than previously following the MY34 planet-encircling dust event (PEDE), with a strong association with dust-devil tracks. Thus, it was proposed that multiple dust-lifting processes trigger RSL activity [15]. Although a detailed explanation of the RSL nature and formation mechanism is still not complete, the latest evidence points further toward a dry mechanism.

Here, we provide further evidence for a dry origin theory of RSL by investigating the colour properties of RSL through multiband photometry obtained from 4-filter Colour and Surface Science Imaging System (CaSSIS, [16]) observations at Hale crater and Horowitz crater, Mars. We compare it with multiband photometry of dark tracks left by the passage dust-devils (DDTs), which are dark marks left by the passage of whirlwinds. Since the latter are well-established as being formed by ferric dust removal and the exposure of underlying, typically ferrous material, the comparative multiband photometry provided by CaSSIS may help us understand whether RSL are consistent with being formed by the removal of dust. This would contribute to show that RSLs are indeed dry flows of dust and sand.

Methodology: We adapted the technique of [11,12] to compute the relative reflectance of RSL in the NIR (936.7 nm), RED (836.2 nm), PAN (675.0 nm) and BLU (499.9 nm) BLU CaSSIS filters. To do this, we select several regions of interest (ROIs) within RSLs at Hale and Horowitz crater. Some examples are in Fig. (1A, 1B). We compute for each filter the RSL relative reflectance by dividing the average I/F from a RSL ROI by the average I/F from a nearby region with the same orientation and slope angle but lacking traces of RSL. We repeat this procedure for DDTs at Horowitz crater. An example is given in Fig. (1C). In our calculations, we apply a first order atmospheric correction by subtracting the I/F of the darkest pixel of each filter before computing the relative reflectance [16,17,18]. Statistical errors are computed by propagating the standard deviation within each ROI.

Results: Relative reflectance of a sample of RSL and DDTs at Hale and Horowitz crater in the CaSSIS filters are reported in Fig. (1D), (1E) and (1F), respectively. In general, the RSL at Hale crater have the darkest relative reflectance profiles, the DDTs at Horowitz crater have the brightness, and the RSL at Horowitz are an intermediate case. Both features have similar relative reflectance profiles within errors, i.e., they are brighter in the BLU than in the PAN, RED and NIR filters. In addition, while there is some variability, there are no significant spectral features that characterize either RSL or DDTS in the latter three bands, where both show an approximately (i.e. within error bars) constant relative reflectance. Some differences within the single profiles exist. For example, the 5 RSL in Hale crater in Fig. (1D) show a higher NIR relative albedo than in the RED, against only few cases in Horowitz RSLs and DDTs Fig. (1 E, F). This variability is small or comparable to the error-bars and probably of both stochastic and/or systematic nature, due to residual variabilities within the material for different RSLs.

Discussion and conclusions: The comparison between relative photometry of RSLs and DDTs in the 4 CaSSIS filters show that these features have a quite similar relative reflectance profile, suggesting that they may have a similar origin. This is particularly clear at Horowitz crater (Fig. 1B, C). In particular, the higher BLU with respect to PAN, RED and NIR relative

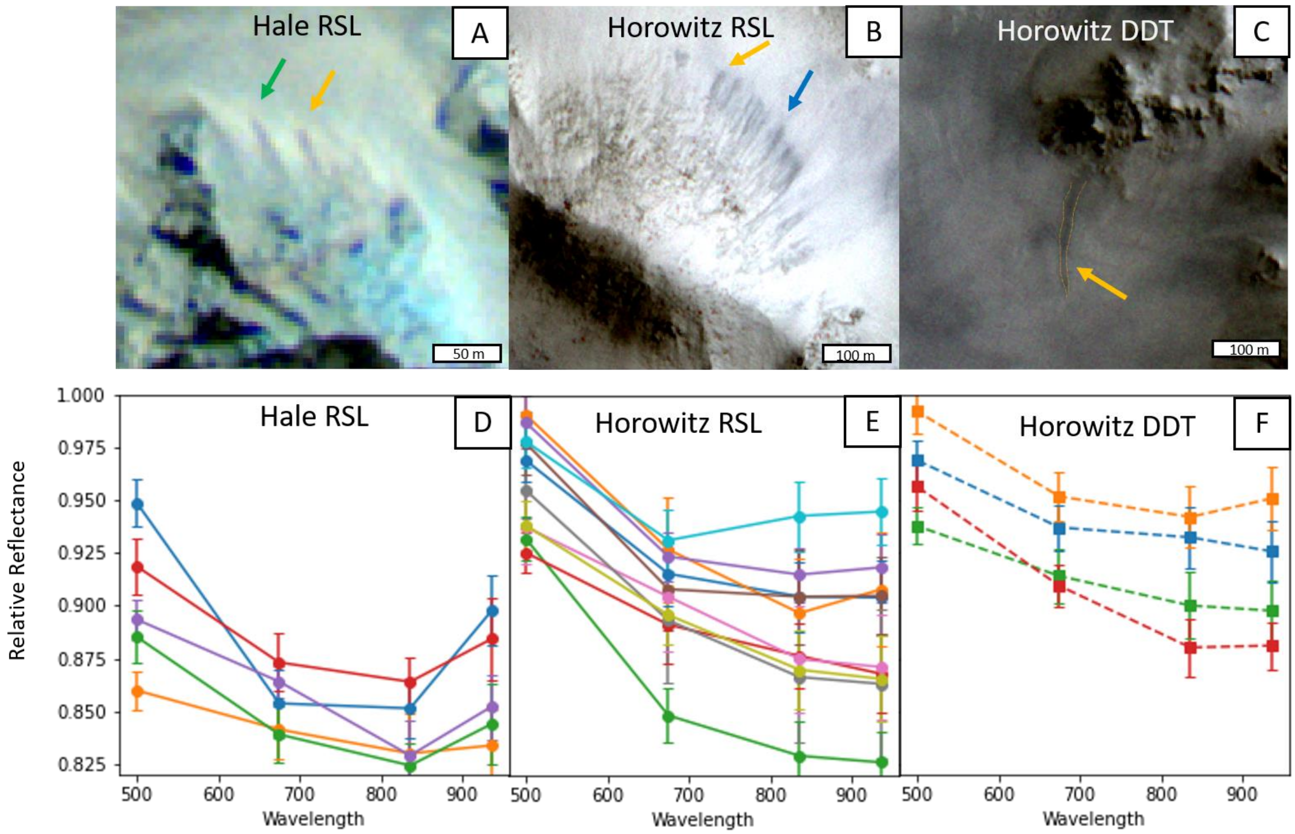

Figure 1: A few examples of A) RSL (arrows) elongating from bedrock outcrops at Hale crater. B) RSL (arrows) at Horowitz crater. C) A Dust devil track (arrow and orange outline) at Horowitz crater. Relative reflectance in the CaSSIS bands of the D) Hale crater and E) Horowitz crater RSLs and F) Horowitz crater dust devil tracks, including the features in panels A, B, C (same colors). Wavelength is in nm. Different colours indicate different RLSs and DDTs within the same image. Only a few examples of RSL and DDTs are shown in the upper panels for clarity

reflectance may suggest that the reflectance profiles of both features could be consistent with a ratio between a ferrous material (numerator), exposed by the removal of a ferric surface material such as the Martian dust (denominator). However, further analyses are needed to corroborate this hypothesis and evaluate it against water-based possibilities. Such an improved photometric characterization, based on the topographic correction of the images using high-resolution CaSSIS DTMs, will be presented at the conference.

Acknowledgments: The authors wish to thank the spacecraft and instrument engineering teams for the successful completion of the instrument. CaSSIS is a project of the University of Bern and funded through the Swiss Space Office via ESA's PRODEX programme. The instrument hardware development was also supported by the Italian Space Agency (ASI) (ASI – INAF agreement no. I/018/12/0), INAF/Astronomical Observatory of Padova, and the Space Research Center (CBK) in Warsaw. Support from SGF (Budapest), the University of Arizona (Lunar and Planetary Lab.) and NASA are also gratefully acknowledged. The study has been supported by the Italian Space Agency (ASI-INAF agreement no. 2020-17-HH.0).

References: [1] A. S. McEwen et al. (2011), Science (6043), 740–743 [2] Levy, J et al. (2012), Icarus, 219, (1), 1-4 [3] McEwen et al. (2014), Nat. Geosci. 7 (1), 53–58 [4] Stillman et al. (2014), Icarus 233, 328–341 [5] Huber et al., (2020) Icarus 335, 113385. [6] Stillman et al. (2016), Icarus 265, 125–138. [7] Abotalib and Heggy (2019) ,Nat. Geosci. 12, 235–241 [8] Wang et al. (2020), Icarus 333, 464–480 [9] Dundas et al. (2017), Nat. Geosci. 10 (12), 903–907 [10] Schmidt et al. (2017), Nat. Geosci. 10 (4), 270–273 [11] Schaefer et al. (2019), Icarus 317, 621–648 [12] Munaretto et al. (2020), PSS 187, (2020), 104947 [13] Vincendon et al. (2019), Icarus 325, 115–127 [14] Dundas et al. (2020), Icarus 343, 2020, 113681 [15] McEwen, A. S. et al. (2021), JGR-Planets, in press. [16] Thomas et al. (2017) Space Sci. Rev. 212 (3–4), 1897–1944[17] Chavez Jr, P. S. (1988) .Remote sensing of environment, 24(3), 459-479. [18] Tornabene et al. 2018, SSR,214(1),18